A Live Light-Weight IPv6 Demonstration Platform for ITS Usages

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Abstract: *In order to improve driving, navigation and security, research on ITS (Intelligent Transportation Systems) has come to contemplate IPv6 as the means to carry the necessary information between the vehicles and the fixed infrastructure. Moreover, an in-vehicle network is expected to be deployed as there will be tens of processing units in such a vehicle. We believe that the required convergence layer communication system should be based on IPv6 and that NEMO Basic Support and enhanced multihoming mechanisms should be used to ensure a permanent and uninterrupted connectivity to the Internet. We quickly review the progress in this area, and we demonstrate the use of such protocols on our testbed which has been designed to validate the basic communication system. This testbed comprises a number of IPv6 sensors and other equipments behind a Mobile Router and can be brought into a vehicle. The overall system can be monitored in real-time from anywhere in the Internet during our live demonstrations.*

Keywords: ITS, IPv6, NEMO Basic Support

INTRODUCTION

The Nautilus6 project [1] has been established within the WIDE organization two years ago to demonstrate the usage of IPv6 mobility and to develop the mechanisms missing for deployment. This indeed requires the specification of an entire communication system, which must include, in addition to mobility mechanisms, other mechanisms for multihoming, access control, and security which best work in a mobile environment. Nautilus6 is also defining usages scenarios and applications which come with it.

Such IPv6 mobility features are expected to be used mainly in Intelligent Transportation Systems (ITS), as it could be assessed by existing effort initiated by or targetted toward the car industry. For example:

- the CALM architecture currently specified at ISO by the technical committee 204 working group 16 (TC204 WG16 [2]),
- the ITS activities in Japan within the WIDE InternetCAR working group and the InternetITS consortium [3],
- the IPv6 e-Vehicle project by Renault in association with Cisco Systems which won the Murai Award in fall 2003 (IPv6 Powered Car).

However, IPv6 and its mobility features could be deployed for many other usages which would benefit from an Internet of wide spread. For instance, it could be used to facilitate the life of the elderly and the disabled [4], for security purposes (e.g. police, firemen), and basically for any person carrying electronic devices.

We advocate that the differences between ITS and other mobility usages are basically politics, economics, policies (the expected use of the system and its expected security level). It has to be noted, though, that most mobility usages would expect Internet connectivity within vehicles of any sort (aircrafts, trains, bus, taxis, trucks, personal cars, police cars, bicycles, etc). So, the underlying communication system must be the same whatever the usage is, but will be tuned differently and may use distinct optional features. For example, the requested quality of service or level of security would be different.

The purpose of this paper is two folds: first, we overview the progress made at the IETF on the mechanisms relevant to meet the needs of the unified communication system, particularly NEMO Basic Support and multihoming. We then describe the work carried on by the Nautilus6 project which is developing such a communication system and a live demonstration testbed.

COMMUNICATION SYSTEM FEATURES AND PROTOCOLS

All applications in a mobile environment require a permanent connectivity to the Internet and continuity of service. In [5], a uniform communication system based on IPv6 is advocated to exchange data between the many CPU units deployed in a vehicle as well as between the vehicle and the infrastructure. Five functional requirements were listed:

- *In-Vehicle Communication System*: next generation vehicles will embed a number of CPUs (sensors, multimedia, navigation); some of them must be interconnected.
- *Permanent Internet Access*: some of the CPUs embedded in the vehicle will have to exchange data with CPUs on the Internet on a regular basis.
- *Wireless Communication and Fast Handovers*: Optimizing the handover delay and providing guarantees against packet loss is necessary for sensitive applications.
- *Vertical Handovers*: the use of multiple technologies is advocated to guarantee ubiquitous Internet access.
- *Scalability and Flexibility*: the system must sustain a growing number of entities (billions), ease of use (for non-specialist persons), flexibility (to bring new features) and backward compatibility with the installed based.

The communication system must use IPv6 everywhere, including an embedded in-vehicle IPv6 network. This in turn requires to manage the mobility of an entire network and the issues which come with it. With the recent advances at the IETF, we can now refine these functional requirements and detail the protocols specified at the IETF that would allow to meet them.

