Ignas Niemegeers
Sonia Heemstra de Groot (Eds.)

LNCS 3260

# Personal Wireless Communications

IFIP TC6 9th International Conference, PWC 2004
Delft, The Netherlands, September 2004
Proceedings

IFIP – TC6

Springer

Ignas Niemegeers
Sonia Heemstra de Groot (Eds.)

# Personal Wireless Communications

IFIP TC6 9th International Conference, PWC 2004
Delft, The Netherlands, September 21-23, 2004
Proceedings



Springer

Volume Editors

Ignas Niemegeers
Delft University of Technology
Center for Wireless and Personal Communication
Mekelweg 4, 2628 DC Delft, The Netherlands
E-mail: I.Niemegeers@ewi.tudelft.nl

Sonia Heemstra de Groot
Twente Institute for Wireless and Mobile Communications
Institutenweg 30, 7521 PK Enschede, The Netherlands
E-mail: Sonia.Heemstra.de.Groot@ti-wmc.nl

Library of Congress Control Number: 2004111956

CR Subject Classification (1998): C.2, H.4, H.3, D.2, K.8

ISSN 0302-9743
ISBN 3-540-23162-5 Springer Berlin Heidelberg New York



Springer is a part of Springer Science+Business Media

springeronline.com


Printed in Germany

Typesetting: Camera-ready by author, data conversion by PTP-Berlin, Protago-TeX-Production GmbH
Printed on acid-free paper SPIN: 11324164 06/3142 5 4 3 2 1 0

# Lecture Notes in Computer Science 3260

# Preface

The IFIP TC-6 9th International Conference on Personal Wireless Communications, PWC 2004 is the main conference of the IFIP Working Group 6.8, Mobile and Wireless Communications.

The field of personal wireless communications is steadily growing in importance, from an academic, industrial and societal point of view. The dropping cost of WLAN and short-range technologies such as Bluetooth and Zigbee is causing the proliferation of personal devices and appliances equipped with radio interfaces. Together with the gradual deployment of powerful wireless infrastructure networks, such as 3G cellular systems and WLAN hotspots, the conditions are being created for affordable ubiquitous communication involving virtually any artifact. This enables new application areas such as ambient intelligence where a world of devices, sensors and actuators surrounding us use wireless technology to create systems that assist us in an unobtrusive way. It also allows the development of personal and personalized environments that accompany a person wherever he or she goes. Examples are Personal Area Networks (PAN) physically surrounding a person, and personal networks with a potentially global reach.

PWC 2004 reflects these developments, which are happening on a global scale. Researchers from all over the world, and in particular a large number from Asia, made contributions to the conference. There were 100 submissions. After a thorough reviewing process, 25 full papers and 13 short papers were retained for presentation in the technical sessions. The papers cover the whole range of wireless and mobile technologies: cellular systems, WLAN, ad hoc and sensor networks, host and network mobility, transport protocols for wireless systems, and the physical layer.

PWC 2004 was made possible by the enthusiasm, dedication and cooperation of many people. In particular we would like to thank the TPC members and the reviewers who were responsible for the high-quality reviewing process, and the Executive Committee for making the final selection of papers and the composition of the sessions. Of course, a special thanks to all the authors who showed their interest in the conference by submitting their papers. Also thanks to the organizations that supported the conference through various forms of sponsoring: KPN Mobile, Nokia, TNO Telecom and WMC. Last but not least, many thanks to the Organizing Committee that worked very hard to make sure that all organizational processes, the website, the electronic submissions, the financials, the social event and all the practical matters, were taken care of.

July 2004

Ignas G. Niemegeers,
Sonia Heemstra de Groot

# Organization

## Executive Committee

### Conference Chair

| | |
|---|---|
| Ignas Niemegeers | Delft University of Technology, The Netherlands |

### Conference Vice Chair

| | |
|---|---|
| Sonia Heemstra de Groot | Twente Institute for Wireless and Mobile Communications, The Netherlands |

### Steering Committee

| | |
|---|---|
| Piet Demeester | Ghent University, Belgium |
| Carmelita Görg | University of Bremen, Germany |
| Sonia Heemstra de Groot | Twente Institute for Wireless and Mobile Communications, The Netherlands |
| Petri Mähönen | RWTH Aachen, Germany |
| Ignas Niemegeers | Delft University of Technology, The Netherlands |
| Homayoun Nikookar | Delft University of Technology, The Netherlands |

