EXPERIMENTS WITH IPV6 NETWORK MOBILITY USING NEMO PROTOCOL

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ABSTRACT

The NEMO (NEtwork MObility) protocol, as normalized by IETF, allows a transparent movement of a whole IPv6 network. This mobile network can thus attach to different points in the Internet without losing TCP/IP connectivity of its mobile nodes. In this paper we briefly describe the NEMO protocol and present a simple architecture deployed to test its main functionalities. We also discuss the results obtained thus far with the use of popular TCP and UDP applications in a mobile environment: video streaming transfer, remote access using SSH and FTP file transfer.

KEYWORDS

IPv6, MIPv6, MIP, NEMO, Network Mobility, Wireless

1. INTRODUCTION

The success and increasing use of mobile IP devices in wireless networks (e.g., laptops, PDAs and cellular phones) allows a growing deployment of Personal Area Networks (PAN). This type of networks enables users to stay connected to the Internet, using different IP devices, without loss of service. As an example, a user with a PDA, a cellular phone, and a laptop can be "online" continuously using all devices, having each one its own Internet access and IP address.

In IPv6 networks (Deering, S., Hinden, R., 1998) it is possible to provide mobility to all the devices in these mobile networks using the MIPv6 (Mobile IPv6) protocol (Johnson, D. et al., 2004 and Soliman, H., 2004). However, the fact that all the network devices are mobile implies that each one must support IPv6 mobility, using MIPv6 protocol. This method is not efficient since all the devices have to implement mobility functions, even those that do not have enough resources to run such protocol. Moreover, usually it is less computationally costly to have several devices sharing the same Internet access and, as for instance in Vehicular Ad-Hoc Networks (VANETs), several devices may be continuously moving all together.

In order to solve such problems, the NEMO (NEtwork MObility) protocol (Devarapalli, V. et al., 2005) extends MIPv6 functionalities and provides mechanisms for network mobility management, enabling the networks to attach to different points in the Internet without loss of its current connections. In this protocol the mobile nodes connections to the Internet are done through a unique device, a mobile device, avoiding the need to have all the mobile devices supporting MIPv6.

This paper presents an architecture to test the features of NEMO and describes some results obtained with typical TCP and UDP based applications.

2. IPV6 NETWORK MOBILITY – NEMO PROTOCOL

A comprehensive technical explanation of IPv6 and NEMO protocols is largely available in literature (Deering, S., Hinden, R., 1998 and Devarapalli, V. et al., 2005 and Manner, J. et al., 2004). Nevertheless, a brief summary of the main terminology and overall functioning of the NEMO protocol is presented.

Let us assume a small local IP network interconnecting a laptop, a PDA and a cellular phone. These devices share a common local network, usually in a wireless environment. In NEMO, the mobility of these IP devices is assured by a Mobile Router (MR) that extends the Mobile Node (MN) functionalities defined in MIPv6 (Johnson, D. et al., 2004). Broadly speaking, this Mobile Router can be the laptop that enables connecting all the IP devices in the local network to the Internet. The laptop can thus change dynamically its point of access to the Internet (for example, during a travel by car or train), keeping intact the IP addresses and network connections of the mobile nodes during the mobility periods. One can say that the network moves itself as a whole without a separate move of each of the nodes. This paradigm can be seen as Network Mobility and implemented by protocol NEMO. This idea confronts the Node Mobility support from previous mobility protocols, such as MIP and MIPv6.

The basic NEMO operation can be seen as follow (Devarapalli, V. et al., 2005): (1) when the MR moves, it informs the Home Agent (HA) about the prefix(es) of the mobile network that the HA should route traffic to; (2) the HA binds the IP address of the MR in the visited network, the Care-of Address (CoA), to its address in the home network, the Home Address (HoA); (3) after the mobile network has moved and the MR's addresses have been bound at the HA, the HA starts routing the traffic targeted to the mobile network to the visited network, through an IPv6/IPv6 tunnel established between both routers (MR and HA). The HA is a router in the home network responsible for routing the traffic it receives, whose destination is the mobile network, to its current location.

The NEMO operation derives directly from the MIPv6 operation. The management of network mobility is done by adding new mechanisms and operations to MIPv6 operation, such as mobile network prefix management by the HA and traffic routing, to and from those mobile networks, by means of the MR and HA (Devarapalli, V. et al., 2005).

3. STATE OF THE ART

The NEMO protocol has been standardized by IETF (Internet Engineering Task Force) and promoted by several entities and research projects such as WIDE/Nautilus6, KAME and TAHI among others.

The NEMO specification is quite recent, and thus there are currently only two well known complete open source and active implementations: SHISA (WIDE project implementation of Mobile IPv6 for both BSD and MacOS) and NEPL (NEMO Platform for Linux). The implementation for Microsoft Windows, MIPv6 Tech Preview, is currently not supported and has been discontinued.

Several related research projects are being developed by some organizations, namely InternetCAR Project (InternetCAR, 2002), E-Bicycle (E-Bicycle, 2006), E-Wheelchair (Ernst, T., 2004), CVIS Project (CVIS, 2007) and IPv6 e-Vehicle (Moos, T., 2003) among others.

