Network Mobility in Satellite Networks

Abu Zafar M. Shahriar, Mohammed Atiqzzaman
Telecommunications and Networks Research Lab
School of Computer Science, University of Oklahoma,
Norman, OK 73019.
{shahriar,atiq}@ou.edu

***Abstract*—Future Low Earth Orbiting spacecrafts will contain several IP-enabled devices that are accessible by users through ground stations. As the spacecraft moves around the Earth, mobility solution, such as Mobile IPv6 can be used to handle the mobility of the devices when satellites handover between ground stations. However, if the devices are connected to an on-board Local Area Network, the mobility management of the devices can be handled in an aggregated fashion using Network Mobility from the Internet Engineering Task Force. NEMO enjoys several advantages, such as reduced signaling, increased manageability and conservation of bandwidth when applied to a set of IP-enabled devices moving together. In this paper, we measure the performance of Mobile IPv6 and NEMO by comparing the performance of the two protocols. We found that NEMO is more effective than MIPv6 when the number of hosts is large.**

***Index Terms*—Host Mobility, MIPv6, Network Mobility, NEMO BSP, Performance analysis, Satellite Network.**

I. Introduction

Spacecrafts and satellites in space contain devices and instruments to sense and takes measurements of Earth and space. Low Earth Orbiting (LEO) satellites handover between ground stations as they rotate around the Earth. Future LEO satellites will contain several IP-enabled devices that are accessible through ground stations by users on Earth. As the spacecraft moves around the Earth, mobility solution, such as Mobile IPv6 can be used to handle the mobility of the devices when satellites handover between ground stations.

Mobility devices, such as those on-board a spacecraft, while connected to the Internet is called host mobility. Existing location-based addressing scheme of the Internet, where addresses valid in a geographical area is not valid in other areas do not permit host mobility. To allow host mobility, Internet Engineering Task Force (IETF) designed Mobile IP (MIP) [1] and MIPv6 [2]. Although MIP or MIPv6 solves the problem of host mobility, it suffers from signaling overhead, handoff latency and inefficient routing.

Host mobility management is not an effective method of managing the mobility of hosts which are moving together, such as in a vehicle, train or satellite. Use of MIP for managing the mobility of such hosts result in inefficiencies such as increased signaling overhead, increased power consumption, requirement for each host to have powerful transceiver to communicate with the access router, etc. Moreover, nodes which are not capable of running MIP can not communicate with the outside world.

To solve the problem of aggregate mobility of hosts, IETF has proposed NEtwork MObility (NEMO) where the hosts that move together are connected in a LAN, and the router in the LAN manages the mobility for all the hosts on the LAN The NEMO Basic Support Protocol (NEMO BSP) [3] from IETF is a logical extension of MIPv6. NEMO BSP performs better than MIPv6 to handle mobility of a large number of nodes, though NEMO BSP has several limitations such as inefficient route for packets, header overhead and all the limitations inherited from MIPv6 that limits its realization in practical networks. The *aim* of this paper is to measure and compare the performance of MIPv6 and NEMO BSP for handling the aggregate mobility of hosts.

The concept of NEMO can also be applied to LEO satellites. Future satellites can contain several IP enabled devices (such as camera, sensors, recording devices etc.) that are connected to the ground stations by using the Internet protocol. As the satellites move around the Earth and connect with different ground stations, the connections of the on-board IP enabled devices have to be handed off between ground stations. NEMO can be applied to satellite networks if we connect the on-board devices in a LAN.

The *objective* of this paper is to compare the performance of MIPv6 and NEMO BSP when several nodes are moving together. The authors are not aware of any such study in the literature. We carry out the performance comparison using ns-2 [4] simulation. Results show that although it is possible to handle mobility of multiple hosts using either MIPV6 or NEMO BSP, the performance of NEMO BSP is better in terms of manageability and signalling overhead for a large number of hosts. The main *contribution* of this paper is the performance comparison of MIPv6 and NEMO BSP.

