Development of a NEMO-based demonstration platform in IPv6

Romain KUNTZ
kuntz@sfc.wide.ad.jp
Master Thesis of Network Computer Engineering
University Louis Pasteur
(DESS reseaux et telecommunications)

University Louis Pasteur, Strasbourg, France

Keio University, Japan

Region Alsace, Boussole scolarship

Nautilus6 working group

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Under the supervision of Thierry Ernst, Keio University, Japan, Philippe Clauss and Thomas Noel, University Louis Pasteur, France.

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Preface

The objective of this internship in the Nautilus6 working group is to work on the development of a NEMO-based demonstration platform in IPv6. This includes working on the hardware side, the implementation side and the improvement of the technology. This document aims at describing each feature of the demonstration platform, followed in appendix A by the author's personal contribution and conclusion, and in appendix B by several interesting usages of IPv6-based technologies.

Contents

Chapter 1

Introduction

1.1 Presentation of the environment

1.1.1 Jun Murai Laboratory and the WIDE organization

Jun Murai Laboratory is located in the Shonan Fujisawa Campus (SFC [1]) of Keio University [2]. Its goal is to support the research of Keio University students by providing computer equipments and fund to research projects. It is the headquarter of the WIDE organization [3].

According to WIDE website [3]: "The aim of the WIDE Project, launched in 1988, is to establish a Widely Integrated Distributed Environment: a new computer environment based on operating systems and communications technology, designed to benefit the human race on a broad scale".

The WIDE organization includes several working groups gathered in research areas, such as the application area, the security area, the transport area, or the Internet area which KAME project [4], USAGI project [5] and Nautilus6 working group [6] belong to. WIDE is more than 400 members strong, coming from around 100 companies and 20 universities in Japan.

1.1.2 The Nautilus6 working group

Objectives

Mobility functions will be essential to achieve the all-IP Internet and to connect all devices to the Internet at any time and any place. To achieve this ubiquitous Internet, we need efficient mobility support mechanisms to maintain ongoing communication flows while on the move. Such mechanism include host mobility support (displacement of a single host in the IP topology without breaking open sessions [7]), network mobility support (displacement of an entire network in the IP topology without breaking open sessions [8]), ad-hoc networking (routing in an infrastructure-less network), in addition to other core IPv6 technologies such as multihoming, auto-configuration, multicast, security, access control etc. The combination of all these technologies will enable on one side cars, trains, airplanes to connect to the Internet and on the other side people carrying IP devices to keep uninterrupted access to the Internet whether they are located at home, office, or commuting between them or shopping. It will also enable new trends, such as PANs (Personal Area Networks, small networks made of a mobile phone, portable music players, PDAs and other devices carried by people) to permanently connect to the Internet via the mobile phone acting as a mobile router. It is in this objective that the Nautilus6 working group [6] was created within the WIDE organization [3].

IPv6 Network Mobility is one of the mobility features Nautilus6 wants to demonstrate through demonstration platforms. The E-bike testbed [9] and E-wheelchair testbed **??** (see appendix **??** will be used to demonstrate the benefits of network mobility (see chapter 2) for all kinds of configurations (for instance nested mobile network or multihomed mobile network). The E-bike testbed would be a portable IPv6 Personal Area Network (PAN) made of several IPv6 devices with several access technologies (802.11b, Ethernet, AirH etc.). It is currently under development and is expected to be a bicycle equiped with PDAs (such as SHARP Zaurus [10]), IPv6 sensors queried with SNMP, an IPv6 camera, and other IPv6 devices that can be tested in our showroom [11]. The E-wheelchair testbed follows technically the same ideas, but it will be set up to demonstrate the benefits of IPv6 and network mobility for health caring.

To demonstrate such technology, we first need to provide a better IPv6 mobility environment, this includes:

- Working on specification and contributing to the IETF effort,
- Working on GNU/Linux and *BSD reference implementations,
- Testing implementations, raising issues and suggesting solutions,
- Working on the application side, by testing IPv6 related librairies and softwares.
- Pushing for deployment of the underlying IPv6 infrastructure.

Members and collaborations

Nautilus6 [6] sits in the Internet area [12] of the WIDE organization. The working group co-chairs are Thierry Ernst (Keio University [2]) and Keiichi Shima (Internet Initiative Japan [13]). The team is composed of members (either students or employees) from japanese and foreign universities [14] such as University Louis Pasteur (Strasbourg, France), Keio University (Japan), ENST Bretagne (Rennes, France), Seoul National University (Korea), Tokyo University (Japan).

We particularly collaborate with the Network Research Group of LSIIT Laboratory in University Louis Pasteur (Strasbourg, France) on IPv6 seamless mobility. We work together on common projects, and share our knowledge by sending students between both laboratories as part of this collaboration: last may, a japanese Nautilus6 member joined the Network Research Group in Strasbourg during one month in order to setup an IPv6 multicast tunnel between both laboratories. We can now access the M6bone (a test network whose aim is to offer an IPv6 multicast service) through Strasbourg. He also setup an indoor testbed similar to Nautilus6's one. Conversely, a Ph.D. student from Strasbourg joined Nautilus6 during one month in August in order to work on seamless mobility with our japanese members.

We also collaborate with the Network and Multimedia Services (RSM) of the ENST Bretagne (Rennes, France) on the operational testbed. As a WIDE working group, Nautilus6 tightly collaborates with other WIDE groups: KAME [4], USAGI [5], TAHI [15], InternetCAR [16], SOI (School of Internet [17]) and E-care [18]. Some international companies also contribute to the working group.