4. ARCHITECTURE

The experiments detailed in this paper are part of an ongoing project in IPv6 (www.ipv6.estg.ipleiria.pt) and its support for mobility. Figure 1 depicts the general architecture deployed to test the NEMO functionalities. The mobile network is served by a MR and has only one node (Mobile Network Node - MNN). There is a correspondent node (CN), used to simulate Internet accesses and with which the MNN exchanges packets. The IP address of the MR in the visited network, the CoA, is automatically configured by the MR, based on the Router Advertisement (RA) messages (Narten, T. et al., 1998) sent by the Access Router (AR), when it moves to the visited network. The figure also depicts the operating system of the nodes in the network, as well as the network mobility software being used.

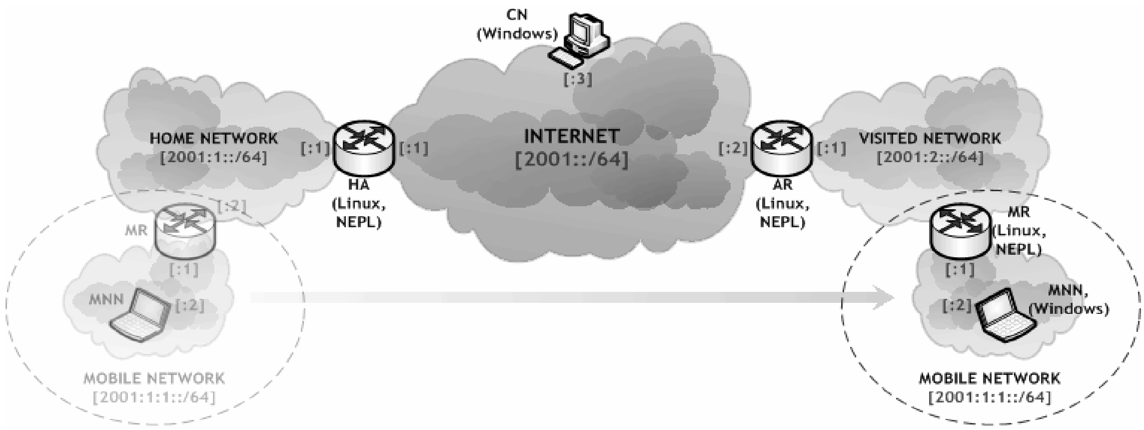

Figure 1. Testbed architecture

A simple set of tests has been performed in order to achieve two major goals: (1) to validate this implementation of NEMO according to the specification and (2) to analyze, with both TCP and UDP based applications, the continuity of established network connections, during the transit of the mobile network from the home to the visited network.

All routers (HA, AR e MR) are Linux (Fedora Core 6) based running NEPL implementation of NEMO. All routers are configured to send RA messages through the Linux IPv6 Router Advertisement Daemon (www.litech.org/radvd/). This daemon runs in every Linux or BSD systems acting as IPv6 routers. It sends periodically RA messages to an Ethernet LAN and when requested by a node sending a Router Solicitation (RS) message (Narten, T., e al., 1998). The RA announcements occur in the minimum admissible interval, so that the MR can detect, as fast as possible, the movement between networks (home and visited), and thus speeding up the handover at the IPv6 network layer. The Access Points (APs), Cisco® Aironet® 350 Series, share the same SSID (Service Set IDentifier), allowing the MR to move between both networks, with no loss of connectivity and transparently to the end user applications. During the movement to the visited network, when the MR detects a stronger signal from another AP with the same SSID, it connects to this AP, executes the physical and link layer handover process and, finally it becomes bound to the visited network.

In the tests, three common Internet applications have been used: video streaming (UDP), SSH remote access (TCP) and FTP file transfer (TCP).

The tests for each specific application enclosed the following actions:

- CN was configured as a video streaming server and started the transmission to the MNN (a video streaming client). While transferring the video stream, the mobile network moves to the visited network and it has been verified that the stream was still being received at the MNN;
- an SSH session was established between the MNN and the AR. Then the mobile network was moved to the visited network and the SSH session was still active (as well as the underlying TCP session);
- an FTP file transfer was initiated on the MNN to the CN and the mobile network was moved between the home and the visited networks several times. At the end, as expected, the file transferred was exactly the same as the original one.

5. RESULTS

After preliminary tests, three main problems arose, related with the NEPL application:

1. when the mobile network was at the origin network, the MR didn't route traffic to the Internet;
2. when the mobile network was moved to the visited network, the MR sent a Binding Update to the HA but the HA didn't send the corresponding Binding Acknowledgement;
3. the tunnel created between the HA and the MR didn´t work in the direction from MR to HA. It was working only in the opposite direction.

After some contacts with the NEPL development team, some answers have been found to the stated problems:

1. the first problem was already a known but unsolved bug. After some messages about this issue, a patch has been released (nemo-0.2-homenet-fix-20070109.diff) in order to fix the problem;

2. in order to solve the second problem, some new developments were initiated. Subsequent to our tests, two experimental patches to the NEPL application have been released (USAGI Project development tree);

3. the last problem was related to the previous one. The solution was to use the OptimisticHandoff option in both the HA and the MR. This option was not available in the existing NEPL release (version 2.0), so we used the 20060725 nightly snapshot released subsequently (version 0.2.1).