Permanent Internet Access: Network Mobility Support

Mobility support is required to guarantee the continuity of the Internet connectivity when the mobile entity is moving and is thus changing its point of attachment to the Internet. As explained in [3], it has to support both mobility of single nodes (e.g. mobile phone, PDA) as well as mobility of an entire network, like sensors embedded in a vehicle, or a PAN (Personal Area Network) carried by a person walking in the street. These mechanisms must handle all possible configurations, including the nesting of mobility entities (a user carrying a PDA getting attached to the in-bus network, a user carrying a PAN getting attached to the in-bus network, or a bus carried by a ferry getting attached to the in-ferry network).

A protocol such as Mobile IPv6 [6] which has been designed to support a single mobile node is not appropriate for in-vehicle networks. This has been fully demonstrated and has led to the set up of a new group working on this matter at the IETF. The NEMO Working Group has thus been established at the IETF in October 2002 and has specified *NEMO Basic Support* [7], a short-term solution that can easily be deployed. The primary objective of this solution is to preserve session continuity between Correspondent nodes (CNs) and all Mobile Network nodes (MNNs) behind the Mobile Router (MR) while this one changes its point of attachment (see Fig.1). The second objective is to manage mobility transparently to the MNNs located behind the MR. These MNNs may be of different types and include *visiting mobile nodes* (VMNs) which are able to move from one access link to another while keeping their connections open, and *local fixed nodes* (LFNs) which cannot move while retaining their connections. 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 MR and its HA (Home Agent) on the home link for each 2-uplet HoA/CoA. VMNs are allowed to manage their own mobility either by means of Mobile IPv6 (e.g. a passenger with a PDA) or by means of NEMO Basic Support (e.g. a passenger carrying a PAN). NEMO Basic Support does allow such nested configurations.

NEMO Basic Support has already been implemented in both Linux 2.6 kernel and BSD variants. The prococol has also been adopted as a component of the CALM architecture currently being defined by ISO [2].

Ubiquity and Redundancy: Multihoming

Although permanent connectivity to the Internet and continuity of service can be offered by NEMO Basic Support, a widespread deployment of a single physical technology or a single Internet Service Provider cannot be expected, nor the usage of a single technology for all types of traffic. Distinct wireless technologies will have to be used according to the location, country regulations and density to offer the required broad connectivity. The system must therefore allow the use of several technologies to accommodate lack of service, loss of access, the breakdown of a specific technology or equipment, and distinct administrative and user policies. Multiple technologies may even be used at the same time for different types of traffic. The communication system must thus support multihomed configurations.

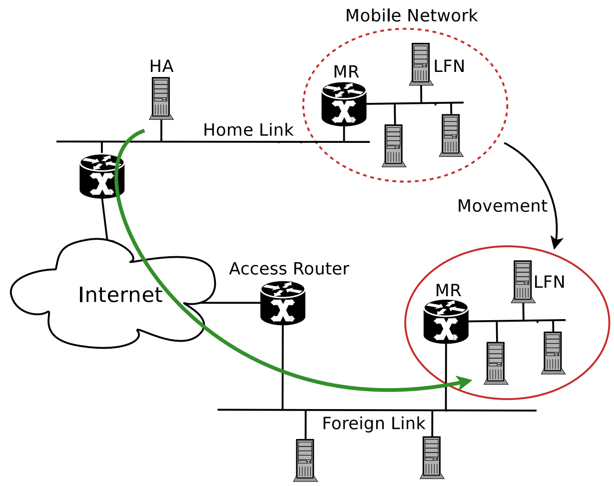

Fig. 1. Entities involved in NEMO Basic Support

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 its 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). The motivation behind multihoming is to provide ubiquitous, permanent and fault-tolerant access to the Internet. This is particularly useful for 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 three separate documents discussed at the IETF:

- In the first document [8] the benefits of multihoming for both fixed and mobile hosts, routers and networks are described, through a number of scenarios, which emphasize the need for multiple interfaces, and the need for multiple exit routers.
- In the second document [9] issues specific to mobile nodes operating Mobile IPv6 are discussed. Situations where a mobile node could be multihomed are classified according to the number of interfaces, home addresses, and care-of addresses. This taxonomy is then used to highlight the issues preventing mobile nodes

operating Mobile IPv6 to be multihomed.

- In the third document [10] submitted and accepted as a NEMO Working Group document, issues specific to mobile networks managed by NEMO Basic Support are described. In this document, the multihomed configurations are classified according to the number of home agents, the number of Mobile Routers, and the number of prefixes. 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.

