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RESOURCE CONSUMPTION IN NEMO ROUTE OPTIMIZATION USING CORRESPONDENT ROUTER

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ABSTRACT

Network mobility (NEMO) is an important requirement for internet networks to reach the goal of ubiquitous connectivity. The IETF design NEMO BSP to manage network mobility in an aggregate way. Standard NEMO suffers from number of limitation and problems such as pinball problem and link-drop problem. In NEMO route optimization, an attacker may induce the mobile router to initiate the route optimization procedure with a large number of correspondent nodes at the same time by sending to a mobile network node of the NEMO a spoofed IP packet that appears to come from a new correspondent node. If the correspondent addresses are real addresses of existing IP nodes, then most instances of the binding update protocol may be successfully completed. The entries created in the Binding Cache are correct but useless. In this way, the attacker can induce the mobile to execute the binding update protocol unnecessarily, which can drain the mobile's resources. A correspondent node can also be attacked in a similar way. The attacker sends spoofed IP packets to a large number of mobiles, with the target node's address as the source address. These mobiles will initiate the binding update protocol with the target node. Again, most of the binding update protocol executions will be completed successfully. By inducing a large number of unnecessary binding updates, the attacker is able to consume the target node's resources. Meanwhile, using the correspondent router will reduce this kind of attack according to its rules and function as a single point of management to optimize on behalf of multiple entities. This research provides an analytical method for evaluating the resource consumption in different NEMO schemes using correspondent router.

***Keywords**: Network mobility, Route optimization, Mobile IPv6, Correspondent router.*

1. INTRODUCTION

Ubiquitous mobile devices and services have recently proliferated widely. The interest of users in mobile accessibility is reflected in the recent surge in cellular communication, but these networks should provide not only voice services but also data services for the mobile entity across heterogeneous environments. Internet protocol (IP) is the basis for continuous internet connectivity of these networks. Users, through IP layers, can access the internet from anywhere at any time. The Internet Engineering Task Force (IETF) for mobile IPs supports the movement of the IP node from one point of attachment to another by supporting mobile IP (MIP) [1] for IPv4 and MIPv6 to support mobility in the IPv6 node [2]. The MIPv6 protocol was proposed to support host mobility. Each mobile node requires two types of IPv6 addresses. The first one is the Home-of-Address (HoA), which acquired from the home link, and the other address is the Care-of-Address (CoA), which is acquired from the foreign access router to maintain global connectivity and reachability. This can be achieved by registering the CoA with the home agent (HA) at the home link. This protocol allows the packets to reach the destined mobile node transparently through the HA. The MIPv6 protocol suffers from pinball problems while routing the packets from the mobile node (MN) → corresponding node (CN) because it is always tunneled through the HA in the home link. Route Optimization (RO) is used to enhance the network performance by making a direct connection

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between MN → CN without passing through the HA[3, 4]. This will provide an optimal path between MN → CN. Currently, the mobile node uses a mechanism known as Return Routability Procedure (RRP) [2]. This mechanism allows the corresponding node (CN) to verify and assure that the collection of MN HoA and CoA is owned by the MN. Next, the MN and CN implement the RO. The MIPv6 protocol with its optimization is satisfactory for host mobility but not for a group of nodes moving as a single unit (similar to a PAN and vehicle network) attached to the internet through its egress interface.

