ABSTRACT

Network Mobility (NEMO) Basic Support protocol is an extension Mobile IPv6. NEMO signaling is performed with extended of Mobile IPv6 messages. NEMO Basic Support protocol is concerned with managing the mobility of an entire network, it provides for devices or vehicles which move to another point of attachment to the Internet. NEMO can maintain sessions established between nodes on the mobile network and the global Internet after the Mobile Router (MR) changes its point of attachment. However, NEMO uses a bi-directional tunnel between the MR and its Home Agent (HA), resulting in a pinball route between 2 nodes. In addition, nested mobile networks will further increase the sub-optimality of routing, causing problems for some application. This proposed solution decreases packet delay, network resource usage and processing delay. Also, the bi-directional tunnel can be avoided, and the level of nesting of mobile networks does not increase packet overhead. This solution only requires modification of the MR.

Keywords
Network Mobility, Mobile IPv6, Mobile Router, Route Optimization

1. INTRODUCTION

The requirement for wireless networking and ubiquitous Internet increases quickly, users need to connect to the Internet anytime. A user may want to use more than one mobile device such as a PDA, a mobile phone, a laptop and sensor devices. In addition, a vehicle (as trains, buses, ships and cars) today requires many sensor devices. Each device may need to connect to the Internet to function completely. Each of these devices have single or multiple network interfaces. If these devices or vehicles move to another point of attachment to the Internet, we need what has been called Network Mobility (NEMO) basic support protocol [1] which is extended from Mobile IPv6 [2] for moving a mobile network.

A difference between Mobile IPv6 and NEMO, is that in Mobile IPv6 each host has the mobility support, but Network Mobility requires only the router to support the mobility function. All nodes which use Mobile IPv6 to support the mobility function need to include Mobile IP support which can be expensive. NEMO can be low-cost, in addition to reducing transmission power, hand-off delays and bandwidth consumption.

Presently, the NEMO Basic Support protocol essentially creates a bi-directional tunnel between a Mobile Network and Correspondent Node (CN) which suffers from sub-optimal routing of packets. In addition, where a mobile network could be attached under another mobile network, which is known as nested mobile networks, it might incur the packet delay and costs of multiple encapsulations. It is a critical problem for some real-time applications such as Video conference and Voice-over-IP. In this paper we propose route optimization in nested mobile networks using Binding Update (BU) for the top-level MR. The next section describes the background of NEMO and problem statement in nested mobile networks. The proposed solution is presented in section 3. In section 4, an evaluation of our solution is given. The next section presents an overview of related work. The end of this paper is the conclusion and future work in section 6.

2. BACKGROUND

2.1 Network Mobility based on Mobile IPv6

The IETF has been working on Mobile IPv6. Mobile IPv6 is a protocol to ensure movement transparency to a single host (Host Mobility). By the use of Mobile IPv6 a node can change its point of attachment without affecting higher level applications. Mobile IPv6 was published as RFC 3775 [2] and RFC 3776 [3]. RFC 3775 describes IPv6 mobility for mobile nodes, more specifically mobile hosts. RFC 3776 specifies the use of IP security in the context of RFC 3775.
A MIPv6 Mobile Node (MN) registers with a Home Agent (HA) and establishes a bidirectional tunnel. One endpoint of the tunnel is fixed at the home agent address. The other endpoint of the tunnel is located at the mobile node’s Care-Of Address (CoA), it changes as the mobile node roams. The association between the Home Address of a mobile node and its CoA is called a binding.

A MN would register a binding between its Home Address (HoA) and Care-of Address (CoA) with the HA. When the MN moves away from home link, it has to send a BU message to inform the HA of its new CoA. When the HA receives this BU, it sends a Binding Acknowledgement to indicate the status of the registration. When packets from the CN are routed to the HA, the packets are tunneled to MN. The HA uses proxy neighbor Discovery [4] to intercept any IPv6 packets addressed to the MN’s home address on the home link. Each intercepted packet is tunneled to the Mobile Node’s care-of address. Packets to the CN are tunneled from the MN to the HA (reverse tunnel) and then routed normally from the home network to the CN.

Route Optimization (RO) between MIPv6 MN and MIPv6 CN works only between MN and CN that support the feature in their IPv6 stacks. MN can also be a CN to communicate with other MN. When RO is established, packets are transmitted directly between the CN and the MN in both directions.