The IETF must decide which issues to solve in priority. Some non-standardized mechanisms already exist, although no single proposition addresses all the issues at once. Multiple Care-of Addresses registration (MCoA [11]), in particular, allows to keep simultaneously several care-of addresses registrations in the home network and to choose (both on a mobile host or a mobile router) the interface used to transmit data. This solution is being implemented in the Nautilus6 project on both Linux and BSD.

Performance Optimization - Routing Optimization and Seamless Mobility

While on the move, connectivity to the Internet can only be maintained through wireless technologies. Wireless technologies suffer longer delay, lower bitrate output, increased error rate. It is therefore necessary to provide redundancy, to optimize the bandwidth consumption and to optimize the end-to-end path. The end-to-end delay can be optimized by avoiding routing via the home network by means of routing optimization mechanisms, whereas seamless mechanisms can diminish the packet loss during handoffs:

a) NEMO Routing Optimization:: The drawback of NEMO Basic Support is that all packets have to be tunneled between the MR and its HA, in both directions (in order to avoid security concerns and to deploy a quick solution). This leads to increased delay (longer paths), packet overhead (multiple encapsulations), particularly in nested NEMO. The problem is documented in a number of documents currently discussed at the IETF. The NEMO Working Group is chartered to output a problem statement and a solution analysis on the matter. A number of solutions exist, particularly [12] which has been implemented on NetBSD in the Nautilus6 project.

b) Seamless mobility:: Each time a mobile node attaches to a new visited link, a new care-of address must be obtained. This handover takes some time because the node must first notice it has moved under a new Access Router, i.e. after it receives a router advertisement (RA) from the Access Router. Then, the node can configure the new care-of address, and register it with its HA. This whole process takes some time and packets are necessarily lost. The FMIPv6 protocol [13] under specification at the IETF and L2 triggers (see for instance [14], [15] can help to reduce such handover delay. We are currently implementing FMIPv6 on both Linux and BSD.

Access Control and Security

To control access in the network, AAA (Authentication, Authorization and Accounting) mechanisms such as PANA, Diameter, and Radius have been developed for a single host seeking access to a network. This must be adapted to the case of a mobile network, particularly for nested configurations. As an instance, the access network which is granting access to a MR doesn't have any means to distinguish a single mobile node from a mobile router with a number of nodes behind. Requesting every single MNN behind the MR to authenticate with the access network would go against the transparency benefit of NEMO Basic Support. So, extensions are needed so that a MR can negotiate access for all the nodes sharing the NEMO prefix. This issue and other issues related to access control are discussed in [16]. We are currently developing our own implementation of Diameter.

Transition Mechanisms

IPv4-only islands will co-exist with IPv6 likely for decades. We therefore need transition mechanisms that would allow IPv6 nodes to communicate with IPv4 nodes, or mechanisms to transmit IPv6 packets over IPv4 islands, like IPv4-only access networks. L2TP (Layer Two Tunneling Protocol: RFC 2661) or DTCP (Dynamic Tunnel Configuration Protocol: RFC 3077) can be used to solve this issue. When using multiple access networks, multiple IPv6-over-IPv4 tunnels may be needed on the same computer. In that case DTCP is easier to setup to the condition we have one DTCP server per tunnel. Note that these transition mechanisms can only be used when the IPv4 address assigned to the interface remains the same while operating the tunnel. In such a case, new mechanisms recently discussed at the IETF in the MIP6 and NEMO WG will be needed.

Auto-configuration

The communication system must be configured without any human action. Care-of addresses obtained on the visited network are already configured automatically thanks to DHCPv6 or IPv6 Stateless Address Configuration. Regarding the prefix assigned to the mobile network and advertised by the MR down to its MNN, the NEMO Working Group is currently working on two dynamic mechanisms, one using DHCPv6 Prefix Delegation, and the other a simple extension of NEMO Basic Support.