IETF has developed a new protocol for network mobility known as NEtowrk MObility basic support protocol (NEMO bsp) [5]. The NEMO bsp extension ensures session continuity for each mobile (supported by MIPv6) or fixed (may be supported by MIPv6 or for those that may not be sophisticated enough to support MIPv6) nodes inside the mobile network. NEMO handles network traffic as a central point of management. It will provide reachability and connectivity for each node inside its network during its movement. In a NEMO network, units are attached and moved to different points in the internet via a specific gateway known as the Mobile Router (MR). This MR has two interfaces: One is the egress interface that connects with the internet in the home or foreign link, and the other is the ingress interface that connects with the whole nodes underneath the MR for both fixed and mobile nodes. Each MR has its own HA at its home link. Each packet that is designated by the MR at the home link can be reached by its HoA acquired from the HA when the MR moved and attached into a new arbitrary access point. First, it acquires a new address from the foreign AR, called the CoA. Second, it delegates a new prefix or set of prefixes (PF) from the access router. Finally, MR registers the CoA and optionally the delegated PFs with its HA by sending a binding update (BU) message containing all NEMO features [5]. When a packet designated, one of the mobile network nodes (MNNs) inside the MR path of the routed packet is CN → MNN_HA → MR_HA → MR → MNN, as shown in Fig. 1.

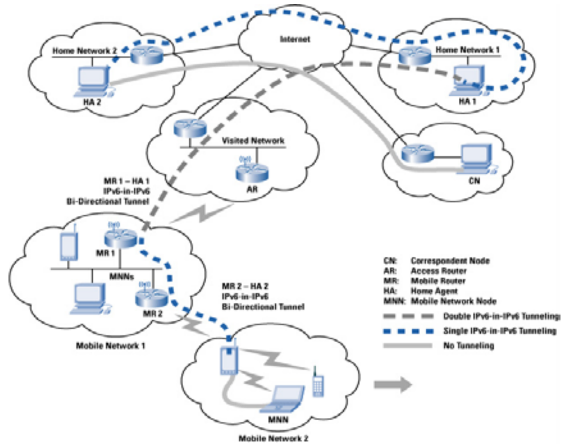

Fig.1. Architecture Of NEMO Showing Suboptimal Path

This NEMO BSP suffers from a suboptimal pathway by using multiple tunnels through multiple home agents (HAs) of the mobile networks, and resulting in several encapsulations. NEMO-RO (NEMO ES) is similar to that adopted by MIPv6-RO [2]. MIPv6 runs RRP to initiate route optimization. MIPv6-RRP is inadequate because it does not support the link prefix or verify whether it is in fact handled by the mobile entity inside the NEMO.

2. SCENARIO ANALYSIS AND USE CASE

A. PREVIOUS ANALYSIS OF THE PROBLEM AND PROPOSED SOLUTIONS

The inefficient-routing problem of NEMO has been solved by a number of route-optimization schemes. An overview of the schemes can be found in [6-8]. These schemes feature a trade-off between the degree of route optimization and the expenses arising from it, such as signaling and memory consumption; these schemes have been evaluated and compared [7] based on the approaches used to improve the route optimization. Among them, the prefix delegation-based schemes perform better than the others in terms of overheads and route efficacy. In prefix delegation-based schemes, the foreign network prefix is made available inside the mobile network so that nodes inside the mobile network can obtain addresses from that prefix. We also consider all schemes that allow nodes inside the mobile network to obtain addresses from the prefix of the foreign network, such as in the prefix delegation-based schemes. Despite the availability of various prefix delegation-based schemes [9-16], different degrees of route optimization with different amounts of signaling have been obtained when following a

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common approach for delegating prefixes depending on the type of nodes and on how the prefix is delegated. These differences affect the performance of the schemes and the overheads arising from the performance gain. Therefore, we choose the delegation schemes as a base work for evaluating the network architectures.

B. NEMO

Network mobility architecture will be summarized in this section to help the reader understand the rest of this paper.

- **NEMO ARCHITECTURE**

Based on the mobile network architecture [5] shown in Fig. 1, mobile network nodes (MNN) are attached underneath the mobile router (MR), which acts as mobile gateway for MNNs. These MNNs are classified into different types, such as standard nodes that are not supported by mobility, called local fixed nodes (LFNs); nodes that mostly reside in NEMO and also have the ability to move from their network to another network, called local mobile nodes (LMNs); and nodes that move from one point of attachment to another, called visited mobile nodes (VMNs). Nested NEMO occurs when one or more MRs is attached to another MR. The term root MR is used to describe each mobile router that connects directly to the wired network through the access router (AR).When mobile network nodes are attached under an MR, the network can also be considered nested. Each NEMO is usually attached to its home network where the home agent (HA) is located. The HA router is responsible for tracking MR movements, which redirect the packets destined for the moved MR while it is away from the home network. The NEMO MNNs and MRs may be registered to different HAs.

