

# INRIA International program - AYAME Proposal 2012

**Name of the project: SIMULBED: Simulator in a Slice or Large-Scale Simulation Testbed for Realistic Evaluation of Network Protocols and Architectures**

## A. Detailed project description

### A1. Description of the research project

Simulators and experimental testbeds are two different approaches for the evaluation of network protocols and they provide a varying degree of repeatability, scalability, instrumentation and realism. Network simulators allow fine grained control of experimentation parameters, easy instrumentation and good scalability, but they usually lack realism. However, there is a growing need to conduct realistic experiments involving complex cross-layer interactions between many layers of the communication stack and this has led network researchers to evaluate network protocols on experimental testbeds.

The use of both simulators and testbeds to conduct experiments grants a better insight on the behavior of the evaluated network protocols and applications. In this project, we focus on the design of SIMULBED, an experimentation platform that aims to provide the best of both worlds. Our project builds on the following state-of-the-art tools and platforms: the open source ns-3 network simulator[1] and the PlanetLab testbed[2]. ns-3 is the first network simulator that includes a mechanism to execute directly within the simulator existing real-world Linux protocol implementations and applications. Furthermore, it can be used as a real-time emulator for mixed (simulation-experimentation) network scenarii. PlanetLab is a well-known international experimental testbed that supports the development and the evaluation of new network services. It is composed of nodes connected to the Internet across the world, and uses container-based virtualization to allow multiple experiments running independently on the same node while sharing its resources.

The overall objective of the project is to make available to networking research community, the SIMULBED platform that will: (1) allow to conduct easily mixed simulation-experimentation evaluation of networking protocols and (2) scale up the size of the PlanetLab experimental testbed, while maintaining a high degree of realism and increasing controllability and reproducibility. We will leverage of the experience of both partners in ns-3 and PlanetLab to design and develop the SIMULBED platform. We will also use the NEPI[3] unified programming environment recently developed in the Planète project-team to help in simplifying the configuration, deployment and run of network scenarios on the platform.

### A2. Expected project outcomes and scientific value

- Project's characteristics, advancement beyond the state-of-the-art:

This project contributes to the area of the evaluation of networking protocols. The deployment of distributed real-time ns-3 simulations over PlanetLab nodes will allow: (1)

to obtain real background traffic conditions for the traffic generated between the difference instances of the simulators; (2) to extend the scalability of the PlanetLab testbed in terms of number of nodes, as each PlanetLab node could be used to simulate tens of nodes. Furthermore, the use of ns-3 on top of PlanetLab nodes that offer realistic network conditions will make easier and more realistic the evaluation of new (non-IP based) network architectures.

- General orientation of the project:

This project is oriented experimental-driven research and relates to the Future Internet initiatives such as FIRE in Europe and GENI in USA on experimental facilities to test and validate new networking solutions. The two project partners are academic with advanced networking architectural and developments skills.

- Project's contribution to fostering young researchers:

From the Japan side, two young researchers who have obtained Ph.D. degree one and two years ago and one Ph.D. student will participate in this project. As well, from the French side, one post-doctoral researcher and one PhD student will participate. They will all be highly involved in this joint work and will participate in the development and the design of the SIMULBED architecture.

### **A3. Presentation of each organization and lead researcher credentials**

#### **Planète EPI, INRIA:**

The Planète project-team conducts research in the domain of networking, with an emphasis on designing, implementing, and evaluating Internet protocols and applications. The main objective of the project-team is to propose and study new architectures, services and protocols to support efficient and secure communication through the Internet. The research topics in which the Planète group is involved span several areas such as: Security in infrastructure-less and constrained networks, New modes of information dissemination; Seamless integration of wireless devices with the rest of network infrastructure; Understanding the Internet's behavior; and Experimental environments for Future Internet architecture. The Planète project-team is involved in the FP7 OneLab2 and OpenLab projects in which Thierry Parmentelat serves as a Technical Director. The Planète group is also strongly involved in the ns-3 open-source project since its beginning in 2006, and contributes to the development of the next version of the well-known network simulator ns-2. They also designed the NEPI unified programming environment for heterogeneous testbeds.