Network Mobility support is concerned with managing the mobility of an entire network. This is when a router connecting a network to the Internet dynamically changes its point of attachment to the fixed infrastructure, thus causing the reachability of the entire network to be changed in relation to the fixed Internet topology. Such a network is referred to as a mobile network. Without appropriate mechanisms to support network mobility, sessions established between nodes in the mobile network and the global Internet cannot be maintained after the mobile router changes its point of attachment. As a result, existing sessions would break and connectivity to the global Internet would be lost.

MIPv6 cannot be used unchanged in this scenario as the network mobility assumption is that a whole network, and its attaching router move as a unit. MIPv6 requires a HA be left attached to the original home network in order to function. Since no remnant of the original network is left, no HA can remain either and MIPv6 must necessarily fail.

NEMO operation is shown as Figure 1. Firstly, operations of the MR are similar with a MN in Mobile IPv6. But the MR is acting as a gateway between an entire mobile network and the point of attachment to the Internet via its egress interface. The MR provides a home address on that interface from the home link where its HA can also be found. When the MR is away from the home link, it is provided a care-of address from the foreign link. Just as in MIPv6, the MR uses a BU to notify its HA of a new CoA, thus new Internet attachment point. The BU contains the new CoA, the router flag, and an optional Mobile Network Prefix (MNP) in the Mobility Header (a new IPv6 extension header) which is used to update the network prefix information. Also, the BU format contains the Home Address of the Mobile Router in Home Address option, carried by the Destination option extension header [5].

The Mobile Network Nodes (MNN) are connected inside the mobile network. MNNs configure their addresses with the Mobile Network Prefix (MNP) which is advertised by the MR. The MNP must be globally routable. The HA is responsible for forwarding all the traffic to the mobile network prefixes (MNNs) toward the care-of address (CoA) of the Mobile Router.

These prefixes are used by the HA to intercept packets addressed to mobile nodes and tunnel them to the MR’s CoA (the HA uses IP-in-IP encapsulation). When the MR receives the tunneled packets, it decapsulates them and forwards them to the MNs. Packets in the reverse direction (packets from MNNs) are also tunneled via the HA in order to overcome Ingress filtering (so called Bi-directional Tunneling). In this case the HA decapsulates packets and forwards them to the CN.

2.2 Problem Statement in Nested Mobile Networks
Nested Mobile Network will occur when there is more than one level of mobile network. Thus the MR attaches behind another MR, it is a mobile network in the upper mobile network. The NEMO basic support protocol uses bi-
directional tunneling, so all packets sent between a Mobile Network Node and its CN are forwarded through MR and HA. A Result would be a pinball route between 2 nodes [7]. If the number of nested levels increases, using NEMO Basic Support will further amplify the sub-optimality of routing.

All packets must transmit from CN to Mobile Network through HA, so transmission time of the packet is normally longer than if the packet is routed straight from the mobile network to the CN. Since both inbound and outbound packet would through the HA of all MR in Nested Mobile Network [8]. These are effects of pinball routing:

- Packet delay because the pinball routing which is a serious problem for real time applications such as Voice over IP (VoIP) and Video conference.
- The efficiency of TCP because the transmission rate of TCP depends upon the round-trip-time of the communication.
- More bandwidth usage and traffic congestion which lead to packet losses.
- Bottleneck in HA or Home Network, since all packets forward through the HA which has been connecting with the home link.

Thus, if the number of mobile networks increases in communication, the number of HAs increase too, so the path would be more sub-optimal routing. An interesting case is where the CN is located in the same set of nested mobile networks with MNN [14].

Each added level of nested mobile networks requires an extra IPv6 header for an additional tunnel encapsulation. This extra IPv6 header is added per level of nested mobile networks shown in Figure 2, thus it can be the multiple encapsulations for data packet which increases extra overhead of the packet.

These effects of multiple encapsulations:

- Increase in packet size, since the encapsulation of packets from the tunneling between HA and MR. It can also reduce the effective bandwidth available.
- Increase processing delay in intermediate hops which encapsulate packets for tunnel of HA and MR.

The overhead per packet of NEMO BS would add a new IPv6 header for tunneling between each MR and HA pair.