- **CORRESPONDENT ROUTER BASED SCHEME**

Correspondent Routers (CR) can be deployed for general scenarios such as, aeronautical, train, bus networks and in the common Internet [17, 18]. If a CR can be found, the route to/from the related CNs can be optimized. However, the load for CR discovery and route optimization can be very heavy considering the unlimited number of CNs.

Some route optimization schemes have been proposed, such as ORC scheme [19]. This scheme introduces the Correspondent Router (CR) which covers a certain number of Correspondent Nodes (CN), and the MR can set up an IP-in-IP tunnel with the CR and bind the Mobile Network's prefix to the MR's Care-of Ad-dress so that the packets to/from the CN will be encapsulated into the MR-CR tunnel and forwarded by the CR without bypassing the HA [17].

Basically, when CR presented it outperform better than the NEMO BSP especially when large network is used. However, the network infrastructure incurs number of problems and limitations due to the use of CR. Therefore, different mechanisms have been proposed to limit the workload when using the CR. For example, the MR can set an upper limit on the total amount of MR-CR tunnels, and the MR discovers CRs only for the sessions with the longest packet delay or largest throughput.

- **NEMO BSP**

In NEMO bsp, MRs delegate a prefix or a set of prefixes [20] from their home network to advertise it inside their network. Each MNN inside NEMO obtains an address from the delegated prefix, called the home of address (HoA), in the home network. When the packets destined for that MNN arrive, they will be routed through mobile network HAs. When NEMO moves from one point of attachment and is attached to a foreign network, the MR will obtain a new address called the care of address (CoA) from the foreign network for each entity inside NEMO. Therefore, when a packet destined for the nest MR arrives, it will be tunneled through all HAs of the parent MRs to reach the designated MR. This insufficient route (pinball routing) results in performance degradation. Therefore, several route-optimization (RO) schemes have been proposed. In this study, we chose to use the prefix delegation schemes to solve the high cost of signaling, location transparency and some deployment difficulties [8]. An overview of prefix delegation-based schemes is presented in the next section.

C. PREFIX DELEGATION-BASED SCHEMES

In a prefix delegation scheme, each MNN (but not LFN) acquires a new care of address from the delegated prefix in a foreign network and establishes a route-optimization scheme such as MIPv6 [2] optimization. The MNN sends its CoA to the HA and CNs through BUs. BUs are sent each time a new address is acquired or request needs are refreshed to establish an optimized path. Prefix delegation schemes vary in the way that they delegate the prefixes, the process used to obtain the CoA and the route-optimization technique

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employed. Four representative prefix delegation schemes are described in the next sections.

- **SIMPLE PREFIX DELEGATION (SPD)**

In this scheme [9], each MR inside NEMO will delegate the foreign network prefix inside its network hierarchically using its router advertisement. A new header option called delegation prefix option is proposed in this scheme, and the MR will use it to advertise the delegation of the prefix. In this scheme, the LFNs are unable to optimize their route because they may not be sophisticated enough to support mobility. Therefore, the MRs to which the LFNs are attached will work on behalf of the LFNs by tunneling through their HAs.

- **MIPV6-BASED ROUTE OPTIMIZATION (MIRON)**

In MIRON [13], PANA [21] and DHCPv6 are used by the MNN to obtain a CoA from the foreign network as the MNN moves. The root MR obtains a CoA from the visited network using DHCPv6 and informs the attached MNNs about this CoA after PANA authentication is established. The MNNs sends a DHCPv6 request vertically until it reaches the visited network; then, this network will reply with a DHCPv6 request with CoA using a reverse path. The MR in MIRON sends a BU request on behalf of the LFNs to establish an optimized path.

