

## Annual Report 2003

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Helsinki 2004

The research and teaching area of the Networking laboratory focuses on communication networks, in particular on layer 3 but also including upper layer issues, and on teletraffic theory. Currently the central research problem of the field is leveraging the Internet into a service network. This requires providing Quality of Service to data transfer with new protocols, improved security features and easy-to-use service platforms.

The teaching curriculum of the Networking laboratory includes three major subjects: Networking Technology, Teletraffic Theory and Telecommunications Management. Under these subjects we run courses on IP technology, circuit-switched networking, teletraffic theory and on service and protocol development.

At the beginning of the year D.Sc (Tech) Heikki Hämmäinen joined the Laboratory as a professor with a focus on the area of Networking Business. During the year professor Hämmäinen widened teaching in the area of Networking business or Telecommunications Management by a Ph.D seminar and a special Assignment on Networking Business. In 2003 we started the Networking Technology major in the International Master's programme in Telecommunications. This has meant that an increasing share of our courses is already taught in English on the master's level.

In 2003, the laboratory staff published 4 international journal papers and 14 papers in conferences. In 2003, two Doctor dissertations and 60 M.Sc theses were achieved by the students of our laboratory. The number of Master theses is an all time record in the history of the Laboratory.

In May 2003, the Networking Laboratory hosted a Joint Research Seminar with our sister Laboratory at Kungliga Tekniska Högskolan (KTH).

In 2003, the laboratory carried on research in several multi-year research projects. The biggest was the Intelligent Routing Network project, one of the NETS spear head projects funded by TEKES and a group of partners with a three year plan. Our wide research project activity is seen in the financing structure in which the share of MinEdu financing has dropped to 38% of the overall budget and in the large number of M.Sc theses that were completed in the Netlab research projects (14).



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Year 2003 was one in a series of strengthening the Networking Laboratory as a research unit. We worked on a large portfolio of projects among which IRoNet, a spear head project in the TEKES NETS program and TIEVA were the largest.

We launched a new area of research, Networking Business when a new professor, Dr. Heikki Hämmäinen took his post on January 1st. Professor Hämmäinen initiated a research group and started teaching the subject. Two new projects were initiated during 2003. NAPS is funded by the Finnish Academy and works on traffic management in Ad hoc Networks. The second new project is funded by the Defence Forces (LATE).

We admitted the first intake of International students into the Networking technology major for the Fall term of 2003. The major is an extension of the Master's programme in Telecommunications at HUT.

Many researchers of the Laboratory earned academic degrees, including the degrees of the Doctor of Science in Technology by Jorma Hirvensalo and Petteri Mannersalo.

The number of M.Sc theses earned by our students in 2003 was 60 which is the largest number in the 60 years the Laboratory has existed. (One of the theses was recorded and reported already in 2002, but the real record is now 60). For three and a half professor man-years during 2003 the number of supervised M.Sc theses continues to be excessively high compared to the HUT average of less than 5 theses per professor. We expect a high workload on supervising M.Sc theses during the coming years to continue. This situation can be corrected in two ways: by hiring new professors and by lowering the intake of students into our major subjects. We believe that both methods need to be used. However, the impact of the lower intake into the degree program on telecommunications over the past couple of years will make a difference only in about five years.

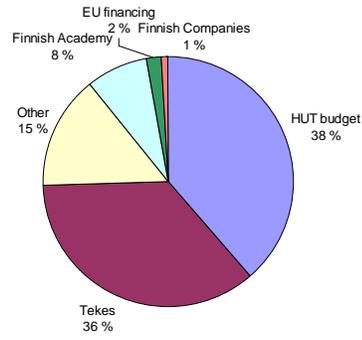
One of our Ph.D students was awarded a new position in the GETA graduate school. Overall the number of Ph.D students in the Laboratory is high.

The positive development in project financed research activities is also visible in the Laboratory spending presented in Figures 1.1 and 1.2. Figure 1.1 shows the diversity of sources of research funding and Figure 1.2 the overall development for the past few years.