The rest of the paper is organized as follows. Sec. II presents previous research in performance evaluation of mobility protocols. Application of mobility protocols in satellite networks is presented in Sec. III. Host mobility and MIPv6 is introduced in Sec. IV followed by network mobility and NEMO BSP in Sec. V. In Sec. VI, we present our simulation results and a comparative performance analysis of MIPv6 and NEMO BSP. Finally, Sec. VII concludes the article with future work for satellite networks.

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II. Previous Research

There has been several research efforts to evaluate the performance of MIPv6 and NEMO BSP separately. An analytical study on HMIPv6 has been carried out by Castellucia [5]. A protocol overview of Mobile IPv6, HMIPv6 and FMIPv6 along with results on handoff latency for MIPv6 can be found in [6]. In [7], Mobile IPv6 and its enhancements are studied that focused mainly on measuring handoff latency. Torrent-Moreno et al. [8] carried out simulation to evaluate and compare the performance of fast handovers schemes of Mobile IPv6 and baseline Mobile IPv6. Handoff performance of mobile host and mobile router was investigated by Omae et al. [9].

Performance of NEMO BSP has been evaluated by simulation to compare the enhanced NEMO BSP schemes with NEMO BSP. Simulation has been used to evaluate and compare the performance of NEMO BSP with various improved NEMO BSP versions [10]–[12]. Experimental evaluation of NEMO BSP has also been reported in the literature [13]–[15].

It is clear from the above discussion that all previous studies were based on separate evaluations of MIPv6 and NEMO BSP. To the best of our knowledge, there has been no effort to evaluate and compare the performance of MIPv6 and NEMO BSP. In this paper, we compare MIPv6 and NEMO BSP with a motivation to quantify the benefits of NEMO over Mobile IPv6.

III. Mobility in Satellite Networks

Spacecrafts communicate with ground stations on the earth and among themselves to transfer data traffic. Depending on the altitude, satellites can be classified into three types: Low Earth Orbit (LEO), Medium Earth Orbit (MEO) and Geosynchronous Earth Orbit (GEO). GEO satellites are stationary with respect to earth and require fewer ground stations. LEO satellites rotate around the earth at a lower altitude than GEO satellites and require larger number of ground stations. LEO satellites are handed off between ground stations and require mobility management to maintain continuous connectivity with hosts on the ground [16].

Satellites carry on-board equipment for data collection in space. The IP-enabled equipment can be considered as mobile nodes in space. Mobile IP [17] [18] and SIGMA [19] have been used for mobility management by considering the equipment as mobile nodes. If the on-board equipment are connected in a Local Area Network on the satellite, the mobility of the hosts can be managed in an aggregated fashion by considering the LAN as a mobile network and managing the mobility of the LAN (in contrast to individual hosts as in Mobile IP), a concept called Network Mobility (NEMO) which is being developed by the Internet Engineering Task Force [3]. NEMO enjoys several advantages, such as reduced signaling, increased manageability and conservation of bandwidth when applied to a set of IP-enabled devices moving together.

IV. Host Mobility

Internet Protocol (IP) [17] and its later version, IPv6 [18] was designed with fixed hosts in mind. Thus, when a host is moving in IPv6 network and eventually gets out of a particular area (called home network of the host), it is not reachable any more in the IPv6 network using its assigned IPv6 address called home address. When a host is out of its home network, its home address is no longer valid in the new network. All the packets sent to its home address reaches its home network (not the new network which the mobile host is in) and as the host is not in its home network, the packets cannot be delivered to the host. As it may appear, the problem can be solved by having the mobile host getting a new valid address whenever it comes to a new network. But transport and higher layers connections can no longer be maintained when the a host changes address. So, to solve the problem of reachability of hosts during movement in the IPv6 network, IETF came up with a new protocol called Mobile IPv6 (MIPv6) [2]. Basic approach of MIPv6 is to keep the mobile host reachable by its home address independent of the location of the mobile host. MIPv6 defines a new IPv6 protocol and new options to support mobility. All IPv6 hosts, whether mobile or stationary, can communicate with mobile hosts. In this section, we describe the core MIPv6 and related performance issues.