- **OPTIMAL PATH REGISTRATION (OPR)**

In OPR [15], the MR obtains its CoA from the prefixes that are delegated to the MRs hierarchically using multicast route advertisement; then, the MRs send a BU to their HA. In OPR, the MNNs are transparent during network movement; this transparency is produced with the address translation. The MRs will perform an address translation to the MNNs to optimize their path using the delegated prefix. The MRs use an address translation table; when they receive a packet from the mobile node, they will replace the source address with a translated address in a new header named the OPR header [15]; otherwise, if the address is not found, they will create a new address using the delegated prefix. In OPR, no binding update request is sent to the CNs, and the reverse operations are made when a packet moves from a CN to an MNN.

- **AD HOC PROTOCOL-BASED (AD HOC-BASED)**

Unlike the other schemes, the scheme proposed by Su et al. [14] uses the Ad hoc protocol (AODV [22]) in MRs to forward packets to the wired network. In the Ad hoc scheme, the router advertisement of the access router is broadcasted by the root MR to the attached MRs, in addition to the network router advertisement owned by the MRs. After mobile-network handoff, the MRs obtains new CoAs using the router advertisement, and the access router path is discovered with the AODV to send the binding update. Meanwhile, the other MNNs are transparent to network movements. Fig. 2 summarizes the routes used by MNNs and the major processes required in the PD-based schemes. In prefix delegation schemes, the route inefficiency overheads are traded off with the processing overheads and signaling overheads at different mobility entities.

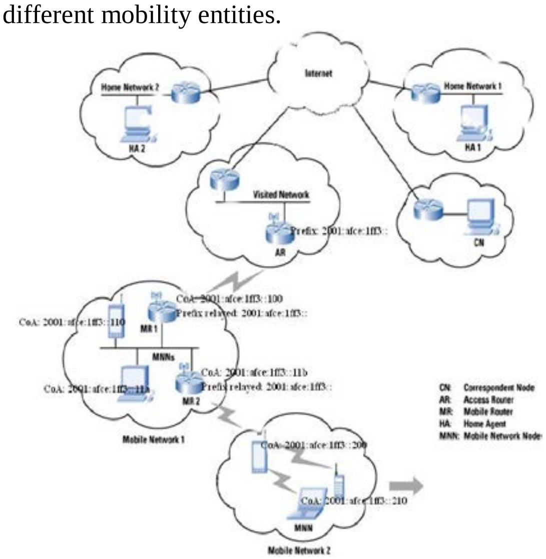

Fig.2. Delegation Approach For Route Optimization In NEMO

3. PERFORMANCE EVALUATION

- **NOTATIONS**:

The symbols used in the selected schemes (x), where x represents the type of scheme, such as SPD, MIRON, OPR and Ad hoc scheme, are defined as follows:

Ω_{BU}^{x}	Cost of Binding Update in Mobile Network for scheme x
β_{mr}^{x}	Cost of Memory required by Mobile Routers for scheme x
n_c	Number of CNs
N_r	Number of MRs in the entire mobile network

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N_v	Number of VMNs in the entire mobile network
N'_r	Number of MRs attached to the root-MR
N'_f	Number of LFNs attached to the MR
N'_m	Number of LMNs attached to the MR
N'_v	Number of VMNs attached to the MR
N_f	Number of LFNs in the entire mobile network
N_m	Number of LMNs in the entire mobile network

- **ANALYTICAL MODEL**

This section discusses an analytical model developed for four selected prefix delegation schemes to perform route optimization for NEMO in both the basic NEMO BSP route optimization (NEMO-RO) and the NEMO BSP using the CR (NEMO-CR) architecture. This analytical model measures the memory overhead and total binding update costs for the selected schemes in both the NEMO-RO and NEMO-CR architectures:
The schemes presented in the following sections are written as shown in the pervious studies performed to compare these selected schemes [23]. These derived models are presented in both the original architecture NEMO-RO and the NEMO-CR.