3. PROPOSED NEMO ROUTE OPTIMIZATION IN NESTED MOBILE NETWORKS

3.1 Goals and Requirements

This proposed solution is most relevant for nested mobile networks. Our solution decreases packet delay, avoids packet delivery through all HAs (avoiding the bi-directional tunnel in NEMO BS protocol), and the levels of nesting mobile network should have no effect to packet overhead [9]. This solution needs to modify the only MR, it uses the existing CN without modification (We assume the CN can support the MIPv6 Route Optimization mechanism.) We do not modify the MNN or the Access Router. The MR must be modified to perform the Route Optimization.

3.2 Proposed Solution

This proposed solution can reduce packet delay, network resources usage and processing delay (less processing delay at the point of encapsulation and decapsulation). Additionally, this solution would mean less packet overheads, and it also avoids routing traffic through the home network, which may be a bottleneck. As a mechanism for route optimization, it should manage both non-nested NEMO and nested NEMO to solve the sub-optimal routing problem from NEMO BS. This solution is designed to solve these problems for small mobile networks (such as mobile network inside a car, train, aircraft, etc.).

In the NEMO BS protocol, the bi-directional tunnel is the default route for the MR. All packets from NEMO are encapsulated at the MR and tunneled to its HA. MNN’s MR should be able to route directly to CN instead of its default tunnel to the MR’s HA. Our solution abstracts this nested mobile network as a single static network and exchanges route information with other MRs in the intra-mobile networks. The MR would make a decision for the route of the destination. If the CN is located via the Internet, this solution applies the top-level MR as gateway that is useful for this situation. Our solution uses the MIPv6 Route Optimization mechanism established to the CoA of the top-level MR as gateway of nested mobile networks to bypass all HAs. All packets meant for nested mobile networks are always directly routed to the CoA of Top-level MR. If CN and MNN are located in same set of nested mobile networks. MNN’s MR should be able to
route directly to CN instead of the MIPv6 Route Optimization mechanism. So the packets destined to other MNNs are routed to the destination in the same nested NEMO based on the routing table of each MR.

Figure 3 Extended RA carries top-level MR’s CoA
This solution must utilize the CoA of the top-level MR to perform the Route Optimization. Other MRs can know the CoA of the top-level MR in the mobile networks using an extended RA (Router Advertisement) message that carries the CoA of the top-level MR as shown in Figure 3. When the top-level MR receives the RA from the AR, it sends the extended RA to the mobile networks. The Extended RA message adds a flag (R flag) indicating that it is a MR. The CoA of the top-level MR must be included in the extended RA. When the top-level MR moves and changes its point of attachment to the internet, the CoA in the extended RA message is changed to the new CoA. When the nest level of a mobile network is larger than 2, the sub-MR must relay the CoA down through the nested mobile networks. Furthermore, the other MRs in nested mobile networks must preserve the CoA of the top-level MR from the extended RA.

3.2.1 Binding Update for CN
The route optimization is initialized by the sub-MR when it receives a tunneled packet from the sub-MR’s HA. A packet tunneled from the HA indicates that an unoptimized flow exits. When the sub-MR has detected such a packet, initialization for the route optimization can be started for the CN. However, receiving a packet must meet all of the conditions for trigger of the route optimization. Moreover, the route optimization may be controlled by some policies, to avoid heavy load to the MR. In this case, when the route optimization cannot be performed, the MR stops initiating the route optimization procedure and follows the plain NEMO Basic Support protocol operation.

Figure 4 shows the signaling involved in optimizing routing using the Mobile IPv6 Return Routability (RR) procedure [6] for authorization. The sub-MR must perform the MIPv6 RR procedure with the MNN’s HoA. The procedure involves sending the home test init (HoTI) and care-of test init (CoTI) messages to the CN and processing the replies (HoT and CoT message). The RR procedure is used to ensure that the MN’s HoA and MN’s CoA are collocated. For our solution, we adopt the procedure described. The sub-MR sends HoTI that is protected by IPsec ESP between the sub-MR and its HA. The HoTI is sent via the MNN address which is encapsulated for tunnel between the sub-MR and its HA. In CoTI case, this solution uses the CoA of the top-level MR for the BU message to the CN, if the RR procedure is used as the authorization method, the CoTI must have been performed for the top-level MR’s CoA. When the top-level MR is requested by the sub-MR, it will send CoTI instead of the sub-MR using the top-level MR’s CoA as the source address. When the top-level MR receives CoT from the CN, it copies a care-of nonce index, care-of cookie and care-of keygen token from that CoT to send a new CoT to the sub-MR.