MONNEMO: A LIVE LIGHT-WEIGHT DEMONSTRATION TESTBED

In order to validate the all-IPv6 communication system, we have designed a light-weight generic demonstration testbed based on NEMO Basic Support and other features such MCoA. It is light-weight in the sense the system could be brought to a conference or workshop for demonstration purposes and generic in the sense it could be embedded in any mobile entity, being a car, a bicycle or a pedestrian. It is thus restricted to a PAN usage and can be applied to ITS applications. One of key advantage of our testbed is that demonstration can be performed lively on the Internet

Features	Protocols	System
Mobility support	Mobile IPv6	Linux 2.6 kernel (MIPL2 from USAGI/HUT), Linux 2.4 kernel (MIPL1 from HUT), BSD variants (SHISA on KAME)
	NEMO Basic Support	Linux 2.6 kernel (NEPL from Nautilus6/HUT), BSD variants (SHISA on KAME), NetBSD (Atlantis from Nautilus6)
Performance	FMIPv6	Linux 2.6 kernel (Nautilus6, based on MIPL2), BSD variants (Nautilus6, based on SHISA)
	NEMO RO	NetBSD (Nautilus6, based on Atlantis)
Ubiquity, redundancy	MCoA [11]	Linux 2.6 kernel (Nautilus6, based on NEPL), BSD variants (SHISA on KAME)
Access Control	Diameter	BSD variants
Transition mechanisms	L2TP, DTCP	Linux and BSD variants
Auto-configuration	NEMO Prefix Delegation	Not started

TABLE I

PROTOCOLS AND IMPLEMENTATION STATUS AT N6

or at conferences, under real mobility and Internet access conditions. Live demonstrations are taking place from time to time and are usually open publicly. Details for remote participation are available in [1, showroom page]. For the purpose of our experimentation depicted below, this communication system has been mounted on a bicycle.

Current communication system

Currently, our communication system comprises the base protocols required to maintain a connectivity of wide spread and reach. We use SHISA extensions on KAME (see [1, implementation page] (modified snapshot 20041108 on NetBSD 1.6.2) that supports NEMO Basic Support and MCoA. NEMO Basic Support is used to maintain connectivity to the home network and MCoA to bind several care-of addresses to the same home address. SHISA has also been extended to support multiple cellular access at the same time on the MR. It can interact with a new daemon to receive some information about PPP links availability, and conclude if a vertical handover is needed or not. For transition between IPv6 and IPv4, we use DTCP to transmit IPv6 packets from our IPv6-only NEMO-PAN over the commercial IPv4-only cellular networks. We favored DTCP over L2TP since it allows to set up easily multiple dynamic IPv6-over-IPv4 tunnels on the same MR. More multihoming mechanisms, Diameter, NEMO Routing Optimization and FMIPv6 will be added to the same platform once fully implemented. The implementation status, on both Linux 2.6 and BSD variants, of the protocols highlighted in section II is shown on Tab.I. More details about the implementation can be found on the Nautilus6 web site [1, implementation page].

Hardware

For the MR, we use a SOEKRIS net4521 motherboard. It has 2 ingress interfaces (one 3G or PHS cellular access, and one 802.11b access). On the ingress Ethernet interface is connected a network composed of several IPv6 nodes (LFNs) such as a PDA or a tiny laptop PC with a camera, and sensors. Those sensors can provide current temperature and humidity, direction, acceleration and geo-localization and are queried using SNMPv1. The PDA or laptop can be used to get or send data over the Internet. This PAN can be carried in a bag, on a bicycle (see Fig.2) or a wheelchair. A Power-over-Ethernet hub is providing power to the sensors, whereas the laptop PC or PDA relies on their own supply

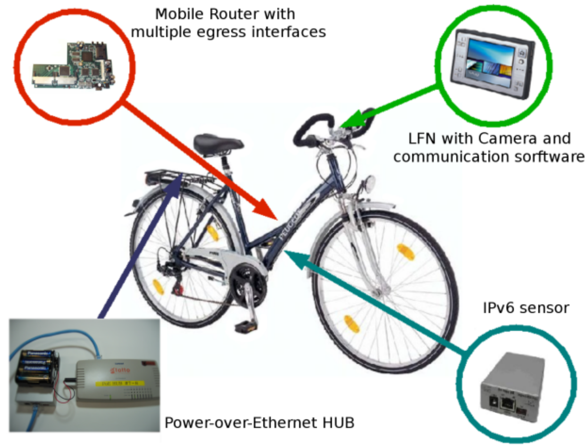

Fig. 2. Equipment on the NEMO-PAN

(we have spare batteries). The SOEKRIS motherboard is powered by an external battery. The system works for an entire day.

