第 VIII 部

nautilus6 project: Research/ Development/Deployment of mobility technologies in IPv6

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Abstract

This report summarizes the activities realized within the WIDE Nautilus6 Working Group during the year 2006.

第 1 章 Introduction

The WIDE[272] Nautilus6 Working Group[165] has been established in fall 2002 to provide a better IPv6 mobility environment to the users. We concentrate our work on research, implementations and demonstrations on various topics around IPv6 and IPv6 mobility: host and network mobility, multihoming, seamless mobility, AAA, security, applications and operations.

第 2 章 Contributors

The following people have contributed to this report (in alphabetical order):

- Martin ANDRÉ (The University of Tokyo, Japan),
- Angeline DELEPLACE (Keio University, Japan and Louis Pasteur University, France),
- Thierry ERNST (Institut National de Recherche en Informatique et en Automatique, France)
- Satomi FUJIMAKI (Keio University, Japan),
- Romain KUNTZ (The University of Tokyo, Japan),
- Jean LORCHAT (Keio University, Japan),
- Koshiro MITSUYA (Keio University, Japan),
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第 3 章 NEMO Basic Support

3.1 NEMO Basic Support implementation

Some efforts have been done on NEPL[168], the NEMO Basic Support implementation for the GNU/Linux operating system, to improve the performance or bring new features to comply to the specification (RFC3963[51]). We thus have contributed some code for optimistic handovers (to reduce the handover time) and Home Address configuration from the Mobile Network Prefix.

We also maintain a NEPL Howto[169], which is a step-by-step documentation to allow any users to build easily a NEMO testbed from scratch.

3.2 Evaluation of the NEMO implementation

Evaluation of implementations is an important step in a protocol development, in order to check if the protocol behaves as expected and with good performances.

Basic performances of SHISA[221], a Mobile IPv6 and NEMO Basic Support stack for the BSD operating systems, has been evaluated and results gathered in a paper[128].

NEPL, the NEMO Platform for Linux[168], has also been evaluated in [128], as well as in [133] using an hybrid measurement method.

Although both implementations are still work in progress, results show that they are already useable with decent performances.

3.3 SHISA NetBSD-current Port

SHISA (further described in [220]) is a Mobile IPv6 and NEMO Basic Support implementation for the BSD operating systems built on top of the KAME IPv6 stack. Although the KAME project concluded its activity in March 2006, the SHISA project is still going on as a separate project to support IETF standard based mobility protocol stack for BSD.

Our next step is to port the stack that depends on the KAME code to the plain BSD operating systems. We are now focusing on the NetBSD-current operating system as the first target operating system. We have completed the porting work of the latest SHISA code to the almost current version of the NetBSD source code. We are periodically catching up the latest NetBSD code (almost every month) and will continue our effort to merge it to the original NetBSD.

3.4 SHISA Gumstix Port

When considering a personal mobile environment, mobile technologies are not very useful if we cannot use them with small devices.

We started an effort to run our SHISA mobility stack on an environment with limited resources. The target platform we chose was the Gumstix products[1]. We ported the NetBSD-current operating system and the SHISA mobility stack to that platform. As of December 2006, the mobile node and mobile router functions are running on the Gumstix connex 400xm hardware. The NetBSD source code for the Gumstix platform has already been merged to the original NetBSD tree. The mobility part will be available publicly when our merging work has been completed.

3.5 NEMO BS IPv4 Network Support

Most of the users in the Internet are now mainly using IPv4. It is impossible for all users to change their infrastructure from IPv4 to IPv6 in a very short time, even if IPv6 has several advantages over IPv4.

We designed a mechanism to distribute IPv4 network prefixes using the NEMO Basic Support (NEMO BS) protocol, and enabled the protocol to support both IPv6 and IPv4 mobile networks. This extension allows the users to keep using the IPv4 Internet as before, and adds all the benefits of the network mobility with NEMO BS. For example, the users can subscribe to multiple upstream ISPs for redundancy, or can distribute outgoing/incoming traffic between multiple NEMO tunnels for load balancing. The idea was first presented in a paper[217], then finally integrated in an IETF draft specification "Dual Stack Mobile IPv6 (DSMIPv6) for Hosts and Routers"[228].