After the RR procedure completes, the sub-MR can send a BU message to the CN using the MNN’s address as HoA in an Alternate Care-of Address mobility option. When the CN receives the BU, if the BU includes an Alternate Care-of Address mobility option, the CN must verify the authenticator by using the address within the Alternate CoA in the calculation. Once the CN has verified the MAC, it can create a Binding Cache entry for the MNN’s address and the top-level MR’s CoA.

3.2.2 Binding Update for Top-level MR
The sub-MR would apply the top-level MR as gateway of nested mobile networks. However, the top-level MR needs a means to trust the BU messages from the sub-MR. In particular, the sub-MR’s BU should be authenticated when the sub-MR sends the BU to the top-level MR for updating the Binding Update database. That is, they need an authentication method. The top-level MR must verify the addresses in the BU. However, the top-level MR needs to avoid retaining state, because an attacker could cause another node (i.e. top-level MR) to do lots of work. The sub-MR sends the BU to the top-level MR’s CoA to inform the MNN and the CN address for the establishment of optimized route. This BU uses a new Top-level MR (T) flag. This T flag bit is set by the MR to request the top-level MR processes the BU for updating the Binding Update database.

The sub-MR starts the process for authentication which is adapted from the RR procedure, and then sends the Mobile Router Test Init (MRTI) that contains the HoA of the sub-MR, A Mobility Header (new type for MRTI) includes the MNN and CN addresses. When the top-level MR has received the MRTI message, it sends the MRT (Mobile Router Test) to the sub-MR’s HoA to the Internet through the top-level MR’s HA, and contains a cryptographically generated token that is generated from the MNN address, CN address and nonce. The MRT message is also protected by IPsec tunnel between the sub-MR and its HA, so it obtains some reasonable assurance that the MR which receives MRT is in fact addressable at its HoA.
When the sub-MR receives the MRT message, it will hash the MR keygen token to form a 20 octect binding management key (Kbm). After the sub-MR has created the Key, it can supply a verifiable Binding Update to the top-level MR. The contents of the BU include the following: Home Address Option that is the MNN’s address, Alternate Care-of Address option that is the CN’s address, MR nonce index and Binding Authorization Data. Rules for calculating the Authenticator value are the following.

\[
\text{Authenticator} = \text{First (96, HMAC\_SHA1 (Kbm, (MNN address | CN address | Mobility Header data)))}
\]

The sub-MR sends BU to the top-level MR to inform address of the MNN and the CN. When the top-level MR receives the BU from the sub-MR, it must check that the BU flags include the T flag and verify the MAC. Afterwards, the top-level MR creates Binding Update database for this BU. The top-level MR will set an expiry time, requiring that the sub-MR must send another BU with T flag to the top-level MR before the Binding Update database expires.

3.2.3 Establishment of Route Optimization

After this procedure has succeeded, packets sent by the CN follow a direct path to the top-level MR, not traversing the HA, as a result of the Route Optimization. These packets contain the top-level MR’s CoA as destination address, and also contain a Type 2 routing header with the MNN’s address as next hop. When the top-level MR receives packets that contain a Type2 routing header, it will process and remove the routing header of the packet, checking if the next hop address belongs to other nodes within nested mobile networks. In order to allow forwarding of such packets, the top-level MR must forward the packet based on its routing table (the routing table that is exchanged with other MRs) after checking the packet. If the MR does not have any explicit routes for the packet, then the packet is silently discarded. In the opposite direction, when the top-level MR receives the packet sent by the nodes within
nested mobile networks. The mechanism first checks destination addresses of a packet, to determine whether the packet is target for NEMO Route Optimization. The source and destination address are compared with an entry in the Binding Update database. If found Route Optimization is enabled for the packet. The top-level MR replaces the source address with the top-level MR’s CoA and inserts HoA destination option that contains the MNN’s address. When the CN receives the packet with HoA destination option, it checks if there is a corresponding Binding Cache entry. The CN must process the option in a manner consistent with exchanging the MNN’s address from the HoA option into the source address field there.

This solution effects to ICMPv6 error messages such as Destination Unreachable and Packet Too Big. Because this solution will add the Home Address Option and change a source address in IPv6 header at the top-level MR, of which the MNN is not aware, this solution needs to modify the top-level MR to manage this problem.

