Nautilus6 WG Activity Report in 2004

Edited by Thierry Ernst (ernst@sfc.wide.ad.jp)[1]
Keiichi Shima (keiichi@iijlab.net)[2]

2005/1/12

[1]Keio University SFC - Jun Murai Lab, Japan
[2]Internet Initiative Japan Inc., Japan

Copyright Notice

Contents

Chapter 1

Introduction

Nautilus6's overall goal is to demonstrate the reality of IPv6 mobility. For this to happen, several technologies must be integrated: host mobility, network mobility, multihoming, seamless mobility, security, access control, and applications to demonstrate usages. Host mobility and network mobility are the core activities. Multihoming is necessary to provide constant access to the Internet and to enhance the overall connectivity, whereas seamless mobility is necessary to enhance the performance of handoffs. Security and access control are required to allow deployment at a commercial level. Regarding this latest activity, Nautilus6 is just seeking to integrate the minimum mechanisms required to convince commercial players that IPv6 mobility is a reality, while applications are necessary to demonstrate the usefulness and readiness of IPv6 mobility. Implementations are being tested and validated on an indoor testbed, and then are demonstrated for a specific usage, while mature features are demonstrated in an operational testbed.

This present report details the progress of the Nautilus6 project for the year 2004. This is the second edition of such a report, after year 2003's progress report [1]

The missions and organization of the Nautilus6 project are detailed in the next section (1.1). This year's progress is summarized in section 1.6. The details on protocol development, standardization, testing, validation and research are reported in separate sections for each activity: Network Mobility in 2, Multihoming in 3, Seamless Mobility in 4 and Security and Access Control in 5. Development of other features such as applications are detailed in 6. In section 7 we then detail how our technologies were demonstrated in Year 2004 and how we plan to demonstrate them further in Year 2005. The progress on our operational testbed are detailed in section 8. In section 9 we conclude this report with perspectives for next year, and the status and contributions of our international partners and individual members.

The interested reader can seek more information on our web site [2] whereas our WIKI page [3] is reserved to WIDE members and Nautilus6 members only.

1.1 Project Overview

1.2 Motivations and Background

Mobility functions will be essential to achieve the all-IP Internet and to connect all devices to the Internet at all 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), network mobility support (displacement of an entire network in the IP topology without breaking open sessions), 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.... 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.

In mobility specifically, a lot of work has already been done at the IETF in various working groups. The IP Routing for Wireless/Mobile Hosts WG (MobileIP) has been discussing host mobility support for a long time and came up with the Mobile IPv6 protocol which adds mobility functions to IPv6 nodes. The NEtwork MObility WG (NEMO) has been established in November 2003 with the goal to add mobile functions to IPv6 routers to allow mobility of entire networks. The context transfer and seamless mobility WG (Seamoby) has been working on standards to improve handoffs (FMIPv6, CARD) and micro-mobility (cellular mobility and paging) [1]. At last but not least, the Mobile Ad-hoc NETworking WG (MANET) has been discussing routing protocols for mobile and dynamic topologies. However, mobility features have been poorly demonstrated and have not been integrated yet. The reason which accounts the most is probably because the focus has always been on the mobility management protocols themselves, and not on the architecture needed to deploy them.

There is thus a need to integrate all IPv6 and mobility features, and to demonstrate how the mobility support mechanism could actually be deployed in a live environment, in an operational, efficient, secure, and integrated manner. For doing so, not only mobility management protocols must be implemented, but also most IPv6 features, access control, key exchange mechanisms, and explicit IPv6 applications that can benefit from mobility functions.

1.3 Missions and Objectives

Nautilus6 is a mission-oriented project established within the WIDE organization in spring 2003, to demonstrate how the long awaited mobile Internet could be actually deployed. For doing so, we aim at demonstrating how IPv6

[1] micro-mobility was later moved to the IRTF, the research side at the IETF

and its mobility features could be implemented, integrated and deployed in an operational, secure, and efficient manner.

Nautilus6 will seek to select and validate IPv6 mobility-related technologies. The WG will use IETF standards whenever appropriate or develop and standardize new ones when those are lacking within the IETF community. The WG will either be testing existing implementations or implement them when none are available. Also, Nautilus6 will design the operational framework of mobile Internet services to accelerate deployment by the commercial ISPs and carriers and will seek for or develop applications to demonstrate the technology. It will also pursue further research into IPv6 mobility. The missions of the Nautilus6 project are therefore:

- To define the necessary protocol suite for commercial operation.
- To push for and contribute to IETF standardization of newly designed or selected protocols if existing standards are not appropriate.
- To develop reference implementations of the required protocols if existing implementations are not appropriate.
- To produce operational technology and Best Current Practices.
- To develop new paradigms to evaluate the proper operation of developed mobility technologies.
- To demonstrate the technology in field trials with business players.
- To show the business reality of IP mobility in order to convince business players.
- To explore the nation-wide business operation.
- To conduct further research in promising areas.

1.4 Technical Activities

In order to achieve our goals, Nautilus6 must conduct parallel activities in a number of areas. Nautilus6 is thus organized into cooperative sub-groups for each of the following activities:

- Host Mobility

  To brush up reference implementations of the IETF Mobile IPv6 specification for BSD and Linux.

- Network Mobility

  To research into and study network mobility, to push standardization at the IETF and develop reference implementations of the IETF NEMO Basic Support specification and related protocols.

- Multihoming

  To research into multihoming issues pertaining to mobility (mobile hosts or routers with multiple interfaces, multiple mobile routers, etc), push for standardization at the IETF and develop the technology which can benefit from it.

- Seamless Mobility

  To study and develop fast handover technologies, such as L2-trigger, and IETF protocols FMIPv6, HMIPv6.

- Security and Access Control for Mobility

  To select key exchange and access control mechanisms adapted to a secure operation of the mobility technologies.

- Services and Applications for Mobility

  To develop demonstrative applications and services that require or benefit from mobility mechanisms.

- Operation and Evaluation of the Mobility Technologies

  To demonstrate the readiness of the technology and evaluate its performance.

1.5 Project Strategy and Time Line

Because each protocol required in our architecture are at various stages of their development process, we cannot demonstrate everything at once right now. Each protocol advance through the following number of steps at its own pace:

- Specification
- Implementation
- Validation
- Demonstration
- Integration within the overall system architecture
- Operational validation and evaluation
- Actual Deployment

1.5.1 Incremental Testbeds

We are therefore developing incremental testbeds which are designed to match the development of the necessary protocols. At the very early stage of the development of a particular protocol, we will implement and test any given new protocol on our **in-door testbed**. Mature implementations will then be demonstrated on a light-weight **demonstration testbed** to validate the integration of the new features with the overall system architecture, to demonstrate it publicly, and to evaluate its performance. The third stage is a (possibly large-scale) **operational testbed** where we want to use the communication system in **real-conditions**. This testbed will be built with the intent to convince business operators that IPv6 mobile technologies are mature for real deployment. Each protocol will be moved further up from the in-door testbed to the real-conditions testbed according to our progress in each of the activities highlighted earlier. Not to say, the testbeds will have to be adapted for each new protocol that is brought in.

1.5.2 Development and Deployment

We will go threw these steps in *two distinct phases*, first the *technical development* of the protocol suite, and then the *actual deployment* of the technology. The realization of the second phase will depend on the results obtained in the first

1st phase: Technical Development (2 years): The first phase is expected to last two years. During that time frame, we will pursue steps going from protocol design up to the operational validation and evaluation. We will be involved in standardizing, implementing, testing, validating, evaluating the performance, demonstrating, documenting, and further researching.

2nd Phase: Actual Deployment (1 to 2 years): Based on the result of the technical development phase, we will seek to demonstrate the operational deployment of the mobility technologies as needed for commercial use, i.e. taking into consideration security aspects (key management mechanisms, access control and accounting) and performance aspects (fast handoffs, etc). For doing so, we should have a joint experiment with commercial ISPs and carriers under a real situation.

1.6 Progress this year

During the course of this year, we have successfully performed the following tasks:

- **Standardization**

  Our members were able to push and influence IETF standardization forward for many specifications as this report shows, particularly in the NEMO Working Group, and other working groups related to mobility.

- **Implementation**

  We have produced or contributed references implementations for NEMO Basic Support and FMIP on both Linux and BSD variants (see sections 2 and 4). Note that it is important for us to implement the same features on the these two distinct operating systems.

- **Testing**

  We have conducted numerous tests of our implementations (see sections 2 and 4) and evaluated the multihoming capabilities of IPv6 references implementations (see section 3. We have also evaluated AAA implementations (see section 5). So far, our tests were always performed indoor. Our technologies must now be fully validated and demonstrated in a more realistic way, i.e. outdoor, within our e-Bike and e-Wheelchair demonstration platforms (see section 7.2).

- **Demonstrations**

  We have developed specific applications to demonstrate our technologies (adaptive applications 6.2 and Zaurus applications 6.1). The technologies we are developing were demonstrated in a few occasions, as this could be seen in section 7.1.

- **Operation**

  We have completed the first phase of our operational experiment based on Zaurus PDAs as this is detailed in section 8.1). We are cooperating with SOI to provide them Mobile-IPv6 enabled PDAs (see 8.2) and we are setting up the second phase of the operational experiment (8.3).

- **Publications**

  Our members have contributed to IETF internet-drafts, RFCs and have published in international conferences and journals. Publications are detailed in section 10.5.

- **Internal Cooperation**

  We have pursued our cooperations with the WIDE Working Groups USAGI, KAME and ICAR (see 7.1.2), and established new cooperations with XCAST (see 6.3), SOI (see 8.2) and eCARE (see 7.2). Internal cooperation between WIDE Working Groups is necessary if we want to be successful to establish an efficient IPv6 communication system for mobile users. For the purpose of enhancing our own communication, we are setting up video-conferencing tools (see sections 6.3 and 6.4).

- **International Cooperation**

  We were successful in pursuing our cooperation bringing together researchers from Japan and France, although all of them have different views, working style, and skills. Details of the output of the cooperation and people involved are in section 10.

Chapter 2

Network Mobility

Thanks to NEtwork MObility (NEMO) support which allows an entire network, referred to as a *mobile network*, to migrate in the Internet topology, anything will soon be connected to the Internet, particularly PANs (Personal Area Networks, i.e. small networks attached to people and composed of Internet appliances like PDAs, mobile phones, digital cameras, etc.), networks of sensors deployed in vehicles (aircrafts, boats, buses, trains), and access networks deployed in public transportation (taxis, trains, aircrafts, trucks and personal cars) to provide Internet access to devices carried by their passengers (laptop, camera, mobile phone, and even PANs). Nautilus6 is participating both into the definition of the problem statement and standardization at the IETF (section 2.1, mostly with the NEMO Working Group), implementation (both under Linux and BSD, see in 2.2, 2.3 and 2.4), and research in enhanced features (i.e. routing optimization, see 2.5). Our contribution regarding multihoming in mobile network environments is described in section 3.