第 4 章 Multihoming

4.1 State of the Art of Multihoming

A site (or a host) is multihomed when it has more than one Internet connection (from one or several providers). Multihoming is common for large networks like company networks or Internet Service Providers: they connect at least to two (or more) providers. The main reasons are for link redundancy (when a link fails, another one is available) and performances (increasing bandwidth, QoS). With the high development of wireless networks, hosts and small networks (e.g. Personal Area Networks, PANs) would also be easily multihomed.

IPv4 multihoming is achieved with BGP that broadcasts routing information, but having for consequence the growth of BGP tables: one multihoming site adds one entry in the global routing system. That multihoming solution could not be applied to IPv6 (except for larger ISPs) as it will imply an explosion of routing tables.

1 http://www.gumstix.com

A solution needs to be found in order to perform IPv6 multihoming. Many approaches are studied[61]. They could be classified as follow:

- Routing approches: they use IPv4 approaches but add some mecanisms in order to alleviate the scalability problems (e.g. IPv6 multihoming with Route Aggregation, IPv6 Multihoming at Site Exit Router, NAROS, Routing Support for IPv6 Multihoming, etc.),
- Mobility approach: it is based on Mobile IPv6,
- Identifier and locator approaches: those solutions separate the function of identifier and locator of the IP addresses (e.g. Layer 3 Shim, Hash Based Addresses, HIP, LIN6, etc.),
- Transport approaches: the transport layer does not support the notion of multihoming. The change of the IPv6 address usually breaks ongoing sessions. Some mechanisms could be added (or new protocols could be defined) in order to support multihoming (e.g. SCTP, DCCP, TCP-MH, etc.),
- Site exit router and host behaviour: some multihoming solutions could be achieved by changing the behaviour of a site's exit router and/or end hosts. For example, packet headers could be manipulated at site's exit routers to perform multihoming.

4.2 Multihoming in nested mobile networks

Multihoming issues in NEMO Basic Support have been studied in [172]. In [50], we discuss about multihoming in nested cases and focus on ONEMO (Optimzed NEMO[267]). We propose a solution in order to choose the path according to some parameters and by using policies. In [155], a first proposition was done to select the path according to the nested level. We propose to use such information combined with the root mobile router (a mobile router that is directly connected to the Internet) connectivity's information to decide which path is the best to use in a nested topology.

4.3 Multiple Care-of Addresses Registration for NEPL

Multiple Care-of Addresses (MCoA) registration[264] allows a multihomed mobile host (node or router) to efficiently use its multiple interfaces with load balancing, load sharing, and fault recovery mechanisms.

So far, no implementations of this protocol were freely available on the GNU/Linux operating system. We thus have implemented and released this year a beta version of MCoA registration for NEPL[159]. The implementation includes a kernel patch that has been merged in the linux kernel tree as of 2.6.19 (2006 Nov. 29th). We are still working on this implementation, however it is already useable with decent performances. We have already successfully used this implementation in several demonstrations this year (see section 10.1). The implementation design and performance tests results have been described in [127].

4.4 Policy Distribution

A multihomed mobile host has to define routing policies in order to efficiently distribute the traffic over its multiple interfaces. Policies must also be installed on the Home Agent where the node is registered. In order to simplify the administrative tasks and keep the hosts synchronized, a policy distribution mechanism between hosts is mandatory.

We are working on the top of the Multiple Care-of Addresses registration protocol[264] to define a solution for Flow Distribution Policy. This solution explains how packets are forwarded from and to a mobile node by using its multiple CoAs, and how to exchange the flow distribution policies between the endpoints of the multiple virtual paths. Our approach supports the separation of registering bindings and exchanging flow distribution policies, unlike other proposed protocols. We submitted the specification as an IETF draft[149] and presented twice the protocol at the IETF MONAMI6 Working Group meetings this year.