Two senior researchers at Planète are involved in this collaboration: Walid Dabbous and Thierry Turlatti. One postdoc, Daniel Camara and one PhD student, Alina Quereilhac (co-supervised by Walid Dabbous and Thierry Turlatti), are working on the enhancements of the ns-3 network simulator and on the design of a unified programming environment for heterogeneous testbeds, respectively. Moreover, Thierry Parmentelat, DREAM Engineer at Planète is highly involved in the design of the evolution of the PlanetLab testbed, and Frederic Urbani, Senior Engineer at Planète is working on the Direct Code Execution functionality of ns-3.

#### **Keio University, Shonan-Fujisawa Campus(SFC)**

Keio has a proud history as Japan's very first private institution of higher learning, which dates back to the formation of a school for Dutch studies in 1858 in Edo (now Tokyo) by founder

Yukichi Fukuzawa. Since the school's inception, the students of Keio have risen to the forefront of innovation in every imaginable academic field, emerging as social and economic leaders. In today's internationally interdependent world, Keio places great effort upon maintaining the finest teaching faculty and superlative facilities. Keio University is a comprehensive academic enterprise with five major campuses – Mita, Hiyoshi, Yagami, Shinanomachi, and Shonan-Fujisawa campuses – in Japan, along with a number of affiliated academic institutions on or near these campuses. In addition, Keio University also operates a high school in New York.

Keio further facilitates the full range of research activities undertaken at the numerous university facilities, by providing support to researchers, creating and promoting comprehensive, interdisciplinary researches throughout Keio University, and returning the fruits of such researches to societies. The Keio Research Institute at SFC is one of the leading institute being as an affiliate research institute of the Graduate School of Media and Governance, the Faculty of Policy Management, the Faculty of Environment and Information Studies and the Faculty of Nursing and Medical Care. The Institute promotes research activities conducted under the collaboration between SFC and outside organizations relating to industries, government, NPOs and regional communities. The aim of the Institute is to conduct integrated, advanced and interdisciplinary research while maintaining close coordination with the real world. Keio was also formed on the notion that an international perspective is essential. In keeping with this spirit, Keio has developed strategic initiatives that enable the university to take a proactive role in the creation of international alliances, and the enhancement of Keio's own global activities, such as Organization for Global Initiatives (OGI) and International Center. Recently, Keio University has been actively engaged in offering degree programs, called "Global 30", delivered in English, attracting greater numbers of international students and promoting the internationalization of the University.

Prof. Osamu Nakamura and Assoc. Prof. Hitoshi Asaeda have involved in this project to mutually conduct the research direction. Hitoshi Asaeda will also work for the design of future internet architecture proposals (Information Centric Networking) on the ns-3 simulator. One young researcher, Hajime Tazaki, in NICT will work on the development of the extension module for the Direct Code Execution of ns-3. He will also take in charge of One Ph.D. student, Tsuyoshi Hisamatsu, will obtain Ph.D. degree at Keio Univ. on March 2012 and start his postdoc from April 2012, and will participate in this project for the testbed design and development. One Ph.D. student, Kazuhisa Matsuzono (co-supervised by Osamu Nakamura and Hitoshi Asaeda), will work on the implementation of tools used for ns-3 and testbed integration.

### **Background of the Principal Investigators on both sides**

- **Walid Dabbous** is a senior researcher at INRIA and professor at the Ecole Polytechnique. His current research interests include Future Internet Architecture and Protocols, Networking Experimental Platforms and Simulators. He graduated from the Faculty of Engineering of the Lebanese University in Beirut in 1986 (Electrical Engineering Department). He obtained his Doctorat d'Université from the University of Paris XI and his Habilitation Diriger des Recherches (HDR) from University of Nice Sophia Antipolis in 1991 and 2008, respectively. He joined the RODEO Team within INRIA in 1987. He is a staff researcher at INRIA since 1991, and leader of the Rodeo (then Planète) team since 1996. His publications are available at URL <http://planete.inria.fr/dabbous>.
- **Osamu Nakamura** is Professor at the Faculty of Environment and Information Studies, Keio University at Shonan-Fujisawa Campus (SFC). His current research interests include high-speed network architecture and interdomain routing operations and experiments. He was a leader of several national projects, for instance, "Dynamic Network Project" (Oct.

2008 – Mar. 2011) funded by National Institute of Information and Communications Technology (NICT) and "Fujisawa Digital Signage Project" (Jun. 2009 – Mar. 2010) funded by Ministry of Internal Affairs and Communications (MIC). Currently he is a leader of "Unwired Research Consortium" at Keio Research Institute at SFC. He obtained his Ph.D. degree from Keio University on 1993. He is a board member of WIDE project.

