Helsinki University of Technology Networking Laboratory
Teknillinen korkeakoulu Tietoverkkolaboratorio
Espoo 2007

ANNUAL REPORT 2006

Editors: Sanna Patana and Jouni Karvo

Helsinki University of Technology
Department of Electrical and Communications Engineering
Networking Laboratory

Teknillinen korkeakoulu
Sähkö- ja tietoliikennetekniikan osasto
Tietoverkkolaboratorio

Distribution:
Helsinki University of Technology
Networking Laboratory
P.O.Box 3000
FIN-02015 TKK
Tel. +358-9-451 2461
Fax. +358-9-451 2474

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PREFACE

The year 2006 was a year of steady operation and consolidation for the Networking Laboratory. An important milestone was that Professor Raimo Kantola got a tenure position in August. A new chair in Networking Technology was also established, more specifically in the area of wireless networking. As of this writing, the applications for the post are being evaluated by external experts, and we can look forward to having a fifth professor in our faculty later in 2007.

In our sister laboratory, Communications Laboratory, two new professors entered their chairs. All these developments strengthen the teaching and research in telecommunications area in our Department. We are also warmly welcoming the opportunity for closer co-operation between the two laboratories.

Our long-time senior engineer Tapio Erke, M.Sc., retired at the end of the year. Tapio has been on leave of absence since 1990 and pursued his career at the Asian Institute of Technology. Before that, Tapio was for many years one of the key persons in our staff. We express our sincere thanks to Tapio for all the work he has done for the Laboratory.

Many students of the Laboratory earned academic degrees. A notable record achieved this year was that three degrees of Doctor of Science in Technology were awarded to our researchers, Eeva Nyberg-Oksanen, Henri Koskinen and Aleksi Penttinen. This shows that our efforts in post-graduate teaching are beginning to bear fruit. It is anticipated that this record is not just a solitary peak but the level of 2-4 doctors per year will continue for a few years to come. The number of M.Sc. theses earned by our students in 2006 was 50, a clear increase compared to the previous year's figure of 44 theses.

The Laboratory was rather successful in getting external funding for research. In addition to the ongoing projects ECOSYS, FANCY and VIVALDI, funded by Tekes, the Academy of Finland and the European Commission, respectively, as well as work funded by the Finnish Defence Forces, three new projects were started in 2006: ABI, CLOWN, COIN, all of them belonging to the GIGA Programme launched by Tekes. ABI, a joint project with VTT and University of Helsinki, is one of the four strategic projects in the GIGA Programme. Further, the laboratory succeeded in acquiring grants for research projects starting in 2007 from the Academy of Finland for the DISTANCE project and from Teknologiateollisuuden 100-vuotissäätiö for "Rethinking the Design of Internet Protocols for a Mobile Future". In addition, the Laboratory also successfully completed numerous cooperation projects directly funded by the industry and set the stage for subsequent activities.

Our internationalization is progressing steadily. In addition to the ongoing EU project, VIVALDI, we have been a member in two EU Networks of Excellence, E-NEXT and Euro-NGI. Both of them ended in 2006 but Euro-NGI was immediately succeeded by a two-year extension Euro-FGI. We have also participated in COST Action 279 that ended in June, and

joined Action 290 at the end of the year. The Laboratory's active contributions to Internet standardization in the IETF are visible from continued co-chairing of one Working Group by Professor Jörg Ott and from the publication of five RFCs on IP-based multimedia communication resulting from this work. The research work of our networking business group got recognition as Professor Heikki Hämmäinen was nominated to the Board of the International Telecommunication Society. During the year, we received in total 12 foreign research visitors to our Laboratory, two of them for a longer stay.

The Laboratory put forward an initiative jointly with Nokia and Siemens to organise a Workshop on autonomics of wireless access networks with the aim of bringing both industrial and academic researchers of wireless access networks to the same forum. The result is a new Workshop organised in conjunction with the WoWMoM 2007 conference to be held in Otaniemi, June 2007, with the title "1st IEEE WoWMoM Workshop on Autonomic Wireless AccesS 2007 (IWAS'07)". Another similar hosting responsibility for Netlab is the Conference on Telecommunication Technoeconomics (CTTE'07) also in Otaniemi, June 2007, to be organized in collaboration with Nokia and University of Athens. The CFPs of IWAS'07 and CTTE'07 are attached to this report.

In August, the Laboratory hosted a joint development day held together with Professor Jarmo Harju's Networks and Protocols Group at the Institute of Communications Engineering of Tampere University of Technology. The focus of the discussions was on teaching issues, in particular, the structure and compatibility of B.Sc. studies at the respective Universities.

Two social events were organized by the Laboratory during the year. A recreation day trip took our crew under the June sunshine and sharp southwest wind to a nearby island Käärmesaari by two 12-oar church boats. The traditional Christmas party, preceded by some physical activities, was this time arranged in the old Oittaa Manor House in Espoo.

The Laboratory as a whole is in a good shape. Its economy is well in balance and with a new professor entering in 2007, and eventually still a sixth one in 2008, also the student-to-professor ratio is coming down to a reasonable level. We are well prepared to meet the future challenges and will be able to devote more of our efforts on research, more active publishing on prestigious forums as well as post-graduate teaching and instruction.

February 16th, 2007

Jorma Virtamo

CONTENTS

1 PERSONNEL 2006

1.1 Professors and Docents

Hämmäinen, Heikki	D.Sc. (Tech.), Professor
Kantola, Raimo	D.Sc. (Tech.), Professor
Ott, Jörg	Dr. Eng., Professor
Virtamo, Jorma	D.Sc. (Tech.), Professor, head of laboratory (2006)
Chakraborty, Shyam	D.Sc. (Tech.), Docent
Kilkki, Kalevi	D.Sc. (Tech.), Docent
Pirinen, Aulis	Ph.D., Docent
Raatikainen, Pertti	D.Sc. (Tech.), Docent
Rahko, Kauko	D.Sc. (Tech.), Professor emeritus

1.2 Administrative personnel, teachers and assistants

Erke, Tapio	M.Sc., Laboratory engineer, on leave
Halkilahti, Raija	Department secretary
Hänninen, Arja	Coordinator
Kosonen, Vesa	M.Sc., University teacher
Nupponen, Esko	Senior laboratory supervisor
Pitkäniemi, Kimmo	IT support
Patana, Sanna	Department secretary
Tarvainen, Mika	Student adviser

1.3 Senior researchers and researchers

Aalto, Samuli	Ph.D.
Ilvesmäki, Mika	D.Sc. (Tech.)
Karvo, Jouni	D.Sc. (Tech.)
Koskinen, Henri	D.Sc. (Tech.)
Lassila, Pasi	D.Sc. (Tech.)
Penttinen, Aleksi	D.Sc. (Tech.)
Töyli, Juuso	D.Sc. (Tech.)
Alonso-Rubio, Jose	M.Sc.
Beijar, Nicklas	Lic.Sc. (Tech.)
Holopainen, Visa	M.Sc.
Juva, Ilmari	Lic.Sc. (Tech.)
Kaleelazhicathu, Renjish	M.Sc.
Kamppari, Sauli	M.Sc.
Kiiski, Annukka	M.Sc.
Kivi, Antero	M.Sc.
Lehtinen, Juuso	M.Sc.
Leino, Juha	M.Sc.
Luoma, Marko	Lic.Sc. (Tech.)
Nieminen, Johanna	Lic.Sc. (Tech.)
Parodi, Flavio	M.Sc.

Peuhkuri, Markus	Lic.Sc. (Tech.)
Smura, Timo	M.Sc.
Susitaival, Riikka	Lic.Sc. (Tech.)
Tallberg, Mathias	M.Sc.
Tirronen, Tuomas	M.Sc.
Töyrylä, Piia	M.Sc.
Verkasalo, Hannu	M.Sc.

1.4 Research assistants and trainees

Apilo, Olli
Aro, Antti-Jussi
Autio, Tuukka
Chen, Shanzhen
Devadoss, Jegadish
Hautala, Mikko
Heikkinen, Mikko
Heikkinen, Timo-Pekka
Hyyryläinen, Tuomo
Ivanov, Yavor
Järvinen, Juha
Keränen, Heikki
Korhonen, Eerika
Kärkkäinen, Teemu
Lamminen, Olli-Pekka
Lindqvist, Kim
Lu, Xiaojun
Luo, Cheng
Mukhtar, Omar
Mäkeläinen, Antti
Nordlund, Timo
Repo, Marko
Simola, Oskari
Solarmo, Eero
Wikström, Jaana

1.5 Part-time teachers

Kiiskinen, Ilkka	S-38.2131, 38.3133, 38.3134 Laboratory Course on Networking Technology
Kneckt, Laura	S-38.1105 Principles in Communication Engineering
Mäkinen, Ilona	S-38.1203 Project Course on Networking Technology
Raatikainen, Pertti	S-38.3165 Switching Technology
Rashid, Abu	S-38.2131, 38.3133, 38.3134 Laboratory Course on Networking Technology
Seppänen, Kari	S-38.3165 Switching Technology
Soldani, David	S-38.3215 Special Course on Networking Technology

Figure 1.1 shows the guest lecturers and the program in S-38.001 Telecommunications Forum.