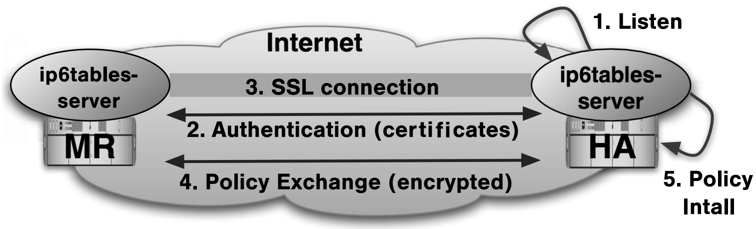

Fig. 4.1. Overview of the policy exchange

We also have partially implemented the solution for the GNU/Linux operating system (See Fig. 4.1 for an overview of the system). Although the framework can be easily ported to other operating systems (such as ∗BSD), some part depends on the policy framework which is tightly integrated into the system. On linux, we have extended the ip6tables software of the netfilter framework[2]. Further technical information can be read in [125]. Our implementation is freely available on our software server[164].

4.5 Multiple NEMOs collaboration

Since NEMO Basic Support was standardized, Internet-connected vehicles and Internet connected Personal Area Networks (PANs) are being deployed. NEMO clusters are thus very likely to appear, for example drivers and passengers who all have a PAN in an Internet-connected vehicle.

At the moment, each Mobile Router of each PAN or vehicle is independently working and maintaining multiple tunnels with their Home Agents. A collaboration among those Mobile Routers could be considered in order to achieve reliability, load sharing, preference settings and efficient battery consumption.

To realize those improvements in the overall NEMO cluster, the Mobile Routers Resource Sharing (MRRS) system was designed. The scenario considered in our MRRS system corresponds to Multiple MRs, multiple HAs and multiple MNPs referred as the case (n,n,n) in [172].

Evaluation results show that the redundancy and the overall bandwidth for the nodes in the mobile network increase while the overall energy consumption is saved. This work will appear as a thesis in [252].

第 5 章　Seamless Mobility

5.1 FMIPv6.org Implementation

The goal of the fmipv6.org project[76] is to provide a fully compliant implementation of the “Fast Handovers for Mobile IPv6” protocol (FMIPv6[124]) and thus to allow improving the handover latency due to Mobile IPv6 procedures on platforms running a Linux kernel.

Efforts have been done to port the FMIPv6.org implementation to work against the latest version of MIPL[145] with newer kernel.

5.2 Layer 2 abstractions

For efficient network communication, it is vital for a protocol layer to know or utilize other layer’s control information. There are several proposals for seamless handovers in IPv6 network such as Fast Handovers for Mobile IPv6 (FMIPv6[124]) and Hierarchical Mobile IPv6 (HMIPv6[227]). In FMIPv6, the network layer must know in advance the indication of a handover from the link layer to achieve seamless handovers. However, control information exchange between protocol layers is not allowed because each protocol layer is designed independently.

To address this problem, we proposed an IETF draft which defines nine kinds of L2 abstractions

2　http://www.netfilter.org

in the form of "primitive" to achieve fast handovers in the network layer. This mechanism is called "L3-driven fast handovers" because the network layer initiates L2 and L3 handovers by using the "primitives".

We started this works in 2002. The first version of the draft (draft-koki-mobopts-l2-abstractions) was submitted in July 2004. We had several presentations in the Mobopts meetings. We also had a presentation at the IEEE 802.21 meeting in March 2005. Finally, it became an IRTF Mobopts Working Group document this year[246].

第 6 章 AAA framework

An AAA framework aiming at demonstrating the applicability of AAA technologies in NEMO environments was deployed in our indoor testbed in January 2006.

6.1 Test scenarios

The following scenarios were tested:

1. Single realm (f-isp.com), authenticating an MR: this first scenario consists in authenticating an MR (that belongs f-isp.com) to the access network before granting IPv6 connectivity.
2. Multi-Realm, authentication of a visiting MR: in this scenario, the MR that belongs to the AAA realm (m-isp.com) is authenticated by the visited realm (f-isp.com).
3. Multi-Realm, authentication of an MNN: In this scenario, the MR that belongs to the AAA realm (m-isp.com) authenticats an MNN that belongs to the realm (f-isp.com).