Communication tools

Nautilus6 is located at Keio University K-square Town Campus [19] in Kawasaki, Japan. As Nautilus6 is composed of members that live in distinct countries, we need to use tools to share our results. We then have a wikiwikiweb [20] where all members can freely report their progress, ask questions, and inform other members about interesting news. We also try to produce as much as we can papers or documents about our results, and put them on the website to get feedback from other members. Also, we use audio and videoconference tools (such as Polycom [21] or Gnomemeeting [22]) to communicate between distant members.

1.2 Structure of this document

One of Nautilus6's main goal is to develop a NEMO demonstration platform such as E-bike [9] and E-wheelchair [23] to demonstrate NEMO (Network Mobility) capabilities and usages. In order to setup such a testbed, we need to work on several important features, described in the following subsections.

1.2.1 Communication system (based on NEMO)

The E-bike and E-wheelchair testbeds are based on the Network Mobility rudiments. We will thus introduce:

- The general concepts of Network Mobility,
- The terminology used in this document,
- The NEMO Basic Support protocol.

We present the general principles in chapter 2: "Network Mobility and NEMO Basic Support".

1.2.2 Choice of the equipment and operating systems

We also need to check which equipment and which operating system we can use on our demonstration platform. This includes:

- Research and review of some interesting equipments that fit to our constraints,
- IPv6 stacks tests and port to the SHARP Zaurus,
- Interoperability tests between Mobile IPv6 stacks.

We describe this survey in chapter 3: "Design of the Demonstration Testbed".

1.2.3 Implementation

We need a NEMO Basic Support implementation for our NEMO demonstration platform. We collaborate with USAGI [5] and GO-Core [24] teams in order to perform this task as following:

- Working on the stack design,
- Implementation on USAGI's IPV6 stack and GO-Core's userland,
- Implementation tests, and interoperability tests with other existing implementations.

We talk about this collaboration in chapter 4: "The NEMO Basic Support implementation".

1.2.4 Multihoming

Multihoming support is very important for our demonstrations. We think it is one of the key feature for a wide deployment of the technology. Working on this feature includes:

- Studying multihoming rudiments and existing solutions,
- Testing multihomed configurations with NEMO Basic Support in order to report potential issues,
- Reporting our results to the IETF, in order to share our results with experienced engineers,
- Working on solutions that will allow us to have full benefit of the technology for our demonstrations.

Our investigations are summarised in chapter 5: "Multihoming activities".

Chapter 2

Network Mobility and NEMO Basic Support

2.1 Network Mobility

This chapter introduces the general concepts of Network Mobility, the terminology used in this report and an overview of the NEMO Basic Support protocol.

2.1.1 General Principles

Nowadays, more and more devices are connected to the Internet, and people would like to stay connected anywhere and anytime: we speak about ubiquitous internet computing. In order to satisfy these constraints, we need to design and develop new solutions, especially on the mobility aspect, for people on the move (for instance passengers in public transportation, or pedestrians in the streets).

On one side the Mobile IPv6 protocol [7] manages mobility for only one host (host mobility support), on the other side Network Mobility (NEMO) manages mobility for one whole network which changes its point of attachment to the Internet and thus its reachability to the Internet topology (network mobility support). As shown on picture 2.1, thanks to NEMO the only computer that needs to have mobility functionnalities when the whole network moves is the one that connects the network to the Internet (this computer is then called a Mobile Router). On the contrary with the Mobile IPv6 approach each host in the network would have to handle mobility.

Running Mobile IPv6 on each node can be expensive, especially for little devices such as sensors, whereas NEMO only requires changes on the router. All others hosts in the moving network do not need any mobility feature, all movements in the Internet topology are be handled by the router, transparently for the hosts.

With NEMO, we can imagine lots of senarii where mobility can play an important role. Using Network Mobility in a train would allow the customers to stay connected to the Internet without disruption during all their trip. Network Mobility in cars as explained in [25] can allow to set up a PAN (Personal Area Network) made of tiny IPv6 sensors that can be queried from outside, and PDAs that can have permanent access to the Internet.

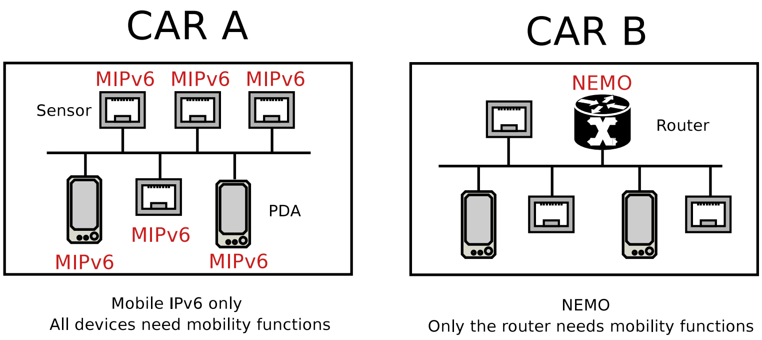

Figure 2.1: Difference between Mobile IPv6 and NEMO Basic Support

We can also imagine how to use this technology for health caring, by setting up little sensor networks for disabled people. The E-wheelchair testbed on which we work will help us to demonstrate such benefits.

2.1.2 NEMO Terminology

The IETF Working Group NEMO (NEtwork MObility) standardises solutions to manage Network Mobility. It specified a solution called NEMO Basic Support [8] that will be described in the next section. First, we give the terminology that will help the reader to understand what the following words refer to. As defined in draft-ietf-nemo-terminology-01 [26] and RFC 3753 (Mobility Related Terminology [27]):

- Mobile Network (NEMO): An entire network, moving as a unit, which dynamically changes its point of attachment to the Internet and thus its reachability in the topology. The Mobile Network is composed of one or more IP-subnets and is connected to the global Internet via one or more Mobile Routers (MR). The internal configuration of the Mobile Network is assumed to be relatively stable with respect to the MR.