HELSINKI UNIVERSITY OF TECHNOLOGY
Networking Laboratory

What's HOT in telecommunications?

Telecom Forum '2006

An open house studia generalia seminar on telecommunications

PROGRAM 2006

26.09. Jaakko Kuosmanen, CEO, ICT Turku Oy
Business Models for Public WLAN

03.10. Klaus Nieminen, Senior Adviser, Ficora
VoIP and WLAN - Changing the Rules ?

10.10. Kalle Tarpila, Head of Business Development, Aina Group Oyj
Virtual Operator - Opportunity and Challenge

17.10. Gonzalo Camarillo, Head of the Adv. Signaling Research Lab, Oy L M Ericsson Ab
The 3GPP and IETF Approaches to Session Control

24.10. Jouni Purontaus, Founder & CTO, Wicom Communications Oy
Success Factors of Voice-over-IP Solutions

31.10. No Lecture

07.11. Tapio Kallioja, CEO, Swelcom Oy
TV Goes On-line

14.11. Markku Hollström, Head of WiMAX Business Program, Nokia Oyj
WiMAX - A Disruptive Technology ?

Carl Schmits, Director, Intel
Delivering Multi-Megabit Wireless Broadband

21.11. Juho Lipsanen, CEO, Telia Sonera Finland Oyj
Success Factors of the Finnish Mobile Services Market

28.11. Bob Iannucci, SVP and Head of Nokia Research Center, Nokia Oyj
Open Platforms in Mobile Devices Industry

Lectures are held at 17:15 - 19:00 in the lecture hall S4, 2nd floor of the Department of Electrical and Communications Engineering Helsinki University of Technology, Otakaari 5A. Bus 102 from Helsinki.
More info: http://www.netlab.tkk.fi/opetus/s383001/

Figure 1.1: Telecom Forum 2006

2 RESEARCH PROJECTS

2.1 ABI

Project leader: Jorma Virtamo **Researchers:** Samuli Aalto, Pasi Lassila, Riikka Susitaival and Tuomas Tirronen

Algorithms for Broadband Infrastructure (ABI) is a 3-year (2006-2008) strategic research project funded by TEKES, Nokia and Ericsson. ABI is a joint project with VTT (Research Professor Ilkka Norros' group) and University of Helsinki (Professor Kimmo Raatikainen's group). The work in ABI by TKK focuses on wireless mesh networks, P2P systems and fountain codes.

Wireless mesh networks continue to be a hot topic in wireless research. The work in 2006 focused on developing further the initial ideas from 2005 on dimensioning of such networks. We developed new optimization formulations and efficient solution methods for obtaining reasonable estimates of the required resources in a wireless multihop network with static nodes subject to flow-level QoS requirements. Additionally, in collaboration with the ABI team fro University of Helsinki, an in-depth state of the art analysis report on wireless mesh networks was produced, which concentrated on analyzing the current status in performance evaluation research, standardization (link layer and IP layer) and prototype development.

Research on P2P systems in 2006 continued the analysis of a single chunk in a BitTorrent-like P2P file sharing system. We considered the mean life time of the system, where the demand for the file fades exponentially as a function of the time. This corresponds to the so-called flash crowd phenomenon. In addition, the impact of the number of chunks and the chunk selection policy was investigated. The analytical and simulation results showed that the optimal number of the chunks remains considerably small; whether there are 10 or 100 chunks does not have a significant influence on the performance anymore.

Research on advanced packet coding methods was continued from PAN-NET project by finalizing the work on degree distribution optimization of LT codes. Two different approaches were considered: optimization via an importance sampling based cost function and an analytical approach using Markov chains and combinatorial techniques for calculating the decoding probabilities. New work on a fountain coding method based on the concept of random linear fountain was started at the end of the year.

2.2 CLOWN

Project leader: Prof. Jorma Virtamo. **Researchers:** Aleksi Penttinen, Riikka Susitaival.

Cross-Layer Optimisation of Wireless Networks (CLOWN) is a 2-year research project funded by Tekes. The project started in May 2006. The objective of the project is to gain comprehensive understanding of the performance problems which stem from cross-layer co-operation or control

mechanism interaction between layers. As a particular feature, the network performance is studied on the flow level.

During 2006 the project focused on studying the cross-layer modelling. The project contributed an overview and literature survey on cross-layer optimisation methods to the state-of-the-art document on wireless mesh networks of the Tekes ABI project. In addition, the research addressed three topics; dimensioning of wireless multihop networks (co-operation with ABI), flow-level performance analysis of complex networks (co-operation with FANCY), and load balancing in wireless networks.

The results of the project in 2006 include several efficient dimensioning methods which can be used to obtain order-of-magnitude estimates of wireless network resources, when the performance requirements are given in terms of average throughputs for file transfers. Development in flow-level performance analysis resulted in novel computational methods which allowed approximating throughput in considerably large networks. The load balancing problem, which consists of combined routing and scheduling in wireless networks, was reduced to a linear programming problem, which allows a simple analysis of the benefits of the cross-layer optimization at the routing-scheduling interface.

2.3 COIN

Project leader: Heikki Hämmäinen, Timo Smura **Researchers:** Annukka Kiiski, Mathias Tallberg, Antero Kivi, Hannu Verkasalo, Juuso Töyli, Tuukka Autio, Kim Lindqvist

COIN (Dynamics of COmpetition and INnovation in the converging Internet and mobile networks) is a 2-year national project (2006-2007) funded by TEKES, Nokia, TeliaSonera, Elisa, DNA, Digita, and the Ministry of Transport and Communications. The project continues and expands the work initiated in the earlier LEAD project (2004-2005).

COIN aims to improve the techno-economic understanding of the dynamics of the national mobile and wireless services market. The key stakeholders of the Finnish mobile market are involved in the project, and the results will contribute to both regulatory and strategic planning. During 2006, our research activities included mobile service usage measurements, study on the effects of handset bundling on the Finnish market, analysis of WiMAX, DVB-H, and mobile VoIP technologies and business models, study on the ecosystem structure for mobile data services, as well as further development of our Mobile Operator Business game.

The mobile service usage measurements were carried out for the second time, in close co-operation with Nokia and the operator partners. Our aim is to repeat the measurements on an annual basis and collect longitudinal data from handsets, routers, and operator databases.

In our handset bundling study, we have produced an impact model describing the effects of bundling on mobile data usage. We have had the possibility to analyze the market situation both before and after bundling was legalized in April 2006.

Market effects of emerging radio technologies have been analyzed by constructing quantitative techno-economic models, utilizing the method-

ology and tools developed by the ECOSYS project. Case studies have been carried out for both WiMAX and DVB-H technologies. Regarding potential technology disruptions, a study on the effects of mobile VoIP services has been initiated.

Our study on the structure of the mobile data service industry, and especially on the impact of mobile virtual network operators (MVNO) there has continued. MVNOs' role in the marketplace has been analyzed by conducting interviews among industry experts and by techno-economic modelling.

Based on the work and findings in our project, we have continued to improve the Mobile Operator Business (MOB) game. The game is currently used for teaching TKK and HKKK students, as well as professionals from the industry.

2.4 DTNPREP

Project leader: Jörg Ott **Researchers:** Cheng Luo

DTNPREP was an industry-funded contracted research project of exploratory nature for a period of three months (Oct-Dec 2006). The project aim was to investigate the suitability of *Identity-based Cryptography (IBC)* for Delay-tolerant Networks (DTNs). For this purpose, a demonstrator setup was specified and developed based upon the DTN reference implementation (Intel/UC Berkeley) which was ported to the Nokia 770 Internet Tablet, a Linux-based embedded mobile device. A DTN-enabled mail application developed at TKK Netlab was enhanced by IBC functionality on the sender and receiver side, and plugged into a prototype IBC infrastructure provided by the project partner. In addition to IBC considerations, the project also investigated leveraging cellular network infrastructure to authenticate users in DTN applications.

The preliminary study carried out in the DTNPREP project was successful and the project will be followed up in 2007 by the *Security using Infrastructure Networks for Delay-tolerant Networking (SINDTN)* project, focusing on an enhanced security architecture for DTNs, addressing the specific needs of mobile ad-hoc communications.

2.5 ECOSYS

Project leader: Heikki Hämmäinen, Renjish Kaleelazhicathu **Researchers:** Timo Smura, Mikko Heikkinen
Project website: www.celtic-ecosys.org

ECOSYS (techno-ECOnomics of integrated communication SYStems and services) is a 3-year international project (2004-2007), part of the EUREKA/CELTIC program. The project covers a set of operator-centric techno-economic investment issues related to fixed, mobile, and convergent networks. Work packages include traffic forecasting, development of techno-economic analysis methodology and tools, and application of these on specific business cases. Our team focuses on mobile and convergence related topics in the project.