A. MIPv6

Home address of the mobile node is the address which is configured from the subnet prefix of the mobile host's home network. When the mobile node comes to a new network (foreign network), it gets a new address which has the subnet prefix of the foreign network. This new address is called Care of Address (CoA). After getting the CoA, the mobile host registers the CoA with a router in its home network called Home Agent (HA) by sending a message called Binding Update (BU) message. HA keeps a cache entry to map the home address to the CoA in the binding cache. BUs are sent frequently (for a while) immediately after the handoff and after that rate of BU sending is reduced just to refresh the binding cache entry periodically. Thus, HA always have the current location of the mobile host.

There are two modes of operation for the mobile host - bidirectional tunneling mode and route optimization mode. Fig. 1 illustrate the bidirectional tunneling mode. In this mode, when a packet is sent to the home address of the mobile host when the mobile host is not in the home network, the packet is routed to the HA. HA finds the CoA from the binding cache and sends the packet to the mobile host by tunneling [20] using IPv6 encapsulation [21].

Fig. 2 shows the schematic view of routing packet in the route optimization mode. In this mode of operation, the mobile host registers its CoA with both HA and correspondent node (the node with which the mobile host communicating). Like HA, Correspondent Node (CN) also have a binding cache. Unlike bidirectional mode, the packets from the CN are directly sent to the CoA (found in the binding cache of CN) of the mobile host. A new type of routing header [18] is used to carry the desired home address of the mobile host while the destination address is set to the CoA. Similarly, the packets, sent to the CN from the mobile host, have the CoA

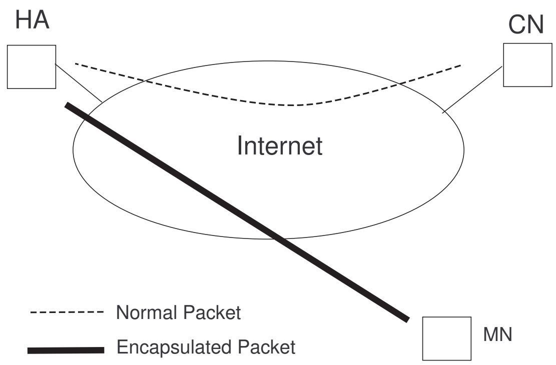

Fig. 1. Routing packet for a mobile node in MIPv6 in tunneling mode.

as the source address while a new destination option header is used to put in the home address of the mobile host.

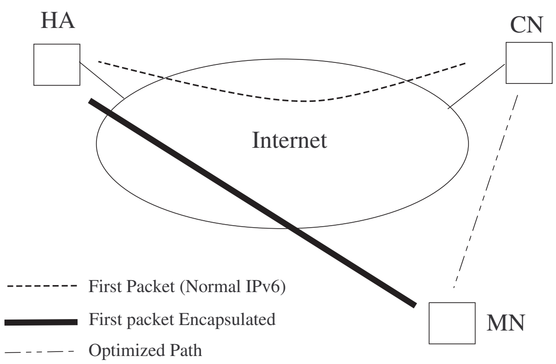

Fig. 2. Packet route for a mobile node in MIPv6 in route optimization mode.

B. Performance Considerations

Although MIPv6 provides the advantage of mobility in IPv6 networks, it is not without cost. The handoff speed of basic MIPv6 is not suitable for realtime traffic. Also the routing path for a packet is longer than it should be when the mobile host is not in its home network. Though this problem of inefficient routing can be solved by operating in route optimization mode (see Section IV-A), this mode of operation needs all the hosts (whether mobile or not) in the Internet to be MIPv6 capable to take advantage of the route optimization feature. This requirement for route optimization poses a challenge to implement MIPv6.

V. Network Mobility

Mobility protocols like MIP or MIPv6 are not suitable to handle network mobility. This is because, it would require each of the nodes of the mobile network to use sophisticated protocols like MIPv6, and location management signaling during handoff causing increased signaling overhead. To manage the mobility of the nodes in a network collectively, one or more routers called Mobile Router (MR) are employed to act as gateways [22] for the nodes in the mobile network. There could be different types of nodes inside the mobile network. A Local fixed Node (LFN) is the one that does not move with respect to the mobile network. But a Local Mobile Node (LMN) can move to other network from the mobile network whereas a Visiting Mobile Node (VMN) can get attached to the mobile network form the another network. A node inside the mobile network can even be an MR itself with an entire mobile network behind it. However, all the nodes within the mobile network reach the Internet through the MRs that are managing mobility. Whenever the point of attachment in the Internet is changed during movement, it is the responsibility of the MRs to perform handoff and keep the transparency of the movement inside the mobile networks. The advantages of realizing network mobility in this way are are as follows:

- Reduced transmission power: Only the MR needs to to be equipped with high-power communication capabilities to communicate with the base stations. The nodes inside the mobile network only needs to communicate with the MR to which the distance is much shorter than that of other access routers. So, nodes inside the mobile network needs low-power radio equipments.
- Supporting movement for MIPv6 incapable nodes: Not all the nodes may run MIPv6 inside the mobile network. But these nodes can be provided mobility support transparently by the MR.
- Reduced signaling overhead and bandwidth consumption: In NEMO BSP only MR is responsible for performing link-layer handoff and network layer signalling during handoff. All the other nodes inside the mobile network that have already established a connection with the MR do not need to perform handoff. Thus signalling overhead and consequently bandwidth consumption during handoff is reduced by much.
- Ease of management: MRs offers an central point of management for mobility features. If any updates is necessary in future, only the MR needs to be updated which is much easier.

These advantages are achieved by NEMO over host mobility when number of simultaneously moving node is large. In this section, we describe the basic protocol for NEMO and the limitations of the protocol.

A. NEMO Basic Support Protocol

In NEMO BSP the network to which a mobile network is usually connected is called the home network. An MR is registered with a router in its home network called Home Agent (HA) and has a Home Address (HoA) through which it is reachable when it is in its home network. MRs are also delegated one or more address prefixes to use inside its network. When the MR moves out of its home network to a foreign network, the MR obtains a new address called Care-of-Address (CoA) from the foreign network. After obtaining the CoA, the MR sends a binding update (BU) to its HA informing the new CoA, and indicating that it is acting as a router by setting a bit in the BU message along with the prefixes of the mobile network. Binding update procedure is similar to that of the MIPv6 except the extra bit setting and sending prefix information. HA sends a positive Binding Acknowledgement (BA) to indicate that forwarding to the MR is set and creates a binding cache entry that maps the HoA and prefixes of MR to the CoA of the MR. Once the binding process is completed, a bi-directional tunnel [20] is established between the HA and the MR. All the packets destined to the mobile network are tunneled to the MR by HA.

Fig. 3 shows the routing of packets for an LFN. When a node outside the mobile network (called Correspondent Node (CN)) sends a packet to a node in the mobile network, the packet is routed towards the HA as the HA advertise the prefix of MR in the network. After receiving the packet, HA tunnels it to the MR by encapsulating the packet. MR receives, decapsulates and forward the packet to the destination node. Packets in the reverse direction also follow the same path.

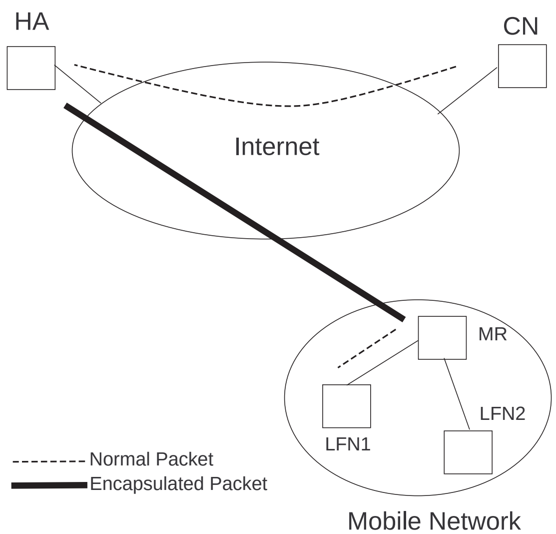

Fig. 3. Packet route for LFN.