2.1 Standardization: NEMO Working Group and NEMO Basic Support

The NEMO Working Group: The NEMO Working Group as been set up at the IETF in October 2002 thanks to our initiative. We are presently chairing this working group. We are authoring the terminology used by the Working Group [4], and we have defined the requirements for support solutions [5]. Those documents are still *work in progress* but should be published as informational RFCs in a few weeks. The NEMO working group is working on a solution termed *NEMO Basic Support* [6] on which we contribute. This specification is in the RFC queue and should be published in early 2005.

Overview of NEMO Basic Support: The primary objective of NEMO Basic Support is to preserve session continuity between CNs (Correspondent nodes) and all MNNs (Mobile Network nodes) behind the MR (Mobile Router) while the MR changes its point of attachment. This protocol associates each egress interface of a MR with two distinct addresses, much like what is done in Mobile IPv6. The *home address* (HoA) serves as a permanent location invariant identifier whereas the *care-of address* (CoA) serves as a routing directive to the current point of attachment. The permanent HoA is obtained in the home network and has the same prefix as the home link. The temporary CoA is obtained in the visited network and formed from the prefix advertised on the visited link. The purpose of the protocol is to establish bi-directional tunnels between the home links and the mobile network for each 2-uplet HoA/CoA. This protocol allows nested NEMO, i.e. mobile networks which MR gets attached to a upper mobile network.

Problem Statement for NEMO Routing Optimization: Network mobility is achieved thanks to NEMO Basic Support which provides movement transparency to nodes behind the mobile router. However, communication between nodes behind the mobile router and their correspondent suffer from sub-optimal routing of the packets through the home agent along with encapsulation overhead at mobile routers. When multiple mobile routers form a topology known as nested mobile networks, such overheads pose crucial problems for real-time applications. At the IETF, we participate to the definition of the problem statement. Besides taking part to discussion on the mailing list, we have submitted a draft to the NEMO Working Group in which we detail the sub-optimal routing problem in nested mobile networks [7]. In this document, we describe the paths packets would take using existing Mobile IPv6 and NEMO Basic Support mechanisms when one or both end nodes of a communication flow are located in a nested NEMO. One of both of the end nodes may themselves be either mobile nodes performing Mobile IPv6, or standard IPv6 nodes performing no mobility function at all. The path can become extremely sub-optimal if no optimizations are provided.

2.2 Implementation: NEMO BS on BSD (Atlantis)

Atlantis is our first implementation of NEMO Basic Support, for BSD systems [8]. Atlantis was built on top of KAME Mobile IPv6. This implementation supports draft-ietf-nemo-basic-support-02 specification and is distributed from the Nautilus6 project. This implementation was used in our demonstrations early this year, but is not maintained anymore, since the developers of this implementation are now focusing on SHISA, the newer implementation of NEMO Basic Support for BSD systems, which is described below.

2.3 Implementation: NEMO BS on BSD (SHISA)

SHISA[9] is a new Mobile IPv6/NEMO implementation which has been built on top of the KAME code by KAME and SFC Mobile IPv6 team with corporation with us. The new code is designed to work as user space programs, whereas the old KAME Mobile IPv6 was built as a kernel function. In the new code, most of Mobile IPv6/NEMO signaling is done in a user space daemon programs. The kernel only provides a few functions which cannot be moved to the user space. These functions are packet forwarding, extension header processing, duplicated address detection and proxy neighbor discovery. Implementing in a user space will reduce the kernel size and make it easy to implement new/enhanced features compared to the kernel implementation. In our project and in other working group in the WIDE project, many experiments have done using the SHISA implementation.

SHISA provides the Mobile IPv6 specification as defined in RFC3775 [10] and RFC3776 [11]. SHISA also provides NEMO Basic support function which is based on draft-ietf-nemo-basic-support-03[6]. Also, SHISA implements some parts of the internet-draft [12] for multi-interface support. Unfortunately, SHISA still have many unimplemented features. The development team will continue to make efforts to implement as many features as possible to make the stack compliant to the Mobile IPv6 and NEMO specifications. The code has been merged to the KAME repository. Anyone who would like to get and test the code can retrieve the source by retrieving the KAME weekly snap-kit. [13]

2.4 Implementation: NEMO BS on Linux (LIMO)

A new Mobile IPv6 stack is currently developed by the WIDE USAGI project [14] and the Go-Core project [15] (from HUT, Helsinki University of Technology [16]). MIPL2 [17] is the name of the user-land developed by Go-Core, above the IPv6 stack developed by USAGI. It aims at implementing the Mobile IPv6 proposed standard (RFC3775 [10]) for Linux 2.6 kernel series.

We started to implement NEMO Basic Support at the end of November 2004, after the first MIPL2 candidate (MIPL2-RC1) was released. Most of the work is done on the user-land side (MIPL2). This implementation is based on the third version of the specification [6]. Basic functions are coded by Ville Nuorvala from Go-Core project. This include the explicit mode signaling between the Mobile Router and the Home Agent, and the needed forwarding features in both nodes. We work on the validation of this implementation (tests and debugging), and on additional coding. We also expect to validate and evaluate this implementation, by participating to interoperability events such as the 6th TAHI event [18] in January 2005.

For the short term, we would like to add the implicit mode, and integrate the NEMO implementation to the main MIPL2 tree. For the middle term, we would like to include prefix delegation features, and support for multiple interfaces, particularly the mechanism defined in [12] already supported by SHISA, the implementation on BSD.

2.5 Research: Route Optimization Scheme for Nested Mobile Networks

This study focuses on sub-optimal routing in nested mobile networks configurations, as overviewed in section 2.1. We propose a generic scheme to provide route optimization in such configuration. As an approach to the problem, we first defined the problem statement, and we analyzed various existing proposals. Based on the analysis, we proposed a route optimization scheme which supports various models of nested mobility. We designed and implemented our solution. Our evaluation was performed using the SHISA implementation of NEMO (see

2.3) on the K2 indoor testbed. Some tests were performed with a Home Agent located in the twin testbed located in ULP Strasbourg, France. Both qualitative and quantitative analysis confirmed effectiveness of the scheme. The scheme shows improvements in packet delay and protocol overhead, while maintaining stability and scalability. The scheme provides sufficient optimization in various scenarios of nested mobile networks. The results of this work is reported in a Master Thesis [19].

Chapter 3

Multihoming

A host is said multihomed when it has several IPv6 addresses to choose between. For a mobile host, this translates into a host either having multiple interfaces, or multiple prefixes being advertised on the link an interface is connected to. For a mobile network, this translates into a mobile network having multiple mobile routers, or a mobile router being multihomed (as a mobile node would). Multihoming offers many benefits to hosts and networks. In particular, it allows route recovery on failure, redundancy and load-sharing. In the forthcoming sections, we describe our contributions at the IETF regarding standardization, and we describe the experimentations conducted in K2 and the research being carried on.

3.1 Standardization: Problem Statement for MIP6 and NEMO

The use of multiple interfaces is foreseen to provide ubiquitous, permanent and fault-tolerant access to the Internet, particularly on mobile nodes (hosts and routers) which are more subject to failure or sudden lacks of connectivity. Individual solutions have been proposed to extend existing protocols but all issues have not been addressed in a single document, and none has been standardized.

As a first step toward standardization, we produced a comprehensive problem statement with the objective to raise the discussion at the IETF and to make sure that forthcoming standards will address all the issues. This problem statement is split into 3 separate documents submitted to the IETF.

In the first draft [20] submitted as an individual contribution to no specified working group, we describe the benefits of multihoming for both fixed and mobile hosts, routers and networks, through a number of scenarios, which emphasize the need for multiple interfaces, and the need for multiple exit routers.

In the second draft [21] submitted as an individual submission to the MIP6 Working Group, we describe issues specific to mobile nodes operating Mobile IPv6. In this document, we propose a taxonomy to classify the situations where a mobile node could be multihomed. This taxonomy is then used to highlight the issues preventing mobile nodes operating Mobile IPv6 to be multihomed.

In the third submitted draft [22] submitted and accepted as a NEMO Working Group document, we describe issues specific to mobile networks managed by NEMO Basic Support. In this document, we propose a taxonomy to classify the situations where a mobile networks could be multihomed. This taxonomy is then used to highlight the issues preventing mobile routers operating NEMO Basic Support to be multihomed and nodes behind the mobile router to get full benefit of the mobile network being multihomed.

This work is performed in collaboration with a number of people from both the WIDE community, and from outside WIDE. Besides Nautilus people based at K2, the main contributors are from Keio University and ULP Strasbourg.

3.2 Tests: Multihomed Mobile Networks

In the previous year, Nautilus6 already performed tests with multihomed fixed routers and multihomed fixed networks (see [23, 24] or [1]). In this year, we conducted further tests, this time in the NEMO context. The objectives are to investigate issues that prevent mobile network to be multihomed under the operation of NEMO Basic Support and to determine which extensions are needed. The tests were performed with Atlantis, our implementation of NEMO Basic Support (see 2.2). We have particularly analyzed mobile networks with multiple mobile routers and those with multiple NEMO-Prefixes. Our results were reported in an Internet Draft [25] to the attention of the NEMO Working Group. In this draft we explained our motivations, the results obtained from the tests, the issues we faced, and we tried to give some clues to solve these problems. We now plan to restart our tests from scratch, using the SHISA/NEMO implementation (see 2) in order to improve our draft and identify the interesting topologies for our demonstration platforms.

3.3 Implementation: Multihoming Support in SHISA

In a mobile environment, the quality of the connectivity changes minute by minute. However, from the layer 3 mobility's point of view, the connectivity will be provided seamlessly to the layer 4 and upper layers. In such an environment, applications sometimes suffer from the change of latency or bandwidth. To solve this problem, we proposed a mechanism which share the information of communication environment between a mobile node and its correspondent node by assigning a unique identifier to each interfaces of the mobile node. The unique identifier assignment and the identifier exchange mechanism, we proposed, is described in [12]. Applications run on these nodes can know the current communication environment based on the ID which is available. The detailed mechanism and the result of evaluation is reported as the WIDE document published from ICAR WG separately [26].

3.4 Research: Multiple Mobile Routers

In a mobile environment, there are two kind of nodes. One is a node which has connectivity to the Internet, the other does not. In a vary basic mobile network environment, all nodes are connected to the Internet through one mobile router which has connectivity to the Internet. However, in such a configuration, connectivity of all nodes inside the mobile network depends on the mobile router's connectivity. To solve this problem, we propose to use multiple mobile routers if there are multiple nodes which have connectivity to the Internet inside the mobile network. Using two or more mobile routers, we can increase stability of the connectivity of the mobile network and we can get more bandwidth by utilizing multiple connections of mobile routers. In our proposal, we have defined a message format to exchange the information of connectivity between mobile routers. We have also implemented the mechanism and designed a sample system which uses the messaging system. We evaluated the validity of our proposed mechanism by testing the sample system. The detailed results are reported in a separate WIDE document [27] and in a Master Thesis [28].