## Main publications of the participants related to the broad topic of the proposal

### INRIA Publications

- A. Abidi, S.M. Gammar, F. Kamoun, W. Dabbous, T. Turletti and A. Legout, "Hybrid approach for experimental networking research", 13th International Conference on Distributed Computing and Networking, (ICDCN), Jan 3-6 2012, Hong Kong, China.
- A. Quereilhac, M. Lacage, C. Freire, T. Turletti, W. Dabbous, "NEPI: An Integration Framework for Network Experimentation", 19th International Conference on Software Telecommunications and Computer Networks (SoftCOM), Sep 15-17 2011, Dubrovnik, Croatia.
- C. T. Sanchez, L. Ahumada, D. Dujovne, S. Ur-Rehman, T. Turletti, W. Dabbous, "Guidelines for the accurate design of empirical studies in wireless networks", 7th International ICST Conference on Testbeds and Research Infrastructures for the Development of Networks and Communities (TridentCom), Shanghai, China, April 2011.
- M. A. Ismail, G. Piro, L.A. Grieco, T. Turletti, "An Improved IEEE 802.16 WiMAX Module for the NS-3 Simulator", in the 3rd International Conference on Simulation Tools and Techniques, Torremolinos, Malaga, Spain, March 15-19 2010 [Best Student Award paper].
- M. Lacage, M. Ferrari, M. Hansen, T. Turletti, W. Dabbous, "Using Independent Simulators, Emulators, and Testbeds for Easy Experimentation", in ACM Operating Systems Review (OSR) journal, Vol. 43, No. 4, December 2009.
- B.B. Romdhanne, D. Dujovne, T. Turletti, "Efficient and Scalable Merging Algorithms for Wireless Traces", 4th Roads Workshop at SOSP, Montana, USA, October 2009.
- M. Lacage, M. Ferrari, M. Hansen, T. Turletti, "NEPI: Using Independent Simulators, Emulators, and Testbeds for Easy Experimentation", 4th Roads Workshop at SOSP, Montana, USA, October 2009.
- D. Dujovne, T. Turletti, W. Dabbous, "Experimental Methodology for Real Overlays", ROADS Workshop, Warsaw, Poland, July 2007.

### KEIO Publications

- Sigeya Suzuki, Rodney Van Meter, Osamu Nakamura, and Jun Murai, "Otedama: A Relocatable RFID Information Repository Architecture", IEICE Trans. on Information and Systems, Vol.E93-D, No.11, pp.2922-2931, November 2010.
- Yasuhiro Ohara, Hiroyuki Kusumoto, Osamu Nakamura, and Jun Murai, "Drouting Architecture: Improvement of Failure Avoidance Capability Using Multipath Routing", IEICE Trans. on Communications, Voi.E91-B, No.5, pp.1403-1415, May 2008.

- Tsuyoshi Hisamatsu and Hitoshi Asaeda, “Adaptive Overlay Network for High-Bandwidth Streaming”, Journal of Information Processing, IPSJ, Vol.20, No.1, 2012.
- Kazuhisa Matsuzono, Hitoshi Asaeda, and Jun Murai, “DP-FEC: Dynamic Probing FEC for High-Performance Real-Time Interactive Video Streaming”, Journal of Information Processing, IPSJ, Vol.20, No.1, 2012.
- Kazuhisa Matsuzono, Jonathan Detchart, Mathieu Cunche, Vincent Roca, and Hitoshi Asaeda, “Performance analysis of a high-performance real-time application with several AL-FEC schemes”, Proc. IEEE LCN, October 2010, Denver, USA.
- Hajime Tazaki, Rodney Van Meter, Ryuji Wakikawa, Thirapon Wongsardsakul, Kanchana Kanchanasut, Marcelo Dias de Amorim, and Jun Murai, “MANEMO Routing in Practice: Protocol Selection, Expected Performance, and Experimental Evaluation”, IE-ICE Trans. on Communications, Vol.93-B, No.8, pp.2004-2011, August 2010.
- Hajime Tazaki, Rodney Van Meter, Ryuji Wakikawa, Thirapon Wongsardsakul, Kanchana Kanchanasut, Marcelo Dias de Amorim, and Jun Murai, “Selecting an Appropriate Routing Protocol for in-field MANEMO Experiments”, Proc. ACM PE-WASUN, pp. 101-107, New York, NY, USA, October 2009.