In addition to the basic government budget, the government directed Academy of Finland and TEKES are the largest sources for research funding.

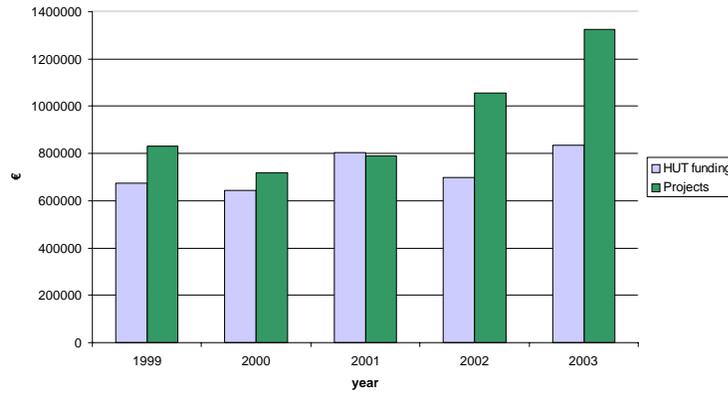
The Laboratory had a development day of teaching in Allergiatalo, Helsinki. There were two social events during the year: a summer trip and the traditional Christmas party, this time in the Clubhouse of the Soukka Sailing Club.

**Funding sources for Networking laboratory 2003**



**Figure 1.1: Financing of the Networking Laboratory 2003**

**Networking laboratory funding 1999-2003**



**Figure 1.2: Financing of the Networking Laboratory 1999-2003**

## 1.1 Motivation of Networking Business activities

When we invited D.Sc (Tech) Hämmäinen to join the Laboratory as a professor in the area of Networking Business, our reasoning was based not only on the apparent popularity of the Telecommunications Management major and the continued need for specialists in this area in the industry.

Looking at the history of the development of Communications Technologies over the past 20 years we can see many technologies that have greatly under-performed on the markets to the expectations that were placed on them at the inception of the technology. At the same time the amount of R&D man-years that need to be invested prior to bringing a new communications technology to the market is not decreasing. When technology becomes more and more powerful the horizons of technical feasibility move farther and farther away from what we use today. However, it seems that performance and even cost of a technology play a lesser and lesser role in the success of a solution of the technology. Market forces and the structure of the value chain in the industry seem to take a bigger and bigger role. The brightest stars among the communications technologies of the past 20 years have been surprises to a large portion of the industry. We can even claim that the success or failure of a technology seems to be impossible to predict with any degree of reliability.

With this background we think that it is important to start looking at the business side of a new technology earlier than before. The business analysis should start when the communications technology is on the drawing boards in the research labs. By initiating a new professorship in the area of Networking Business we intend to achieve a cross-fertilization of the technology research and provide early input to the Business studies while companies have not yet made huge R&D investments into a new technology.

## 1.2 International Activities

In the Fall of 2003, we received the first intake of international students in the Networking technology major that is now a part of the International Master's program in Telecommunications. The total number of credit units we teach in English is now more than 30 out of the total of about 53 for the year (not including individual assignments and labworks). The courses that are taught in English include nearly all Ph.D level courses and seminars as well as the Master's level courses that are needed in the International Major. In addition, in 2003, already 80 percent of the Master's theses that were supervised by our professors, were written in English.

During 2003, we joined the EuroNGI Network of Excellence that is a European Research Community in the area of teletraffic theory and performance analysis. We also participated in creating the E-Next NoE and joined the Consortium when it started in January 2004. E-Next is focused on Networking Technology.

There we received 29 foreign visitor to our laboratory, including the group of staff from our sister Laboratory at KTH led by professor Gunnar Karlsson. On May 23rd we had a one day seminar on topics of ongoing research in our laboratories followed by a dinner at Kappeli. Seminars like

this, alternately at HUT and KTH, have already become a tradition.