3.5 Research: Multihoming in Nested Mobile Networks

Multihoming a nested mobile network raises new issues for hosts: how to maintain IPv6 communication to all nodes inside a mobile network, how to allow nodes to choose the best default router in a multihomed mobile network. We have studied what are the implications of multihoming and the aggregation of several mobile networks. This study resulted into proposing an optimization in Router Advertisement to allow hosts to discover the hierarchy of Mobile Routers in nested mobile networks. This work was published in [29]

3.6 Research: Miscellaneous

We contributed to the writing of some research papers: mobile networks with multiple access interfaces [30], mobile nodes with multiple interfaces [31, 12], and mobile networks with multiple routers [32, 33, 34].

Chapter 4

Seamless Mobility

Seamless mobility, i.e. without disruption of service, minimum loss of packets, and minimum disturbance for the user, is necessary in order to deploy mobility services. We have therefore implemented seamless mechanisms specified by the IETF (i.e. FMIPv6), on both Linux (see 4.3) and BSD (see 4.2) operating systems. We also worked on L2 triggering mechanisms (see 4.4) and improved our wireless emulator (see 4.5.

4.1 FMIPv6 Protocol Specification Overview

The FMIPv6 protocol enables a MN to rapidly handle L3 handovers. It allows nodes to make use of link layer information (e.g. a decline in signal strength) and request information on neighboring APs (Access Point) and ARs (Access Router) before actually switching to the new network. The protocol offers some more facilities such as packet buffering by routers, tunnel establishment with a previous router etc. FMIPv6 is used as an extension to MIPv6. It is supposed to optimize and not replace it. FMIPv6 is Layer2 protocol agnostic. Both BSD and Linux implementations are planning on making use of Nautilus6 work on L2 Trigger standardization such as:
http://www.ietf.org/internet-drafts/draft-ietf-dna-link-information-00.txt
http://www.ietf.org/internet-drafts/draft-koki-mobopts-l2-abstractions-01.txt

4.2 FMIPv6 Implementation on BSD (TARZAN)

The BSD FMIPv6 implementation (TARZAN) is designed to work as a SHISA[9] extension (Fig.4.1). It is mainly situated in the user process space. We use an inter Layer Information Exchange System (LIES)[35] for the L2 Trigger feature.

In December 2004, we had a demonstration of a reactive mode of operation (Fig.4.2). In the future, we plan to evaluate the implementation using the Wireless Environment Emulator[36, 37]. The deadline for stable release of TARZAN is end of March.

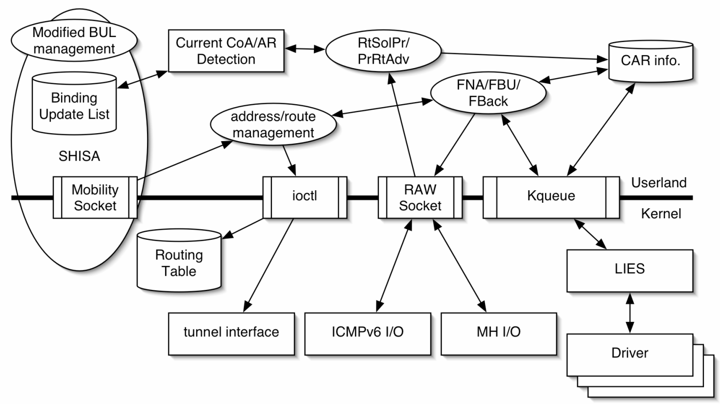

Figure 4.1: FMIPv6 on BSD design

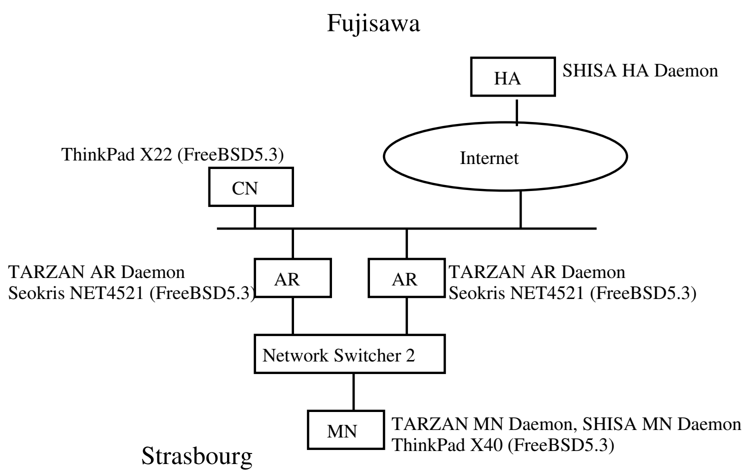

Figure 4.2: FMIPv6 on BSD testbed

4.3 FMIPv6 Implementation on Linux

The Linux FMIPv6 implementation is designed to work as a MIPL2 extension. It is situated in the user process space. We use methods provided by the wireless tools package to communicate with the kernel and the network card driver. Incoming 802.11b events are received through RTNETLINK sockets and card control requests leave through ioctl . We have constructed a custom testbed for the development of the Linux implementation (Fig.4.3).

We are currently in the process of implementing the Access Router. Previewed deadline for stable release is end of March.

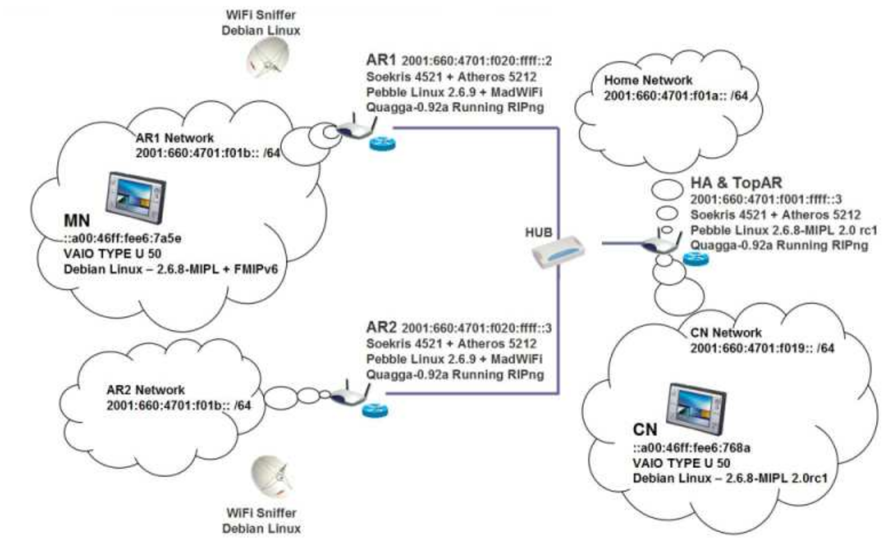

Figure 4.3: FMIPv6 on Linux testbed

4.4 inter-Layer Information Exchange System (LIES)

For the L2 Trigger standardization, we proposed some abstractions of L2 information [38]. We also proposed an inter Layer Information Exchange System (LIES) [35] as an implementation of L2 Trigger.

In LIES, a protocol entity in the protocol layer can obtain information of other protocol entities in other protocol layers. In addition, a protocol entity in a protocol layer can notify occurrence of an event to other protocol entities in other protocol layers. LIES does not introduce dedicated system calls. It makes use of existing system calls such as kqueue and socket.

We are currently in the process of developing new sophisticated implementations of LIES on BSD and LINUX, and applying LIES onto TARZAN 4.2.

4.5 Wireless Environment Emulator (NX-02)

The Wireless Environment Emulator[36, 37] was developed as an equipment which can conduct a handover experiment realtime without using any actual wireless access technology. One of the feature of the Wireless Environment Emulator is that it not only changes characteristics and connection state of a virtual wireless link based on a scenario, but that it can provide a mobile node with the information about a wireless link's state using the Physical Information Protocol that we proposed (Fig.4.4).

In 2004, we improved its flexibility for constructing network topology, and developed an interactive user interface. We plan to use it to evaluate FMIPv6.

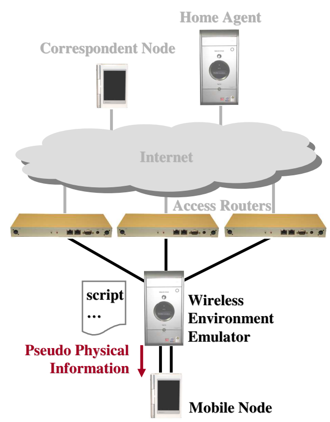

Figure 4.4: Wireless Environment Emulator

Chapter 5

Security and Access Control

The Mobile IP Authentication, Authorization, Accounting (AAA) was conceived to allow Mobile IP users to access resources being provided by an administrative domain different than their home domain. The role of the Security and AAA team is to investigate the security and access control issues related to mobility and to design the AAA infrastructure while testing and contributing to different implementations to bring them to the N6 demonstrations.

The actual requirements for mobility in term of AAA are as follows. First, Inter-domain authentication of users in roaming situations must be provided, this means that the access servers must be able to authenticate users belonging to some administrative domain by contacting the authentication servers of the user's home domain. Secondly, automatic bootstrapping of the authentication process with minimal interaction with the users. And finally, the whole infrastructure must be completely secure, providing message integrity and authenticity.

The NEMO use case has the same requirements as the classic Mobile IP use case. However in a deployment point of view of the AAA infrastructure for NEMO will be slightly different, indeed, we consider NEMO's AAA infrastructure requires more AAA entities. We are currently discussing the final architecture of the AAA framework to be used with NEMO and specifically within the e-Wheelchair demonstration, and also for the operational testbed.

The AAA infrastructure being adopted is based on the Diameter [39] protocol as a back-end authentication framework and the PANA [40] protocol as a front-end, providing secure way to bootstrap the authentication process and transport the authentication messages in a secure manner.

The PANA protocol is the interface between the user and the back-end AAA framework. Enforcement points implements the access rights to the network and are commanded by the PANA processes in-order to allow or deny users requests to use the access servers.

The back-end part based on the Diameter protocol will use the EAP-TLS [41] standard as authentication mechanism.

5.1 Test of the Implementation

An AAA mechanism is an essential component when we consider to operate mobility services as commercial services. We need to identify the users who use the services and we need to charge some fee if the service is not free. As described above, we may need some extension or special processing for mobility services, however, the basic AAA mechanism can be shared with other services. We had a small testing camp to experience some AAA implementations to understand the current software situation. Unfortunately, not so many implementations of AAA mechanism are available currently. We tried to install and operate two AAA implementations. One is a DIAMETER implementation provided by INT and the other is OpenDiameter, an open source DIAMETER implementation.

- INT Implementation

  At the moment of this testing work, the INT implementation was in a pre-release status. The implementation included PANA and DIAMETER functions which runs on the FreeBSD4 + KAME Mobile IPv6 system. The topology we used with the test is described in figure5.1. We succeeded to compile and install the software as described in the figure, however, we failed to operate the nodes as we expected. We saw some PANA request messages sent from the Mobile Node and DIAMETER messages sent from the AAAL server to the AAAH server. However the AAAH server didn't work properly and we gave up the test.