6.2 Software used

- FreeBSD 5.4
- MR/HA: KAME snapshot: kame-20060123-frebsd54-snap.tgz
- WIDEDiameter: WIDE implementation of Diameter[23], the WIDEDiameter API was used to implement and deploy a Diameter-EAP[69] application.
- PANA[77]: Implemented by INT (France), used in the front-end of the AAA framework to carry EAP messages.

6.3 Conclusion

The AAA framework deployment was successful and the readiness of the existing implementations of AAA technologies could be tested.

第 7 章 Security

7.1 Security Setup How-to for SHISA/MIPL

One of the most difficult tasks when configuring Mobile IPv6 function is to set up IPsec security parameters. We summarized the required security parameters to operate Mobile IPv6 service and published a document as a WIDE Technical-Report[216].

第 8 章 Applications

8.1 SONAR

It is important for both network researchers and operators to know the behavior of mobile nodes (mobile hosts and mobile routers), and to find anomalies in their behavior.

SONAR[230] is a set of free tools to build a statistics repository containing detailed information of mobile nodes. Users can send statistics information about their mobility system to a statistics repository by using these tools. The repository shows the history and analysis results of the collected data (Fig. 8.1). The analysis includes classification of mobility, MIPv6/NEMO protocol evaluation, network access technologies

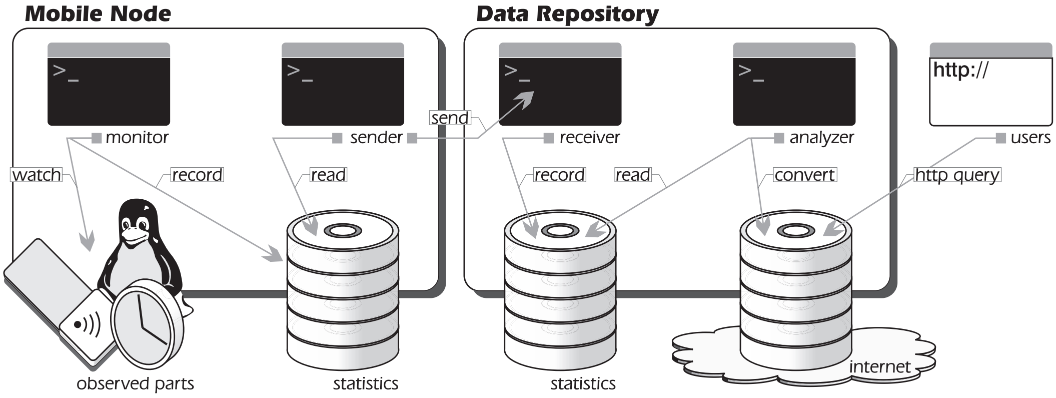

Fig. 8.1. The SONAR architecture

benchmark and correlation between L2 and L3 technologies. We further describe the overview of the SONAR project in [148].

We finished to develop the mobile host clients for Linux (MIPL[145] and NEPL[168]), FreeBSD (SHISA[221]), and NetBSD (SHISA) and some experiments using this client were performed. The source code of the sonar mobile host client has been released[230] in order to get a larger user base and more statistics into the repository. However, more developments are needed because security features are lacking and the statistic module of the mobility protocols is not well tested yet. We are working on this with the developers of the mobility protocols.

We just started to develop the home agent client and some features were tested during a conference[3]. It currently supports only NetBSD (SHISA). We will continue the development next year.

The data repository server has also been updated because the new clients are capable of retrieving more statistics parameters than at the begining. This was finished at end of September 2006. We are also discussing how to provide the statistic information to the public regarding user privacy issues.

8.2 SIP Communicator

SIP Communicator[223] is a project which aims to provide a full solution for communication with Instant Messaging — currently the Jabber, ICQ/AIM and MSN protocols are supported — as well as audio and video call with SIP. It is mainly developed by the Louis Pasteur University in Strasbourg, France. The SIP Communicator supports both IPv4 and IPv6 and is thus a great tool to be used in our demonstrations.