During 2006, we continued with our work on fixed-mobile convergence

(FMC) studies. Besides taking care of the overall leadership for this work package, we were the editor for one of the deliverables. The project identified two business cases for further analysis, namely, the migration to FMC case of an integrated operator (owning both fixed and mobile networks) and an operator in an emerging market such as Malaysia. An 8 year study period starting from 2007 in a Western European context was considered. Two deliverables related to these studies were produced. We at TKK were involved in the modeling and analysis of the integrated operator case.

The main objectives of our study were to identify and measure the additional or delta benefits generated by an integrated operator due to the migration of its networks and services to FMC. Related to this case, we participated in discussions on the overall architecture, services, pricing network and service dimensioning and cost assumptions to be considered. We also contributed to the quantitative modeling of two key parts, IMS (IP Multimedia Subsystem) and Unlicensed Mobile Access (UMA/GAN) rollout scenarios. The preliminary and final results were presented in two deliverables, both of which are available at the project website.

Our analysis, based on the results, show the existence of benefits of FMC for an integrated operator. Cost trends show an increase, especially in the operating expenditure (OPEX), at the initial period of study followed by considerable cost savings at the later stage. Even though there is no significant increase in revenue generated, migration to FMC helps to retain the customers, thereby preventing loss of market share and revenue.

In 2006, the ECOSYS project organized the 5th conference on Telecommunication Techno-economics (CTTE) in Athens, Greece. A Delphi survey was conducted as part of the conference on the topic of convergence. TKK was involved in the coordination and development of questionnaire for the survey. The survey covered convergence from the viewpoint of potential services, its revenue and terminals. The results of the survey were distributed to the participants and used by the project in the FMC business case studies.

TKK was also involved in the dissemination of results achieved in this project through conference and journal papers.

The ECOSYS project concludes in April 2007.

2.6 E-NEXT

Project leader: Raimo Kantola **Researchers:** Marko Luoma, Heikki Hämmäinen, Markus Peuhkuri, Mika Ilvesmäki, Johanna Antila, Nicklas Beijar, Renjish Kaleelazhicathu, Jörg Ott, Piia Töyrylä

E-NEXT is a Network of Excellence in the Sixth EU Framework Program. The purpose of E-NEXT is to advance collaboration between the Networking Technology Laboratories of the participating Universities in Research and Doctoral studies. E-NEXT organizes conferences and workshops and runs joint work group activities in the areas of Ambient and Mobile Networking, Scalable Networking, Self-Aware Networking, Content Networking and Service Aware Networking. E-NEXT also has organized its own Doctoral School of Advanced Topics In Networking (SATIN).

A NoE like E-NEXT does not pay for the research work itself, it only

has a budget for covering cooperation expenses.

During 2006 we participated in several E-NEXT work group activities, conference organization activities and in the SATIN Doctoral School.

2.7 Euro-NGI/Euro-FGI

Project leader: Jorma Virtamo **Researchers:** Samuli Aalto, Ilmari Juva, Pasi Lassila, Juha Leino, Aleksi Penttinen, Riikka Susitaival, Tuomas Tirronen.

Euro-NGI/Euro-FGI is a Network of Excellence (NoE) in the Sixth EU Framework Programme. The 3-year first phase Euro-NGI was completed at the end of November 2006 and was immediately succeeded by a 2-year extension phase Euro-FGI. Altogether 58 Universities and Research Institutes participate in this NoE.

The purpose of Euro-NGI/Euro-FGI is to foster collaboration between the partners in the broad area of Next Generation Internet research and development. Euro-NGI/Euro-FGI organizes conferences, workshops, summer schools and special courses for doctoral students. The flagship conference NGI 2006 was held in Valencia in April 2006. Two papers from the Networking Laboratory were presented in this conference. In addition, the NoE facilitates mobility of researchers between the participating institutions.

A NoE like Euro-NGI/Euro-FGI funds the actual research work only to a very limited extent; its budget is mainly intended to cover cooperation expenses. Within Euro-NGI/Euro-FGI, however, a special mechanism, so-called mini-projects, has been created for a more focused collaboration. Networking Laboratory participated actively in the Cellular2 mini-project.

2.8 FANCY

Project leader: Jorma Virtamo **Researchers:** Samuli Aalto, Ilmari Juva, Juha Leino, Riikka Susitaival

Flow Aware Networking: Applications and Analysis (Fancy) started in 2005 and continues until the end of 2007. The work is funded by the Academy of Finland. Goal of the project is to apply flow-aware methods for traffic engineering and quality of service provisioning of the Internet, both in wired and wireless environment. In 2006 work was done mainly on balanced fairness, scheduling disciplines and traffic matrix estimation. In addition, load balancing problem in a dense wireless multihop network was studied.

The knowledge of the current traffic demands between the origin-destination pairs of the network is a necessary input in many traffic engineering and dimensioning tasks. Estimating the traffic matrix on the basis of link load measurements, however, is a strongly under-determined problem and poses a big challenge. In the project, the study of origin-destination traffic characteristics of Funet network measurements was continued, with the goal of studying the validity of several key assumptions involved in traffic matrix estimation. As it was found that these assumptions, while fairly justified, rarely hold perfectly, a comparative study on how sensitive current traffic matrix estimation methods are to their underlying assumptions was

performed.

Analysis of size/age-based scheduling disciplines was continued in 2006. By utilizing the so called Gittins index approach (originally developed for multi-armed bandit problems), an optimized distance-aware scheduling discipline was derived for elastic flows in a cellular system. As an application, it was found out that for Pareto-type flow size distributions, the size-based information is more important than the location information. Size/age-based scheduling disciplines were also studied in the context of bandwidth sharing networks. A method was developed to improve the delay performance of any stable state-dependent bandwidth allocation policy, such as the balanced fair, the max-min fair, or the proportionally fair policy. To retain the stability of the system, the optimal size-based discipline, SRPT, is applied only locally within each route.

Balanced fairness (BF) is a novel resource sharing scheme which defines how to share capacity of a network to different flows in such a way that the resulting system is insensitive allowing flow-level performance evaluation. A simple approximate method was developed for estimating the flow level performance of systems using balanced fair resource allocation. The approximation is based on light and heavy load asymptotics of the throughput curve. Derivative of the throughput with respect to the load parameter was given and a conjecture presented for the derivative at heavy traffic. Based on the asymptotic behaviour, an interpolation was used to estimate the throughput for intermediate loads. A formulation of BF in case of continuous class index was given and applied to calculate the user experienced throughput in a 2-cell cellular system with link adaptation (continuous range of nominal link rates). The approximation method was further extended to make use also of the second derivatives at low load. The method was applied to performance analysis of wireless multihop networks and multipath fixed networks.

A new approximative method for performance evaluation called value extrapolation was developed. The method is based on extrapolation of the so-called value function in the Markov Decision Process (MDP) formulation of the problem and allows one to accurately estimate performance measures that can be expressed as the expectation of an arbitrary function of the state of the system even with a heavy truncation of the state space. BF and value extrapolation were used to analyze the effect of different operation policies in a simple two base-station system.

In a very dense multi-hop wireless network, the load balancing problem separates into two different parts: a) On the microscopic level one has to use an efficient forwarding method maximizing the intensity of sustainable flow in a given direction. The maximum intensity is a kind constant of medium; by time sharing between different directions it sets an upper bound on so-called scalar flux the medium can sustain. b) On macroscopic level, the underlaying network fabric appears as a continuous medium characterized by the maximum sustainable scalar flux. The task of load balancing is to find the paths between different OD pairs such that the maximum scalar flux in the network is minimized.

In our work [hyytiä2006b], we have found some lower bounds for the optimized (minmax) scalar flux. Then we have given a general expressions

for calculating the scalar flux with a given set of paths. In particular, for the case of a circular disk with uniform traffic matrix, we give simple and efficient formulas for calculating the scalar flux for a general family of paths [hyytiä2006c].

Finding the optimal set of paths is a difficult problem. We have approached it with studying some parametrically defined sets of paths and making optimization over the parameters. In our studies we have been able to reduce the minmax scalar flux from 0.637 down to 0.384 with single path routing and to 0.379 with multipath routing [hyytiä2006b], [hyytiä2006c].

2.9 InHoNets

Project leader: Heikki Hämmäinen **Researchers:** Mathias Tallberg, Timo Nordlund

InHoNets (Interconnected Broadband Home Networks) is a 2-year national project (2006–2007) funded by TEKES, Ericsson, Nokia, Elisa, Digita and YLE. This project focuses on wireless broadband home networks, interconnectivity to infrastructure networks and seamless internetworking between several home networks through broadband access networks. The research aims at ensuring reliable and secure broadband end-to-end connectivity between peer devices within one home, but also between several home networks. The home network is a challenging environment since the target recipient is a consumer without ICT expertise. In addition to developing system architectures and internetworking solutions, the project also analyze business value systems.

During 2006, the emphasis of our work was put on business scenario work in order to link the business modelling with the technical architecture tasks. In 2006 we also contributed in the project deliverables as planned. The research in 2007 will build on the first year scenario analysis and move deeper into business models and operator strategies for the digital home and playable aspects of home network related business simulation. The key findings on business models and operator strategies for single home wireless hotspots will be modelled as new functionality and also experimented using an operator business game/simulation. As a research methodology in this project we use systematic interviews, case studies, industry scenario analysis, and constructive modelling.