Fig. 4 shows a packet going through multiple tunnels in a nested mobile network. In case of nested network, an MR (nested MR) with its network moves inside another mobile network under another MR (root MR). The nested MR obtains a CoA from the prefix of the root MR and performs binding procedure with the HA of nested MR. When a CN sends a packet to a node inside the mobile network of the nested MR, HA of the nested MR intercepts, encapsulates and tunnels the packet to the CoA of the nested MR. Since this CoA is configured from the prefix used by the root MR, the packet will be again intercepted by the HA of the root MR. HA of the root MR will again encapsulate the packet and tunnel it to the root MR. Root MR decapsulates the the packet and forwards it towards the nested MR. Nested MR again decapsulates the packet and sends it to the destination node inside its network. Therefore, two tunnels exists and a packet is encapsulated twice for a single level of nesting.

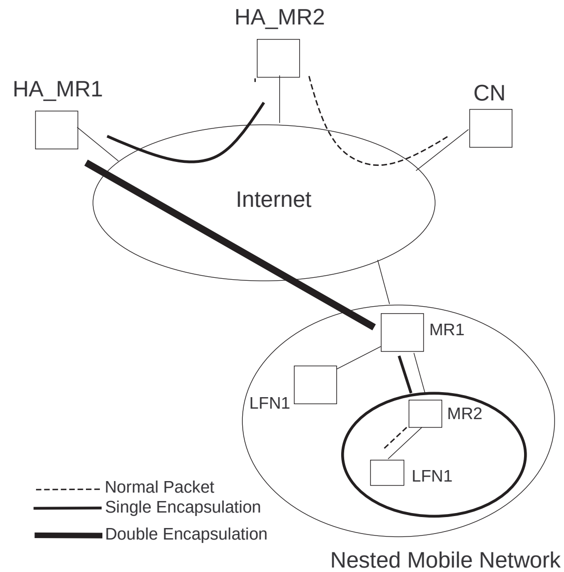

Fig. 4. Multiple tunneling in nested mobile network.

B. Limitations

NEMO BSP is a logical extension to the MIPv6 discussed in Sec. IV-A by increasing the capability of an MIPv6 node to act as a router with the capability of registering nodes for its own network. So, NEMO BSP poses several limitations when applied to practical networks and extends the limitations of MIPv6. This section presents the limitations of NEMO BSP.

1) Inefficient Routing: As it is evident from Figs. 3 and 4 that packets sent by CNs do not reach a node inside the mobile node directly. All the packets reach the mobile network through a bidirectional tunnel which is setup between the HA and the MR. Thus if the MR moves away from the HA, the path traversed by packets will be very long even when the mobile network is linked with the same network as the CN. This long route causes a longer time to reach the destination when a shorter path exists. The scenario is even worse in case of nested mobile network where packet have to go through multiple tunnels causing the round trip time to increase. This is termed as *pinball routing* problem, and the problem continues to get worse with the increase in the level of nesting.

Another problem associated with the pinball routing problem is the *header overhead*. As a packet passes through each tunnel it is encapsulated by the HAs. So, the packet size is increased that requires more bandwidth. Moreover, the time required for encapsulation and decapsulation increases the time required for packet delivery in addition to the time required due to pinball routing.

2) Handoff performance: Handover procedure of an MR as presented in Sec. V-A is similar to that of a MIPv6 node [2]. When an MR moves to a foreign network, it has to discover an access router and obtain a new CoA from the access router. Then the MR has to complete the binding procedure with the HA. This handoff procedure introduces delay in the middle of ongoing connections. The delay increases when the mobile network is nested. In case of a nested mobile network the nested MRs' binding update will suffer additional delay due to multiple indirections involved in the route that reinforce the delay caused by the handoff process itself.

VI. Results

In this section, we compare the performance of MIPv6 and NEMO BSP by simulating the scenario when multiple nodes are moving together. We developed NEMO BSP on ns-2 by extended the MobiWan [23] implementation of MIPv6. We measured and compared the throughput, packet loss and signaling overhead for both the protocols.

A. Simulation scenario

Figs. 5 and 6 show the topology used in our simulation for NEMO BSP and MIPv6, respectively. For MIPv6, all mobile nodes moving together individually connect to the base stations. We used seven base stations in the simulation, with one of the base stations as the HA. For NEMO BSP, a mobile network consisting of a mobile router and several LFNs, connects to the different base stations as the network moves. Packets are sent from CN to the mobile nodes or LFNs using FTP.