### Organizing Committee

| | |
|---|---|
| Nico Baken | Delft University of Technology, The Netherlands |
| Laura Bauman | IRCTR, Delft University of Technology, The Netherlands |
| Wendy Murtinu | Delft University of Technology, The Netherlands |
| Ignas Niemegeers | Delft University of Technology, The Netherlands |
| Homayoun Nikookar | Delft University of Technology, The Netherlands |
| Ad de Ridder | IRCTR, Delft University of Technology, The Netherlands |
| Nan Shi | Delft University of Technology, The Netherlands |
| Alex Slingerland | Delft University of Technology, The Netherlands |
| Mia van der Voort | IRCTR, Delft University of Technology, The Netherlands |

## Technical Program Committee

| | |
|---|---|
| Arup Acharya | IBM T.J. Watson Research Center, USA |
| Dharma Agrawal | University of Cincinnati, USA |
| Paolo Bellavista | Università degli Studi di Bologna, Italy |
| Hans van den Berg | TNO Telecom/University of Twente, The Netherlands |
| Mauro Biagi | INFO-COM, University of Rome "La Sapienza", Italy |
| Chris Blondia | University of Antwerp, Belgium |
| Andrew Campbell | Columbia University, USA |
| Augusto Casaca | INESC-INOV, Portugal |
| Claudio Casetti | Politecnico di Torino, Italy |
| Piet Demeester | Ghent University, Belgium |
| Sudhir Dixit | Nokia, USA |
| Laura Marie Feeney | Swedish Institute of Computer Science, Sweden |
| Zhong Fan | Toshiba Research, UK |
| Luigi Fratta | Politecnico di Milano, Italy |
| Rajit Gadh | UCLA, USA |
| Silvia Giordano | SUPSI, Switzerland |
| Carmelita Görg | University of Bremen, Germany |
| Sonia Heemstra de Groot | Twente Institute for Wireless and Mobile Communications, The Netherlands |
| Geert Heijenk | University of Twente, The Netherlands |
| Georgios Karagiannis | University of Twente, The Netherlands |
| Mohan Kumar | University of Texas at Arlington, USA |
| Anthony Lo | Delft University of Technology, The Netherlands |
| Antonio Loureiro | Federal University of Minas Gerais, Brazil |
| Hiroyuki Morikawa | University of Tokyo, Japan |
| Luis Muñoz | University of Cantabria, Spain |
| Ignas Niemegeers | Delft University of Technology, The Netherlands |
| Homayoun Nikookar | Delft University of Technology, The Netherlands |
| Stephan Olariu | Old Dominion University, USA |
| Niovi Pavlidou | Aristotle University of Thessaloniki, Greece |
| Ramjee Prasad | Aalborg University, Denmark |
| Jan Slavik | Testcom, Czech Republic |
| Ivan Stojmenović | University of Ottawa, Canada |
| Rahim Tafazolli | University of Surrey, UK |
| Samir Tohmé | École Nationale Supérieure des Télécommunications (ENST), France |
| Christian Tschudin | University of Basel, Switzerland |
| Jörg Widmer | Swiss Federal Institute of Technology, Lausanne (EPFL), Switzerland |
| Magda El Zarki | University of California at Irvine, USA |
| Djamal Zeghlache | Groupe des Écoles des Télécommunications-Institut National des Télécommunications (GET-INT), France |