2.10 International Otaniemi (INTO)

Project leader: Raimo Kantola

The aim of the project is to advance the internationalisation of TKK. The project is funded by the Association of Technology Industries of Finland which has appointed the steering group of the project as well. The aim is to develop one or two strategic actions in order to further the internationalisation of TKK. The project covers the whole internationalisation strategy of TKK as a part of its entire strategy. This project focuses on measuring what we have achieved particularly in international education. It focuses also on defining actions which are based on present achievements. What is more, our aim is to find out what kind of expectations the Finnish employ-

ers have on TKK's internationalisation. The reason is that TKK doesn't live in a vacuum and TKK has to develop its operations in co-operation with all stakeholders.

The project is divided in two phases. First we collected data on the success of TKK's international operations until now. We also collected data on what kind of expectations are placed on us the employers.

In practice we collected data from registers, from a survey directed to all TKK alumni graduated between 1/2001-6/2006 and from a survey directed to human resources managers. We widened our view by interviewing some top directors in big Finnish companies.

In the second phase we will treat our data and evaluate those actions which could be realised by TKK in order to further its internationalisation.

2.11 IVIHUT

Project leader: Jörg Ott **Researchers:** Omar Mukhtar, Jegadish Devadoss, Shanzhen Chen

IVIHUT was a contracted research project funded by the industry for the year 2006. The project focus was on *Interactive Video* applications on mobile nodes running over wireless networks. The general aims were to explore error resilience mechanisms for packet-based video transmission over heterogeneous fixed and wireless networks and to investigate different (mobile) video applications. Different research and engineering aspects of mobile video communications were addressed in the project as described in the following.

Starting from integrating RFC 3984-based H.264 video encapsulation into an embedded mobile device for IP-based interactive video communications, a general framework was developed for simulating losses in heterogeneous wireless networks. Based upon the framework, a simulation tool chain was created encompassing an existing video encoder and decoder, a batch-based UMTS link simulator, and the network simulator *ns-2*, the latter of which was extended to interface to the encoder/decoder as well as to the UMTS link simulator. Media-aware FEC encoding/decoding modules for proactive error resilience were added and a set of analysis tools (operating on the output files) complete the tool chain. During the course of the project, the initial file-based interface between the components (used for batched simulations) was enhanced to become a TCP-based interface, thus enabling interactive end-to-end feedback loops between sender and receiver (see figure 2.1).

Figure 2.1: IVIHUT Simulation Tool Chain

On the mobile application side, an extensive report on today's landscape of (mobile) multimedia conferencing standards and standards devel-

opments was produced, particularly taking into account activities from the IETF, 3GPP, and the Open Mobile Alliance (OMA). Finally, a study on disconnection tolerance for mobile video applications was conducted.

The IVIHUT project will be continued in 2007 as *Adaptive Video over Wireless (AVoW)* project, focusing on interactive error resilience and mobile application aspects.

2.12 LATE

Project leader: Markus Peuhkuri **Researchers:** Mikko Hautala, Heikki Keränen, Antti Mäkeläinen and Marko Repo

LATE project focuses on simulation-based performance evaluation of wireless LANs ja MANs (IEEE 802.11, 802.16) on different usage scenarios. Using Mobile IPv6 on WLAN environment was studied using simulation models built for ns2 and Omnet++ simulators in the spring resulting two diploma thesis. In the autum, research started on application-level mobility management using SIP protocol, group mobility and mobility support on IEEE 802.16e (Mobile WiMAX).

2.13 TIEVA

Project leader: Marko Luoma **Researchers:** Markus Peuhkuri, Mika Ilvesmäki, Olli-Pekka Lamminen, Timo-Pekka Heikkinen, Juha Järvinen, Visa Holopainen, Piia Töyrylä

TIEVA is a research project for analyzing and development of network layer operations of a large service provider network. Network is analyzed by using distributed passive and active measurements. Distributed passive network measurement is a suitable tool for constructing comprehensive picture of network traffic. Active measurements on the other hand reveal the operational level of the network. Based on the information gathered from these measurements steps for the network development are constructed. These steps are validated through simulations utilizing models derived from the network measurements. Usual development steps contain dimensioning, changes of topology, and changes of traffic control within the network. The overall goal of TIEVA project is to create a network that can withstand sudden and unusual overloads, errors and traffic patterns. To facilitate this background research on routing stability and network path restoration is executed.

2.14 VIVALDI

Project leader: Jörg Ott **Researchers:** Teemu Kärkkäinen, Nicklas Beijar, Lu Xiaojun, Tuomo Hyyryläinen

VIVALDI is an IST FP6 project funded by the European Commission in which two leading companies in the satellite ground segment area, one software development house, two service providers and two academic partners cooperate. The partners are from seven Different countries, three are SMEs. The project started in January 2006 and has a total duration of 24 months.

The objective of the project is to advance the state of the art of interactive broadband satellite access by optimal convergence of session-based services over the European satellite return link standard DVB-RCS. Specifically the project aims to research and develop the architecture, technologies and protocols necessary for ensuring SIP and other VoIP technologies can operate efficiently in two-way satellite networks. Networking Laboratory's main responsibilities in the project include analysis of signaling protocols and media flow characteristics, and final testing and validation of the solutions developed.

Geostationary satellite networks pose a challenging environment for IP telephony due to the physical link conditions and the diversity of the network scenarios. DVB-RCS links are characterized by long physical propagation delays and low available bandwidth, creating a need for efficient QoS provisioning. Any solutions need to be flexible in order to meet the requirements of the diverse network scenarios and the heterogeneous environment where end-point cooperation cannot be relied upon.

In 2006, the main activities were focused on developing a DiffServ-based architecture for flexible QoS provisioning capable of real-time detection and classification of media flows. The result of the activities was a complete architecture as well as a prototype implementation. Further activities included analysis of call signaling protocols and other related technologies. In 2007, the main focus will shift to the development of a testing setup for the validation of the solutions implemented by the project partners.

2.15 WIDENS – Wireless DEployable Network System

Project leader: Raimo Kantola **Researchers:** Jouni Karvo

The purpose of WIDENS is to design, prototype and validate a vertically integrated rapidly deployable and scalable communication system for future public safety, emergency and disaster applications.

The project focuses on designing a single hot spot, which can be easily deployed, optimized for high bitrate throughput (over 2Mbit/s) and interoperable with existing core networks and present private mobile radio systems (such as TETRA and Tetrapol).

The system concept is based on ad hoc network technologies, and the technological approach focuses on adaptations of existing technologies for the purposes of meeting the public safety requirements. The target terminal nodes include both physical, link and network routing layers, and feature asynchronous and synchronous high bitrates, direct mode group communications, strong authentication and confidentiality and quality of service.

The project ended during 2006. In January, we demonstrated the system at Sophia-Antipolis, France. The demonstration included the deployment tool developed in the Networking laboratory. The purpose of the deployment tool is to aid the command and control on-scene on the awareness of the network status. The tool shows node locations and link qualities, and suggests places for additional relay nodes to be placed on the scene. The project also produced two conference papers during 2006.

3 TEACHING

3.1 Course descriptions

This is the full list of courses in our curriculum:

Studia generalia:

- S-38.3001 Telecommunications Forum (Telecommunications Forum)

Basic courses for all students studying telecommunications:

- S-38.1105 Principles in Communication Engineering (Tietoliikennetekniikan perusteet)
- S-38.1145 Introduction to Teletraffic Theory (Liikenneteorian perusteet)

Courses concerning communications and networks:

- S-38.3115 Signaling Protocols (Televerkon merkinannot)
- S-38.3165 Switching Technology (Välitystekniikka)
- S-38.3180 Quality of Service in the Internet (Palvelunlaatu Internetissä)
- S-38.2188 Communications Networks (Tietoliikenneverkot)
- S-38.3192 Network Service Provisioning (Verkkopalvelujen tuotanto)
- S-38.3193 Wireless networks (Langattomat verkot)
- S-38.2121 Routing in Communication Networks (Reititys tietoliikenneverkoissa)

Courses on Networking Business:

- S-38.3041 Networking Business (Operaattoriliiketoiminta)
- S-38.3042 Seminar on Networking Business (Tietoverkkoliiketoiminnan seminaari)
- S-38.3045 Special Assignment on Networking Business (Tietoverkkoliiketoiminnan erikoistyö)

Courses on Teletraffic Theory:

- S-38.3148 Simulation of Data Networks (Tietoverkkojen simulointi)

Courses on protocols and services:

- S-38.3150 Network Multimedia Protocols and Services
- S-38.3153 Security in telecommunications (Tietoliikenteen tietoturva)
- S-38.3157 Protocol Design (Protokollasuunnittelu)

Seminars, laboratory works, special assignments:

- S-38.2131 Laboratory course on Networking Technology A (Tietoverkkotekniikan laboratoriokurssi A)
- S-38.3133 Laboratory course on Networking Technology B (Tietoverkkotekniikan laboratoriokurssi B)
- S-38.3134 Laboratory course on Networking Technology C (Tietoverkkotekniikan laboratoriokurssi C)
- S-38.3138 Networking Technology, special assignment (Tietoverkkotekniikan erikoistyö)
- S-38.1203 Project course on Networking Technology (Tietoverkkotekniikan projektityö)
- S-38.3310 Thesis Seminar on Networking Technology (Tietoverkkotekniikan diplomityöseminaari)

Postgraduate courses include:

- S-38.3155 Challenged Networks
- S-38.4030 Postgraduate Course on Networking Technology (Tietoverkkotekniikan lisensiaattikurssi)
- S-38.3141 Teletraffic Theory (Teleliikenneteoria)
- S-38.3143 Queueing Theory (Jonoteoria)
- S-38.3183 Internet Traffic Measurements and Measurement Analysis (Internetliikenteen mittaus ja mittausten analysointi)
- S-38.4149 Postgraduate Course in Teletraffic Theory (Teleliikenneteorian lisensiaattikurssi)
- S-38.3205 Individual Course on Networking Technology (Tietoverkkotekniikan yksilöllinen opintojakso)
- S-38.3215 Special course on Networking Technology (Tietoverkkotekniikan erikoiskurssi)
- S-38.4360 Research Seminar on Networking Technology (Tietoverkkotekniikan tutkijaseminaari)

Some of the courses provided by Networking laboratory were lectured in English. A detailed breakdown by the language and course level is given in the following table.

Table 3.1: The number of ECTS points offered on courses lectured in Finnish and in English

	undergraduate	graduate	post-graduate
Finnish	10	16	18
English	12	17.5	39

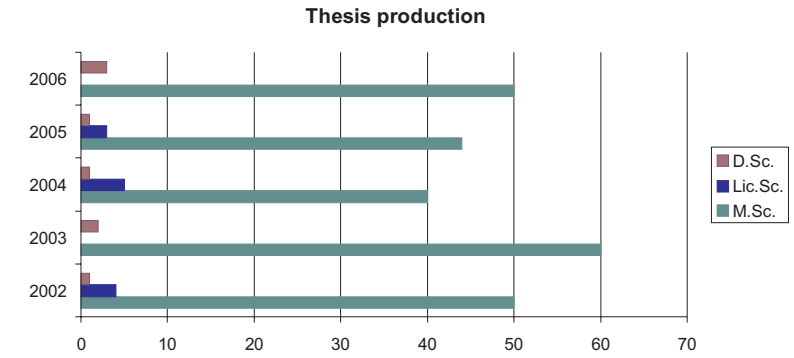
3.2 Theses

The key results of teaching in the Networking Laboratory in 2006 can be summarized as

50 Master's theses, and

3 Doctoral dissertations

The development of thesis production is shown in Figure 3.1



Year	2002	2003	2004	2005	2006
D.Sc.	1	2	1	1	3
Lic.Sc.	4	0	5	3	0
M.Sc.	50	60	40	44	50

Figure 3.1: Thesis production 2001-2006

Doctor of Technology

Henri Koskinen Performance Studies of Wireless Multihop Networks

Wireless multihop networks represent a fundamental step in the evolution of wireless communications, a step that has proven challenging. Such networks give rise to a wide range of novel performance and design problems, most of which are of a geometric nature. This dissertation addresses a selection of such problems.

The first part of this thesis presents studies in which the network nodes are assumed to receive signals sufficiently clearly only from within some fixed range of operation. Using this simple model, the first two problems addressed are to predict the probabilities that a network with randomly placed nodes is connected or completely covers a given target domain, respectively. These problems are equivalent to determining the probability distribution of the minimal range providing connectivity or coverage. Algorithms for determining these threshold ranges for a given set of network nodes are developed. Because of the complex nature of these problems in finite settings, they are both approached by empirically modeling the convergence of these distributions to their known asymptotic limits. Next, a novel optimization problem is presented, in which the task is to make a given disconnected network into a connected one by adding a minimal number of additional nodes to the network, and heuristic algorithms are proposed for this problem.

In the second part, these networks are studied in the context of a more realistic model in which the condition for successful communication between network nodes is expressed as an explicit minimum value for the received signal-to-noise-and-interference ratio. The notion of the threshold range for connectivity is first generalized to this network model. Because connectivity is now affected by medium access control (MAC), two alternative MAC schemes are considered. Finally, an infinite random network employing slotted Aloha is studied under this model. Since the probability of successful reception in a random time slot is a function of the locations of other nodes, this temporal probability is a random variable with its own probability distribution over different node configurations. Numerical approximations for evaluating both the mean and the tail probability of this distribution are developed. The accuracy of these approximations can be improved indefinitely, at the cost of numerical computations.

Eeva Nyberg-Oksanen Performance Evaluation of Multicast Networks and Service Differentiation Mechanisms in IP Networks

The performance of a communication network depends on how well the network is designed in terms of delivering the level of service required by a given type of traffic. The field of teletraffic theory is concerned with quantifying the three-way relationship between the network, its level of service and the traffic arriving at the network. In this thesis, we study three different problems concerning this three-way relationship and present models to assist in designing and dimensioning networks to satisfy the different quality of service demands.

In the first part of the thesis, we consider service differentiation mechanisms in packet-switched IP networks implementing a Differentiated Services (DiffServ) architecture. We study how bandwidth can be divided in a weighted fair manner between persistent elastic TCP flows, and between these TCP flows and streaming real-time UDP flows. To this end, we model the traffic conditioning and scheduling mechanisms on the packet and the flow level. We also model the

interaction of these DiffServ mechanisms with the TCP congestion control mechanism and present closed-loop models for the sending rate of a TCP flow that reacts to congestion signals from the network.

In the second part, we concentrate on non-persistent elastic TCP traffic in IP networks and study how flows can be differentiated in terms of mean delay by giving priority to flows based on their age. We study Multi Level Processor Sharing (MLPS) disciplines, where jobs are classified into levels based on their age or attained service. Between levels, a strict priority discipline is applied; the level containing the youngest jobs has the highest priority. Inside a particular level, any scheduling discipline could be used. We present an implementation proposal of a two-level discipline, PS+PS, with the Processor Sharing discipline used inside both levels. We prove that, as long as the hazard rate of the job-size distribution is decreasing, which is the case for Internet traffic, PS+PS, and any MLPS discipline that favors young jobs, is better than PS with respect to overall mean delay.

In the final part, we study distribution-type streaming traffic in a multicast network, where there is, at most, one copy of each channel transmission in each network link, and quantify the blocking probability. We derive an exact blocking probability algorithm for multicast traffic in a tree network based on the convolution and truncation algorithm for unicast traffic. We present a new convolution operation, the OR-convolution, to suit the transmission principle of multicast traffic, and a new truncation operator to take into account the case of having both unicast and multicast traffic in the network. We also consider different user models derived from the single-user model.

Aleksi Penttinen Algorithms and Performance Evaluation Methods for Wireless Networks

The performance of wireless networks depends fundamentally on the characteristics of the radio resource. In this thesis we study methods that can be used to improve performance of wireless networks. We also study methods that can be used to analyze the performance of such networks.

In the first part of the thesis, we propose algorithms for multicast routing and max-min fair link scheduling in wireless multihop networks. The multicast routing problem is to find a minimum-cost sequence of transmissions which delivers a message from a given source node to a set of destination nodes. We propose three efficient multicast routing algorithms for certain common instances of the problem. The first algorithm assumes fixed transmission costs and constructs an efficient multicast tree in a centralized fashion. The second algorithm can be used to minimize only the number of transmissions in the multicast tree, but it has a distributed implementation. The last algorithm is applicable in scenarios where the network nodes can control their transmission range and the objective is to minimize the power consumption of the multicast tree. In the max-min fair link scheduling problem one attempts to assign transmission rights to flows in a wireless multihop network so that the long-term flow rates become

max-min fair. We present a low-complexity, low-overhead distributed algorithm for the problem.

The second part comprises of the flow-level performance analysis of elastic data traffic in wireless networks. The network is modeled in a dynamic setting, in which flows (e.g., file transfers) arrive stochastically and depart upon completion. We discuss how a recently introduced resource allocation concept, balanced fairness, can be applied to wireless networks and devise an efficient computational scheme for solving the resulting joint problem of scheduling and resource allocation. Additionally, we propose an alternative method to approximate the flow throughput under balanced fairness in arbitrary networks. Finally, we adapt balanced fairness to a model where flows are indexed by a continuous variable. The model can capture, e.g., location-dependent features of flows.

Masters of Science

The employers of our Master's thesis students are shown in Figure 3.2.