The default range of 802.11 in ns-2 is 240 meter; the base stations were thus placed 370 meter apart to form continuous wireless coverage with enough overlapping area. The velocity of the mobile nodes or network was set to 5 meter per second. The mobile nodes or the mobile network is initially connected to the home network through home agent.

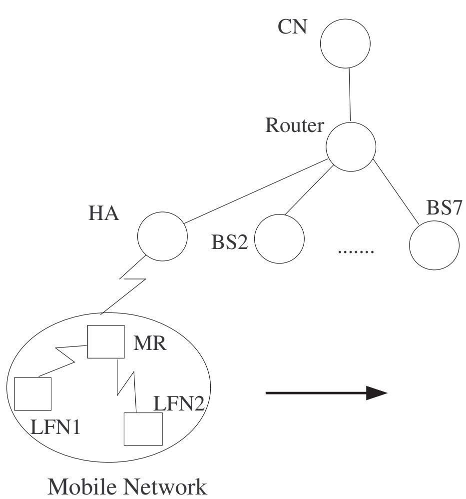

Fig. 5. Topology used for simulating NEMO BSP.

B. Simulation results

In this section, we present performance comparison of MIPv6 and NEMO BSP, using results obtained from simulations described in Sec. VI-A.

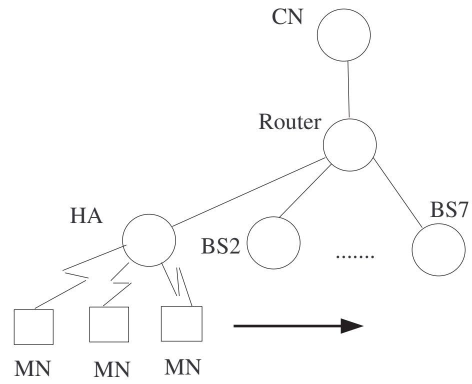

Fig. 6. Topology used for simulating MIPv6.

1) Throughput: Throughput is computed by adding the number of bytes received at all the nodes per second. Fig. 7 shows the throughput of MIPv6 and NEMO BSP as a function of the number of nodes. Throughput of MIPv6 is slightly better than that of NEMO BSP for the following reason. The performance of TCP, which is used as the transport layer protocol by Ftp, degrades with increase in the Round Trip Time (RTT) of the connection. NEMO BSP, having two wireless hops in contrast to one in case of MIPv6, has a higher RTT than MIPv6. Therefore, the throughput of NEMO BSP is lower than MIPv6.

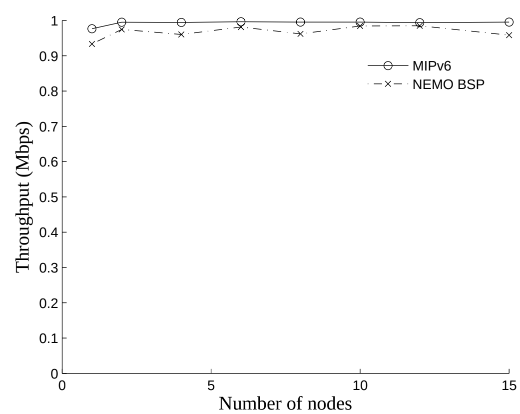

Fig. 7. Aggregated throughput for mobile nodes or LFNs vs number of nodes for MIPv6 and NEMO BSP

2) Signalling overhead: Signalling overhead is measured by the number of BUs (see Secs. IV-A and V-A) sent by all the mobiles nodes (or MR in case of NEMO BSP) to the HA. Fig. 8 shows the number of BUs sent as a function of the number of nodes for both MIPv6 and NEMO BSP. The number of BU is independent of the number of LFNs in case of NEMO BSP. This is expected, as only MR sends BU to the HA during handoff, regardless of the number of nodes in the mobile network. But for MIPv6, the number of BUs grows linearly with increase in the number of nodes. The linear increase in case of MIPv6 is due to each mobile node individually sending BU to the HA during handoff.