The tests showed the robustness of the NEPL implementation of NEMO. During the transition of the mobile node from the home to the visited network, the existing sessions were kept while the whole network was moving.

However, some events that caught our attention were reported. During the first test we noticed that, when the mobile network moved from the home network to the visited one, or vice-versa, there was a short disturbance (between 2 to 3 seconds) in video reception at the MNN, which indicated that an handover took place and the consequent loss of some stream packets. After the short video outage, the video continued playing again perfectly in the MNN.

In both the second and third tests it has been noticed that, after several network transitions between home and visited networks, the TCP sessions were still active between the MNN and the AR even with some dropped packets.

Figure 2 illustrates the interaction between MNN and AR during the mobile network transit. It depicts a time/packet sequence graph of an SSH session, using Wireshark, based on the packets captured in the output interface of the MR. In this graph it is possible to identify both handovers corresponding to the movement in both directions (seconds 34 to 49 and 85 to 88).

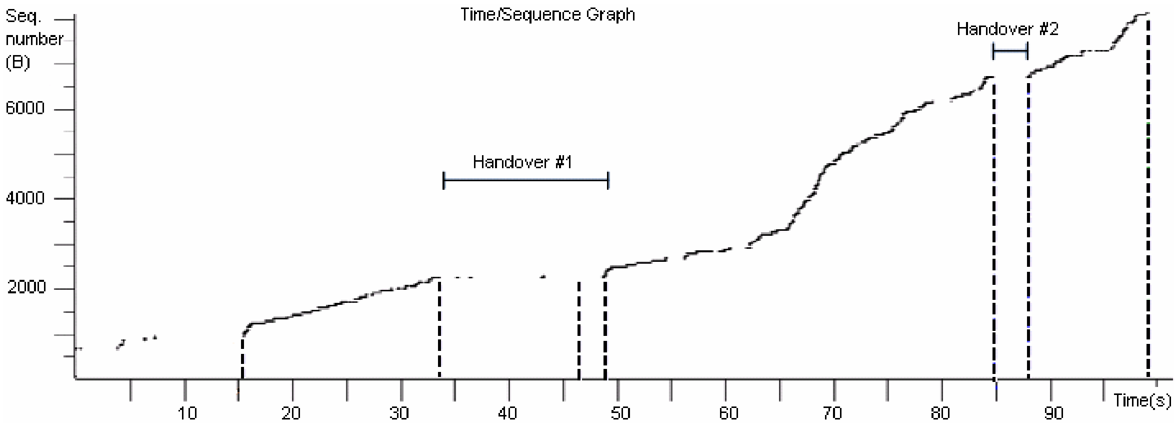

Figure 2. SSH session time/sequence graph (Wireshark) during mobile network movement.
0 s: SSH session start; 15 s: “find /” command execution; 34 s: L2 handover and packet loss start; 46 s: L3 handover start, 1st binding update sent; 49 s: 2nd binding update sent, L3 handover end, TCP traffic reception again; 85 s: L2 handover and packet loss start; 88 s: binding update sent, L3 handover end, TCP traffic reception again; 99 s: SSH session end.

It is also possible to verify that there is no data loss in the SSH session, because there is no difference in the sequence numbers before and after the handovers.

The set of three experiments described above have been carried out several times in order to confirm the obtained results. This network was implemented in a very restricted and controlled environment and all the systems have been configured in order to use only the extremely necessary network services.

6. CONCLUSIONS AND FUTURE WORK

In this paper we briefly described the NEMO protocol and presented a simple network architecture implemented and used to test its functionalities. NEMO functioning has been tested by analyzing the behavior of mobile nodes running three different applications: video streaming transfer (UDP), SSH remote access (TCP) and FTP file transfer (TCP).

Based on the tests results one can conclude that TCP/IP connections between MNN and CN are maintained during network handovers. Despite some packet loss during handovers, there is no data loss and TCP communications were able to recover. In the video streaming transfer, some stream packets have been lost but this doesn't interfere with the final results.

Despite its recent deployment and some immaturity of its current implementations, we may notice that this technology has potential in a near future, in both wired and wireless environments, based on the effective mobility of a whole network. These experiments gave us confidence to continue the tests with NEMO and the development of applications that can solve real world problems. The ability to move a network as a whole, instead of moving independently each mobile node, can be of great benefit to some real applications. For instance, the salesmen that usually carries a PDA, a laptop and a cellular phone and need immediate access to the network all day long, when visiting the customers. It could be easier and safer to have Internet access through one mobile router (e.g., the laptop) instead of having different accesses for each device.

We intend to optimize the experiments done so far and analyse the use of NEMO in a bigger network. We also intend to quantify the packet loss and delay in the handover process. These measures will be of great importance to infer about the appropriateness of NEMO in real world networks.

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