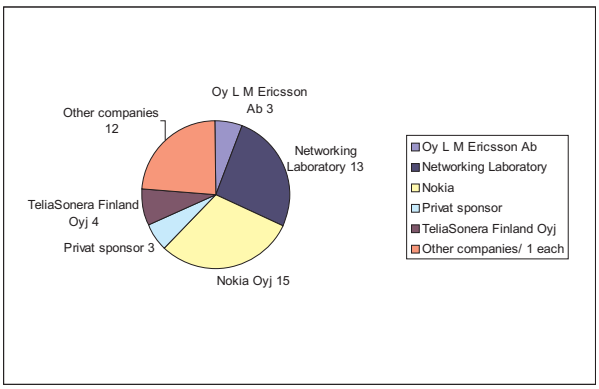


Figure 3.2: Employers of Master's thesis students 2006

- Anttila, Erkko: Open Source Software and Impact on Competitiveness: Case Study, Nokia
- Apilo, Olli: Performance of Randomized Forwarding Methods in Large Ad Hoc Networks, TKK, Netlab
- Ayyash, Mohammad: Quality of Service Analysis of Real Time Applications in Ad Hoc Networks, TKK, Netlab
- Flythström, Johanna: Impact of Patent Licensing Policies on Technology Business, Nokia IPR
- Halminen, Joni: Impact of Emerging Wireless Broadband Technologies and Services on Operator Strategies, TeliaSonera Finland Oyj

- Hautala, Mikko: Mobile IPv6 Performance in 802.11 Networks: Handover Optimizations on the Link and Network Layer, TKK, Netlab
- Hietikko, Juhani: Implementation of MAC-c Protocol for an Improved UMTS Internet Access, Nokia Networks
- Holopainen, Visa: Liikenteen hallinta autonomisen alueen sisäisen reititysprotokollan metriikoiden avulla, TKK, Netlab
- Ivanov, Yavor: Label Switched Virtual Private Networks- Scalability and Performance Analysis, TKK, Netlab
- Jiang, Bo: Clustering Extension of Ad-Hoc On-Demand Distance Vector Routing Protocol, TKK, Netlab
- Keränen, Heikki: An Overview of Mobile IPv6 Home Agent Redundancy, TKK, Netlab
- Kettunen, Juhamatti: Decentralized Session Initiation Protocol framework in Multihop Ad hoc Routing Environment
- Kielinen, Mikko: Matkapuhelintiheyden kasvun tekijät kehittyvillä markkinoilla, Nokia
- Kilpinen, Markku: National Home Network Strategy: Case South Korea, FinPro, Korea
- Kivi, Antero: Mobile Internet Usage Measurements - Case Finland, TKK, Netlab
- Kolmonen, Joonas: The Use of Hardware Simulation in Smartphone Projects, Nokia
- Koskenheimo, Kimmo: TriplePlay-palvelun ryhmälähetys- ja palvelunlaatuparametrien optimointi, Elisa Oyj
- Koskenheimo, Kirsi: Verification of a GPRS Charging System in a Simulated Test Environment, Oy L M Ericsson Ab, Finland
- Kuisma, Jarkko: Optimization of Cost and Quality in Global Customer Deliveries of Network Infrastructure Products, Nokia
- Laimio, Jussi: Pakettivälitteisyyden vaikutukset matkapuhelinoperaattorin keskusverkon kustannusrakenteeseen, TeliaSonera Finland Oyj
- Lehtinen, Juuso: Design and Implementation of Mobile Peer-to-Peer Application, TKK, Netlab
- Leskelä, Antti: Usable Security: Finding Solutions for Bringing Usability to Security Products, Freelancer
- Mahkonen, Heikki: Detecting Wireless Network Attachment, Oy L M Ericsson Ab, Finland

- Markkola, Paavo: Design and Implementation of the Operation and Maintenance Software for a New GSM Transcoder, Nokia Networks
- Mukhtar, Omar: Design and Implementation of Bundle Protocol Stack for Delay-Tolerant Networking, TKK, Netlab
- Mäkinen, Mikko: 3G Media Gateway Software for GSM Transcoder, Nokia Networks
- Nieminen, Mikko: Troubleshooting in Live WCDMA Networks, Nokia
- Palokangas, Antti: Tietoliikenneverkon valvonta eräässä yrityksessä, Outokumpu Stainless Oy
- Pelkonen, Mari-Jaana: Estimating 3G Long-Term Evolution End-to-End Performance Compared to High-Speed Downlink Packet Access, Nokia Networks
- Pihlajamäki, Antti: Comparison of Mobile Interconnection Architectures, TeliaSonera Finland Oyj
- Pullola, Esa-Pekka: Extending Active Base Station Radio Links for Improved Uplink Scheduling, Nokia Networks
- Ralli, Timo: National Strategies for Public WLAN Roaming, TKK, Netlab
- Rantala, Valtteri: A Validation Methodology for Graphics Processors, ATI Technologies Finland
- Raunio, Jukka: IP-pakettien pakkaus UMTS-verkossa, Nokia
- Salmela, Niklas: Challenges and Limitations in a Back-end Controlled SmartHome, Siemens Oy
- Salomaa, Sami: Verkko-operaattorin provisiointijärjestelmän vaihdon vaikutukset palveluoperaattorin järjestelmiin, DNA Finland
- Sederlöf, Tom: Interactivity in Mobile TV, Nokia
- Taipale, Tuukka: Comparison of Routing Software in Linux, Nokia Networks
- Tirronen, Tuomas: Optimizing the Degree Distribution of LT Codes, TKK, Netlab
- Turunen, Lauri: Televerkon verkkotietojärjestelmän määrittely ja käyttöönotto, Corenet Oy
- Vardar, Tuna: Scalable Routing Mechanism in Ad Hoc Networks, TKK, Netlab
- Varis, Olli-Pekka: Remote Management of People Flow Systems in Buildings, KONE Oyj

- Vesterinen, Matti: Analysis of Future Mobile Instant Messaging Markets, Nokia Networks
- Virtanen, Jussi: Conferencing Using Instant Messaging in the IP Multimedia Subsystem, Oy L M Ericsson Ab, Finland
- Wahlberg, Carl: Erään Internetpalveluntarjoajan verkon valvonnan kehittäminen, Eunet Finland
- Wahlroos, Wille: Replicating Information in a Power Distribution Management System
- Wang, Xiao: An Authorization System for Grid Applications, CERN, Geneva
- Wirta, Jussi: Integration of Location Based Services with Mobile Business Processes Management, Fujitsu Services Oy
- Öfversten, Antti: Market Entry Strategies for Payment Software Modules, Innopoli
- Österman, Sauli: Combining Circuit and Packet Based Services in Converging Networks, TeliaSonera Finland Oyj

4 ACTIVITIES

4.1 Participation in conferences and meetings

- Samuli Aalto
  - IEEE Infocom 2006 Conference, Barcelona, Spain, April 23-28, 2006
  - EURO XXI Conference, Reykjavik, Iceland, July 1-6, 2006
  - StoPeRA Workshop, CWI, Amsterdam, Holland, November 8-10, 2006
- Jose Costa-Requena
  - MobileMAN Project Meeting, Pisa, Italy, January 27-30, 2006
- Mikko Heikkinen
  - ECOSYS Meeting, Crete, Greece, September 2-9, 2006
- Heikki Hämmäinen
  - MOB (Mobile Operator Business Game) presentation, Peking, China, March 29 - April 2, 2006
  - 5th Conference on Telecommunication-Techno-Economics CTTE 2006, Athens, Greece, June 5-9, 2006
  - ITS 2006, Peking, China, June 11-16, 2006
  - ECOSYS Meeting, Helsinki, Finland, November 20-23, 2006
- Mika Ilvesmäki
  - IPS-MoMe 2006, Salzburg, Austria, February 26 - March 1, 2006
- Ilmari Juva
  - NGI 2006 Conference, Valencia, Spain, April 2-6, 2006
  - ICC 2006, Istanbul, Turkey, June 11-14, 2006
- Renjish Kaleelazhicathu
  - ECOSYS Meeting, Oslo, Norway, February 5-9, 2006
  - ECOSYS Meeting, Sophia Antipolis, France, April 1-6, 2006
  - WTC/ISSLS Conference, Budapest, Hungary, April 29 - May 3, 2006
  - ECOSYS Meeting and CTTE Conference, Athens, Greece, June 3-10, 2006
  - ECOSYS Meeting, Crete, Greece, September 2-9, 2006

  - ECOSYS Meeting, Helsinki, Finland, November 20-23, 2006

- Raimo Kantola
  - Networking 2006, Coimbra, Portugal, May 14-19, 2006
- Jouni Karvo
  - IEEE COMSWARE 2006 Conference, Delhi, India, January 6-14, 2006
  - WIDENS Meeting, Sophia Antipolis, France, January 22-27, 2006
  - IST Mobile and Wireless Summit, Mykonos, Greece, June 4-9, 2006
  - IEEE GLOBECOM 2006, November 27th - December 1st, San Francisco, California, USA
- Annukka Kiiski
  - CTTE 2006 Conference, Athens, Greece, June 7-10, 2006
  - ITS Conference, Amsterdam, Holland, August 21-25, 2006
- Henri Koskinen
  - PE-WASUN'06 Workshop, Torremolinos, Spain, October 2-7, 2006
- Vesa Kosonen
  - SEFI 2006 Conference, Uppsala, Sweden, June 28 - July 1, 2006
- Teemu Kärkkäinen
  - VIVALDI Project Meeting, Berlin, Germany, September 18-20, 2006
  - VIVALDI Project Meeting, Tel Aviv, Israel, December 16-20, 2006
- Pasi Lassila
  - Med HocNET 2006 Conference, Lipari, Italy, June 14-18, 2006
- Juuso Lehtinen
  - CCNC 2006 Conference , Las Vegas, USA, January 7-11, 2006
- Mukthar Omar
  - RealMAN 2006 Workshop, Florence, Italy, May 25-27, 2006