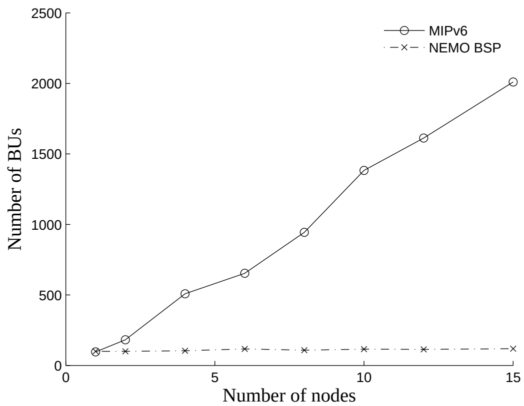

Fig. 8. Number of binding update sent vs Number of nodes for MIPv6 and NEMO BSP

3) Percentage packet drops: Packet drop (%) for MIPv6 is defined as the ratio of the number of TCP packets received at all the mobile nodes to the number of TCP packets received at the HA. Packet drop (%) for NEMO BSP is defined as the ratio of the number of TCP packets received at all the LFNs to the number of TCP packets received at the HA. Packet drops as a function of the number of nodes is shown in Fig. 9. Two factors contribute to packet drops: (i) wireless channel contention, and (ii) packet losses during handoff due to unavailability of connection.

As seen in Fig. 9, for small number of nodes, packet drop during handoff is almost equal for both protocols due to similar handoff delay. However, drops from channel contention is higher for NEMO BSP due to packets traversing two wireless hops. Consequently, packet drop in NEMO BSP is higher than MIPv6 for smaller number of nodes.

For large number of nodes, handoff delay for MIPv6 is larger than NEMO BSP due to higher channel contention resulting from larger number of BU packets during handoff. The higher channel contention results in increased RTT for the BU packets. Increased handoff delay thus causes more packet drops (which dominates over drops due to channel contention) for MIPv6 during handoff.

For NEMO BSP, only MR sends BUs, resulting in no channel contention during handoff. This gives rise to lower handoff delay (resulting in lower packet drops) for NEMO BSP over MIPv6.

C. Comparison of MIPv6 and NEMO BSP

Analysis of the results indicates that throughput of NEMO BSP is slightly less that that of MIPv6. But NEMO BSP has the advantage of imposing less processing task on the home agent due to reduced number of signaling messages. Also, reduced number of signaling message cause less delay during handoff and hence the number of packet drops during handoff is less for NEMO BSP when large number of node is

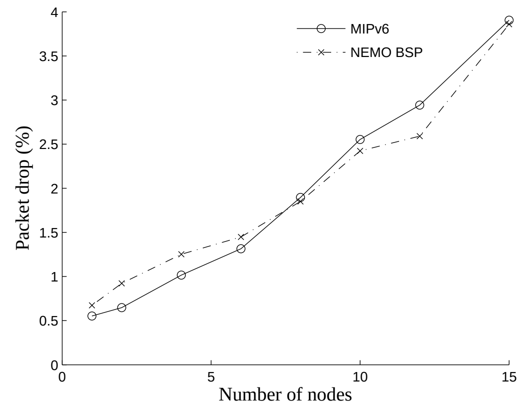

Fig. 9. Percentage packet drop vs Number of nodes for MIPv6 and NEMO BSP

involved. The packet drop during handoff will cause realtime applications to suffer more in case of MIPv6. Moreover, as mentioned in Sec. V, NEMO BSP has the advantage of increased manageability and simulation results reveals that this advantage is achieved without any significant sacrifice in the throughput.

VII. Conclusion

In this paper, we compared the performance of MIPv6 and NEMO BSP by simulation. Results shows that NEMO BSP has advantages of less signaling overhead than MIPv6, while the throughput reduction in case of NEMO BSP due to one extra hop is negligible. Our main focus was to quantify the benefits of NEMO BSP over MIPv6 and to show that NEMO BSP is better than MIPv6 when several nodes moving together. Handoff delay for MIPv6 and NEMO BSP are yet to be measured. We also intend to measure the performance of both MIPv6 and NEMO BSP for satellite networks and compare the results.

References

[1] C. Perkins, "IP mobility support for IPv4," RFC 3220, January 2002.