## Referees

Imad Aad
Arup Acharya
Dharma Agrawal
S. Aust
Paolo Bellavista
Hans van den Berg
Pavel Bezpalec
Mauro Biagi
Ramón Agüero Calvo
Augusto Casaca
Claudio Casetti
Dave Cavalcanti
Y. Che
Antonio Corradi
Piet Demeester
Hongmei Deng
Sudhir Dixit
M. Elkadi
Paul Ezchilvan
Zhong Fan
Laura Marie Feeney
N. Fikouras
Luigi Fratta
Susan Freeman
Rajit Gadh
Silvia Giordano
Carmelita Görg
Antonio Grilo
Meetu Gupta
Sonia Heemstra
Geert Heijenk
Jeroen Hoebeke
J. Hrad
Z. Irahhauten
Martin Jacobsson
Gerard Janssen
Georgios Karagiannis
A. Könsgen
M. Koonert
K. Kuladinithi
Dirk Kutscher
E. Lamers
Benoit Latre
Tom Van Leeuwen
Xi Li
Anthony Lo
Weidong Lu
Petri Mähönen
Peter Martini
Ruben Merz
Hiroyuki Morikawa
Anindo Mukherjee
Luis Muñoz
Ignas Niemegeers
Homayoun Nikookar
Mario Nunes
Stephan Olariu
Evgeny Osipov
Niovi Pavlidou
Paulo Pereira
Liesbeth Peters
Neeli Prasad
Ramjee Prasad
Vassilis Prevelakis
Janne Riihijarvi
Hartmut Ritter
R. Schelb
Vivek Shah
David Simplot-Ryl
Jan Slavik
Alex Slingerland
Ivan Stojmenović
A. Timm-Giel
Christian Tschudin
U. Türke
Einar Vollset
Boris Šimák
Natasa Vulic
Haitang Wang
L. Wang
Shu Wang
Jörg Widmer
Magda El Zarki
Djamal Zeghlache
Tomas Zeman

## Sponsoring Institutions

# Lecture Notes in Computer Science

For information about Vols. 1–3124

please contact your bookseller or Springer

Vol. 3263: M. Weske, P. Liggesmeyer (Eds.), Object-Oriented and Internet-Based Technologies. XII, 239 pages. 2004.

Vol. 3260: I. Niemegeers, S.Heemstra de Groot (Eds.), Personal Wireless Communications. XIV, 478 pages. 2004.

Vol. 3255: A. Benczúr, J. Demetrovics, G. Gottlob (Eds.), Advances in Databases and Information Systems. XI, 423 pages. 2004.

Vol. 3254: E. Macii, V. Paliouras, O. Koufopavlou (Eds.), Integrated Circuit and System Design. XVI, 910 pages. 2004.

Vol. 3253: Y. Lakhnech, S. Yovine (Eds.), Formal Techniques in Timed, Real-Time, and Fault-Tolerant Systems. X, 397 pages. 2004.

Vol. 3249: B. Buchberger, J.A. Campbell (Eds.), Artificial Intelligence and Symbolic Computation. X, 285 pages. 2004. (Subseries LNAI).

Vol. 3246: A. Apostolico, M. Melucci (Eds.), String Processing and Information Retrieval. XIV, 316 pages. 2004.

Vol. 3241: D. Kranzlmüller, P. Kacsuk, J.J. Dongarra (Eds.), Recent Advances in Parallel Virtual Machine and Message Passing Interface. XIII, 452 pages. 2004.

Vol. 3240: I. Jonassen, J. Kim (Eds.), Algorithms in Bioinformatics. IX, 476 pages. 2004. (Subseries LNBI).

Vol. 3239: G. Nicosia, V. Cutello, P.J. Bentley, J. Timmis (Eds.), Artificial Immune Systems. XII, 444 pages. 2004.

Vol. 3238: S. Biundo, T. Frühwirth, G. Palm (Eds.), KI 2004: Advances in Artificial Intelligence. XI, 467 pages. 2004. (Subseries LNAI).

Vol. 3232: R. Heery, L. Lyon (Eds.), Research and Advanced Technology for Digital Libraries. XV, 528 pages. 2004.

Vol. 3224: E. Jonsson, A. Valdes, M. Almgren (Eds.), Recent Advances in Intrusion Detection. XII, 315 pages. 2004.

Vol. 3223: K. Slind, A. Bunker, G. Gopalakrishnan (Eds.), Theorem Proving in Higher Order Logics. VIII, 337 pages. 2004.

Vol. 3221: S. Albers, T. Radzik (Eds.), Algorithms – ESA 2004. XVIII, 836 pages. 2004.

Vol. 3220: J.C. Lester, R.M. Vicari, F. Paraguaçu (Eds.), Intelligent Tutoring Systems. XXI, 920 pages. 2004.

Vol. 3217: C. Barillot, D.R. Haynor, P. Hellier (Eds.), Medical Image Computing and Computer-Assisted Intervention – MICCAI 2004. XXXVIII, 1114 pages. 2004.

Vol. 3216: C. Barillot, D.R. Haynor, P. Hellier (Eds.), Medical Image Computing and Computer-Assisted Intervention – MICCAI 2004. XXXVIII, 930 pages. 2004.