### 1.3 Social impact of our Activities

According to the new University law the Universities are assigned the so called third task in parallel with Research and Higher Education. The task is to contribute the development of welfare and the society at large.

Naturally, we contribute most through our research. However, during 2003 we were active in other ways as well. Through articles in Finnish Journals and Newspapers (Talouselämä and Helsingin Sanomat) we participated in discussion about the state of the Information Society as well as the question of broadband to the home. The latter topic is closely related to our research on Quality of Service because the deployment of QoS in IP networks happens only if a wide range of applications run on the networks and that is dependent on the wide adoption of broadband services in society at large.

The preprints of the articles can be found in [http://www.netlab.hut.fi/~kantola/list\\_of\\_my\\_writings.html](http://www.netlab.hut.fi/~kantola/list_of_my_writings.html)

During the year, I participated in the core IP networking interest area thematic group in the TEKES NETS program. Our goal is to smooth the way for our research results down the innovation chain and to bring people from the academia and the companies closer together to work on goals of mutual interest in the NETS framework. The topic of interest during the year was peer-to-peer traffic and its impact on the underlying IP-network. The Group organized a workshop on Peer-to-peer in Dipoli in November that I chaired.

### 1.4 Summary

We finish the year with positive expectation of the future in terms of our national and international impact, the number and level of the degrees earned by our students and continued managed expansion of our research activity. A rather wide research activity is crucial for maintaining a wide portfolio of in-depth courses on the M.Sc and postgraduate curricula in networking, teletraffic theory, protocols and services and network economics. It is also crucial for solving the problem of the lack of teachers we continue to have.

May 21st, 2004

Raimo Kantola

Laboratory staff and personnel can be reached by e-mail with address: first-name.lastname@netlab.hut.fi

### 2.1 Professors and Docents

Aalto, Samuli	Ph.D., Professor (pro tem 1.8.2002-31.7.2003)
Hämmäinen, Heikki	D.Sc. (Tech.), professor
Jormakka, Jorma	Ph.D., Professor
Kantola, Raimo	D.Sc. (Tech.), Professor, head of laboratory
Virtamo, Jorma	D.Sc. (Tech.), Professor (on leave 1.8.2002-31.7.2003)
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

### 2.2 Administrative personnel, teachers and assistants

Erke, Tapio	M.Sc., Laboratory engineer, on leave
Hänninen, Arja	Administrative assistant
Koivisto, Johanna	Student adviser
Kosonen, Vesa	M.Sc., university teacher
Matinlauri, Anni	Student adviser
Nupponen, Esko	Senior laboratory supervisor
Pitkäniemi, Kimmo	PC support
Patana, Sanna	Department secretary
Planman, Irma	Department secretary

### 2.3 Senior Researchers and researchers

Aalto, Samuli	Ph.D.
Karvo, Jouni	D.Sc. (Tech.)
Kuusela, Pirkko	Ph.D.
Lassila, Pasi	D.Sc. (Tech.)
Zhang, Peng	Ph.D.

Hyytiä, Esa	Lic.Sc. (Tech.)
Ilvesmäki, Mika	Lic.Sc. (Tech.)
Luoma, Marko	Lic.Sc. (Tech.)
Mölsä, Jarmo	Lic.Sc. (Tech.)
Nyberg, Eeva	Lic.Sc. (Tech.)
Peuhkuri, Markus	Lic.Sc. (Tech.)
Ahvenainen, Marko	M.Sc.
Antila, Johanna	M.Sc.
Bai, Xiaole	M.Sc.
Beijar, Nicklas	M.Sc.
Costa Requena, Jose	M.Sc.
Daskalova, Evgenia	M.Sc.
Jussila, Ville	M.Sc.
Juva, Ilmari	M.Sc.
Kaleelazhicathu, Renjish	M.Sc.
Kiiski, Annukka	M.Sc.
Koskinen, Henri	M.Sc.
Leino, Juha	M.Sc.
Matuszewski, Marcin	M.Sc.
Nieminen, Laura	M.Sc.
Paju, Antti	M.Sc.
Penttinen, Aleks	M.Sc.
Susitaival, Riikka	M.Sc.
Willa, Kirsi	M.Sc.
Zhou, Wenpeng	M.Sc.