Monitoring Software

We have developed a modular Java application to process the data originating from the PAN. It is modular in the sense it is designed to process different types of data (SNMPv1 sensors information, pictures from the web camera, instant messaging text). On the server side, we retrieve a map based on the current GPS coordinates. The map and all data are saved in an IPv6-compliant postgreSQL7.4 database (with complementary informations like ping and number of hops to the PAN). Those data can either be stored and kept for further analysis, or overwritten with next values. On the client side, the map is displayed together with the data provided by the sensors, average speed, an updated picture of the scene (it could be a video when the available bandwidth is higher), instant messages written from the PAN, and other useful data. The application can be run as a command-line or as an applet integrated in a PHP website (see Fig.3). The use of a central database regrouping general session information (title and manager, prefix of the MR, MAC addresses of the sensors and their types, location and time shift of the session, number of people connected to the demonstration at a given time) enables us to easily administrate and control our demonstrations and to evaluate the performance of the system. It is also used so people who do not have IPv6 connectivity can follow our demonstrations, by fetching the latest data from the database instead of directly accessing the PAN.

Communication Sofware

The monitoring software on the PAN side, used on a LFN, includes features to communicate with monitors located anywhere on the Internet. Pictures can easily be taken and be sent automatically when pressing a button on the touch screen, either to a web server, or posted to a blog with some comments from the PAN user. Besides this, the PAN user can also exchange mails with dedicated persons, use the chat system (see Fig.4) and browse the Internet. All of these operations are performed in IPv6 only.

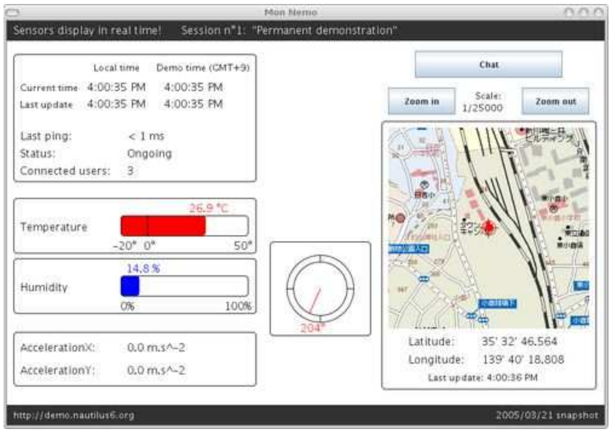

Fig. 3. MonNemo: Monitoring software for the PAN

Fig. 4. The chat system on the LFN in the PAN

Scenario

The equipment has been installed on a trekking bicycle. The front bag contains all the equipment but the temperature sensor which must be isolated from the heat generated. On the networking side, the Mobile Router can choose between two egress interfaces to connect to the internet. In one configuration, we use one cellular access technology and one wireless LAN access and the MR switches between those according to their availability. In the second configuration, we use two different cellular access technologies and the MR chooses the one available, but also according to the length of time each technology was used. In both cases, the PAN user can decide a preference for each interface. Once set up, the cyclist is leaving. Thanks to the monitoring software, anyone can monitor the whereabout of the cyclist, and the cyclist can find his way on the displayed map. He can also communicate with peers using the communication software. In our experiment, the cyclist went from K2 campus at Shin-Kawasaki, Japan to Kamakura, and from then back to Yokohama. Longer experiment will be performed.

Data Gathering

In order to gather some statistics about the performance of the NEMO-PAN, we setup several tools on the Mobile Router, Local Fixed Nodes and Correspondent Nodes. Netperf is a network performance benchmark that we use to measure data transfer and request/response performance using IPv6 TCP or UDP streams. Netstat also provides many interesting interface and protocol statistics. Smokeping graphically displays latency and packet loss between two end-nodes. MRTG allows to process SNMP data to display graphs. Also, SHISA's implementation provides statistics about NEMO Basic Support and Mobile IPv6 signaling messages exchanged by the MR with the Home Agent. All those statistics are regularly gathered on a web server. The database used for the monitoring software is also a very useful source of information. It can gather many informations such as the reachability of the LFN, latency and number of hops to the NEMO-PAN, or how many people are connected to the PAN.

Evaluation

The interface selection mechanism on the MR allows to switch to the best interface available. The time needed for this operation is the one needed for a Binding Update / Binding Ack exchange between the MR and its HA. The unreachability of the PAN caused by this switch is around a second, but it also depends on the access technologies used. We are currently analyzing the data. More demonstrations will be performed with selected monitors widely spread in the Internet. A thorough performance analysis of the communication system will be performed under different scenarios, including one where the monitors are also located in other NEMO-PANs. All the results will be reported in a forthcoming paper.