Vol. 3210: J. Marcinkowski, A. Tarlecki (Eds.), Computer Science Logic. XI, 520 pages. 2004.

Vol. 3208: H.J. Ohlbach, S. Schaffert (Eds.), Principles and Practice of Semantic Web Reasoning. VII, 165 pages. 2004.

Vol. 3207: L.T. Yang, M. Guo, G.R. Gao, N.K. Jha (Eds.), Embedded and Ubiquitous Computing. XX, 1116 pages. 2004.

Vol. 3206: P. Sojka, I. Kopecek, K. Pala (Eds.), Text, Speech and Dialogue. XIII, 667 pages. 2004. (Subseries LNAI).

Vol. 3205: N. Davies, E. Mynatt, I. Siio (Eds.), UbiComp 2004: Ubiquitous Computing. XVI, 452 pages. 2004.

Vol. 3203: J. Becker, M. Platzner, S. Vernalde (Eds.), Field Programmable Logic and Application. XXX, 1198 pages. 2004.

Vol. 3202: J.-F. Boulicaut, F. Esposito, F. Giannotti, D. Pedreschi (Eds.), Knowledge Discovery in Databases: PKDD 2004. XIX, 560 pages. 2004. (Subseries LNAI).

Vol. 3201: J.-F. Boulicaut, F. Esposito, F. Giannotti, D. Pedreschi (Eds.), Machine Learning: ECML 2004. XVIII, 580 pages. 2004. (Subseries LNAI).

Vol. 3199: H. Schepers (Ed.), Software and Compilers for Embedded Systems. X, 259 pages. 2004.

Vol. 3198: G.-J. de Vreede, L.A. Guerrero, G. Marín Raventós (Eds.), Groupware: Design, Implementation and Use. XI, 378 pages. 2004.

Vol. 3194: R. Camacho, R. King, A. Srinivasan (Eds.), Inductive Logic Programming. XI, 361 pages. 2004. (Subseries LNAI).

Vol. 3193: P. Samarati, P. Ryan, D. Gollmann, R. Molva (Eds.), Computer Security – ESORICS 2004. X, 457 pages. 2004.

Vol. 3192: C. Bussler, D. Fensel (Eds.), Artificial Intelligence: Methodology, Systems, and Applications. XIII, 522 pages. 2004. (Subseries LNAI).

Vol. 3190: Y. Luo (Ed.), Cooperative Design, Visualization, and Engineering. IX, 248 pages. 2004.

Vol. 3189: P.-C. Yew, J. Xue (Eds.), Advances in Computer Systems Architecture. XVII, 598 pages. 2004.

Vol. 3186: Z. Bellahsène, T. Milo, M. Rys, D. Suciu, R. Unland (Eds.), Database and XML Technologies. X, 235 pages. 2004.

Vol. 3185: M. Bernardo, F. Corradini (Eds.), Formal Methods for the Design of Real-Time Systems. VII, 295 pages. 2004.

Vol. 3184: S. Katsikas, J. Lopez, G. Pernul (Eds.), Trust and Privacy in Digital Business. XI, 299 pages. 2004.

Vol. 3183: R. Traunmüller (Ed.), Electronic Government. XIX, 583 pages. 2004.

Vol. 3182: K. Bauknecht, M. Bichler, B. Pröll (Eds.), E-Commerce and Web Technologies. XI, 370 pages. 2004.

Vol. 3181: Y. Kambayashi, M. Mohania, W. Wöß (Eds.), Data Warehousing and Knowledge Discovery. XIV, 412 pages. 2004.

Vol. 3180: F. Galindo, M. Takizawa, R. Traunmüller (Eds.), Database and Expert Systems Applications. XXI, 972 pages. 2004.

Vol. 3179: F.J. Perales, B.A. Draper (Eds.), Articulated Motion and Deformable Objects. XI, 270 pages. 2004.

Vol. 3178: W. Jonker, M. Petkovic (Eds.), Secure Data Management. VIII, 219 pages. 2004.

Vol. 3177: Z.R. Yang, H. Yin, R. Everson (Eds.), Intelligent Data Engineering and Automated Learning – IDEAL 2004. XVIII, 852 pages. 2004.