## 2.4 Research assistants and trainees

Bai, Xiaole	Creado, Jarrod
Guiton, Emmanuel	Gutiérrez, Juan
Huttunen, Jari	Järvinen, Juha
Kaikkonen, Sampo	Kneckt, Laura
Kokko, Juha-Pekka	Matinlauri, Anni
Parkkari, Jussi-Pekka	Pradas Adán, Jose
Pitkänen, Mikko	Pulkkinen, Piia
Sarala, Risto	Suominen, Niko
Tallberg, Mathias	Timonen, Vesa
Tormo Mas, Ricardo	Viipuri, Timo
Viskari, Janne	Zhang, ChenXin
Zhou, Yi	Zhou, Wenpeng
Zhu Haifeng	

## 2.5 Part-time teachers

Kyntäjä, Timo	S-38.157 Protocol Design
Nardone, Massimo	S-38.153 Security of Communication Protocols
Nieminen, Klaus	S-38.001 Telecom Forum
Pärssinen, Juha	S-38.157 Protocol Design
Räisänen, Vilho	S-38.215 Special Course in Networking Technology
Seppänen, Kari	S-38.165 Switching Technology
Uusitupa, Seppo	S-38.105 Principles in Communications Engineering

The guest lecturers and the program in S-38.001 Telecommunications Forum are shown in Figure 2.1.



HELSINKI UNIVERSITY OF TECHNOLOGY  
Networking Laboratory

What's HOT in telecommunications?  
Telecom Forum '2003  
An open house studia generalia seminar on telecommunications

PROGRAM 2003

- 30.09. Juha Heinänen, Dr. Tech.  
WLAN roaming - How to make it happen?
- 07.10. Anssi Vanjoki, Nokia, Executive Vice President  
Mobile multimedia - Personal multimedia
- 14.10. Vesa Sadeharju, 3i Finland Oy, Director  
Funding of hi-tech start-ups
- 21.10. Max Björkgren, Radionet, CTO  
WLAN hotzone - Opportunity for operators and service providers
- 28.10. Jari Vainikka, Nokia, Director  
Standardization - A driving force?
- 04.11. Lauri Kuokkanen, Ultra-Crea Oy, Business Development Director,  
Entrepreneurship
- 11.11. Ari Tolonen, DNA Finland Oy, CEO  
Role of mobile challenger
- 18.11. Antti Kohtala, Ministry of Transport and Communications, Director  
Role of mobile media convergence
- 25.11. Tapio Karjalainen, Radiolinja, CEO  
New drivers of mobile business
- 02.12. Hendrik Berndt, DoCoMo Communications Laboratories Europe, SVP, CTO  
Advanced service provisioning in 4G-mobile systems

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.hut.fi/opetus/s38001/>

Figure 2.1: Telecom Forum 2003

### 3.1 AHRAS

**Project leader:** Jorma Virtamo, Samuli Aalto **Researchers:** Henri Koskinen, Juha Leino, Laura Nieminen, Aleksi Penttinen

Project AHRAS concentrates on the routing and other traffic related issues in wireless ad hoc networks. The project started in 2001 and it is funded by the Finnish Defence Forces Technical Research Centre.

The research in the project in 2003 covered routing algorithms, topology related issues, game-theoretical network models and simulator development. Research on routing produced two algorithms; one for improving the capacity of wireless multihop networks by utilizing topology information, and another for energy conserving multicast tree construction. Also a method to analyze the effect of routing to flow throughput in ad hoc networks was developed. In network topological studies, the project concentrated on new parametric models to describe the robustness of ad hoc networks as well as the coverage of sensor networks. This part of the work was done in collaboration with the NAPS project, under which the work is described in some more detail. Third topic of the project adopted a game-theoretic approach on the networks and addressed the advantages and disadvantages of a single network node in participating in the network operation. Advantages were shown to depend on the locations of the nodes as well as the routing algorithms used in the network. Development of the ad hoc network simulator program AHN was continued and it was expanded to support different mobility models for simulation.