- OpenDiameter

  OpenDiameter is an open source DIAMETER implementation distributed from http://www.opendiameter.org/. The software distribution includes only library functions which can be used when someone tries to implement a DIAMETER software. We searched for the implementation which uses the library provided by the OpenDiameter, however we couldn't find any implementation available at the moment.

In our project, most of AAA implementation works are being done by INT members. They are rewriting the code. A new DIAMETER implementation, which is different from the old implementation we used in this test event, is planned to be implemented next year. We will re-organize a test event when we get a new implementation. As described in the section 8.3, the Nautilus6 project also plans to start a general purpose mobility service. In the service, we will provide home agent service including AAA service. The new implementation will be used in the mobility service.

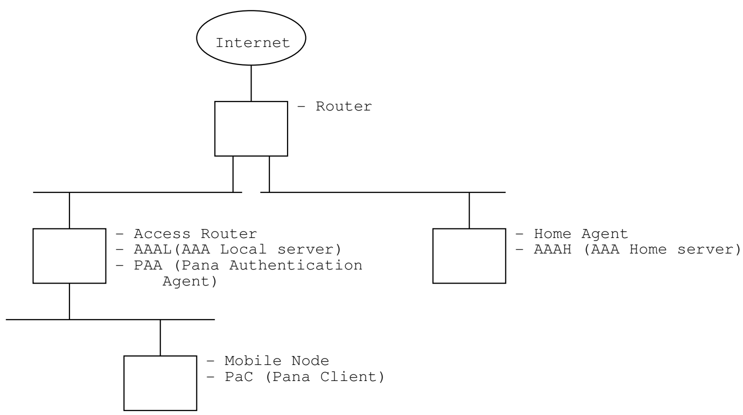

Figure 5.1: The topology we used at AAA camp

Chapter 6

Applications and Miscellaneous Activities

In this section, we detail the other types of developments that we had to carry on during the course of this year. This includes the development of IPv6 applications, applications specifically developed on the Zaurus PDA, and video-conferencing applications. In addition to that, we also established a multicast connectivity.

6.1 Applications on Zaurus

This year, we created a complete cross-compiling environment for the original Sharp ROM[1], after writing a survey about the different ROMs and cross-compiling possibilities[2].

We also created a L2TP package for Zaurus [42] so that IPv6 access can be provided over IPv4-only networks. We configured and tested it so that it could work with different kinds of connections (WiFi, b-mobile, Air-H, Ethernet card), and installed a public server in K2 Campus. This work is a contribution from ENST-Bretagne partners.

Finally we cross-compiled MPEG4IP [43], a streaming solution, based on free and open standards. We had to work with its programmer Bill May to solve a few bugs and several other problems, like the MP3 decoder which was too slow on the Zaurus, or the fact that the cross-compiler for the Sharp ROM is based on an old and unsupported version of the GCC compiler.

6.2 Adaptive Applications

The objective of such applications is to improve the user experience, in an environment where network conditions may change, which happens frequently in mobile environments: for example when moving farther or closer to an access point, when moving from one access network or from one access technology to

[1] http://www.nautilus6.org/operation/download/cross_install-2.95.tar.bz2
[2] http://www.nautilus6.org/operation/zaurus.html

another.

In a Mobile Network, this requires:

- The detection of the network conditions by the Mobile Router;
- Possibly, the publication of application profiles, sent by applications running on nodes inside the NEMO (for example, a Streaming Client can notice the MR it would like to use the connection with the maximum bandwidth, even if the error rate is higher);
- Communication between the MR and the nodes of the Mobile Network, to advertise the current status of the network;
- The adaptation in itself (for example, a Streaming Client will ask the Streaming Server to send the data with a different bitrate).

The first Adaptive Application was a streaming solution, to receive videos inside the Mobile Network, based on: Darwin Streaming Server modified for IPv6, MPEG4IP, and MPEG-4 / MP3 files. Technical details can be found in [44], section 2.4 and 2.6.

This was used during the UNS demonstration (see 7.1.4), with those modifications:

- The MR retrieves interface information using local Telnet; we now need a better solution, like NEMO-level socket.
- Pre-decided bandwidth information is sent to the Streaming Client with a fixed address / port; we are now studying how to standardize what to send, and how to transmit it, for example the MR could broadcast the information inside the NEMO (using new or existing packets), or only send to applications which registered.
- The Client requests the same video but with a different bitrate to the Streaming Server;
- To hide the handover (1 to 4 seconds without connectivity), it starts playing at the same timestamp and leaves the video window opened.

6.3 Applications for Videoconferencing

Videoconferencing tools are interesting for several reasons:

- Many are IPv6-enabled, and can use unicast or multicast streams;
- They can use a very broad range of bandwidths;
- They have important real-time constraints;
- They are very "visual".

First, we are using them in Nautilus6 to demonstrate the IP-layer protocols we develop and promote : changes in network properties can be directly *seen* by users (video stopping a few seconds during a handover, quality or responsiveness of the stream changing, etc).

Secondly, when associated with appropriate measurement tools, they are useful applications to validate the protocol performances.

Since the Nautilus6 Working Group is composed of people working in many different places, Videoconferencing also enables us to collaborate more easily.

Finally, before promoting technology to the rest of the world, it seems important to use it ourselves, to understand what people really need, find new ideas on how to use these tools, and convince people that they are now mature.

Therefore, we have investigated several solutions [45]:

- Based on H.323: commercial solutions (Polycom, Sonycom), as well as free softwares (NetMeeting, GnomeMeeting, XMeeting, Zmeeting).
- We plan to test solutions based on SIP, like the JAVA application SIP Communicator.
- Using multicast protocols: VIC and RAT, modified to support IPv6.

We are also interested by the versions of VIC and RAT which support the XCast protocol, which presents great advantages over unicast and multicast, for applications where limited numbers of users need to transmit data to private multicast groups. We are working in collaboration with the WIDE XCast Working Group as well as with the ARMOR team (IRISA Rennes) (see 10.1.2) which are developing and deploying it.

We are finally supporting people from PLANETE (INRIA Sophia Antipolis) who is the porting VIC and RAT to the Zaurus (see 10.3) Their intent is to develop parts of the Virtual Reality environment (Virtual Eye [46]) on a PDA-like platform. Since their application is originally implemented for IPv4, they started by porting it to IPv6.

6.4 Set-up of a Multicast link between ULP and K2

With the aim of validating the compatibility of our protocols (particularly NEMO Basic Support) with multicast capabilities, we have set up a multicast tunnel between K2 and ULP. We also want to conduct research activities to optimize multicast routing in mobile environments. A third purpose, is to actually use multicast capabilities for our internal video-conferences, though non-multicast mechanisms could also be used, as the study in the previous section (6.3 suggests). We may want to establish a native multicast connectivity between WIDE and Renater in order to achieve this objective, based on true need.

Chapter 7

Demonstration of the technologies

In the first section 7.1 below, we detail what we demonstrated at a number of events (Networld and Interop, ORF, UNS) and testing performed with the ICAR Working Group. These demonstrations have always been performed indoor, on a table, in a small booth. This is one of the parameter that highly contribute to the lack of attractivity of our technologies which, by essence, should be demonstrated in the open air while moving, i.e. where we actually need it.

In the year 2005, we will of course need to present our work indoor, on a table, as we always did. However, for our own experiments, and at some limited events, we can demonstrate an actual use of the technology, i.e. outdoor. As detailed in section 7.2, we are designing an experimental testbed which is portable, and which can be configured in different ways according to the purpose of the demonstration, the protocols being demonstrated, and, most importantly, the usage being demonstrated: presently, we have two usages in mind, e-Bike for leisure, and e-Wheelchair for people with disabilities, but any other could be envisioned.

7.1 Indoor Demonstrations

7.1.1 IPv6 ShowCase in Networld+Interop

Networld+Interop is one of biggest exhibitions of networking technology, services and equipments in Japan. The exhibition has a special booth for IPv6 service and products called IPv6 ShowCase. We had a demonstration of a combination of NEMO and multicast (using the remote subscription method) with the Atlantis NEMO implementation at IPv6 ShowCase. We also performed interoperability of NEMO basic support with the mobile routers provided by Cisco Systems, and interoperability of Mobile IPv6 with KASAGO IPv6/Mobile IPv6 implementation provided by Elmic Systems Inc.

Figure7.1 shows the topology we used at IPv6 ShowCase. Multicast stream was provided by BroadBand ShowCase, which is another special booth held at Networld+Interop for broadband services. Our mobile router (Mobile Router 1) received the stream and forwarded to the internal mobile network. Our home agent (Home Agent 1) served home agent service to a mobile node from Elmic Systems (Mobile Node) and a mobile router from Cisco Systems (Mobile Router 2) in addition to our mobile router (Mobile Router 1). Also, a home agent from Cisco Systems (Home Agent 2) served its function to our implementation (Mobile Router 3) as well as theirs (Mobile Router 4).

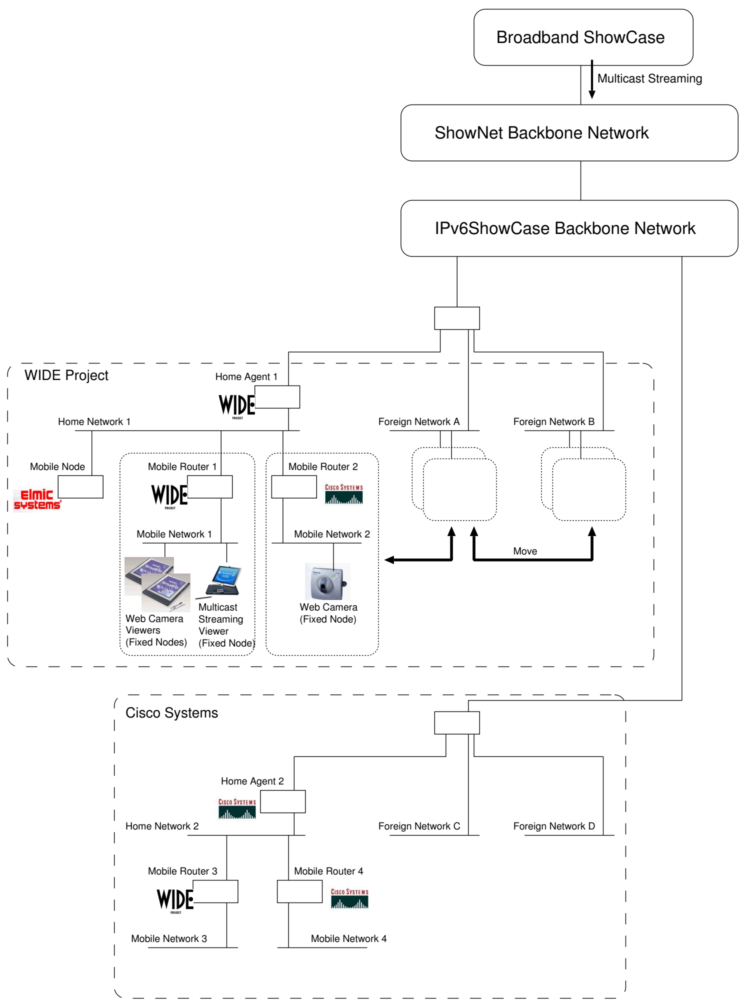

Figure 7.1: The topology we used at the IPv6 ShowCase

7.1.2 Cooperation with iCAR

Due to the use of similar network technologies, Nautilus6 and the ICAR Working Group [47] worked together in several events.