- Mobile Router (MR): A router capable of changing its point of attachment to the network, moving from one link to another link. The MR is capable of forwarding packets between two or more interfaces, and possibly running a dynamic routing protocol modifying the state by which it does packet forwarding.

- Mobile Network Prefix (NEMO-Prefix or MNP): A bit string that consists of some number of initial bits of an IP address which identifies the entire Mobile Network within the Internet topology. All nodes in a Mobile Network necessarily have an address containing this prefix.

- Mobile Network Node or MNN: Any node (host or router) located within a mobile network, either permanently or temporarily. A Mobile Network Node may either be a mobile node or a fixed node.

- Nested Mobile Network: A Mobile Network is said to be nested when a Mobile Network is getting attached to a larger Mobile Network. The aggregated hierarchy of Mobile Networks becomes a single Nested Mobile Network.

- Ingress interface: The interface of a MR attached to a link inside the Mobile Network.

- Egress interface: The interface of a MR attached to the home link if the MR is at home, or attached to a foreign link if the MR is in a foreign network.

2.2 NEMO Basic Support

In this section we briefly present the NEMO Basic Support protocol, as defined at the IETF [8].

The NEMO Basic support protocol is an extension to the Mobile IPv6 protocol [7]. It enables the support for network mobility. This extension is backward compatible with Mobile IPv6, so a NEMO-compliant Home Agent can also be used as a Mobile IPv6 Home Agent. The NEMO Basic Support protocol ensures session continuity, connectivity and reachability for all the nodes in the Mobile Network, even as the Mobile Router changes its point of attachment to the Internet. The solution supports both mobile nodes and hosts that do not support mobility in the Mobile Network.

The protocol is based on Home Agent, Binding Update messages, and the use of a bi-directionnal tunnel. The pictures 2.2, 2.3 and 2.4 (taken from [28]) basically illustrate the principles of this solution.

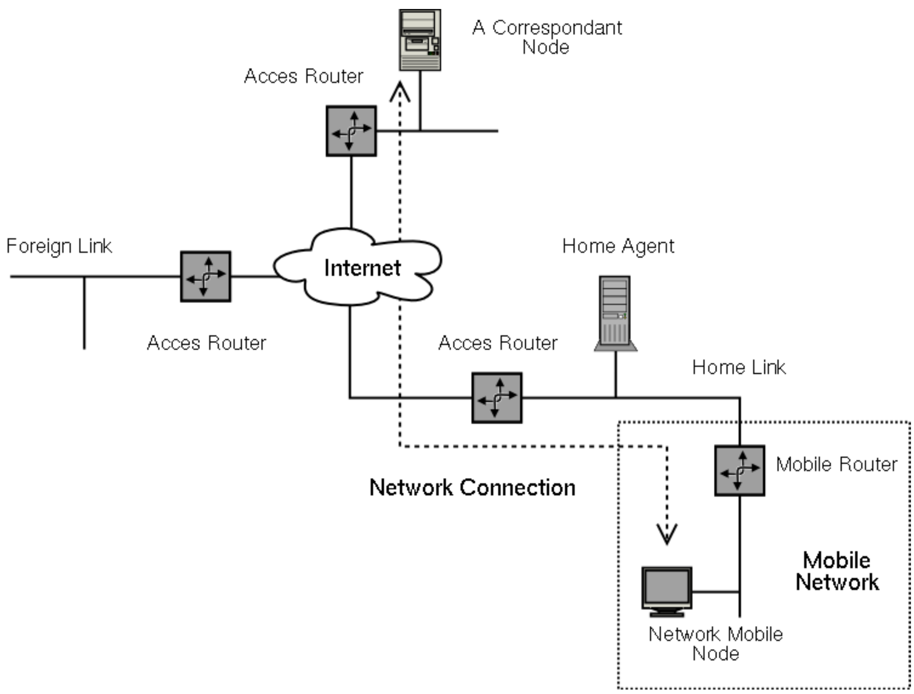

Figure 2.2: The Mobile Network is on its Home Link and a Correspondent Node communicates with a Mobile Network Node which is inside the Mobile Network. The Home Agent and the Access Router of the Home Link can be the same node.

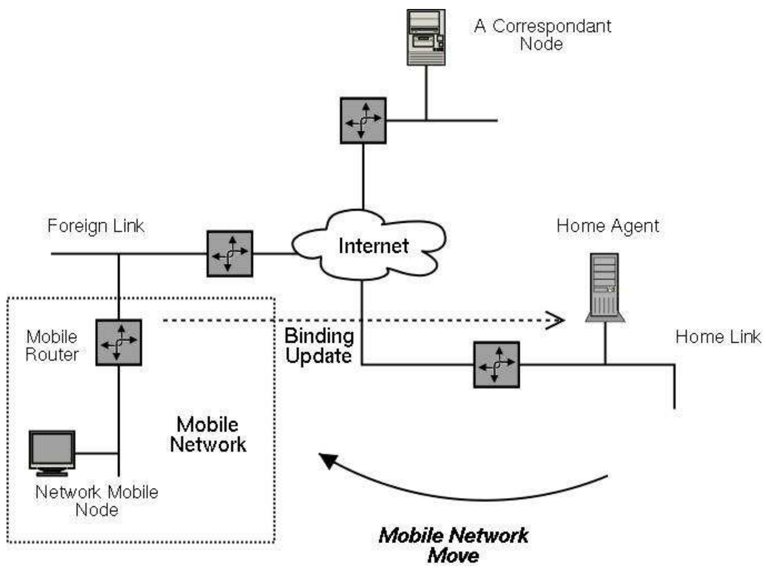

Figure 2.3: The Mobile Network changes its point of attachment to the Internet. The Mobile Router sends a Binding Update message to its Home Agent to inform it of its new reachable address (its Care-of Address), and of the prefix(es) announced in the mobile network (the NEMO-prefix(es)).