We have contributed to this software by providing, among others, specific packages for the MacOS X and Debian GNU/Linux operating systems, and adding the support for Growl[3] notifications to the MacOS X SIP Communicator client. Also, we contributed a java version of the ilbc codec[2] and are working on a linux native datasource to lower audio latency.

第 9 章　Operation

9.1 Operational Home Agent Service

The Operational Home Agent Service is meant to provide a full featured IPv6 Mobility service to promote the use of mobility and as a playground for experimental protocols deployment.

The service has already been opened for WIDE members and will shortly be opening publicly. It is composed of three distinct elements:

- Home Agents — currently a NetBSD 2.0.2 server setup in K2 campus with the SHISA

3 http://growl.info

Mobile IPv6 implementation[221] — providing the mobility service;
- Web interface aiming at simplifying all the operations in which the user is involved (see section 9.2 and 9.3);
- Live CD supporting MIPv6 to enjoy quickly the mobility service (see section 9.4).

9.2 Current web interface

The purpose of the web based interface is to provide easily to the users a Home Address (HoA) and the Security Associations (SAs) needed to configure a Mobile Node. This interface provides also the means to create a personalized LiveCD (see subsection 9.4) to easily test the IPv6 mobility.

The current version of the web interface is available on Nautilus6 servers[163]. It is developed in PHP. This system uses a MySQL database for users, HoA and SAs management. The first version of the web interface was released in the middle of July. The service has already been opened to WIDE, Nautilus6 and CNRS members. We further describe the web based interface in [80].

A new version of the interface is currently under development and should be soon released (see section 9.3).

9.3 New web interface

The original web interface could hardly be extended and adapted to newer functionalities. We decided to redesign it as well as the associated database from scratch to take in account the problematics related to the upcoming mobility technologies, such as multihoming, MCoA, NEMO Basic Support and Home Agent Redundancy. The new web interface is also designed to propose support for internationalization and to offer simple administration of the Home Agent (monitoring of the Home Agent with SONAR, user management, HA configuration). With the new web interface, the service gains in functionalities and reliability.

The first version of the new web interface has been presented presented during the WIDE meeting in December and is to be released at the beginning of 2007.

This interface is based on the Ruby on Rails web framework.

9.4 Nautilus6 Live CD

The Nautilus6 Live CD is part of the Operational Home Agent Service and was originally developed to get instant access to the Mobility service. It is capable of connecting to the Home Agent at boot time thanks to the MIPL Mobile IPv6 implementation[145] and includes many softwares related to IPv6 and mobility.

The Live CD is generated through the web interface and contains personal security parameters to register with the Home Agent.

第 10 章 Demonstrations

10.1 Demonstrations at the WIDE Camp, Spring and Autumn 2006

The WIDE Camps are a very good place to hold network experiments. During those events, IPv6 connectivity is offered to the camp attendees. We have taken this opportunity to setup several mobility demonstration to both the Spring and Autumn camp this year.

10.1.1 Smooth Handover Demonstration using SHISA

NEMO Basic Support (NEMO BS) adds mobility functions to the IPv6 routers. The network behind the mobile router becomes logically static. This function is useful when a network has a lot of nodes that do not have any mobility functions but move with the whole network. The typical usage of this technology is the network provided in transportation systems like buses, trains or airplanes.

In the base specification of NEMO BS, a mobile router can use only one IPv6 address at a time as its attachment point to the Internet. Therefore, the mobile router and its mobile network will face service disruption of the network connectivity while the mobile router is moving from one network to another network.

We had performed two operational experiments of network mobility. The first one is an experiment using only the base NEMO BS function, this experiment was reported as a part of the last year's activity report. The second one, held on March 2006, is a seamless handover experiment by using multiple network interfaces.

In these experiments, the mobile networks were real conference networks which held a few hundred people. The result shows that the multiple interfaces usage provides one-third to one-tenth of the packet loss rate compared to the case that is not using such multihoming technology. Also, most of the attendees at the conference did not notice the movement, which means that the technology can be used as a realistic solution to achieve seamless handovers. Results of this experiment are further described in [219].