[2] D. B. Johnson, C. E. Parkins, and J. Arkko, "Mobility support in IPv6," Internet Draft, June 2003.

[3] V. Devarapalli, R. Wakikawa, A. Petrescu, and P. Thubert, "Network mobility (NEMO) basic support protocol," Internet-Draft, January 2005.

[4] "The network simulator - ns-2," http://www.isi.edu/nsnam/ns/.

[5] C. Castelluccia, "HMIPv6: A hierarchicalmobile IPv6 proposal," in *ACM Mobile Computing and Communication Review (MC2R)*. April 2000, ACM SIGMOBILE.

[6] N. Montavont and T. Noel, "Handover management for mobile nodes in IPv6 networks," *IEEE Wireless Communications Magazine*, August 2002.

[7] R. Hsieh, A. Seneviratne, H. Soliman, and K. El-Malki, "Performance analysis on hierarchical mobile IPv6 with fast-handoff over end-to-end TCP," in *IEEE Global Telecommunications Conference (GLOBECOM)*, 2002.

[8] M. Torrent-Moreno, X. Perez-Costa, and S. Sallent-Ribes, "A performance study of fast handovers for mobile IPv6," in *IEEE International Conference on Local Computer Networks*, October 2003.

[9] K. Omae, M. Inoue, I. Okajima, and N. Umeda, "Handoff performance of mobile host and mobile router employing HMIP extension," in *Wireless Communications and Networking*, March 2003, pp. 1218–1223.

[10] H. Cho, E. K. Paik, and Y. Choi, "Rbu+: Recursive binding update for End-to-End route optimization in nested mobile networks," in *Springer*, 2004, pp. 468–478.

[11] H. Petander, E. Perera, K.C. Lan, and A. Seneviratne, "Measuring and improving the performance of network mobility management in IPv6 networks," *IEEE Journal on selected areas in communications*, vol. 24, no. 9, pp. 1671–1681, September 2006.

[12] C.M. Huang, C.H. Lee, and J.R. Zheng, "A novel SIP based route optimization for network mobility," *IEEE Journal on selected areas in communications*, vol. 24, no. 9, pp. 1682–1691, September 2006.

[13] M. Watari, T. Ernst, and J. Murai, "Routing optimization for nested mobile networks," *IEICE transaction on communication*, vol. E89-B, no. 10, pp. 2786–2793, October 2006.

[14] M. Calderon, C. J. Bernardos, M. Bagnulo, I. Soto, and A. de la Oliva, "Design and experimental evaluation of a route optimization solution for NEMO," *IEEE Journal on selected areas in communications*, vol. 24, no. 9, pp. 1702–1716, September 2006.

[15] A. Banno, T. Oiwa, and F. Teraoka, "χLIN6-NEMO: A network mobility protocol based on lin6," *IEICE transaction on communication*, vol. E88-B, no. 7, pp. 2765–2776, July 2005.

[16] M. Atiquzzaman, S. Fu, and W. Ivancic, "Trash-sn: A transport layer seamless handoff scheme for space networks," in *NASA Earth Science Technology Conference (ESTC)*, Palo Alto, CA, June 2004.

[17] "Internet protocol," Internet Draft, September 1981.

[18] S. Deering and R. Hinden, "Internet protocol, version 6 (IPv6) specification," Internet Draft, December 1998.

[19] S. Fu, M. Atiquzzaman, L. Ma, and Y.-J. Lee, "Performance of sigma: A seamless handover scheme for data networks," *Wireless Communications and Mobile Computing*, vol. 5, no. 7, pp. 825–845, Nov 2005.

[20] A. Conta and S. Deering, "Generic packet tunneling in IPv6 specifications," RFC 2473, December 1998.

[21] D. Farinacci, T. Li, S. Hanks, D. Meyer, and P. Traina, "Generic routing encapsulation," Internet Draft, March 2000.

[22] T. Ernst and H-Y. Lach, "Network mobility support terminology," Internet draft, November 2006.

[23] "Mobiwan:ns-2 extensions to study mobility in wide-area IPv6 networks," http://www.inrialpes.fr/planete/mobiwan/.