- Jörg Ott
  - VIVALDI Project Kickoff Meeting, Brussels, Belgium, February 7-8, 2006
  - Upperside SIP 2006, Paris, France, February 20-24, 2006
  - 65th IETF Conference, Dallas, USA, March 19-26, 2006
  - VIVALDI Project Meeting, Stuttgart, Germany, April 5-6, 2006
  - Meeting of the DTNRG of the IRTF, San Francisco, USA, May 15-18, 2006
  - ETRICS 2006 Conference, Freiburg and Exam discussion in Bremen, Germany, June 5-10, 2006
  - 66th IETF 'Tellitec', Montreal, Canada, July 9-14, 2006
  - IVIHUT Project Meeting, Nice, France, August 24-27, 2006
  - SIGCOMM 2006 Workshop, Pisa, Italy, September 11-16, 2006
  - VIVALDI Project Meeting, Berlin, Germany, September 18-20, 2006
  - Seminar on Naming and Addressing for Next Generation Internetworks, Dagstuhl, Germany, October 29-November 1, 2006
  - Infocom TPC Meeting, Chicago, USA, November 3-11, 2006
  - 67th IETF, San Diego, USA, November 3-11, 2006
  - 1st MobiArch Workshop, San Francisco, USA, November 30 - December 2, 2006
- Aleksi Penttinen
  - ICC 2006, Istanbul, Turkey, June 11-15, 2006
  - PE-WASUN'06 Workshop, Torremolinos, Spain, October 2-7, 2006
- Timo Smura
  - ECOSYS Meeting, Sophia Antipolis, France, March 31 - April 6, 2006
  - ECOSYS Meeting and CTTE Conference, Athens, Greece, June 2-9, 2006
  - ITS Conference, Amsterdam, Holland, August 21-25, 2006
  - PhD Summer School, Skagen, Denmark, August 7 - September 1, 2006
  - ECOSYS Meeting, Crete, Greece, September 2-9, 2006
  - ECOSYS Meeting, Helsinki, Finland, November 20-23, 2006
- Riikka Susitaival
  - P2P-HPCS06 Workshop in ICCS Conference, London, United Kingdom, May 28 - June 1, 2006

- IWSOS Workshop, Passau, Germany, September 17-20, 2006

- Mathias Tallberg
  - MOB (Mobile Operator Business Game) presentation, Peking, China, March 29 - April 2, 2006

- Tuomas Tirronen
  - EuroNGI PhD-course, Brest, France, June 11-17, 2006
  - EuroNGI Summer School, Laredo, Spain, September 3-9, 2006
  - RESIM 2006 Conference, Bamberg, Germany, October 8-10, 2006

- Juuso Töyli
  - MOB (Mobile Operator Business Game) presentation, Peking, China, March 29 - April 2, 2006

- Hannu Verkasalo
  - Nokia SP360 Workshop, Beijing, China, November 10-18, 2006
  - CICT Conference, Copenhagen, Denmark and MUM Conference, San Francisco, USA, November 29 - December 7, 2006

- Jorma Virtamo
  - NGI 2006 Conference, Valencia, Spain, April 2-6, 2006
  - Sigmetrics 2006 Conference, Saint Malo, France, June 27 - July 1, 2006
  - Euro-NGI Cellular2 meeting, Pisa, Italy, October 8, 2006
  - Performance Evaluation Methodologies and Tools Conference, Pisa, Italy, October 9-13, 2006

4.2 Academic activities

- Raimo Kantola
  - External Examiner of Doctoral Thesis, Marcus Hidell, Kungliga Tekniska Högskolan, Sweden, 2006

- Jörg Ott
  - Evaluation of Scientific Qualification for the position of Professor in Distributed Systems and Data Communications, University of Helsinki, Finland, 2006
  - External Examiner of Doctoral Thesis, Jari Korhonen, TUT, Finland 2006

  - Member of PhD Committee for Anders Lindgren, Luleå, Sweden, 2006
  - Opponent to Erik Eliasson, KTH, Sweden, 2006
- Jorma Virtamo
  - Opponent to Dmitri Moltchanov, Tampere University of Technology, Finland, 2006

4.3 Visits abroad

- Heikki Hämmäinen
  - Visiting lecturer in PhD Summer School, Skagen, Denmark, August 30 - September 1, 2006
- Juuso Töyli
  - University of Iceland-MBA Program, December, 2006

4.4 Foreign visitors in 2006

The laboratory had the honor to host the following visits:

- Albayrak, Songul from Yildiz Technical University, Turkey
- Ayesta, Urtzi from Universite de Nice-Sophia Antipolis/INRIA, France
- Bormann, Carsten from Universität Bremen, Germany
- Borst, Sem from Eindhoven University of Technology, The Netherlands
- Durak, Lutfiye from Yildiz Technical University, Turkey
- Hidell Marcus from Grading Committee, Stockholm, Sweden
- Mr. Ismail from NUST, Pakistan
- Kamal, Shahid from Ministry of Foreign Affairs, Pakistan
- Körner, Ulf from Kungliga Tekniska Högskolan, Sweden
- Lindgren, Anders from Luleå Universität, Sweden
- Mecuria, Fisseha from Etiopia
- Medina, Díez from Universidad San Pablo-CEU, Madrid
- Naeem, Tahir from COMSATS, Institute of Information Technology, Pakistan
- Passarella, Andrea from CNR, Italy

- Thiran, Patrick from École Polytechnique Fédérale de Lausanne, Switzerland
- van den Berg, Hans from TNO, The Netherlands
- Vicent, Pla from Universitat Politecnica de Valencia (UPV), Spain
- Yildirim, Tulay from Yildiz Technical University, Turkey
- Zaidi, S.M. Junaid from COMSATS, Institute of Information Technology, Pakistan

5 PARTICIPATION IN BOARDS AND COMMITTEES

5.1 University boards and committees

- Samuli Aalto
  - Member of Scientific Council at the Department of Electrical and Communications Engineering
- Arja Hänninen
  - Member of the Council of Helsinki University of Technology
  - Member of the Quality Committee of Helsinki University of Technology
- Raimo Kantola
  - Director of the Master's Programme in Communications Engineering (and the former Programme in Telecommunications)
  - Director of International Study Affairs at the Department of Electrical and Communications Engineering
  - Member of the Degree Programme Council at the Department of Electrical and Communications Engineering
  - Member of Strategy group at the Department of Electrical and Communications Engineering
  - Member of the Internationalization Committee at TKK
- Markus Peuhkuri
  - Member of Committee of Post Graduate School at Department of Electrical and Communications Engineering
- Juuso Töyli
  - Deputy member of the Departmental Council, Department of Business Technology, Helsinki School of Economics

5.2 Other boards and committees

- Heikki Hämmäinen
  - Member of the Board of International Telecommunication Society
  - Member of the Board of the Research Foundation of Helsinki Telephone Company
  - Session chair of the 17th Annual IEEE International Symposium on Personal, Indoor and Mobile Communications, Finland

- Member of the Technical Program Committee of the Telecommunication Techno-Economics CTTE'06, Greece
- Member of the Technical Program Committee of the Mobility Roundtable, Finland, 2006
- Member of the Technical Program Committee of the Technology Trends Seminar
- Member of the Technical Program Committee of the Nokia-TKK Workshop, Finland
- Member of the Technical Program Committee of the IEEE Globecom'06, World Class Solutions Symposium
- Member of the Technical Program Committee of the IST Mobile&Wireless Communications Summit 2006

- Raimo Kantola
  - Chair of the 1st IEEE WoWMoM Workshop on Autonomic Wireless AccesS 2007 (IWAS07)

- Jouni Karvo
  - Member of the Technical Program Committee of IEEE GLOBECOM-NGN 2006
  - Member of the Technical Program Committee of IEEE ITRE 2006

- Marko Luoma
  - Member of the Board of Creanord Oy

- Jörg Ott
  - Member of the Technical Program Committee of VTC Fall Spring 2007, Infocom 2007, RealMAN 2006, Third Annual VoIP Security Workshop 2006, WNEPT Workshop 2006, Workshop on Challenged Networks (CHANTS) 2006, MobiArch Workshop 2006, SIP Conference 2007
  - Session chair of IEEE Infocom 2006 Conference, Barcelona, Spain, April 24-28, 2006
  - Session chair of RealMAN 2006 Workshop, Florence, Italy, May 25-27, 2006
  - Session chair of CHANTS Workshop, Pisa, Italy, September 11-16, 2006

- Markus Peuhkuri
  - Vice-member of Ministry of Treasure project group Information Security Levels in Goverment