CONCLUSIONS AND NEXT STEPS

We have set up a light-weight demonstration platform designed to validate our communication system based on NEMO. By being portable to international workshops and showrooms and by allowing live public Internet monitoring of our demonstrations, we are further demonstrating the benefits of a NEMO Basic Support powered mobile network and how this communication system can meet the needs of ITS and other applications which typically run in a mobile environment. We are currently concentrating our effort on the combined demonstration and evaluation of some of the features. The project is half-way to meet its objectives.

We are working on a number of open issues, particularly those related to multihoming which must be fixed in order to provide an unlimited connectivity to the network, i.e. how to use simultaneous interfaces on the MR and how to determine the best interface for each application. We are also going to include into our demonstration system *NEMO Route Optimization*, *Multihoming* and *Access Control* mechanisms on which we are presently working on. We will also be able to conduct interoperability testing between a Linux-based NEMO-PAN and a BSD-based NEMO-PAN as we are also currently developing NEMO Basic Support on Linux 2.6 (this implementation called NEPL was tested at the last TAHI test event and was reasonably well rated).

Acknowledgments

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REFERENCES

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

[2] CALM - Medium and Long Range, High Speed, Air Interfaces parameters and protocols for broadcast, point to point, vehicle to vehicle, and vehicle to point communication in the ITS sector - Networking Protocol - Complementary element. Draft ISO/WD 21210, ISO, Technical Committee 204, WG16, February 2005. Work in progress.

[3] Thierry Ernst, Koshiro Mitsuya, and Keisuke Uehara. Network Mobility from the InternetCAR Perspective. *JOIN: Journal on Interconnection Networks*, 4(3), September 2003.

[4] 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.

[5] Thierry Ernst and Keisuke Uehara. Connecting Automobiles to the Internet. In *ITST: 3rd International Workshop on ITS Telecommunications*, Seoul, South Korea, November 2002.

[6] David B. Johnson, C. Perkins, and Jari Arkko. Mobility Support in IPv6. Request For Comments 3775, IETF, June 2004.

[7] Vijay Devarapalli, Ryuji Wakikawa, Alexandru Petrescu, and Pascal Thubert. Network Mobility (NEMO) Basic Support Protocol. Request For Comments 3963, IETF, January 2005.

[8] Thierry Ernst, Nicolas Montavont, Ryuji Wakikawa, EunKyoung Paik, ChanWah Ng, Koojana Kuladinithi, and Thomas Noël. Goals and Benefits of Multihoming. Internet Draft draft-ernst-generic-goals-and-benefits-01, IETF, February 2005. Work in progress.

[9] Nicolas Montavont, Ryuji Wakikawa, and Thierry Ernst. Analysis of Multihoming in Mobile IPv6. Internet Draft draft-montavont-mobileip-multihoming-pb-statement-03.txt, IETF, February 2005. Work in progress.

[10] ChanWah Ng, EunKyoung Paik, and Thierry Ernst. Analysis of Multihoming in Network Mobility Support. Internet Draft draft-ietf-nemo-multihoming-issues-02, IETF, Feburary 2005. Work in progress.

[11] 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, June 2004.

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

[13] Rajeev Koodli. Fast Handovers for Mobile IPv6. Internet Draft draft-ietf-mipshop-fast-mipv6-03.txt, IETF, October 2004.

[14] Nicolas Montavont and Thomas Noel. Seamless Handover Optimization Based on L2 Triggers Information. *Journal of Internet Technology, special issue on Heterogeneous IP Networks*, to appear.

[15] N. A. Fikouras, A. J. Konsgen, and C. Gorg. Accelerating Mobile IP Hand-offs through Link-layer Information. In *Proceedings of the International Multiconference on Measurement, Modelling, and Evaluation of Computer-Communication Systems (MMB)*, Aachen, Germany, September 2001.

[16] Saber Zrelli, Thierry Ernst, Julien Bournelle, Guillaume Valadon, and David Binet. Access Control Architecture for Nested Mobile Environments in IPv6. In *4th Conference and Security and Network Architecture (SAR)*, Batz-sur-Mer, France, June 2005. http://www-lor.int-evry.fr/sar05.