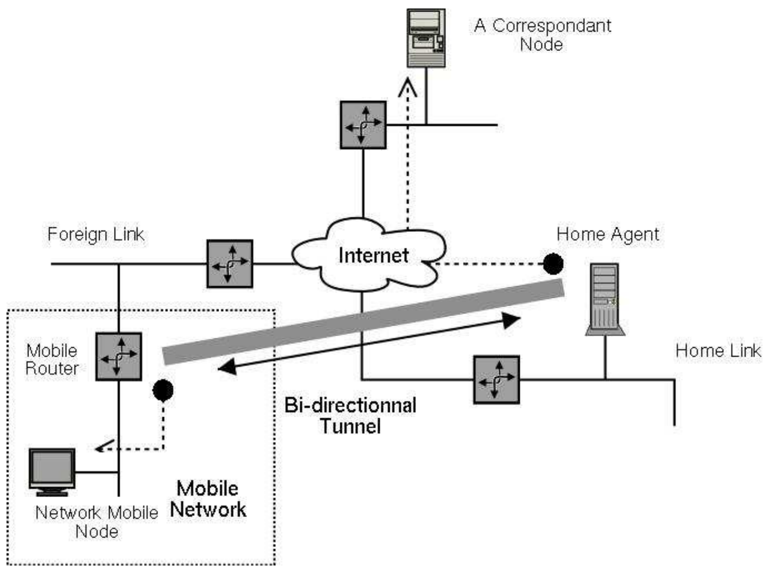

Figure 2.4: A bi-directional Tunnel is established between the Mobile Router and its Home Agent. All the traffic to or from the NEMO-prefixes (for instance the traffic between the Mobile Network Node and the Correspondent Node) transit through this tunnel, thus all previous connections are preserved.

Chapter 3

Design of the Demonstration Testbed

Nautilus6 already has an operational testbed for Mobile IPv6 [29]. About forty persons are equiped with a SHARP Zaurus [10], that includes a Mobile IPv6 stack in order to test IPv6 softwares in mobility environment. On the other hand, the NEMO demonstration platform is a testbed for network mobility, we then have new constraints compared to host mobility. We thus need to investigate the possibilities to implement NEMO Basic Support for our demonstration testbed, this means:

- Which equipment is the best for demonstration purposes, which one can provide the best battery life, with minimum space and weight, and Unix (either *BSD or GNU/Linux) operating system support.
- Which operating system and IPv6 stack is able to welcome the NEMO implementation.

Only few small equipments support UNIX systems, so we have concentrated our survey on SOEKRIS motherboard [30], SHARP Zaurus SL6000 [10], HP iPAQ [31] and SONY VAIO U50/70 [32]. About the operating system, we had two possibilities : *BSD or GNU/Linux. We also had to choose on which Linux kernel version we will work: 2.4 kernel or 2.6 kernel.

In order to find the best solution to implement NEMO for demonstration purposes, we tried to summarize all possibilities, what are the advantages and drawbacks for each one.

We wrote a report [33] about this survey in order to share our study and conclusions with other Nautilus6 members. We summarize here the most important points and tests we have performed to achieve this task. We do not speak about the SOEKRIS motherboard, neither about the HP iPAQ since these solutions did not fit to our constraints due to power or operating system issues. On the other hand we speak about the tests and work performed on the SHARP Zaurus, which represent the most significative amount of work on this survey. Also, we speak about the issues we met with such an embedded platform.

3.1 The Zaurus solution

The SHARP Zaurus SL6000 [10] is a thin and light PDA, which comes with a long lifetime battery. It runs with Linux operating system, and the kernel source tree is provided by SHARP

[34]. We worked on the SHARP Zaurus SL6000 since we can use several wireless devices at the same time on this PDA; this is important because we plan to use it as a router.

The kernel provided by SHARP is a 2.4.18 kernel. SHARP does not have any plan to release a 2.6 kernel on Zaurus, so we can only use 2.4.18 kernels, for which we can test two different IPv6 stacks that could welcome the NEMO implementation: the one released by USAGI [5], or the one produced by Motorola Labs (known as LIVSIX [35]). We will detail here both possibilities.

3.1.1 Linux 2.4.18 and USAGI stack

One of the possibility is to use the 2.4.18 kernel for Zaurus provided by USAGI that includes their IPv6 stack. But we face several drawbacks using it:

- Their stack for 2.4 kernel contains deprecated MIP6 (Mobile IPv6) code,
- It will never be included in the mainline kernel,
- And it is not supported anymore by USAGI.

Also, they do not plan to backport MIP6 code from 2.6 kernel to 2.4 kernel at the moment. As the NEMO implementation is based on MIP6 implementation, we cannot count on this solution to implement NEMO Basic Support.

3.1.2 Linux 2.4.18 and LIVSIX stack

Another possibility is to cross-compile 2.4.18 kernel provided by SHARP with the LIVSIX stack [35] support for the Zaurus. The LIVSIX stack presents several advantages:

- It includes NEMO implementation,
- It supports Mobile Router and Mobile Host over GRPS, UMTS and WLAN,
- It supports Nested Mobile Network,
- The source code is freely available, we can use and modify it for demonstrations purposes,
- It is still supported by the developpers.

This solution is very interesting to get quickly an embedded Mobile Router for our NEMO demonstration platform. So we worked on a port of LIVSIX stack for Zaurus SL6000, and wrote a document [36] to summarize the procedure and tests performed on this device. This document is freely available on Nautilus6 website [6].