Vol. 3176: O. Bousquet, U. von Luxburg, G. Rätsch (Eds.), Advanced Lectures on Machine Learning. IX, 241 pages. 2004. (Subseries LNAI).

Vol. 3175: C.E. Rasmussen, H.H. Bülthoff, B. Schölkopf, M.A. Giese (Eds.), Pattern Recognition. XVIII, 581 pages. 2004.

Vol. 3174: F. Yin, J. Wang, C. Guo (Eds.), Advances in Neural Networks - ISNN 2004. XXXV, 1021 pages. 2004.

Vol. 3173: F. Yin, J. Wang, C. Guo (Eds.), Advances in Neural Networks – ISNN 2004. XXXV, 1041 pages. 2004.

Vol. 3172: M. Dorigo, M. Birattari, C. Blum, L. M. Gambardella, F. Mondada, T. Stützle (Eds.), Ant Colony, Optimization and Swarm Intelligence. XII, 434 pages. 2004.

Vol. 3170: P. Gardner, N. Yoshida (Eds.), CONCUR 2004 - Concurrency Theory. XIII, 529 pages. 2004.

Vol. 3166: M. Rauterberg (Ed.), Entertainment Computing – ICEC 2004. XXIII, 617 pages. 2004.

Vol. 3163: S. Marinai, A. Dengel (Eds.), Document Analysis Systems VI. XI, 564 pages. 2004.

Vol. 3162: R. Downey, M. Fellows, F. Dehne (Eds.), Parameterized and Exact Computation. X, 293 pages. 2004.

Vol. 3160: S. Brewster, M. Dunlop (Eds.), Mobile Human-Computer Interaction – MobileHCI 2004. XVII, 541 pages. 2004.

Vol. 3159: U. Visser, Intelligent Information Integration for the Semantic Web. XIV, 150 pages. 2004. (Subseries LNAI).

Vol. 3158: I. Nikolaidis, M. Barbeau, E. Kranakis (Eds.), Ad-Hoc, Mobile, and Wireless Networks. IX, 344 pages. 2004.

Vol. 3157: C. Zhang, H. W. Guesgen, W.K. Yeap (Eds.), PRICAI 2004: Trends in Artificial Intelligence. XX, 1023 pages. 2004. (Subseries LNAI).

Vol. 3156: M. Joye, J.-J. Quisquater (Eds.), Cryptographic Hardware and Embedded Systems - CHES 2004. XIII, 455 pages. 2004.

Vol. 3155: P. Funk, P.A. González Calero (Eds.), Advances in Case-Based Reasoning. XIII, 822 pages. 2004. (Subseries LNAI).

Vol. 3154: R.L. Nord (Ed.), Software Product Lines. XIV, 334 pages. 2004.

Vol. 3153: J. Fiala, V. Koubek, J. Kratochvíl (Eds.), Mathematical Foundations of Computer Science 2004. XIV, 902 pages. 2004.

Vol. 3152: M. Franklin (Ed.), Advances in Cryptology – CRYPTO 2004. XI, 579 pages. 2004.

Vol. 3150: G.-Z. Yang, T. Jiang (Eds.), Medical Imaging and Augmented Reality. XII, 378 pages. 2004.

Vol. 3149: M. Danelutto, M. Vanneschi, D. Laforenza (Eds.), Euro-Par 2004 Parallel Processing. XXXIV, 1081 pages. 2004.

Vol. 3148: R. Giacobazzi (Ed.), Static Analysis. XI, 393 pages. 2004.

Vol. 3146: P. Érdi, A. Esposito, M. Marinaro, S. Scarpetta (Eds.), Computational Neuroscience: Cortical Dynamics. XI, 161 pages. 2004.

Vol. 3144: M. Papatriantafilou, P. Hunel (Eds.), Principles of Distributed Systems. XI, 246 pages. 2004.

Vol. 3143: W. Liu, Y. Shi, Q. Li (Eds.), Advances in Web-Based Learning – ICWL 2004. XIV, 459 pages. 2004.

Vol. 3142: J. Diaz, J. Karhumäki, A. Lepistö, D. Sannella (Eds.), Automata, Languages and Programming. XIX, 1253 pages. 2004.

Vol. 3140: N. Koch, P. Fraternali, M. Wirsing (Eds.), Web Engineering. XXI, 623 pages. 2004.