### 3.2 COST 279

**Project leader:** Jorma Virtamo **Researchers:** Samuli Aalto, Jouni Karvo, Pirkko Kuusela, Pasi Lassila, Eeva Nyberg-Oksanen, Riikka Susitaival

COST 279, a joint project with VTT Information Technology, is the Finnish contribution to the European COST 279 Action, "Analysis and Design of Advanced Multiservice Networks Supporting Mobility, Multimedia, and Internetworking". The project started in 2001 and it is funded by Tekes and industrial partners. In 2003, our focus was on the three research areas listed below.

QoS mechanisms for the Internet: This work was carried in collaboration with U. Ayesta from INRIA, Sophia Antipolis, and mainly concentrated on differentiated scheduling of the "mice" and the "elephants". Internet measurements show that a small number of large TCP flows (the "elephants") are responsible for the largest amount of data transferred, whereas most of the TCP sessions are made up of few packets (the "mice"). Several authors have invoked this property to suggest the use of scheduling algorithms which favor short jobs, such as LAS (Least Attained Service), to differentiate between short and long TCP flows. A packet level stateless, threshold based scheduling mechanism for TCP flows, RuN2C, was pro-

posed. An implementation of this mechanism, which has the advantage of being TCP compatible and progressively deployable, was studied. The behavior of RuN2C was compared with LAS based mechanisms through analytical models and simulations. As an analytical model, a two level priority Processor Sharing PS+PS was used. In the PS+PS system, a connection is classified as high or low priority depending on the amount of service it has obtained. It was shown that PS+PS reduces the mean response time in comparison with standard Processor Sharing when the hazard rate of the file size distribution is decreasing. By simulations we study the impact of RuN2C on extreme values of response times and the mean number of connections in the system. Both simulations and analytical results show that RuN2C has a very beneficial effect on the delay of short flows, while treating large flows as the current TCP implementation does. In contrast, we find that LAS based mechanisms can lead to pathological behavior in extreme cases. As another topic related to QoS in the Internet, a study was started on evaluating the goodput of a single TCP source on a low bandwidth lossless GPRS link experiencing sudden increases in RTT, i.e., delay spikes. Such spikes trigger spurious timeouts that reduce the TCP goodput. This work continues in 2004.

Traffic engineering in IP/MPLS networks: Multiprotocol Label Switching (MPLS) provides new possibilities for improving the performance of IP networks. Notably the explicit routing of MPLS facilitates balancing the load by moving traffic from a congested part of the network to some other part in a well controlled way. Work was started on an adaptive load balancing mechanism based on measured link loads without knowledge of the full traffic matrix. As an objective for load balancing minimizing the maximum link utilization and minimizing the mean delay in the network were used. A simple distributed algorithm making adaptively incremental changes in traffic routing (splitting) was presented. In addition, a numerical method was developed to evaluate the performance of the algorithm. The method was applied to three test networks. The results are very promising and show that the maximum link utilization and the mean delay obtained in a reasonable number of iterations are very close to the optimal values, even with random traffic fluctuations in the time-scale of the measurements. The convergence properties of the algorithm were also studied as a function of adaptation granularity.

Traffic related issues of multicast connections: Multicast was compared to a combination of unicast and broadcast in transmitting popular content, for example, in a cell of a mobile network. As an extension of earlier work, large deviations technique was used to approximate the multicast gain (i.e. the increase in the number of supported users compared to plain unicast) in a cell with high capacity. As another contribution the gain achieved with combining unicast with broadcast was evaluated.