4. EVALUATION

For Route Optimization in nested mobile networks using BU for the top-level MR, the key implementation of this solution is the management of the MIPv6 RO between the MNN and CN, and the BU for the top-level MR. The MR has to perform the RR procedure instead of MNN, it can be modified with the existing MR function. The MR is acting as the sub-MR, it must send the message to request the top-level MR to send the CoTI via CoA of the top-level MR. Also, the MR can perform the MIPv6 RO, and it must be modified to forward the packet which carries a Type2 routing header to the destination in nested mobile networks. The packet of MNN is sent to the CN, the top-level MR can insert the Home Address option for the flow which is target of RO. In addition, the MR must maintain the Binding Update database of MNN and CN pair which is performing the route optimization. The BU for the top-level MR is added for the new MR function. Furthermore, the MR is acting as the top-level MR, it must be able to receive this BU and add the binding of MNN and CN flow in the Binding Update database. The functions required by the implementation are modifications to the existing SHISA mobility stack [15] on FreeBSD 5.4.

We experiment three different scenarios to compare between the NEMO Basic Support protocol and our solution. We use Netperf to measure TCP and UDP throughput. CN is the client and MNN is the server. The first scenario is non-nested mobile network. Second scenario is nested mobile networks as shown in Figure 5. Third scenario is nested mobile network which is 3 levels of nesting, HA1 has the binding of MR1 and MR3, and HA2 has the binding of MR2. All scenarios run on FreeBSD 5.4 with SHISA, the MR machines run our solution that extends the NEMO Basic Support protocol by SHISA.

4.1 UDP Throughput

The UDP throughput is compared between the NEMO Basic Support protocol and our solution in three scenarios. The CN uses Netperf in IPv6 and sends UDP packets with a payload size of 1024 bytes so we avoid fragmentation when the Path MTU is exceeded.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>NEMO BS</th>
<th>Our solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-nested NEMO</td>
<td>89.22 Mbps</td>
<td>90.74 Mbps</td>
</tr>
<tr>
<td>Nested NEMO</td>
<td>85.85 Mbps</td>
<td>90.50 Mbps</td>
</tr>
<tr>
<td>Nested NEMO (3 MRs)</td>
<td>33.62 Mbps</td>
<td>90.44 Mbps</td>
</tr>
</tbody>
</table>

Table 1 shows the results, the evaluation finds the maximum UDP throughput that can be sent from the CN to MNN in several scenarios. The maximum UDP throughput is higher when our solution is operated. In 3 levels of nesting, the UDP throughput of NEMO Basic Support protocol is 33.62 Mbps that is very low because of network congestion caused by the pinball routing. Our solution can improve efficiency of the throughput. Moreover, NEMO Basic Support adds an extra IPv6 header for tunneling of 40 bytes per level of nesting. It can lead to reduce PMTU that impacts to the performance. On the other hand, our solution needs to add 24 bytes, even if the level of nesting increases. Our solution, the packet loss is 0.09% in scenario 3, but packet loss of NEMO Basic Support protocol is 63.62% because each level of nesting in NEMO requires a tunnel between the MR and its HA.

4.2 TCP Throughput

The TCP throughput is compared between the NEMO Basic Support protocol and our solution in three scenarios.
The CN uses Netperf (with TCPIP6_STREAM) to send TCP packets to MNN.

Table 2 Comparison of TCP throughput

<table>
<thead>
<tr>
<th>Scenario</th>
<th>NEMO BS</th>
<th>Our solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-nested NEMO</td>
<td>78.01 Mbps</td>
<td>87.74 Mbps</td>
</tr>
<tr>
<td>Nested NEMO</td>
<td>66.02 Mbps</td>
<td>84.72 Mbps</td>
</tr>
<tr>
<td>Nested NEMO (3 MRs)</td>
<td>31.50 Mbps</td>
<td>81.96 Mbps</td>
</tr>
</tbody>
</table>

Table 2 shows the results, the maximum TCP throughput is also higher when our solution is operated. In 3 levels of nesting, the TCP throughput of NEMO Basic Support protocol is 31.50 Mbps but our solution can improve efficiency of the throughput. In NEMO Basic Support protocol, 3 levels of nesting make the longer path that is CN – HA1 – HA2 – HA1 – Router – MR1 – MR2 –MR3 – MNN. It increases the packet delay and packet overhead from encapsulations that may require packets to be fragmented.