- Juuso Töyli
  - Chairman of the board, Oy Mobilium Ltd

  - Chairman of the board, Oy J&AT Management Ltd

- Jorma Virtamo
  - Member of IFIP Working Group 6.3, Performance of Communication Systems
  - Member of the Management Committee of COST Action 290, Traffic and QoS Management in Wireless Multimedia Networks
  - Member of the Technical Program Committee of the 20th International Teletraffic Congress ITC-20, Ottawa, Canada, June 17-21, 2007
  - Member of the Technical Program Committee of the 3rd EURO-NGI Conference on Next Generation Internet Networks, Trondheim, Norway, May 21-23, 2007
  - Member of the Technical Program Committee of HET-NETs'06 International Working Conference, Ilkley, U.K, September 11-13, 2006

5.3 Referee activities

- Samuli Aalto
  - Reviewer for the following scientific journal: Performance Evaluation
  - Reviewer for the following conferences: NGI 2006, ICT 2006, ITC 20
- Nicklas Beijar
  - Reviewer for IEEE Wireless Communications and Networking Conference 2007
- Renjish Kaleelazhicathu
  - Reviewer for the following scientific journal: Special Issue "Wireless and Mobile Network Management Research in Asia" for the International Journal of Network Management (IJNM) Volume 17, Issue 2 (March/April 2007)
  - Reviewer for the following conference: 15th IST Mobile&Wireless Communications Summit, Myconos, Greece, 2006
- Jouni Karvo
  - Reviewer for the following conferences: IEEE GLOBECOM-WirelessComm 2006, NGI 2006

- Pasi Lassila
  - Reviewer for the following scientific journals: IEEE Transactions on Wireless Communications, IEEE Transactions on Mobile Computing, IEEE Transactions on Selected Areas in Communications, IEE Electronics Letters, European Journal of Operational Research
  - Reviewer for the following conferences:IEEE Infocom 2007, WiOpt 2007, ITC 20, IEEE Globecom 2006
- Marko Luoma
  - Reviewer for the following scientific journals: IET Electronics Letters, IET Proceedings, ACM Transactions on Multimedia Computing, Communications and Applications
- Jörg Ott
  - Reviewer for R&D project proposals for IWT in Flanders, Belgium
  - Reviewer for various ACM and IEEE journals and magazines
- Aleksi Penttinen
  - Reviewer for the following conferences:IEEE Globecom'06, IEEE ICC 2007, WiOpt'07
- Riikka Susitaival
  - Reviewer for the following conferences: NGI 2006, IEEE Globecom 2006
- Juuso Töyli
  - Reviewer for the following scientific journal: Purchasing and Supply Management
- Jorma Virtamo
  - Reviewer for the following scientific journals: IEEE Transactions on Networking, IEEE Journal on Selected Areas in Communications, Eurasip Journal on Wireless Communications and Networking
  - Reviewer for the following conferences: NGI2006, WiOpt'07, ITC-20

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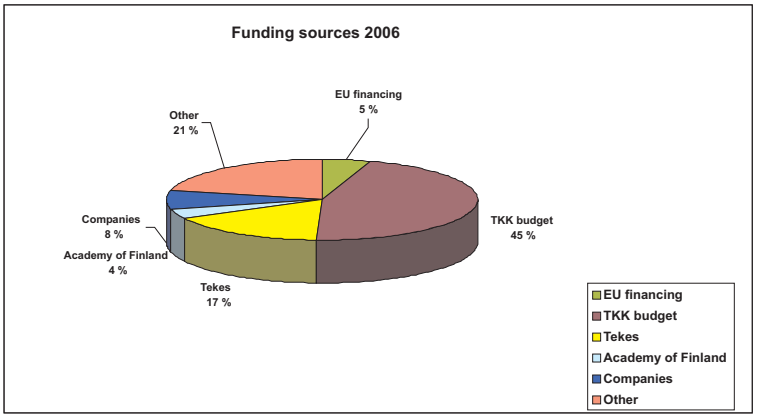
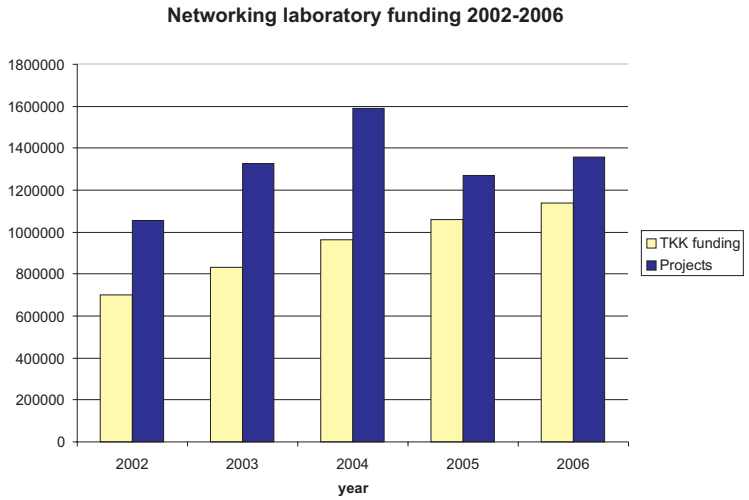
A LABORATORY FUNDING



A.1 Funding sources



A.2 Development of funding

B SCIENTIFIC MEETINGS INVOLVING NETWORKING LABORATORY

1st IEEE WoWMoM Workshop on Autonomic Wireless AccesS 2007 (IWAS07)

In conjunction with IEEE WoWMoM 2007

In order to support different products, services, pricing or business models, etc. solutions must be open standard and flexible enough. These principles are being explored e.g. in the 3G Long Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WiMAX) standardization fora.

The 1st International Workshop on Autonomic Wireless AccesS (IWAS) provides a venue for academic and industrial research communities for exchanging ideas and experience on autonomic wireless access mobile systems.

For practical arrangements, such as

- travel, please consult the WoWMoM 2007 travel page.
- registration, please consult the WoWMoM 2007 registration page.

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IWAS07 Call For Papers

1st IEEE WoWMoM Workshop on Autonomic Wireless AccesS (IWAS07)

in conjunction with WoWMoM 2007, Helsinki.

IWAS 2007 is soliciting original and previously unpublished papers addressing research challenges and advances towards autonomic control and management of future wireless access networks and systems. Access network devices and wireless terminals are becoming more and more complex, and they include support for multiple wireless technologies. Access networks are dynamically optimized for applications under different conditions, and service performance is affected by a large number of parameters and control algorithms. From the end users perspective, however, multi-access networks are desirable only if they do not deteriorate the quality of experience. It is therefore of vital interest to operators and vendors to minimize operational effort and cost and add intelligence to terminals, network elements and management tools through the adoption of Autonomic Communications and Computing (ACC) principles for self-configuring and self-optimizing access systems.

In order to support different products, services, pricing or business models, etc. solutions must be open standard and flexible enough. These principles are being explored e.g. in the 3G Long Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WiMAX) standardization fora.

The 1st International Workshop on Autonomic Wireless AccesS (IWAS) provides a venue for academic and industrial research communities for exchanging ideas and experience on autonomic wireless access mobile systems. Papers that present work, validated by experimentation, simulations, or analysis, as well as position papers and paper discussing concepts, architectures and interfaces are solicited, on the topics including, but not limited to

- architectures and protocols for self-optimization, self- configuration and autonomic control for wireless access
- autonomic authentication and authorization systems
- management of autonomic cellular evolution
- what is to be standardized for autonomic wireless access
- cognitive radio and networks
- radio network planning for autonomic wireless access
- management concepts for self-managing systems
- autonomic control for mobility management
- policy management for autonomic wireless networks
- autonomic control in multi-access terminals
- human machine interface in policy based managing of network
- autonomic fault management and recovery systems
- allocation of autonomic control decisions to terminals and to the network in B3G systems
- algorithms for autonomic radio resource control in future wireless access networks
- adaptive and autonomic capacity allocation and resource management
- load balancing in wireless access networks
- autonomic control over opportunistic spectrum access
- autonomic scheduling
- testing, verification and validation principles for autonomic systems and networks
- performance gains from autonomic control
- testbeds and measurements of wireless autonomic systems

Papers should be original material in the IEEE two column format limited to 6 pages.

Important dates

Extended!

- Full paper submission: February 11th 2007
- Notification of acceptance: March 15th 2007
- Final papers due: April 9th 2007

Submission implies the willingness of at least one of the authors to register and present the paper. Accepted papers must be presented at the workshop and will appear in the WoWMoM proceedings.

6th Conference on Telecommunication Techno-Economics 14-15 June 2007, Helsinki, Finland

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Following the success of CTTE 2006, held in Athens with the technical sponsorship of IEEE Communications Society, the CTTE 2007 in the next event in the series of international conferences/workshops, dedicated to the economics of new telecommunication services and technologies. CTTE is the major international event for the presentation of original and fundamental concepts and studies in the field of telecommunications techno-economics. It also serves as a forum for communication among researchers and practitioners working in a wide variety of scientific areas with a common interest in improving techno-economics and advanced telecommunications and services.

Important dates

Submission deadline:
~~**Mar. 15, 2007**~~
Mar. 31, 2007 (Deadline extended)

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