Nautilus6 has participated in iCAR tests in SFC campus in June, by setting up several Mobile Routers and one Home Agent. It was the occasion to write a document to set up a MR or a HA from scratch (see Nautilus6 Wiki).

In August, Nautilus6 attended the iCAR camp in NAIST, to test and gather statistics with streaming applications, with different kind of connection technologies. Technical details can be found in [44], section 2.5 and 3.2.

For the ITS World Congress [48], held in October 2004 in Nagoya, Nautilus6 helped for the demonstrations, as well as for the conception of the system to evaluate the demonstration set up by iCAR.

7.1.3 Demonstration at ORF

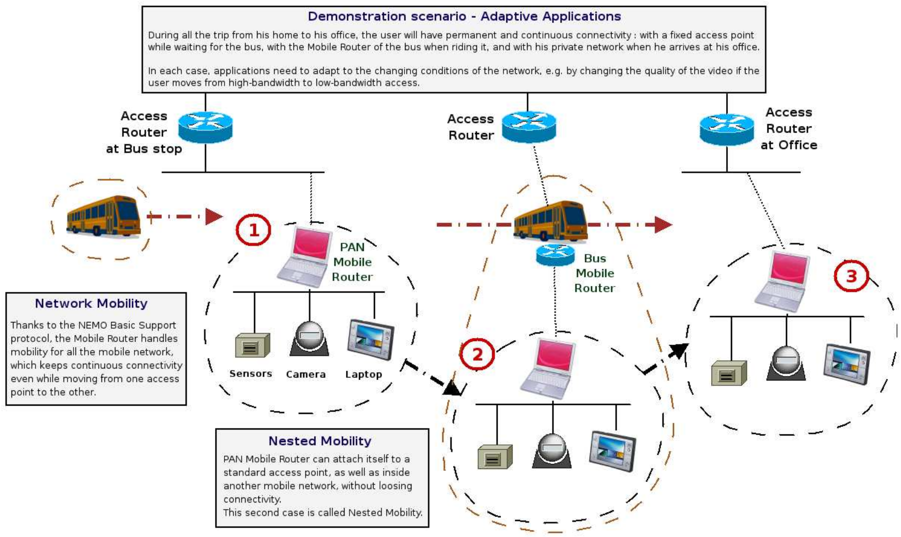

Figure 7.2: ORF demonstration topology

Nautilus6 has participated to the Open Research Forum event [49], held in November 2004 in Roppongi (Tokyo). We have demonstrated Network Mobility, Nested Mobility and MR-MR communication (figure 7.2). A Personal Area Network (PAN) could move to three different foreign networks, including one Mobile Network (Nested case). A Mobile Network Node in the PAN acted as a Streaming Video Client, displaying video from a camera that was itself a MNN from another Mobile Network. Several IPv6 sensors as well as an IPv6 camera inside the PAN could be monitored from the Internet, thanks to a JAVA software installed on a Correspondent Node (figure 7.3).

7.1.4 Demonstration at UNS

Nautilus6 has participated to the Ubiquitous Network Symposium (UNS), held in November 2004 in Odaiba (Tokyo). We have demonstrated Network Mobility, Nested Mobility, adaptive video streaming and flow encryption using IPsec. A Personal Area Network (PAN) could move from one foreign network to a Mobile Network (Nested case). The Streaming Video Client in the PAN could adapt the video streaming flow thanks to a simple protocol between the Mobile Router and the Mobile Network Node (see 6.2). The signaling informations between

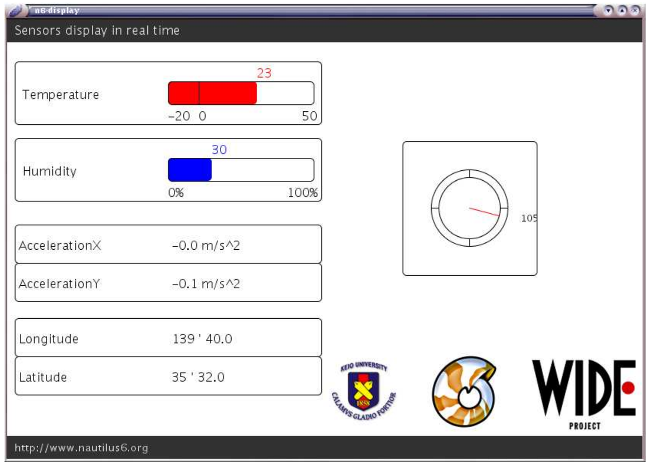

Figure 7.3: Real-time display of sensors inside a NEMO

the Mobile Router and its Home Agent were protected by IPsec, and we could monitor the packets on a sniffer located on the path between the MR and its Home Agent. Also, a Correspondent Node could monitor the IPv6 sensors located in the PAN, and displayed these informations on screen with a JAVA software (figure 7.3).

7.2 Outdoor Demonstration: e-Bike and e-Wheelchair

7.2.1 Common Communication System

Our intend this year is to demonstrate real usages of our technologies, outdoor, on a PAN-like architecture. Feature will include at first NEMO BS, in a nested fashion, multihoming, and if possible seamless, security and AAA mechanisms.

The communication system will have to support the following features and protocols:

- NEMO Basic Support to handle network mobility and horizontal handovers (handovers between the same access technology),
- Some multihoming features, to support multiple mobile routers and multiple interfaces, especially vertical handovers (handovers between different access technologies),
- Security and AAA features, in order to guarantee confidentiality and propose access control mechanisms,
- Seamless Mobility, for instance FMIPv6, to perform fast handovers, transparently to the users,
- Some Multicast features, for example XCAST streaming from the Mobile Network,

- A protocol between the Mobile Router and the Mobile Network Nodes to advertise some of the interesting network informations. Such a protocol could be used by the adaptive applications to adapt their flows to the current network conditions.

7.2.2 Usages

We are thinking about 2 usages: e-Bike for leisure, and e-Wheelchair for people with disabilities. We have already bought the equipments and we are finalizing the setup. e-Wheelchair will be a simple variant of the e-Bicycle systems described in the first section below. Besides e-Bike and e-Wheelchair, the base system could be configured in as many denominations as there are usages to demonstrate. The communication system and the equipments described in this section will remain mostly the same whatever the usages, but the system will have to be configured in a way that matches the user requirements according to its usage. For instance, the e-Bicycle described below doesn't have the same reliability, security and access control requirements if it's used for leisure, for sightseeing, or for firemen in the forest. Similarly, e-Wheelchair will have to be adapted to the handicap of its user.

- **e-Bike:** we plan to demonstrate e-Bike between Tokyo and the Hamanako lake, where the next WIDE camp will be held in March 2005. Two distinct platforms are designed at both K2, Japan and ULP, France (see in subsections below).

- **e-Wheelchair:** the development of Internet technologies based on the IPv6 protocol can allow real-time monitoring of people with health deficiencies and improve the independence of elderly or disabled people. We are currently designing the necessary communication system based on IPv6 protocols, and we are developing an electronic wheelchair to demonstrate the benefit of IPv6 and mobility technologies for health-care usages. This work is performed in cooperation with the e-Care project based at Keio University [50, 51, 52], and might involve the Handicom team based at INT Evry [53] (also see section 10). The motivations for this usage and the details of the communication system have been published in [54], whereas discussion about specific constraints and applications for this platform can be seen in [55, 44]. The requirements from the point of view of the users and the details of this communication system are currently being discussed with e-Care which have experience with the real needs of disabled or elderly people.

- **Others:** we expect members of nautilus6 to actually use the system in their own way. We are for instance thinking the design a real life game in Tokyo or Yokohama involving players carrying a PAN and using IPv6 technologies.

7.2.3 System Overview at K2

The E-Bike (figure 7.4) is composed of a Personal Area Network (PAN, figure 7.5). We use the following equipments for the PAN:

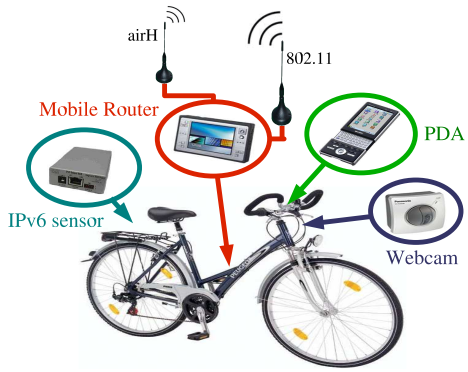

Figure 7.4: The E-Bike

- A Mobile Router. We use a SONY VAIO U70 for our Linux platform, and a SOEKRIS net4521 for our NetBSD platform. We are also looking for other small equipments that could act as a Mobile Router. We have listed some interesting devices in a report [56]. Basically we are looking for a small and light device, with battery or easy to power, including several network interfaces (Ethernet, 802.11, bluetooth, and PCMCIA in order to use 3G cards), that could run a Linux (2.6 kernel) or *BSD operating system,
- A PANASONIC IPv6 webcam, to provide streaming video or pictures from the mobile network,
- Several IPv6 sensors, such as temperature/humidity, acceleration, direction, and GPS sensors,
- A SHARP Zaurus PDA, that can act as a video streaming player or can be used to browse the Internet. It can act as a Volatile Mobile Node and be brought outside of the Mobile Network by the user,
- A power-over-ethernet (PoE) hub [57], that provides power to the sensors and the SOEKRIS board. We can plug up to four PoE devices on the hub.

7.2.4 System Overview at ULP

Our E-Bike (figure 7.6) is a little bit different from the K2 one. We use the following devices for the PAN:

- A Mobile Router. We use a SOEKRIS net4521 Card with Ethernet, GPRS/UMTS, and two 802.11 interfaces as a mobile router. The Internet connectivity is ensured by GPRS/UMTS and 802.11 interfaces whereas the second 802.11 interface works in Ad Hoc mode in order to offer Internet connectivity to the user terminal. A Hub (or a Switch) will be connected to the SOEKRIS Ethernet port and will bind the different IPv6 sensors to the Mobile Router.

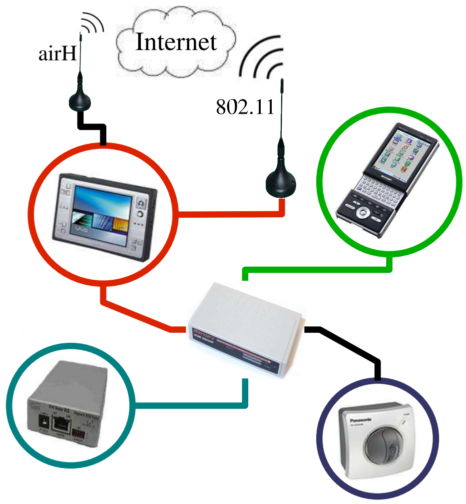

Figure 7.5: The Personal Area Network

- Several IPv6 sensors, such as temperature/humidity, acceleration, direction and GPS sensors.
- A SHARP Zaurus CL-760 PDA as user terminal.
- A Hub or a Switch, in order to bind all IPv6 sensors to the Mobile Router.
- A 12V battery pack, in order to power all devices except user terminal.