#### **A4. History of the collaboration between the two teams**

Back in September 2001, Dr. Hitoshi Asaeda worked with the Planète research project-team as a specialist research engineer for three years and a half. During this period, he strongly contributed to the activities in the multimedia multicast protocols domain, publishing both academic papers and internet-drafts at IETF. He developed BSD kernel implementation of several multicast protocols. In 2004, he became the leader of a project funded by Hitachi research labs on MANET security. Since 2001, the Planète project-team and Dr Hitsohi Asaeda are still collaborating with a very good relationship and regular visits. Dr Asaeda recently co-authored a paper published in IEEE LCN and IETF internet-drafts with Vincent Roca, who is a researcher in the Planète project-team.

Dr. Hajime Tazaki had been collaborating with the Planète project on the enhancement of the ns-3 network simulator since 2009. The work mainly focused on the support of the Quagga routing protocol software suite, and on the development of some functionalities for the DCE mechanism of ns-3. On March 2010, right after the WNS3 Workshop on ns-3 in Spain, Hajime visited INRIA Sophia-Antipolis to work on the improvement of DCE module. In his PhD, Hajime used ns-3 as a key evaluation tool to validate his proposed mobile network architecture.

This project has an important educational component as it will allow exchange of junior researchers and graduate students between the two partner institutions. Keio and INRIA partners are respectively and actively involved in the education of graduate/undergraduate students at the University of Keio and at the University of Nice, Sophia Antipolis. Funding from the AYAME program will allow them to increase the participation of students from both institutions in this project. Both partners will benefit from some periodic and very valuable visits which will make their collaboration even more fruitful.

In this context, the two groups will leverage their expertise on the design and the evaluation of networking protocols and architectures.

#### **A5. Scientific work program**

*Duration of the project : 2 years*

As mentioned before, this project aims to make available to the networking research community SIMULBED, a platform that: (1) allows to conduct easily mixed simulation-experimentation evaluation of networking protocols and (2) scales up the size of the PlanetLab experimental testbed, while maintaining a high degree of realism and increasing controllability and reproducibility. We will use the NEPI[3] unified programming environment recently developed in the Planète project-team to help in simplifying the configuration, deployment and run of network scenarios on the platform.

PlanetLab is one of the most known experimental testbed in the networking community. It is a globally distributed testbed designed for network experimentation and composed of nodes connected to the Internet across the world. PlanetLab uses container-based virtualization to allow multiple experiments running independently on the same node while sharing its resources. However, the use of network virtualization has a cost: some tasks are made more complex than in a classical (non-virtualized) environment. In particular, slivers (which are isolation units for experiments running in PlanetLab) do not have full root privileges. Therefore operating system calls to set up routes, tunnels, or IP filters, among others, are forbidden. This makes difficult the evaluation of new network architectures. To get round this problem, we will use the ns-3 simulator on top of PlanetLab nodes. ns-3 is the first network simulator that converts transparently and efficiently network packets to and from simulation objects, hence enabling transparent support for real-time simulation in every ns-3 model. It provides a high degree of realism. Therefore it is easy to use it as a real-time emulator in a larger testbed. It is also possible to execute directly within the simulator unmodified network protocol implementations and applications, using the Direct Code Execution (DCE) feature. Using DCE, ns-3 trades off scalability for realism by embedding within the simulator existing protocol implementations that were never designed to run in a simulator. It makes possible to considerably increase the realism of a simulation while retaining its repeatability and ease of debugging. It also make it trivial to repeat and compare the result of the same experiment in a testbed by using the same protocol implementation in both cases. In DCE, the Virtualizing Dynamic Loader (VDL) Executable and Linkable Format (ELF) loader is used to both virtualize access to every global and static variable and to redirect function calls to system facilities from their normal implementation to a simulation implementation. However, the memory and CPU cost of virtualizing a single external protocol implementation for execution within the simulator should be maintained as low as possible to be able to run simulations which process many packets per second and include a large numbers of instances of this protocol implementation. Moreover, the current DCE library is still incomplete from the perspective of replacing all the functionality provided by normal system libraries. Therefore, we will need to increase its functionality coverage by adding the missing wrapper functions.