10.1.2 Fault-Tolerant Network using NEPL

The IPv6 camp network was actually a mobile network connected via an IPv6 Mobile Router. We have setup several multihoming configurations, including the usage of Multiple Care-of Addresses registration, to perform load-balancing and fault-tolerance at the gateway, thus ensuring a good service transparently to the IPv6 camp users. A summary of those experiments can be read in [125].

10.1.3 Home Agent Service Demonstration

The WIDE Camp 2006 held in Autumn was also the occasion for the Home Agent Service demonstration. The attendees of the camp could register to the service and move from one room to another while being reachable all along. We monitored the activity of the Home Agent during the whole camp with the SONAR monitoring tool. This was the first "real-life" testing session for the Operational Service and the output of the latter experiment served as a basis for the evaluation of the service[3].

10.2 E-Bicycle demonstration on the Tour de France

We have setup an E-Bicycle demonstration on the Tour de France[4] in July 2006. The Tour de France is a bicycle race event all around France every year in July. This demonstration has been setup in collaboration with French partners: the ENST Rennes, INRIA Rocquencourt, and Louis Pasteur University in Strasbourg.

It has involved two bicycles and a car that embedded a Mobile Network (Fig. 10.1). Anybody in the Internet could monitor the bicycle's whereabouts from a web-browser thanks to the MonNemo application[154]: location on a map, pictures of the surrounding, temperature and humidity in the area etc. Video from the vehicle was sent using XCAST6[5], a new and flexible scheme for multicast.

The motivation and scenario have been further explained in a paper[53] and all the technical information to setup such demonstration has been gathered in a WIDE Technical-Report[126].

10.3 The First Thailand IPv6 summit

The Thailand IPv6 Forum has organized the First Thailand IPv6 Summit, an international seminar, in order to create public awareness about the necessity of IPv6 technologies.

We have prepared two IPv6 Network Mobility (NEMO) demonstrations to be presented to the public during this Summit, on May 3rd and 4th 2006. The first demonstration explained the basic principles of the NEMO technology through the E-Bag (a Personal Area Network that can be easily carried by people). The second demonstration aimed at explaining the need of Dual Stack

4 http://www.letour.fr/indexus.html
5 http://www.xcast.jp

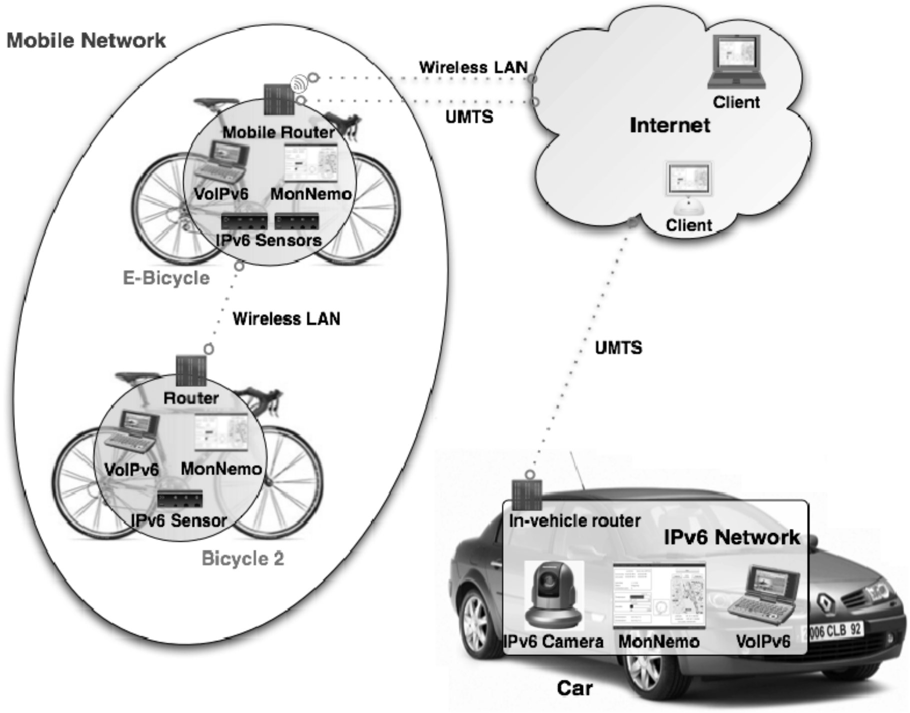

Fig. 10.1. The Tour de France Demonstration Scenario

Mobile IPv6 (DSMIPv6[228]). Besides those demonstrations, we have presented two Open Source NEMO Basic Support implementations, that were used to setup those demonstrations: SHISA[221], a mobility stack for BSD Operating Sytems, and NEPL[168] which is developped for the GNU/Linux Operating System.