The conclusions of this work are that the LIVSIX IPv6 stack works fine on SHARP Zaurus, but we face some issues. The most important is that we cannot use the Zaurus as an IPv6 router with the LIVSIX stack port: we have some problems to statically configure the ingress interface of the Zaurus. It is a critical point, since without router functionnalities we cannot use the Zaurus as a Mobile Router.

3.2 The Sony VAIO U50/70 solution

The new SONY VAIO type U50 or type U70 models [32] can be very interesting for our needs. With this equipment we have the advantages of all others solutions without their drawbacks.

It is a very small and light laptop, that comes with batteries. It has a wireless lan card and a CF slot so we can have at least two network interfaces at the same time. We can use Linux or *BSD operating systems, and we do not need to cross compile any software because it is built on a x86 architecture.

With this equipment, we can:

- Use existing NEMO implementations on NetBSD, it will allow us to have very quickly a Mobile Router that works,
- Use a GNU/Linux Operating System with LIVSIX stack (either for 2.4 kernel or for 2.6 kernel): we will not have to port the stack and it works better than on Zaurus.

Once we have our own NEMO basic support implementation on USAGI stack for 2.6 kernel, we will be able to test it on this equipment without any effort. The SONY VAIO U50/70 is therefore a very interesting solution for our NEMO demonstrations.

3.3 Conclusion

We can only use the SHARP Zaurus with a Linux operating system, on a 2.4 kernel. The SONY VAIO U50 or U70 gives us the choice of the operating system, the ease of use and a standard environment based on a x86 architecture. Thus we will use the SONY VAIO for demonstration purposes with existing NEMO implementations (*BSD or other).

For the long run, we plan to develop our own NEMO implementation based on USAGI MIP6 code on 2.6 kernel because:

- USAGI's stack is more famous and more complete, and on the long term their MIP6 code will certainly be included in the mainline kernel. If we want wide deployement of the technology this is the best choice.
- There are some licence issues with the LIVSIX stack, about commercial exploitation,
- We need to have our own implementation reference on Linux,
- The choice of the 2.6 kernel for a Linux implementation is the best choice for a long term use if we want to produce a reference implementation.

Chapter 4

The NEMO Basic Support implementation

Nautilus6 aims at developing a NEMO Basic Support implementation on GNU/Linux. We first need to choose the IPv6 stack to work on. Then we have to design the NEMO Basic Support implementation with the help of other people involved in this project. We will then start to implement the protocol on the stack, and finally test the implementation.

4.1 The IPv6 stack

In order to implement NEMO Basic Support protocol, we are looking for a high quality IPv6 stack for GNU/Linux on 2.6 kernel that also provides mobility functionnalities. USAGI project [5] works to deliver a production quality IPv6 and IPsec protocol stack for the Linux system. They collaborate with GO-Core project to also support the Mobile IPv6 protocol [7]. USAGI team takes care of the kernel side, and GO-Core works on Mobility support on the userland side (MIPL, Mobile IPv6 for Linux [37]). As we work very close to USAGI team, their stack and MIPL is certainly the best choice to add NEMO Basic Support functionnalities on 2.6 kernel.

4.2 The design

At the moment, NEMO Basic Support is defined as a NEMO working group internet draft at the IETF. The third version of the draft (draft-ietf-nemo-basic-support-03 [8]) is the reference on which we base our implementation. Other implementations have been studied in order to complete our knowledge about the NEMO protocol, especially the one included in LIVSIX stack [35], and the one produced by Nautilus6 on NetBSD [38].

The userland (MIPL2) released by GO-Core project is the mobility daemon (mip6 daemon) on top of which we implement NEMO Basic Support. Since most of the work will be done on it, we have also studied and tested it to improve our knowledge of the development environment.

4.3 The implementation

The mip6 daemon released by GO-Core and the kernel released by USAGI are still work in progress. The userland is stable enough to add it NEMO features, so we started to work on it at the beginning of August.

In order to stay synchronised with USAGI, we have regular meetings to present the NEMO implementation current status, raise and discuss the current issues we face. We also just started to collaborate with GO-Core project to start the NEMO Basic Support implementation on the userland side. All our progresses in this work are updated on Nautilus6's wikiwikiweb [20], in order to share issues and conclusions with our teammates. At the moment these reports are confidential and only disclosed to Nautilus6 and WIDE members. The NEMO Basic Support implementation is still in progress, some issues related to the kernel are solved, but it still needs work on the userland side to add the routing and signalling needed for the NEMO Basic Support protocol.

4.4 Future work

Once the NEMO Basic Support implementation is finished, we still have much work to improve it.

First we need to test it and track the bugs. Nautilus6 has an indoor testbed devoted to protocol testing, so we will have to deploy a NEMO Home Agent and a Mobile Router, and tests all basics scenarii to check that the implementation behaves as expected.

Also, TAHI [15], a team whose objectives are to develop and provide verification technology for IPv6, plans to work on a test sequence for NEMO Basic Support. It will help us to improve the quality of our implementation.

Then we will have to perform interoperability tests with other existing NEMO implementations, for instance the one produced by Nautilus6 on NetBSD [38] and on the new WIDEMIP/SHISA stack [39] released by WIDE organization.

Also, as discussed in the next chapter, we want to support multihomed topologies with our NEMO implementation. That's why we will have to test and implement new mecanisms to be able to use Mobile Routers with several Care-of Addresses and Home Addresses, Home Agent that can register several Care-of Addresses for the same NEMO-prefix, support for multiple Home Agent, and other key features.

We also would like to test our NEMO implementation's behaviour in multicast environment, thus test Mobile Network topologies with Mobile Network Nodes (MNN) as multicast sources or recipients.