Vol. 3139: F. Iida, R. Pfeifer, L. Steels, Y. Kuniyoshi (Eds.), Embodied Artificial Intelligence. IX, 331 pages. 2004. (Subseries LNAI).

Vol. 3138: A. Fred, T. Caelli, R.P.W. Duin, A. Campilho, D.d. Ridder (Eds.), Structural, Syntactic, and Statistical Pattern Recognition. XXII, 1168 pages. 2004.

Vol. 3137: P. De Bra, W. Nejdl (Eds.), Adaptive Hypermedia and Adaptive Web-Based Systems. XIV, 442 pages. 2004.

Vol. 3136: F. Meziane, E. Métais (Eds.), Natural Language Processing and Information Systems. XII, 436 pages. 2004.

Vol. 3134: C. Zannier, H. Erdogmus, L. Lindstrom (Eds.), Extreme Programming and Agile Methods - XP/Agile Universe 2004. XIV, 233 pages. 2004.

Vol. 3133: A.D. Pimentel, S. Vassiliadis (Eds.), Computer Systems: Architectures, Modeling, and Simulation. XIII, 562 pages. 2004.

Vol. 3132: B. Demoen, V. Lifschitz (Eds.), Logic Programming. XII, 480 pages. 2004.

Vol. 3131: V. Torra, Y. Narukawa (Eds.), Modeling Decisions for Artificial Intelligence. XI, 327 pages. 2004. (Subseries LNAI).

Vol. 3130: A. Syropoulos, K. Berry, Y. Haralambous, B. Hughes, S. Peter, J. Plaice (Eds.), TeX, XML, and Digital Typography. VIII, 265 pages. 2004.

Vol. 3129: Q. Li, G. Wang, L. Feng (Eds.), Advances in Web-Age Information Management. XVII, 753 pages. 2004.

Vol. 3128: D. Asonov (Ed.), Querying Databases Privately. IX, 115 pages. 2004.

Vol. 3127: K.E. Wolff, H.D. Pfeiffer, H.S. Delugach (Eds.), Conceptual Structures at Work. XI, 403 pages. 2004. (Subseries LNAI).

Vol. 3126: P. Dini, P. Lorenz, J.N.d. Souza (Eds.), Service Assurance with Partial and Intermittent Resources. XI, 312 pages. 2004.

Vol. 3125: D. Kozen (Ed.), Mathematics of Program Construction. X, 401 pages. 2004.

# Table of Contents

# Self-Organization of Wireless Networks: The New Frontier (Keynote Speech)

Sudhir Dixit

Nokia Research, Burlington, MA, USA
sudhir.dixit@nokia.com

**Abstract.** The size of the internet will increase with the mainstream adoption of the broadband mobility connecting a myriad of devices and sensors at homes and businesses and the use of IPv6. All this will add to the spatio-temporal complexity of the network topology and dynamics. We present a brief overview of the role that self-organization can play in this new era of complexity. Issues of QoS, scalability, robustness, and reachability, among others (e.g., heterogeneity) will dominate the research in the future. First, we present the definition, scope, and applicability of self-organization. Then we briefly articulate the need for self-organization, and some recent breakthrough advances in this emerging area of research. This is followed by some near- and long-term scenarios where self-organization can be applied, and some results that we have obtained. We conclude the talk with a discussion on the key challenges that lie ahead.

I. Niemegeers and S. Heemstra de Groot (Eds.): PWC 2004, LNCS 3260, p. 1, 2004.

# The Impacts of Signaling Time on the Performance of Fast Handovers for MIPv6*

Seung-Hee Hwang[1], Youn-Hee Han[2], Jung-Hoon Han[1], and Chong-Sun Hwang[1]

[1] Dept. of Computer Science and Engineering, Korea University, Seoul, Korea, {shhwang,frajung,hwang}@disys.korea.ac.kr

[2] i-Networking Lab., Samsung Advanced Institute of Technology, Yongin, Kyungki-do, Korea, yh21.han@samsung.com

**Abstract.** A Fast Handover protocol (FMIPv6) in IETF working group is proposed to reduce the handover latency in Mobile IPv6 standard protocol. The FMIPv6 proposes some procedures for fast movement detection and fast binding update to minimize the handover latency. Additionally, to reduce the lost packets caused by a handover, this protocol introduces buffers in access routers. However, the handover latency or the amount of lost packets are affected by the time to send signals such as Fast Binding Update message for the fast handover. In this paper, we inspect the impacts of the signaling time on packet loss and handover latency in FMIPv6 through the numerical analysis, we propose the optimal signaling time to improve the performance of FMIPv6 in terms of the handover latency and lost packets.