More information can be read in a WIDE Technical-Report[218].

10.4 Ubiquitous Network Symposium

We had a demonstration at the CEATEC Japan 2006, which is the biggest exhibition for consumer electronics products in Japan, as a part of the Ubiquitous Network Symposium partners. The contents of the demonstration were almost the same as the demonstration held at the First Thailand IPv6 Summit (see Section 10.3), with new versions of the SHISA and NEPL implementations.

第 11 章 IPv6 Mobility Promotion & Publication

As part of its IPv6 mobility promotion goal, Nautilus6 has successfully organized the 1st International WOrkshop on NEtwork MObility which was collocated with ICOIN held in January 2006 in Sendai, Japan, and the 2nd edition, which will be held next year, still in Japan, this time collocated with the SAINT conference. Nautilus6 contributed to the set up and organization of the workshop by chairing the workshop and leading the review process and providing some facilities like holding the web pages and mailing lists. Nautilus6 also contributed numerous papers to both events ([50, 125, 128, 148, 217, 253]).

Thierry Ernst also served as guest-editor in a special issue on Mobile Routers and Network Mobility in the IEEE Journal on Selected Areas in Communications published in September 2006 (Volume 24 number 9) and published several papers[64, 66, 267] which are direct outputs of Nautilus6 activities completed at Keio University in 2006.

第 12 章　IPv6 Mobility Standardization at IETF

Nautilus6 is heavily involved in IETF standardization, with its members chairing two working groups (IETF NEMO Working Group and IETF MONAMI6 Working Group). The set up of the MONAMI6 Working Group in 2005 is a direct output of Nautilus6 whose members contributed most of the lobbying and problem statement work. Nautilus6 members co-authored numerous working group or individual drafts: our contribution include the update of existing Working Group internet drafts [65, 67, 172] and the revision of former individual drafts accepted this year as Working Group internet drafts [68, 156, 264], Nautilus6 members also provided some insight and implementation feedback which helped improving several protocol specifications ([65, 67, 68, 77, 149, 156, 172, 228, 246, 264]).

第 13 章　IPv6 Mobility Standardization at ISO

Through Thierry Ernst's participation to ISO TC204 Working Group 16 which is standardizing the CALM protocol architecture for Intelligent System Transportation, Nautilus6 is providing some insight on IPv6 protocols and is serving as a non-official liaison with the IETF. In 2006, we were less active than in previous years, but we still contributed on the ISO mailing list and attended the meeting held in Sophia-Antipolis in February 2007.

第 14 章　Conclusion

This year, the WIDE Nautilus6 Working Group has made important progress in the multihoming and operational activities. We have tried to demonstrate our work as much as possible to the public through various demonstrations all over the year, using attractive applications developed in our group. Next year will be an important step as we expect to open our operational service to anyone, bringing the mobility to the end-users. Such operation will need the support of our other activities in the research, implementation, and demonstration sides.

第 15 章　Next Steps

During the past several years, the WIDE Nautilus6 Working Group developed many core protocol stacks (e.g. MIPv6/NEMO BS protocols) and important applications (e.g. the home agent web interface) to utilize them. In next year, we will focus on integrating these technologies into one. We set the home agent service as the core part of the integration work and merge necessary technologies for deployment into the service. The final goal of the integration is to create a complete service package that provides all mobility functions for operators.

Acknowledgments

The Working Group Chairs would like to thank all the Nautilus6 members for their participation in the group during this year, through their contributions in our activities and participations to our Mailing Lists.

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