4.5 Conclusion

The NEMO Basic Support implementation on USAGI's stack and MIPL2 is still a work in progress. We expect to release a functional implementation soon, thanks to the tight collaboration between Nautilus6, USAGI and GO-Core. A NEMO implementation on 2.6 kernel will allow wide deployement of this technology, that's why we have high expectation from this collaboration.

Chapter 5

Multihoming activities

5.1 Multihoming Overview

Multihoming in Mobile Networks is very important as we expect future wide deployment of the technology. We can imagine many scenarii where multihomed Mobile Routers or multihomed Mobile Networks are essentials: for instance we can have a multihomed Mobile Network with interfaces that provide different connection types as 802.11 for bandwith, and UMTS for a larger coverage, while the Mobile Network is away from a hotspot. But this is not the only benefit we can get from multihoming, we can also expect redundancy, load sharing, and load balancing. In [40] the authors attempt to define the goals and benefits of multihoming for fixed and mobile hosts and routers, illustrated with a set of real-life scenarii.

Nautilus6 already perfomed tests with multihomed fixed routers and multihomed fixed networks [41]. We now would like to investigate the issues we can face with multihomed Mobile Routers or multihomed Mobile Networks. Our work on this activity is based on earlier investigations, such as [28] and the analisys of multihoming in NEMO described in [42]. These documents attempt to list the issues that may arise when mobile networks are multihomed while mobility supports is taken care by NEMO Basic Support. A toxonomy is proposed to classify the possible multihomed configurations. Also, [43] tries to list what the NEMO Basic Support protocol lacks to support multihomed topologies.

We now focus on the configuration where a Mobile Network is composed of multiple Mobile Routers that advertise multiple NEMO-Prefixes, each Mobile Router associated to the same or different Home Agents. The aims of these tests are to help us to identify new issues, to improve our documents and to propose solutions to the issues we face. We also need to discuss on which issues and solutions Nautilus6 will focus on. The documents listed above helped us to identify the interesting multihomed topologies and to set up test scenarii based on these topologies.

5.2 Tests and report

The main goal of the tests is to raise the issues that may happen when we have Mobile Networks with multiple Mobile Routers that advertise multiple NEMO-prefixes, especially in case of Mobile Router's interface failure and Mobile Network movements.

These tests are still under progress. We work on our indoor testbed using Nautilus6 NEMO implementation on NetBSD [38] and dedicated to test protocols and Mobile Network topologies. After analysing the interesting topologies listed in [42], we set up a new network topology with one multihomed mobile network (including two Mobile routers) and one or two Home Agent depending on the scenarii. The Mobile Routers may also be multihomed (i.e. with several egress interfaces), and at least one NEMO-Prefix is advertised in the Mobile Network. We focus our tests on the Mobile Routers' egress or ingress interface failure, in order to check what are the lacks of the NEMO Basic Support protocol to transparently recover in case of failure. One example of the topologies tested is presented on picture 5.1.

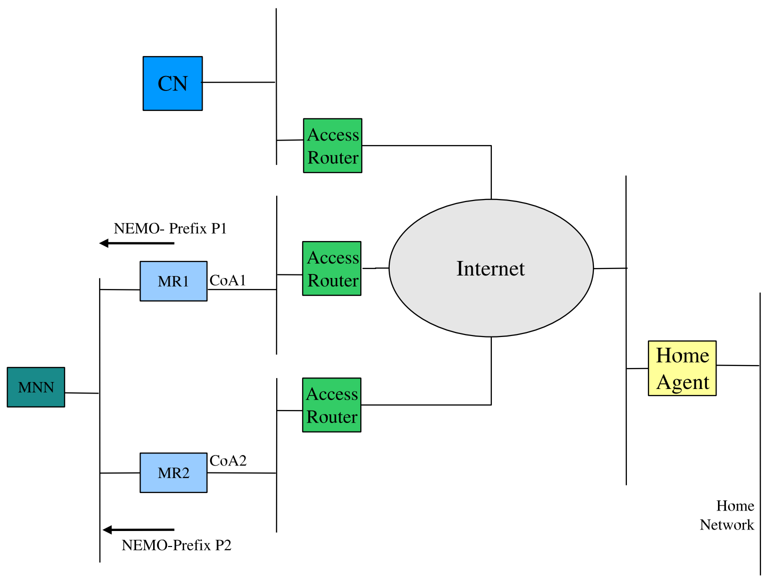

Figure 5.1: A multihomed Mobile Network. Each Mobile Router advertises a different NEMO-Prefix and registers to the same Home Agent.

Thanks to these tests, the more important issues we raise are:

- The Mobile Network unreachability due to the binding de-registration delay on the Home Agent,
- The switching delay from the failed Mobile Router to another Mobile Router,
- Routing loop when failed MR's binding lifetime expires, if the Home Agent has no binding nor routing information for the NEMO-prefix in its routing table,
- Asymmetric communication between MNNs and correspondent nodes, for instance incoming traffic via one Mobile Router and outgoing traffic via another Mobile Router.

We first reported our results on Nautilus6's confidential wikiwikiweb [20]. In order to share our results with all interested people, we decided to write and submit a new internet draft to the IETF. This document [44] explains our motivations, the tests we performed, the issues we faced, and try to give some clues to solve these problems. As our tests are still under progress, this document will be updated when we have new results to share. This document was presented at the 60th IETF in San Diego, during the NEMO working group session [45].

5.3 Next steps

We still have some work to perform on this activity. First, we need to continue our investigation on the topologies we could not test yet due to some NEMO Basic Support implementation issues. The results of these tests will allow us to improve our documents and the official document at the IETF NEMO working group [42]. We will then need to investigate the solutions to the issues we raised. We started to give some clue in our internet draft [44], but other documents such as [46] explore path to solve the issue of site multihoming (site that has more than one connection to the public Internet). We will then have to discuss the issues Nautilus6 should work on, in the scope on multihomed Mobile Networks.