The ULP E-Bike will support the same features and protocols as the K2 one.

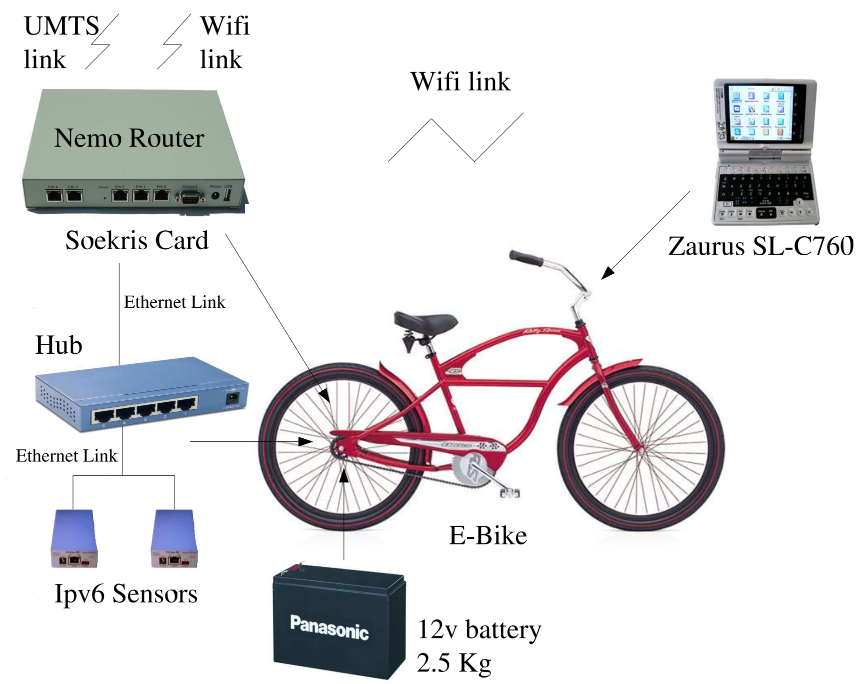

Figure 7.6: ULP E-Bike

Chapter 8

Operational Set-Up of the Technologies

Right now, only host mobility (i.e. Mobile IPv6) and companion IPv6 protocols developed by other WIDE working group (mainly KAME and USAGI) have reached the level of maturity needed for an operational use. One of the current Nautilus activity is thus the development of an operational testbed to demonstrate the usefulness and readiness of the Mobile IPv6 protocol.

Last year, Mobile IPv6 and applications to benefit from mobility were developed on a PDA running Linux (Zaurus from Sharp). IPv6 applications included web browsing, emailing, and voice over IP. This PDA was distributed to a number of WIDE members. Conclusions of this experiment are devised in section 8.1.

A new experiment is now being set up with the SOI working group in order to distribute teaching materials to students in their whereabouts , still on the same PDA, but enriched with new the Zaurus applications detailed in section 6.1. Details of the collaboration with SOI are given in section 8.2. Besides this experiment with SOI, we are also planning to set up a real operational platform for Layer 3 mobility. Details of our plans are indicated in section 8.3. In both the experiment with SOI and the operational platform, statistics will be collected to assess the performance and use of Mobile IPv6.

8.1 Conclusions on 1st Phase Zaurus Experiment

We provided a Layer-3 mobility service by operating a home agent which was located at K2 and provided around 40 Zaurus (with wireless LAN card, 512MB extension storage and a headset) to WIDE/Nautilus6 members with Mobile IPv6 stack and VoIP/Video streaming applications developed by the USAGI project. Through the operation, we got the following results:

- Home agent operation
  - The service was stable enough.

  - However, we saw a few kernel crashes, during managing IPsec Security Association/Policy database. This bug was not fixed, and we continue to investigate this problem on the new implementation (SHISA).
  - The registration procedure to add/remove mobile nodes to the service was very hard. Fortunately, this time, we used almost static configuration for all mobile nodes, that made it easier to manage nodes, but if we accept more users and need to dynamically add/delete nodes, we need some advanced configuration interface for the service.

- Zaurus operation
  - Most users did not use Zaurus for the experiment.
  - Applications we provided were not very attractive for them. e.g. VoIP application needs partners but each participant doesn't know other participants enough to talk with a VoIP application.
  - Connection problem. Most users had IPv6 connectivity on both their companies and homes. However, while they are home or in company, they usually use a PC and not Zaurus. We need to provide an easy tunneling solution in future experiments.

Most of users who joined this experiment said that Zaurus is not suitable device for always connected environment mainly because of battery life. Also, the VoIP application we provided was not a suitable application to make people use Zaurus, since most of users didn't turn on the device. We need to consider seriously what is the need for mobility and what kind of device are good to realize it.

We are now planning to set up an operational platform which is described later, which should solve the management problem described above by providing some user interface. About user nodes, we have already set up a L2P tunnel server to solve the accessibility problem. Also, we need to investigate the user needs to make them use the layer-3 mobility service. We also planning a new application which we think people are interested in.

8.2 Experiment: Cooperation with SOI

The WIDE Working Group School of Internet (SOI) [58] is dedicated to distributing university-level courses, using IPv6 Internet technologies. For the moment, watching their streaming courses requires a standard computer with correct bandwidth. The objective of the collaboration with Nautilus6 [55] is to allow people to listen to courses while moving, for example during the time they spend everyday when commuting from their homes to their working place. The sound is the most important at that moment, but the user may also want to look at the slides or just plain text going with the course. Thus, it can be useful to have a terminal with a screen, but that is still light and that can be held in one hand.

Therefore, we need a small device (like cell phone or PDA), Internet connectivity (at least enough to listen to sound, i.e. 16 Kbps), and Mobile IPv6 to provide for continuous access. We proposed the following system architecture to SOI:

- Zaurus PDA using Sharp's original ROM, which was modified by USAGI to support MIP6;
- WiFi and Air-H or b-mobile cards for the connectivity;
- L2TP with the server installed in K2 Campus, to have IPv6 even in IPv4-only networks;
- Darwin Streaming Server;
- mp4player cross-compiled for Zaurus (see 6.1), and modified to support bookmarks and synchronized slides display.

This work is currently under progress, and should be deployed before the WIDE camp in spring 2005.

8.3 Next Steps: Set Up of an Operational Platform

We are planning to provide a real operational platform for Layer 3 mobility service. The operational platform will be something different from the operational experiment we did with Zauruses this year. The operational experiment mostly focused on Zaurus support and we focused on applications on Zaurus and the usage of a small mobile device, like Zaurus.

In order to demonstrate its operational value, dynamic security and access control mechanisms must be brought to the users. In our newly planning operational platform, we will host not only Zauruses but also various mobile devices, including PC, embedded devices, and other systems which supports the IETF standard Mobile IPv6 and NEMO protocols. Network mobility and multihoming features will be added later once they reach a sufficient level of maturity. Performance mechanisms such as seamless mobility and route optimization will also have to be considered in the future.

The operational platform will be constructed step by step. Here is the current plan of the platform construction:

1. Build the basic platform which has a single home agent.
2. Add a web-based user interface to register the mobility service. This includes,
   - Getting a home address/mobile network prefixes.
   - Getting security parameters which are required to operate Mobile IPv6 and NEMO.
   - Some monitoring functions to check the activity of the home agent and mobile nodes/routers.
3. Start operation of this platform.
4. Open this platform to the public.
5. Add more enhancement.

- Add a dynamic keying support used by mobility protocols.
- Add an AAA based authentication framework.
- High availability mechanism.
- Multicasting support.

Right now, we are trying to start the platform before the end of February 2005, possibly involving our French partners (ULP already hosts a HA, this computer will be upgraded for the operational service).

Chapter 9

Conclusions and Perspectives for Next Year

As the testbed showed, we are in the process of realizing effective demonstrations. The operational testbed is particularly important as this is the first-ever such an effort is conducted in the world. As the development of the necessary protocols goes, we will be able to enrich the operational testbeds and demonstrate tremendous applications and usages of the mobility technology. The current operational testbed will serve as a base.

Particularly, network mobility features will allow us to bring the technology to new areas where Internet technologies were not yet envisioned, such as bicycles or wheel chairs. While the E-Bike testbed may seem at first sight funny or useless, the E-Wheelchair testbed is likely closer to the real usages expected from the Internet technologies. Once this is demonstrated, it will not take long before we are able to equip buses, taxis, trains, robots or people, which will allow communication from everywhere, at anytime, with anybody and in any form, voice and video.

We will also need to conduct an evaluation of the proper operation of implemented protocols and the overall communication system. This evaluation should be performed both based on collected statistics, interoperability testing, and simulation or analysis. We will also need to bring the knowledge of the technology to the users, i.e. by writing documentation to teach how to use and configure the protocols.

Chapter 10

Contributors

The Nautilus6 Working Group is mostly based at K2 and is composed by individual members coming either from WIDE (any WIDE member can join Nautilus6) or not (non WIDE member must first have their institution sign a MOU [1] with WIDE).

10.1 International Collaboration

In order to achieve the integration and deployment of IPv6, the simultaneous efforts conducted in countries that favor IPv6 must be brought together. Particularly, Japanese researchers (mainly WIDE) are the IPv6 leaders in the world, while French account for some of the pioneer researchers in IPv6 and as the leaders in Europe. Korea is also one of the countries that has the most significantly demonstrated its commitment to IPv6. In addition, the need for more cross-relationships between those countries are generally emphasized by their governments. Complementary efforts conducted in the world in IPv6 can easily be put together based on the already established relationships between WIDE and foreign researchers and organizations. Nautilus6 is spreading its memberships based on existing foreign relationships particularly with French and Korean researchers.

10.1.1 WIDE Associated Teams

WIDE members coming from the following labs have contributed to this year's Nautilus6 activities:

- Jun Murai Lab, Keio University SFC Campus, Japan [59]
- Teraoka Lab, Keio University Yagami Campus, Japan [60]
- Esaki Lab, Tokyo University Hongo Campus, Japan [61]
- Internet Initiative Japan (IIJ)
- Shinoda Lab, JAIST, Japan [62]
- and other individual WIDE members

[1] Memorandum of Understanding

10.1.2 Foreign Associated Teams

The following non-WIDE labs have signed a MOU with WIDE and have contributed to this year's Nautilus6 activities:

- LSIIT at Université Louis Pasteur Strasbourg (ULP), France [63]
- RSM at ENST Bretagne (ENSTB), engineering school, France [64]
- LOR at INT Evry, engineering school, France [65]
- France Telecom Research and Development (FT R&D), France.
- MMLAB at Seoul National University (SNU), Korea [66]
- ARMOR at INRIA (IRISA), public research institute, France [67]

Individual Nautilus6 members also maintain cross-relationships with individuals from other countries and institutions, particularly on IETF activities, as this can be seen from our students exchanges (see 10.2 below) and common publications (see 10.5 below).