## 1 Introduction

In mobile network, a mobile user should communicate with its correspondent nodes via its IP address regardless of its location. However, the IP address is some location-dependent, so its IP address may be changed at its location change, and its communication also may be disconnected at its new location. To solve this problem, Mobile IP is proposed [1].

In MIPv6, MN has a home IP address (HoA) for identification and a temporal IP address for routing information. When MN moves to a new subnet, that is, it may disconnect with the current link and connect with a new link in link layer, and it should obtain a new temporal address called Care-of-Address (CoA) through stateless or stateful (e.g. DHCPv6) address auto-configuration [2] according to the methods of IPv6 Neighbor Discovery [8]. Then MN should register the binding its new CoA with its HoA to its home agent (HA) and its CNs. Therefore MN can maintain the connectivity with CNs regardless of its movement.

On the other hand, when MN in MIPv6 conducts these procedures which are called a *handover*, there is a period the MN is unable to send or receive packets;

* This works was supported by the Korea Rearch Foundation Grant (KRF-2003-041-D00403)

I. Niemegeers and S. Heemstra de Groot (Eds.): PWC 2004, LNCS 3260, pp. 2–13, 2004.

that is, the *handover latency* is defined as a duration from reception of last packet via previous link to reception of first packet via new link. This handover latency results from standard Mobile IPv6 procedures, namely movement detection, new Care of Address configuration and confirmation, and Binding Update, as well as link switching delay, and these procedures are time consuming tasks, so it is often unacceptable to real-time traffic such as VoIP.

To reduce the handover latency, Fast handovers for Mobile IPv6 (FMIPv6) [3], has been also proposed in IETF. FMIPv6 supports a fast handover procedure allowing starting handover in advance a movement [3]. In this proposal, MN obtains the new CoA (NCoA) before actual movement to new subnet through newly defined messages: *Router Solicitation for Proxy* (RtSolPr) and *Proxy Router Advertisement* (PrRtAdv). It also register its NCoA to previous AR (PAR) to indicate to forward the packets to its NCoA, so as soon as MN moves to the new subnet and connect with a new link, it can receive the forwarded packets from PAR. If feasible, buffers may exist in PAR and NAR for protecting packet loss. Therefore this proposal reduces the service disruption duration as well as the handover latency [3]. However, the various signaling in FMIPv6 makes it complicated to analyze the performance, which should be investigated, so we analyze the signaling time of FMIPv6 on the performance in terms of handover latency, packet loss, and required buffer size.

This paper is organized as follows: we will describe FMIPv6 protocol in Setion 2; we will expain the analytic models and calculate the performance functions for the handover latency, the number of lost packets, and the required buffer size, and then we will show the numerical results in Section 3; we will inspect of signaling time on the performance of FMIPv6 and propose the optimal signaling time for more effective FMIPv6 in Section 4; and we will conclude this paper with some words in Section 5.

## 2 FMIPv6

FMIPv6 is proposed to reduce the handover latency of MIPv6 by providing a protocol to replace MIPv6 movement detection algorithm and new CoA configuration procedure. Providing FMIPv6 is operated over IEEE 802.11 network, the new AP is determined by the scanning processes. The new associated subnet prefix information is obtained through the exchange of the *Router Solicitation for Proxy* (RtSolPr) and *Proxy Router Advertisement* (PrRtAdv) messages. Although the sequential L2 handover processes of scanning, authentication, and re-association are performed autonomously by firmware in most existing IEEE 802.11 implementations, these processes should not be executed autonomously in FMIPv6 to exchange RtSolPr and PrRtAdv messages, and *Fast Binding Update* (FBU) and *Fast Binding Acknowledgement* (FBAck) messages.

In FMIPv6 operated over IEEE 802.11 network, MN firstly performs a scan to see what APs are available. The result of the scan is a list of APs together with physical layer information, such as signal strength. And then, MN selects one or more APs by its local policy. After the selection, MN exchanges RtSolPr and PrRtAdv to get the new subnet prefix. In fact, there may or may not some delay