### 3.3 FIT: Future Internet – Traffic Handling and Performance Analysis

**Project leader:** Jorma Virtamo **Researchers:** Samuli Aalto, Johanna Antila, Laura Knecht, Pirkko Kuusela, Juha Leino, Anni Matinlauri, Vesa Timonen

FIT is a three-year project funded by the Academy of Finland continu-

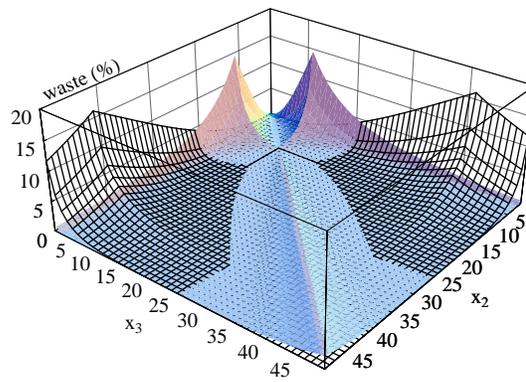


Figure 3.1: The capacity waste in a 3-link hypercycle.

ing to the end of 2004.

In the Internet, the bandwidth resources of the network are shared between all concurrent traffic flows, e.g. by TCP congestion control mechanism, with the objective of obtaining some kind of fairness between different flows. Many definitions for what fairness means have been developed, including the classical max-min fairness, proportional fairness and more general utility based fairness criteria. A new notion of fairness, called balanced fairness (BF), has recently been introduced by Bonald and Proutière. The most important property of BF is that it leads to completely insensitive network performance which is a very desirable property from the point of view of networks design and management. Another remarkable property of BF is that the performance in a real dynamic setting, where new flows arrive stochastically and depart upon completion, can be evaluated in an analytic form for many important network topologies.

An important contribution of the FIT project has been the development of an efficient recursive method for an exact calculation of the normalization constant of a BF system (from the normalization constant all the performance metrics can be easily derived). The method has been applied to practically important topologies for access networks, like parking lot and general tree with and without access rate limits. As an important side result it was proven that BF is Pareto efficient in all tree networks.

As noted before, the distinguishing feature of BF is the insensitivity of its performance measures. In contrast, all utility based fairness schemes are sensitive except for some special network topologies, where they coincide with BF. An extensive study of the sensitivity properties of various schemes was undertaken in a Master's thesis completed in 2003. The study confirms that the non-BF schemes are sensitive though the sensitivity on the flow size distribution is not very strong. More pronounced is the sensitivity with respect to so-called time scale changes. It was also found that, largely speaking, BF provides a reasonably good approximation for the performance of max-min fairness. Furthermore, it was confirmed that in a network topology called hypercycle, BF is not Pareto efficient but some capacity is wasted. This is illustrated in Figure 3.1. Fortunately it turns out that in a dynamic

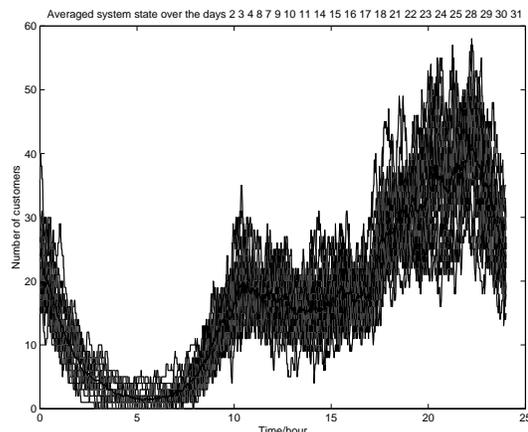


Figure 3.2: The number of student users as a function of time during the weekdays in October of 2002

setting the impact of the capacity waste is minor. An analytical representation for the balance function of a symmetric 3-link hypercycle was also obtained.