10.2 Student Exchanges

Following the signature of the MOU, we were able to exchange students in both directions for a few months. These exchanges were very valuable as they help to enforce links between different labs. We will pursue such exchanges. The following students have gone abroad, in either directions:

- Romain Kuntz: Master student from ULP visiting K2 for a 6-months internship, working on NEMO and multihoming. Romain is now working at K2 as a research assistant.
- Francois Leiber: Master student from ENSTB visiting K2 for a 6-months internship, working on applications and the set up of the demonstrations. Francois is now working at K2 as a research assistant.
- Nicolas Montavont: PhD student from ULP, visiting K2 for a few weeks to work on multihoming in nested mobile networks and multihoming activities at the IETF (Mobile IPv6, NEMO).
- Emil Ivov: PhD student from ULP, visiting K2 for a few weeks to work on the FMIPv6 implementation.
- Yasuo Ashina: Master student from Tokyo University visiting ENSTB for 2 months, working on the Zaurus operational platform.
- Koshiro Mitsuya: PhD student from Keio University visiting ULP a couple of times to set up a NEMO testbed, FMIPv6 testbed, and multicast capabilities.
- Koki Mitani: Master student from Keio University visiting ULP a week to set up a FMIPv6 demo.
- Eun Kyoung Paik: PhD student from SNU, visiting K2 for 6 months, working on multihoming in NEMO.

10.3 Cooperation with other teams

During this year, we have collaborated with the following teams:

- KAME (WIDE Working Group, Japan) [68]
- USAGI (WIDE Working Group, Japan) [14]
- SOI (WIDE Working Group, Japan) [58]
- InternetCAR (WIDE Working Group, Japan) [47]
- eCARE (team based at Keio SFC, Japan) [51, 52, 50]
- XCast (WIDE Working Group, Japan), [69]
- Handicom (INT Evry, France) [53]
- PLANETE (INRIA Sophia-Antipolis), France

10.4 Participating People

The following people have contributed to this year's Nautilus6 activities:

- Thierry Ernst, from Keio University (SFC) is co-chair of N6 and is working mainly on the NEMO activity, the multihoming activity and the design of the NEMO demonstrations. He is authoring or participating to a number of drafts [4, 5, 20, 7, 21, 22, 12, 25], conference papers [70, 71, 54, 72, 29, 30, 32] and journals [33].
- Keiichi Shima, from IIJ, is co-chair of N6 and is working mainly on Mobile IPv6 and NEMO implementation.
- Koshiro Mitsuya, from Keio Universtity (SFC) has contributed to most of the implementations (FMIPv6, NEMO, ...) [8], to the set up of our testbeds. He is in charge of the network administration at K2.
- Romain Kuntz, from Keio University (SFC), has contributed on the NEMO activity on Linux, the multihoming activity, and the design of the NEMO demonstration testbeds. He authored [25, 56, 73, 74]. He is in charge of the network administration at K2.
- Francois Leiber, from Keio University (SFC), has contributed applications and on the demonstration activities. He authored [44, 55].
- Masafumi Watari, from Keio University (SFC) is working on RO in nested mobile networks. His work is detailed in [7] and [19]. He performed his evaluations on both indoor testbeds located at K2, Japan and ULP, France. He has contributed some text in 2.5 and has also helped in network administration tasks.
- Manabu Tsukada, from Keio University (SFC), is working on multihoming. His work is detailed in his Master Thesis [28] and [27].

- Koki Mitani, from Keio University (Yagami), has contributed mostly to the seamless mobility activity (FMIPv6 on BSD, LIES, Wireless Environment Emulator). He authored [36, 75, 38, 37].
- Rie Shibui, from Keio University (Yagami), has contributed mostly to the L2 Trigger activity (LIES), and the Wireless Environment Emulator. She authored [35].
- Emil Ivov, from Université Louis Pasteur, has contributed mostly to the seamless mobility activity (FMIPv6 on Linux). He authored [76].
- Martin André, from Université Louis Pasteur, has contributed mostly to the seamless mobility activity (FMIPv6 on Linux).
- Nicolas Montavont, from Université Louis Pasteur, has contributed mostly to the multihoming activity and authored a paper [29] and internet draft [21] in cooperation with Nautilus while visiting K2. He recently completed his PhD dissertation [77].
- EunKyoung Paik, from Seoul National University, has contributed mostly to the multihoming activity. While visiting K2, she wrote her PhD dissertation [34], authored some papers in cooperation with Nautilus [32, 33] and participated to [20, 22, 25].
- Julien Bournelle, from INT Evry, is participating to the AAA activity. He has implemented the AAA features tested at K2, as outlined in section 5.
- Saber Zrelli from JAIST is participating to the AAA activity. He is currently defining the AAA requirements and designing the AAA infrastructure for mobility. He is also testing the INT implementation and has contributed some text in section 5
- Other people from ULP, Keio University, Tokyo University, ENSTB, INT Evry, FT R&D, INRIA, KAME, and USAGI have either participated to some of our activities or to discussions on our mailing list.

10.5 Summary of Publications involving Nautilus6 members

Nautilus6 members have been involved, either as first authors, secondary authors, reviewers, or advisers, in the following publications:

Activity NEMO:
PhD Thesis: [34]
Master Thesis: [19, 73]
Papers: [71, 32, 33, 31, 74]
Drafts: [6, 4, 5, 7, 78, 79]
Technical Reports: [56, 8]

Activity Multihoming:
PhD Thesis: [77, 34]
Papers: [70, 30, 32, 29]
Drafts: [12, 80, 20, 21, 22, 25]
Bachelor thesis[28]

Activity Seamless Mobility:
Master Thesis: [75]
Papers: [35, 36]
Drafts: [38]
Technical Reports: [37]

Miscellaneous activities
Papers: E-Wheelchair [54, 55], XCAST [72]
Master Thesis: [44]

Bibliography

[1] Thierry Ernst, Keiichi Shima, Koshiro Mitsuya, and al. Nautilus6 Working Group Activity Report in 2003. In *WIDE Project Activity Report 2003*, March 2004. http://member.wide.ad.jp/draft/wide-draft-nautilus6-2003activityreport-03.pdf.

[2] Nautilus6 Working Group, WIDE Project. Web page, As of January 2005. http://www.nautilus6.org.

[3] Nautilus6 Working Group WIKI, WIDE Project. URL, As of January 2005. http://www.nautilus6.org/confidential/n6wiki/pukiwiki.php.

[4] Thierry Ernst and Hong-Yon Lach. Network Mobility Support Terminology. Internet Draft draft-ietf-nemo-terminology-02.txt, IETF, October 2004. Work in progress.

[5] Thierry Ernst. Network Mobility Support Requirements. Internet Draft draft-ietf-nemo-requirements-03.txt, IETF, October 2004. Work in progress.

[6] Vijay Devarapalli, Ryuji Wakikawa, Alexandru Petrescu, and Pascal Thubert. Network Mobility (NEMO) Basic Support Protocol. Internet Draft draft-ietf-nemo-basic-support-03.txt, IETF, June 2004. Work in progress.

[7] Masafumi Watari and Thierry Ernst. Route Optimization with Nested Correspondent Nodes. Internet Draft draft-watari-nemo-nested-cn-00.txt, IETF, February 2004. Work in progress.

[8] Koshiro Mitsuya. Atlantis: Nautilus6 NEMO Basic Support Implementation. Implementation Report ir-nemo-bs-20040712-MitsuyaK.pdf, WIDE at Keio University, April 2004. http://www.nautilus6.org/doc/ir-nemo-bs-20040712-MitsuyaK.pdf.

[9] SHISA: an implementation of Mobile IPv6 within the KAME IPv6 stack, January 2005. http://www.mobileip.jp/, http://www.kame.net/.

[10] Johnson, D. and Perkins, C. and Arkko, J. Mobility Support in IPv6. Request For Comments (RFC) 3775, IETF, June 2004.

[11] Arkko, J. and Devarapalli, V. and Dupont, Francis. Using IPsec to Protect Mobile IPv6 Signaling Between Mobile Nodes and Home Agents. Request For Comments (RFC) 3776, IETF, June 2004.

[12] Ryuji Wakikawa, Keisuke Uehara, Thierry Ernst, and Kenichi Nagami. Multiple Care-of Address Registration on Mobile IPv6. Internet Draft draft-wakikawa-mobileip-multiplecoa-03.txt, IETF, June 2004.

[13] KAME weekly snap-kit. ftp://ftp.kame.net/pub/kame/snap/.

[14] USAGI Working Group: IPv6 and IPsec protocol stack for the Linux system, WIDE Project. Web page, As of January 2005. http://www.linux-ipv6.org.

[15] GO project, Service Architecture for the Nomadic Internet Users of the Future. Web page, As of January 2005. http://go.cs.hut.fi/.

[16] Helsinki University of Technology. Web page, As of January 2005. http://www.hut.fi/.

[17] MIPL, Mobile IPv6 for Linux. Web page, January 2005. http://www.mobile-ipv6.org.

[18] The 6th IPv6 Interoperability Test Event, organised by TAHI Project, January 2005. http://www.tahi.org/inop/6thinterop.html.

[19] Masafumi Watari. A Route Optimization Scheme for Nested Mobile Networks. Master's thesis, Keio University, Japan, Graduate School of Media and Governance, March 2005.

[20] Thierry Ernst, Nicolas Montavont, Ryuji Wakikawa, Eun Kyoung Paik, Chan Wah Ng, Koojana Kuladinithi, and Thomas Noël. Goals and Benefits of Multihoming. Internet Draft draft-ernst-generic-goals-and-benefits-00, IETF, July 2004. Work in progress.

[21] Nicolas Montavont, Ryuji Wakikawa, and Thierry Ernst. Analysis of Multihoming in Mobile IPv6. Internet Draft draft-montavont-mobileip-multihoming-pb-statement-01.txt, IETF, July 2004. Work in progress.

[22] Chan Wah Ng, Eun Kyoung Paik, and Thierry Ernst. Analysis of Multihoming in Network Mobility Support. Internet Draft draft-ietf-nemo-multihoming-issues-01, IETF, October 2004. Work in progress.

[23] Tsukada, Manabu and Mitsuya, Koshiro and Charbon, Julien. *Test of multihoming with KAME implementation*, September 2003. Internal-Memo (in Japanese).

[24] Julien Charbon, Manabu Tsukada, and Koshiro Mitsuya. Testing result of multihoming without mobility. Technical report, July 2003. http://www.sfc.wide.ad.jp/~tu-ka/TermProWeb/report.html.

[25] Romain Kuntz, EunKyoung Paik, Manabu Tsukada, Thierrry Ernst, and Koshiro Mitsuya. Evaluating Multiple Mobile Routers and Multiple NEMO-Prefixes in NEMO Basic Support. Internet-Draft draft-kuntz-nemo-multihoming-test-00.txt, IETF, July 2004.