SIMULBED will allow to run hybrid networking scenarii involving both simulators and real nodes. While these scenarii are simple to state, the complexity of deploying, and configuring correctly these experiments put them out of reach of most experimenters. Indeed, the complexity of setting them up is very high: users must configure compatibly both their testbed and their simulation, which makes it impossible to use the native setup capabilities of each experimentation tool and thus, requires a lot of manual work. Then, another contribution of this project is to implement mechanisms to simplifying the description and deployment of such mixed network experiments scenarii. Specifically, we will extend the NEPI unified programming environment developed at the Planète to fit the specific requirements of the SIMULBED platform. We need also to propose some algorithms that help in distributing a networking simulation scenario in multiple real nodes. This problem is challenging because it is necessary to minimize the traffic exchanged between real nodes and to ensure to keep the CPU load of real nodes as low as possible.

At a later stage, we plan to evaluate the utility and efficiency of the SIMULBED testbed by validating new network architectures because the two partners are both involved in designing innovative protocols for the Future Internet.

To summarize, we list the planned tasks as follows:

- Year 2012:
  - Enhancement of DCE emulation library (FR, JP)
  - Design mechanisms to synchronize the distributed simulation on multiple nodes (FR,JP)
  - Design algorithms to minimize the traffic exchanged between real nodes (JP)
  - Design mechanisms to make easier set-up and run of mixed experiments (FR)
- Year 2013:
  - Implement tunneling device on PlanetLab (FR)
  - Design mechanism to distribute simulation scenarios in multiple nodes (FR,JP)
  - Evaluate the efficiency of SIMULBED with the validation of innovative network architectures (FR,JP)

Teleconference meetings will be held once a week. A joint website for the SIMULBED AYAME project to present our scientific goals, work in progress and future published papers along with a presentation of the updated technical developments, will be created.

## **A6. Exchanges schedule for Year 1**

*Exchanges scheduled from France to the partner country (researchers' name, including students, and expected duration of stays)*

1. Intermediate meeting at Keio University at SFC  
Duration: October or November, 2012, 4 or 5 days  
Participants: Walid Dabbous, Frederic Urbani, Daniel Camara, Alina Quereilhac
2. Intermediate meeting at Keio University at SFC  
Duration: June or July, 2013, 4 or 5 days  
Participants: Thierry Turletti, Daniel Camara, Thierry Parmentelat, Alina Quereilhac

*Exchanges scheduled from the partner country to France (researchers' name, including students, and expected duration of stays)*

1. Kickoff meeting at INRIA Sophia Antipolis  
Duration: May or June, 2012, 4 or 5 days  
Participants: Hitoshi Asaeda, Hajime Tazaki, Tsuyoshi Hisamatsu
2. Intermediate meeting at INRIA Sophia Antipolis  
Duration: April or May, 2013, 4 days  
Participants: Hitoshi Asaeda, Hajime Tazaki, Tsuyoshi Hisamatsu
3. Wrap-up meeting at INRIA Sophia Antipolis  
Duration: February, 2014, 4 days  
Participants: Hitoshi Asaeda, Hajime Tazaki, Tsuyoshi Hisamatsu

## A7. Additional information

## B. Project funding

### B1. Expected expenditures for Year 1

		Senior researcher	Postdoc	PhD student	Others Others	Total Total
Visits from Inria to partner	Nb of persons Estimated costs	1 4K Euros	1 4K Euros	1 4K Euros	1 4K Euros	4 16K Euros
Visits from partner to Inria	Nb of persons Estimated costs	2 1,004,666 JPY		1 502,333 JPY		3 1,507,000 JPY

### B2. Budget proposal for Year 1

Financial support request to INRIA <sup>a</sup> under the Associate Team program	16000 Eur
<sup>a</sup> The maximum amount awarded by INRIA is 20000 Eur per year	
Expected financial and/or material contribution from the international partner to the project Equipments: Desktop PC x 1, Note PC x 4, VMware software x 2 = 980,000 JPY Travel: 1,507,000 JPY Total: 2,487,000 JPY	2,487,000 JPY
Total	Eur

## References

- [1] The ns-3 network simulator. URL: <http://www.nsnam.org/>.
- [2] The PlanetLab open experimental platform. URL: <http://www.planet-lab.org/>.
- [3] The NEPI Integration framework for network experimentation. URL: <http://yans.pl.sophia.inria.fr/trac/nepi/wiki>.