The concept of BF was extended to the case where the constraints are more complicated than fixed link capacity constraints such as occurring when the flows are to be split over several routes and the constraints are then of the type encountered in multicommodity flow problems. This extension was further developed to solve the joint problem of scheduling and resource sharing in an ad hoc network, where the simultaneous use of some links is limited by the interference, in such a way that the resources are maximally utilized while preserving the balance property guaranteeing the insensitivity and robustness of the system. In addition, analytical tractability is retained, at least for smaller systems.

Work on insensitive adaptive routing was started. In insensitive routing, not only the capacity allocations are balanced but also, separately or jointly, the arrival rates determined by the probabilistic routing.

Packet scheduling is the principal resource allocation mechanism underlying QoS differentiation. The decisions as to when packets are transmitted have a great impact on performance parameters such as throughput, delay or delay jitter. In a Master's thesis completed in 2003, issues related to quality differentiation, traffic mapping and scheduling in DiffServ were studied. Absolute capacity differentiation and proportional delay differentiation with delay bound with various packet schedulers were investigated by simulations. Provisioning and differentiation were found difficult with static resource allocation methods. It was suggested that an adaptive scheduler with delay bound should be used for resource allocation.

Collection and analysis of the HUT modem pool statistics started in the previous projects was continued. In addition to the earlier samples from years 1997 and 1998, we got new samples in 2001 and 2002. An illustration of the results for 2002 is given in Figure 3.2.

A comparison with the results of 2001 shows that the daily usage profile

has remained very much the same but the overall traffic level has decreased almost to a half, presumably due to a shift from modem to ADSL connections.

### 3.4 FUNET

**Project leader:** Raimo Kantola **Researcher:** Janne Viskari

In Janne's master thesis we did a survey on the use of telephony services in the Finnish Universities and Polytechnics. The purpose was to explore the potential and timing for deploying Voice over IP in this community. The project was carried out with CSC/FUNET as the paying partner. The survey collected statistics on the cost of calls for different Universities and Polytechnics. It was remarkable to find out that approximately 90 percent of the costs are already today incurred due to mobile calls and calls to mobiles. The part of the survey on the role of telephony for the community found that telephony does not have a strategic role for the Universities and Polytechnics. Based on the findings, the conclusion of the survey was that any new telephony solution should be mobile driven and that outsourcing and organizing as large buying consortiums for services as possible would be a sensible thing to do.

### 3.5 IRoNet – Intelligent Routing Network

**Project leader:** Raimo Kantola **Researchers:** Samuli Aalto, Johanna Antila, Pasi Lassila, Markus Peuhkuri, Riikka Susitaival, Ilmari Juva, Jari Huttunen, José Pradas, Marko Luoma, Mika Ilvesmäki, Sampo Kaikkonen, Jouni Karvo, Wenpeng Zhou, Piia Pulkkinen, Peng Zhang, ChenXin Zhang, Xiaole Bai, Kei Uchida, Evgenia Daskalova, Juha-Pekka Kokko, Marcin Matuszewski, Jussi-Pekka Parkkari, Yi Zhou, Haifeng Zhu

IRoNet studies the additional intelligence that is needed in the IP network in order to support Quality of Service. IRoNet scope covers the packet forwarding plane, the control plane and the management plane functionality needed in an IP network in order to fulfill the operator's popular vision of All-IP network and to provide a QoS enhanced Internet. In particular, the main areas of interest are traffic classification, modelling of the forwarding plane algorithms, routing and management support for the whole system. The project uses mathematical modeling of the forwarding plane mechanisms and the behavior of traffic streams, simulations of protocols and algorithms, traffic and performance measurements and prototyping of the mechanisms and algorithms particularly in the control and management planes. The activity is planned for three years and it started in 1/2002.

During 2003 we continued to refine the methodology of traffic classification and build a large QoS prototype in which we can verify our earlier results on traffic classification and policy based management of QoS. Using simulations we studied novel packet scheduling algorithms. We continued enlarging the mathematical modelling of end-to-end TCP behavior. In QoS routing the focus was on simulating the concept of Multi-Class Routing. In this approach the idea is that each DiffServ traffic class is routed separately and has its own routing table in each of the routers. Each class

may also use a different routing algorithm.