[26] Koshiro Mitsuya. A dynamic adaptation mechanism of applications in a mobile network. WIDE Memo wide-draft-icar-gnob-00.pdf, Keio University, January 2005.

[27] Manabu Tsukada, Koshiro Mitsuya, Masafumi Watari, and Keisuke Uehara. A dynamic sharing mechanism of internet connectivity in mobile network. WIDE Memo wide-draft-icar-mmrm-00.pdf, Keio University, January 2005.

[28] Manabu Tsukada. Multiple Mobile Router Management, January 2005.

[29] Nicolas Montavont, Thierry Ernst, and Thomas Noel. Multihoming in Nested Mobile Networks. In *International Symposium on Applications and the Internet (SAINT) - IPv6: Technology and Deployment Workshop"*, Tokyo, Japan, January 2004.

[30] Thierry Ng, Chan Wah amd Ernst. Multiple Access Interfaces for Mobile Nodes and Networks. In *IEEE International Conference on Networks (ICON)*, Singapore, November 2004.

[31] Ryuji Wakikawa, Susumu Koshiba, Thierry Ernst, Julien Charbon, Keisuke Uehara, and Jun Murai. Enhanced Mobile Network Protocol for its Robustness and Policy Based Routing. *IEICE Transactions on Communications, Special Issue on Internet Technology IY*, 2004.

[32] EunKyoung Paik, HoSik Cho, Thierry Ernst, and Yanghee Choi. Load Sharing and Session Preservation with Multiple Mobile Routers for Large Scale Network Mobility. In *AINA: International Conference on Advanced Information Networking and Applications*, Fukuoka, Japan, March 2004.

[33] Paik Eunkyoung, Cho HoSik, Thierry Ernst, and Yanghee Choi. Design and Analysis of Resource Management Software for In-Vehicle IPv6 Networks. *IEICE Transactions on Communications*, E87-B(7), July 2004.

[34] EunKyoung Paik. *Performance Enhancement for IPv6 Network Mobility*. PhD thesis, Seoul National University, South-Korea, School of Electrical Engineering and Computer Science, August 2004.

[35] Rie Shibui, Koki Mitani, and Fumio Teraoka. LIES:A inter Layer Information Exchange System for Mobile Communication. In *The Sixth Workshop on Internet Technology (WIT2004)*, December 2004. (in Japanese).

[36] Koki Mitani, Rie Shibui, and Fumio Teraoka. Experimental Implementation of the Wireless Environment Emulator for IP Mobility Experiment. In *IPSJ SIG-DPS*, number 118, June 2004. (in Japanese).

[37] Koki Mitani, Rie Shibui, and Fumio Teraoka. *Specifications of Wireless Environment Emulator (NX-02)*, December 2004. Internal-Memo (in Japanese).

[38] Koki Mitani, Rie Shibui, and Fumio Teraoka. Unified L2 Abstractions for L3-Driven Fast Handover. Internet Draft draft-koki-mobopts-l2-abstractions-01.txt, IETF, October 2004. Work in progress.

[39] P. Calhoun, J. Loughney, E. Guttman, G. Zorn, J. Arkko. *Diameter Base Protocol*, September 2003. RFC 3588.

[40] D Forsberg, Y. Ohba, B. Patil, H Tschofenig, and A. Yegin. Protocol for Carrying Authentication for Network Access (PANA). Internet Draft draft-ietf-pana-pana-07, IETF, December 2004. Work in progress.

[41] B. Aboba and D. Simon. *PPP EAP TLS Authentication Protocol*, October 1999. RFC 2716.

[42] Bruno Deniaud and Francois Leiber. L2TP for Zaurus. http://www.nautilus6.org/operation/doc/howtousel2tp.txt.

[43] Francois Leiber. How to cross-compile MPEG4IP for Zaurus. http://www.nautilus6.org/operation/doc/tc-mpeg4ip_cross_compilation-LEIBER.txt.

[44] Francois Leiber. IPv6 applications to demonstrate IP-layer mobility mechanisms, September 2004. http://www.nautilus6.org/doc/tc-application-20040920-LEIBER.pdf.

[45] Francois Leiber. A survey about Videoconferencing. http://www.nautilus6.org/confidential/doc/tc-demo-Videoconferencing-LEIBER.html.

[46] Virtual-Eye : A Large Scale Virtual environment. URL. http://www-sop.inria.fr/planete/software/V-Eye/.

[47] InternetCAR Working Group (ICAR), WIDE Project. Web page, May As of 2002. http://www.sfc.wide.ad.jp/InternetCAR.

[48] Intelligent Transportation Systems. Web page, October 2004. http://www.itswc2004.jp/.

[49] The "Open Research Forum" (ORF) 2204, November 2004. http://www.kri.sfc.keio.ac.jp/english/event/orf.html.

[50] Healthcare Informatics Research Laboratory, Keio University Research Institute at the Shonan-Fujisawa Campus. Web page, Last visited January 2005. http://www.kri.sfc.keio.ac.jp/english/laboratory/ecare.html.

[51] e-Care Town Fujisawa Project Consortium, Keio University Research Institute at SFC. Web page, Last vitited January 2005. http://www.kri.sfc.keio.ac.jp/english/consortium/ecare.html.

[52] e-Care Town Fujisawa Project Consortium, Keio University Research Institute at SFC. Web page, As of 2004. http://www.e-care-project.jp/english/index.html.

[53] Handicom: Handicap Engineering and Communication Lab, at INT Evry. Web page, Last visited January 2005. http://www.int-evry.fr/handicom.

[54] Thierry Ernst. E-Wheelchair: A Communication System Based on IPv6 and NEMO. In *2nd International Conference on Smart Homes and Health Telematic (ICOST)*, Singapore, September 2004. Keio University, Japan. http://icost2004.i2r.a-star.edu.sg.

[55] Francois Leiber. Adaptive Applications and Usages of Mobility in IPv6. In *Journées Scientifiques Francophones*, Tokyo, Japan, November 2004. http://www.nautilus6.org/doc/misc-application-JSF-200411-LEIBER.pdf.

[56] Romain Kuntz. Devices for a Mobile Router. Technical report, Nautilus6, December 2004. http://www.nautilus6.org/doc/tc-demo-small-mr-20041216-KuntzR.pdf.

[57] Romain Kuntz. Transform a hub ELECOM Laneed LD-PSW08N/AT into a PoE hub. Technical report, Nautilus6, December 2004. http://www.nautilus6.org/doc/tc-poe-hub-20041221-KuntzR-html/poe-hub.html.

[58] School of Internet (SOI) Working Group, WIDE Project. Web page, Last visited January 2005. http://www.soi.wide.ad.jp/.

[59] Jun Murai Lab, Keio University Research Institute at SFC. Web page, Last visited January 2005. http://www.kri.sfc.keio.ac.jp/english/laboratory/internetR.html.

[60] Teraoka Lab, Keio University at Yagami. Web page, Last visited January 2005. http://www.tera.ics.keio.ac.jp/.

[61] Esaki Lab, Tokyo University at Hongo Campus. Web page, Last visited January 2005. http://www.hongo.wide.ad.jp/.

[62] Shinoda Laboratory at JAIST, Japan. Web page, Last visited January 2005. http://shinoda-www.jaist.ac.jp/index.html.en.

[63] LSIIT, Université Louis Pasteur (ULP), France. Web page, Last visited January 2005. http://clarinet.u-strasbg.fr/english/index_en.php.

[64] RSM (Multimedia Networks and Services) department at ENST Bretagne, France. Web page, Last visited January 2005. http://www.enst-bretagne.fr/recherche/depts/depts/presentation.en.php?idD=7.

[65] LOR (LOgiciels-Réseaux) department at INT Evry, France. Web Page, Last visited January 2005. http://www.int-evry.fr/lor/eng/index.php.

[66] MMLAB, Seoul National University (SNU), Korea. Web page, Last visited January 2005. http://mmlab.snu.ac.kr/.

[67] ARMOR (Architecture and Models of Networks) project at IRISA, France. Web page, Last visited January 2005. http://www.irisa.fr/armor/index-eng.htm.

[68] KAME Working Group, WIDE Project. Web page, As of 2004. http://www.kame.net.

[69] Yuji Imai. XCAST Related Researches. Web page, As of October 2004. http://wiki.xcast.jp/cgi-bin/xcast-wiki.pl.

[70] Thierry Ernst and Julien Charbon. Multihoming with NEMO Basic Support. In *First International Conference on Mobile Computing and Ubiquitous Computing (ICMU)*, Yokosuka, Japan, January 2004.

[71] Thierry Ernst. Les Reseaux Mobiles dans IPv6, Support Nécessaire au Multimédia. In *Première Conférence Nationale sur le Multimédia Mobile (MCube)*, Montbelliard, France, March 2004.

[72] Thierry Ernst. Decreasing Mobile IPv6 Signaling with XCAST. In *The International Conference on Information Networking (ICOIN)*, Jeju, South-Korea, January 2005. (to appear in).

[73] Romain Kuntz. Development of a NEMO-based demonstration platfrom in IPv6. Master's thesis, Université Louis Pasteur, Strasbourg, France, September 2004. http://www.nautilus6.org/doc/tc-demo-platform-20041110-KuntzR.pdf.

[74] Romain Kuntz. IPv6 Network Mobility, Usage and Demonstration. In *Journées Scientifiques Francophones (JSF)*, Tokyo, Japan, November 2004. http://www.nautilus6.org/doc/misc-network-mobility-jsf-20040913-KuntzR.pdf.

[75] Koki Mitani. A Seamless Mobility Mechanism Based on Inter-Layer Control Information Exchange Architecture. Master's thesis, Keio University Graduate School of Science and Technology Yagami Campus, 3-14-1 Hiyoshi Kohoku-ku, Yokohama-shi Kanagawa-ken 223-8522, Japan, February 2005.

[76] Emil Ivov and Thomas Noel. Optimizing sip application layer mobility over ipv6 using layer 2 triggers. IEEE Vehicular Technology Conference (VTC'04), September 2004.

[77] Nicolas Montavont. *Multiple Interfaces Management and Fast Handover Mechanisms on an IPv6 Terminal (Gestion Optimisée d'Interfaces Multiples et Prise en Compte des Déplacements Rapides sur un Terminal IPv6 Mobile)*. PhD thesis, Université Louis Pasteur, Strasbourg, France, Département Informatique, Laboratoire LSIIT, UMR CNRS-ULP 7005, September 2004.

[78] Pascal Thubert, Ryuji Wakikawa, and Vijay Devarapalli. NEMO Home Network Models. Internet Draft draft-ietf-nemo-home-network-models-01, IETF, October 2004. Work in progress.

[79] Pascal Thubert and Nicolas Montavont. Nested NEMO Tree Discovery. Internet Draft draft-thubert-tree-discovery-01.txt, IETF, October 2004. Work in progress.

[80] Nicolas Montavont, Thomas Noel, and Mohammed Kassi-Lahlou. Mipv6 for multiple interfaces. Technical Report draft-montavont-mobileip-mmi-01.txt, IETF, October 2003. Work in progress.