4.3 Comparison of RTT

We measure the RTT on average between the MNN and the CN. The measurement is based on Ping6 program with a packet size of 64 bytes as shown in Table 3.

Table 3 Comparison of RTT

<table>
<thead>
<tr>
<th>Scenario</th>
<th>NEMO BS</th>
<th>Our solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-nested NEMO</td>
<td>0.637 ms</td>
<td>0.461 ms</td>
</tr>
<tr>
<td>Nested NEMO</td>
<td>1.187 ms</td>
<td>0.605 ms</td>
</tr>
<tr>
<td>Nested NEMO (3 MRs)</td>
<td>1.347 ms</td>
<td>0.724 ms</td>
</tr>
</tbody>
</table>

The packet delay of NEMO Basic support protocol is higher because the packets are delivered through the HAs. In our solution, the RTT is 0.724 ms in 3 levels of nesting, it is about half of the RTT in NEMO Basic Support protocol.

4.4 Comparison of Packet Overhead

In the NEMO Basic Support protocol overhead are affected by the number of levels of mobile network nesting which the number of encapsulations needed for each packet. Our solution decouples the network nesting depth from the packet overhead. Figure 6 shows the packet overhead from each method as the nesting depth is increased. The packet overhead of NEMO Basic Support protocol increases with each level of nesting whereas our solution maintains a constant overhead of 24 bytes per packet. We also avoid use of a tunnel between a MR and its HA.

Figure 7 compares the additional NEMO packet overhead with the packet size, showing the percentage of overhead in each packet, assuming a packet data size of 50 bytes, and the IPv6 header size of 40 bytes. The overhead of NEMO Basic Support quickly becomes large for small data packets, such as may be found in voice transmission, as the level of network nesting increases. This may have significant effects for some real-time applications.

5. RELATED WORK

Our solution utilizes the CoA of the top-level MR as gateway of nested mobile networks to perform NEMO route optimization. Moreover, the solution can avoid using a bi-directional tunnel in NEMO Basic Support protocol. ONEMO [13] uses the CR and the Nest Entrance Point, which is the CoA of the root-MR. Once the root-MR decapsulates the packet, it’s routed down the nest to the destination. The bi-directional tunnel is required for ONEMO. RRH [10] proposed a new Routing Header, called RRH and RH2 extension, to record intermediate CoA of MRs in nested mobile networks into the packet header. It needs extended RH2 to route from the HA to first the MR in NEMO, and the level of nesting mobile networks effects the packet overhead. MIRON [12]
proposes a route optimization for NEMO based on MIPv6. It can use the route optimization support for MIPv6 available in the CN. In nested mobile networks, the MIRON use a MIRON Access Router (MAR) that is a modified AR for some operations required by MIRON (e.g. modified DHCPv6 relaying function). The Route Optimization Using RIPng protocol [11] provides Visited Mobile Router in NEMO to register with its HA of its location, which would be top-level MR through the use of any types of conventional routing protocol such as RIPng. It also needs to forward through 2 HAs and the bi-directional tunnel.

6. CONCLUSION
In this paper we proposed route optimization in nested mobile networks using BU for the top-level MR. This proposed solution can reduce packet delay, network resources usage and processing delay from NEMO Basic Support protocol. Also, the bi-directional tunnel can be avoided. In addition, the levels of nesting mobile networks have no effect to packet overhead, so this solution means less packet overheads. The proposed solution can manage both non-nested NEMO and nested NEMO. It uses the MIPv6 Route Optimization mechanism using the CoA of the top-level MR as gateway of nested mobile networks to perform route optimization. This solution needs to modify only the MR, it operates with an existing CN which supports MIPv6. This proposed solution is simple to implement. In evaluation, our solution shows efficiency in three scenarios, the UDP and TCP throughput are higher when our solution is operated. Furthermore, the packet delay and packet loss can be decreased. But the evaluation depends upon the topology of the test environment. Thus, the results can be different in another configuration. Future work of this solution should be to study what needs to be done to improve signaling messages and reliability. The proposed solution might not be the best solution, but it can bypass all HAs and avoid the bi-directional tunnel in NEMO Basic Support protocol that causes the small packet overhead, nevertheless, it is idea in order to perform NEMO route optimization.

7. REFERENCES