- **COST OF BINDING UPDATE**

The cost of BU is measured by the number of BUs sent from a mobile network during handoff. This cost depends on the number of MNNs and CNs.

In the SPD scheme, the cost of BU at NEMO-RO is given by

$$\Omega_{BU}^{SPD} = (n_c + 1)(N_r + N_m + N_v) \quad (1)$$

Where (n_c+1) is the number of BUs from each MNN. The BU cost of the SPD scheme in NEMO-CR is given by

$$\Omega_{BU}^{SPD} = 2(N_r + N_m + N_v) \quad (2)$$

For MIRON, with NEMO-RO,

$$\Omega_{BU}^{MIRON} = (n_c + 1)(N_r + N_m + N_v) + n_c N_f \quad (3)$$

For MIRON, with NEMO-CR,

$$\Omega_{BU}^{MIRON} = 2(N_r + N_m + N_v) + N_f \quad (4)$$

OPR with NEMO-RO is given by

$$\Omega_{BU}^{OPR} = N_r \quad (5)$$

OPR with NEMO-CR is given by

$$\Omega_{BU}^{OPR} = N_r \quad (6)$$

For Ad hoc with NEMO-RO, Eq. (7) is used

$$\Omega_{BU}^{Adhoc} = (n_c + 1)(N_r + N_m + N_v) \quad (7)$$

For Ad hoc with NEMO-CR, Eq. (8) is used:

$$\Omega_{BU}^{Adhoc} = 2(N_r + N_m + N_v) \quad (8)$$

- **MEMORY OVERHEAD COST**

Memory overhead cost represents the additional information (number of IPv6 addresses located in mobile router memory) that consumes memory to accomplish route optimization. Memory overhead depends on the number of CNs and MNNs.

In an SPD, the cost of memory overhead is derived as shown in Eq. (9) for NEMO-RO:

$$\beta_{mr}^{SPD} = 2N'_r \quad (9)$$

SPD memory cost with NEMO-CR

$$\beta_{mr}^{SPD} = 2N'_r \quad (10)$$

MIRON memory cost with NEMO-RO

$$\beta_{mr}^{MIRON} = 2(N_r + N_m + N_v + n_c N'_f) \quad (11)$$

MIRON memory cost with NEMO-CR

$$\beta_{mr}^{MIRON} = 2(N_r + N_m + N_v + N'_f) \quad (12)$$

OPR memory cost with NEMO-RO

$$\beta_{mr}^{OPR} = 2N'_r + 3n_c(N'_v + N'_m + N'_f + N'_r) \quad (13)$$

OPR memory cost with NEMO-CR

$$\beta_{mr}^{OPR} = 2N'_r + 3(N'_v + N'_m + N'_f + N'_r) \quad (14)$$

Ad hoc memory cost with NEMO-RO

$$\beta_{mr}^{Adhoc} = N_v + N_m + N_r \quad (15)$$

Ad hoc memory cost with NEMO-CR

$$\beta_{mr}^{Adhoc} = N_v + N_m + N_r \quad (16)$$

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- **RESULTS AND DISCUSSION**

In this section, we present the numerical values for each of the selected schemes and different cost types. These costs are presented as a function of MNNs, CNs, LFNs and MRs. The system parameters used in this work as well as the typical values used in previous works [23-26] are shown in Table 1.

Table1. The System Parameters

Parameters	Values
n_c	5
N_f	400
N_m	20
N_v	400
N'_r	2
N'_f	2
N'_m	2
N'_v	10
N_r	20
N_f	400

The values in Table 1 are used to obtain the costs formulated in the analytical-model section. Meanwhile, Fig. 3 shows the impact of the number of CNs on the number of binding updates in a mobile network using the original architecture and the new NEMO-CR with the four selected schemes. Moreover, increasing the number of CNs in the NEMO-RO will lead to an increase in the number of BU messages, especially when signaling storm occurs after handoff and for MIRON and Ad hoc protocols, where the number of BU reaches 21440 BU messages and 11440 BU messages, respectively, when the number of CNs increases to 25. The four delegation schemes that remain near the x-axis when increasing the number of CNs with the new proposed architecture NEMO-CR are shown in Fig. 3; therefore, with the new architecture, signaling load and bandwidth consumption will be reduced and aggregate performance will be enhanced.