5.4 Conclusion

Multihoming support is important in Mobile Networks as we expect redundancy, fault tolerance, load sharing, load balancing and high coverage. The NEMO Basic Support protocol needs new extensions to fully support such features. The internet draft we wrote [44] aims at reporting the issues we face in such multihomed Mobile Networks, especially with multiple Mobile Routers advertising multiple NEMO-Prefixes. This document must be the starting point to discuss the issues Nautilus6 should work on, and to help us to design a NEMO implementation on GNU/Linux that does not prevent future multihoming extensions.

Chapter 6

Conclusion

In order to set up a NEMO demonstration platform, we need to work on several complementary sides. We have first investigated the hardware we will use for the testbed. We plan to use the SONY VAIO U50/U70 as a Mobile Router, PDAs and IPv6 devices such as sensors or webcam as Mobile Network Nodes. Then we need a NEMO Basic Support implementation in order to get a embedded Mobile Network. At the moment we work on a Linux implementation for 2.6 kernel, collaborating with USAGI and GO-Core projects. Finally, in order to expect wide deployment of this technology, we need to bring additional key features such as multihoming mecanisms.

This work is still in progress, but we expect to demonstrate shortly these technologies through our NEMO demonstration platforms: E-bike and E-wheelchair.

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Appendix A

Contributions to Nautilus6

A.1 Introduction

I have joined Nautilus6 at the beginning of April, in Keio University K2 campus (Shin-Kawasaki, Japan [19]). I will continue working in this working group after the end of the internship, therefore some of the goals and tasks described in this section are still under progress.

In this section I explain how I contributed to Nautilus6 on the demonstration plateform environment. My main working activities are focused on the NEMO (Network Mobility) demonstration platform, this includes the networking, the implementation and the hardware sides. I also contributed to related activities. As all my work is related to Network Mobility and the NEMO Basic Support protocol, chapter 2 introduces this protocol and its usages.

A.2 Tasks

A.2.1 Main activities

I contributed to Nautilus6 by working on the design and the implementation for the E-bike and E-wheelchair testbeds. I focused on the equipment, the protocol and the multihoming sides.

The equipments

I wrote a report about the survey on the equipment and operating systems available for NEMO demonstrations [33]. Also, all my work on the SHARP Zaurus and LIVSIX stack is reported in a document available on the Nautilus6 website [36].

The protocol

We have just started a collaboration with USAGI and GO-Core project in order to produce a NEMO Basic Support implementation on Linux 2.6 kernel. I regularly participate to the USAGI meetings and setup a common meeting with GO-Core in order to synchronise our effort on this task.

Multihoming

Before joining Nautilus6, I did not have any knowledge about multihoming. I first read specifications and documents in order to bring my knowledge to the level needed for that task. I participated to the tests described in chapter 5 with teammates involved in Nautilus6. We also co-wrote an internet draft [44] submitted to the IETF in order to share our results.

A.2.2 Miscellaneous contributions

During this intership I have contributed to Nautilus6 in several other domains, such as improving the IPv6 environment, network and system administration, or participating to some experiments.

Improving the IPv6 environment

As we work to improve IPv6 related technologies, one important thing is to use IPv6 as much as possible for our work. I participated to the Zaurus experiment [29], which goal is to test the benefit of Mobile IPv6, thanks to the MIP6 stack released by USAGI project for the Zaurus C760 and C860. I tried to share my experience by improving the documents released on our website [29], and writing new documents for Zaurus users.

We set up an IPv6 showroom on Nautilus6 website [11] to show great IPv6 devices in action. I set up an IPv6 webcam and an IPv6 temperature sensor which may be consulted with MRTG [47] graphs. This showroom is a place where we can show real-time activities thanks to IPv6 and test devices that we will use for our demonstration platform.

Network and system administration

I took part in Nautilus6's network and system administration. On one side the indoor testbed updates to the latest NEMO Basic Support implementation let me improve my skills on netBSD [48] operating system. On the other side, the administration of our main server (user management, software installation, website management etc.) allowed me to improve my skills on the freeBSD [49] operating system.

Miscellaneous

I participated to experiments organised by other laboratories, such as InternetCAR project [16], that aims at demonstrating IPv6 for Intelligent Transportation System (ITS). The purpose of their experiments is to set up an outdoor testbed with cars that includes a Mobile Router and IPv6 sensors, and to test some applications that use SNMP to query the sensors while cars are moving.

I also plan to participate to the "Journees Scientifiques Francophones" (JSF [50]) in order to present the IPv6 Network Mobility to inexperienced people. We have submitted a paper [51] and we hope it will be selected for a presentation during the meeting that will take place in November. We believe that it is important to present such technology to the public, in order to aware them of its possiblities.

A.3 Personal conclusion

During this internship, I applied and improved many of my skills in administration and development. I also took part in new activities such as Network Mobility and multihoming, domains that I did not realise the scope when I first joined Nautilus6. My work on the NEMO implementation allowed me to improve my skill in protocol implementation, and the tests and draft writing in the multihoming activites allowed me to see another side of the research in computer science.

Working in an international team and collaborating with different projects such as GO-Core or USAGI projects is a great opportunity to share our points of view and working methods.

This intership allowed me to complete the competence expected from an engineer in research, development and international relationship. I will go on working in Nautilus6 on the NEMO demonstration platform in the following months, I hope this experience will give me all the skills to aspire to an international career.

This internsip in the midst of Keio University helped to enhance the collaboration with University Louis Pasteur in Strasbourg. I hope that the Région Alsace will take hold of this opportunity to develop and improve new businesses with Japanese industries on IPv6-related technologies.