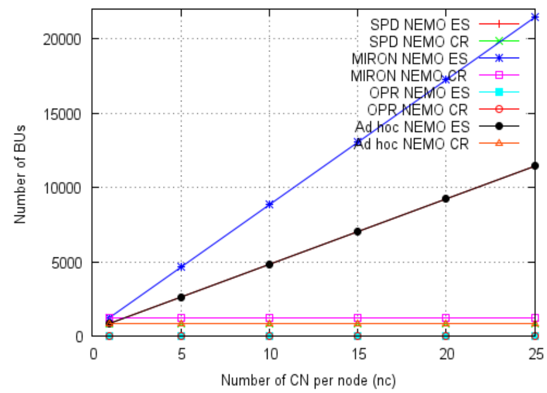

Fig.3. The Cost Of Binding Update In A Mobile Network For Both NEMO-RO And NEMO-CR

The communication between an MNN and one or more CNs will consume MR memory. Fig. 4 shows the impact of increasing the number of CNs on the MR Memory overhead in the NEMO-RO and NEMO-CR architectures. The highest memory overhead is observed when using the OPR scheme due to the tracking of all communication between the MNN and CNs; this is unlike the use of the OPR scheme in a NEMO-CR architecture, where it remains constant and less affected by increasing the number of CNs. The memory overhead at MIRON scheme within NEMO-RO architecture is less affected compared with the OPR NEMO-RO because it only tracks the LFNs through its CN communication. However, because we use the NEMO-CR with MIRON, the consumption of memory overhead is reduced and remains constant while increasing the number of CNs. The consumption of memory overhead for both Ad hoc protocols and SPD is lower in both the NEMO-RO and NEMO-CR because these architectures only track the session continuity; moreover, for SPD, the memory overhead is near the x-axis in both architectures because of the hierarchical prefix delegation.

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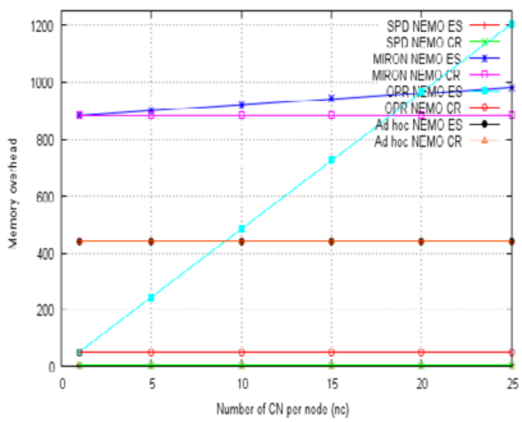

Fig.4. The Impact Of The Number Of Cns At Memory Overhead In Both NEMO-RO And NEMO-CR

4. CONCLUSIONS

The NEMO basic support protocol supports the movement and changes in the point of attachment of entire networks. This solution suffers from a number of limitations and problems that affect network performance, such as signaling overhead, memory overhead, header overhead and network delay. Due to these limitations, route-optimization procedures may not be supported in NEMO-RO architectures. To overcome and alleviate the performance penalty, correspondent router entity have designed and evaluated with four selected schemes. This architecture NEMO-CR supports the route-optimization procedure to enhance manageability, conservation of bandwidth and network performance in an aggregated way. In a NEMO-CR network, CN is easy to "plug and play", and applying modifications to the CR is more reliable and scalable than trying to modify the CN. This paper examines four selected schemes and showed the superiority of the CR in different route optimization schemes. However, CR may face a lack in signaling cost and security considerations when signaling storm happened. Therefore, more investigations are required as a future work.

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