Appendix B

IPv6 usages

Not only the IPv6 protocol will allow to support much more IP addresses than IPv4, but it will also bring new security, mobility and quality of services mecanisms. In this appendix, we will introduce some great IPv6 and mobility usages.

B.1 The E-bike testbed

The E-bike testbed will be used to demonstrate the benefit of network mobility for all types of configurations (for instance multihomed mobile network, as described in chapter 5). E-bike would be a portable IPv6 Personal Area Network (PAN) made of several IPv6 devices with several access technologies.

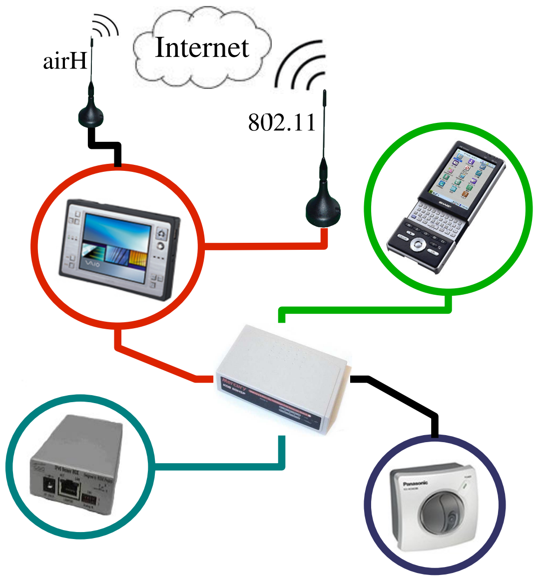

Figure B.1: The PAN (Personal Area Network) of E-bike is composed of a Mobile Router with multiple interfaces, and several IPv6 devices.

E-bike is currently under development and is expected to be composed of:

- A Mobile Router with several Internet accesses (IEEE802.11b and cellular technology), that will provide IPv6 connectivity to the moving network.
- A PDA (a Sharp Zaurus) that will provide an Internet access on the bike,
- IPv6 sensors (temperature/humidity sensor, GPS sensor, direction sensor) which can be queried using SNMPv1 and IPv6,
- A IPv6 camera, reachable with an Internet browser from anywhere in the world with IPv6,
- A Power-over-Ethernet Hub, that will provide power to some devices,
- A bicycle.

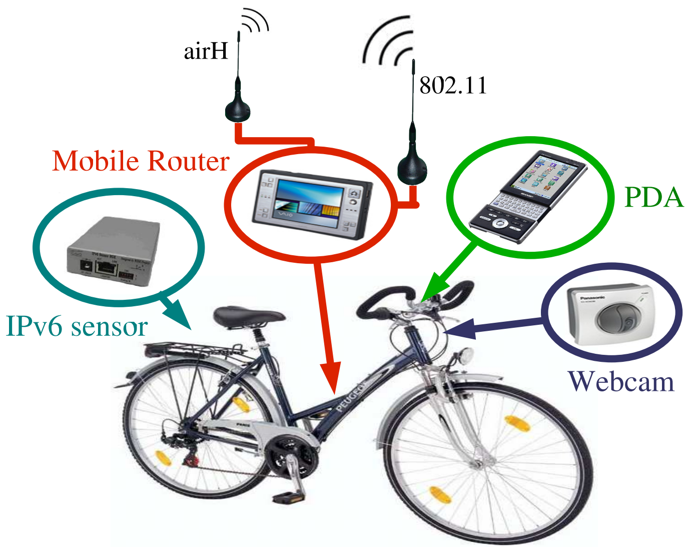

Figure B.2: E-bike. Thanks to the Mobile Router, all devices such as the sensors, the PDA or the webcam can access the Internet and be reached from the Internet, without disruptions.

Such a testbed is easy to move around and thus ideal for demonstrations at remote sites. We can think about a lot of scenarii that can be demonstrated using such a tiny, funny, convenient and inexpensive testbed: video streaming while on the move, real-time monitoring while on the move, adaptive applications (access networks and quality changes over time). It will be enough to convince many people about the usefulness of the underlying technology.

B.2 The E-wheelchair testbed

As described in [23], the aim of E-wheelchair is to help disabled people to improve their independence. The underlying technology is the same as E-bike, and we will use such communication system for health-care usages. The PAN on the wheelchair will allow real-time monitoring and video-conference with the family or the doctors.

The E-wheelchair testbed will be setup in collaboration with E-care [18].The current status of the testbed can be checked on Nautilus6's wikiwikiweb [52].

Figure B.3: E-wheelchair. Disabled people will be able to keep in touch and improve their independence.

B.3 E-agriculture

E-agriculture is part of the e! project, a serie of experiments started in 2002 in Japan to demonstrate the utility of the information technology in different fields. E-agriculture aims to improve the traceability of cows and beef throughout their growth and distribution process, using IPv6. It explores the possibility of applying networking technology to the field of agriculture.

This experiment is developped and run by NEC Engineering. They specially developped modules equipped with temperature sensor and IEEE802.11b Wireless LAN adapter, that have been attached to cows raised in an actual ranch in Gifu prefecture (Japan). These modules can communicate using the Mobile IPv6 protocol through wireless LAN access points installed in various locations around the ranch.

This system allows one to monitor the movement of cows by looking at which access point the cow is linked. Also, temperature sensors are located at the back of the tail of cows, and provide the body temperature of cows in real-time. Managing the health of the animals by monitoring their body temperature helps to prevent the loss of animals due to diseases.

In addition, the project considers a system that uses lower digits of the IPv6 address to directly represent information such as species, part of the animal, and weight of the meat. This system is based on the idea that if such information were coded with numbers and incorporated into the IPv6 address, it would be easier to track the information in real-time. It is based on the fact that IPv6 supports so many addresses that we can treat them almost as if they are for single-use.

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