### 3.6 MobileMAN

**Project leader:** Raimo Kantola **Researchers:** José Costa Requena, Nicklas Beijar

MobileMAN is an European project investigating the potential of the Mobile Ad hoc NETWORK (MANET's) paradigm. We are participating in this project with multiple European research entities such as CNR (National Italian Research institution), Eurecom, Cambridge University, SUPSI (Switzerland University Polytechnic). The project aims to define and develop a metropolitan area, self-organizing, and totally wireless network called the Mobile Metropolitan Ad hoc Network (MobileMAN).

The main technical outputs expected of this project include the following:

1. Development, validation, implementation and testing of the architecture, and related protocols, for configuring and managing a MobileMAN. The research is conducted spanning all layers in the networking hierarchy. Our research combines advanced communications and networking research with basic research.
2. Physical implementation of this architecture for lower layers (i.e., wireless technologies). This will be done by improving the existing IEEE 802.11 wireless technologies for dealing with bursty access environments as self-organized networks.
3. Integration of applications on top of the self organized network.
4. Validation of the self-organizing paradigm from the social and economic standpoint.

During this year, we continued the development of the ad hoc routing testbed that is an integral part of the three-year research plan.

The prototype runs on iPaq palmtops that have Linux OS. In the routing software we have moved the forwarding functions into the Linux kernel. The nodes can run several routing protocols. Currently operational routing protocols are AODV and OLSR, and we are working on ZRP. The nodes are grouped into "smart" and "dummy" nodes. Smart nodes can provide additional services, such as a gateway to a base station or an Access Point. Our goal is to implement service discovery in the prototype.

We are also playing with putting SIP and VoIP on top of the routing package. Currently these are working, but so far the voice quality is less than satisfactory.

A routing testbed is useful because simulations seem to produce rather arbitrary results for the benefits of each routing protocol being evaluated.

### 3.7 NAPS

**Project leader:** Jorma Virtamo **Researchers:** Henri Koskinen, Pasi Lassila

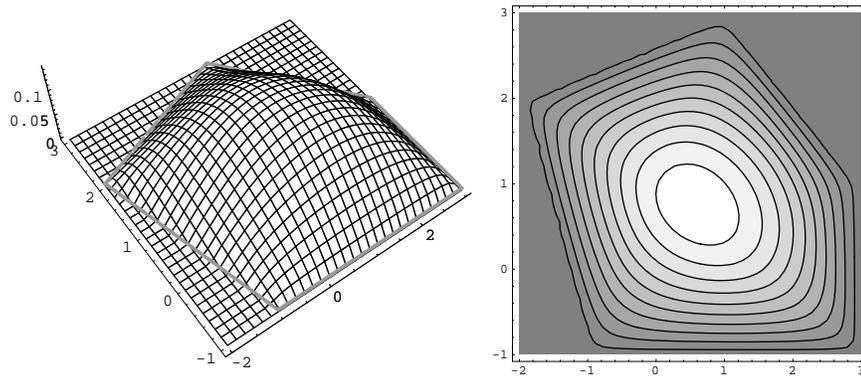


Figure 3.3: The spatial distribution of a node (left figure) and its equivalent contours (right figure) in the RWP model for a pentagonal region.

NAPS (Networking and Architecture for Proactive Systems) is a 3-year project (2003-2005) funded by the Academy of Finland. It is part of the research programme on Proactive Computing (PROACT). The research consortium of NAPS is coordinated by Helsinki Institute for Information Technology, Basic Research Unit, with subprojects at the Networking Laboratory (HUT) and the Laboratory for Theoretical Computer Science (HUT).

The project studies dynamically organized wireless ad hoc networks. In 2003, problems in the field of stochastic geometry that arise in such networks were studied. One of them is the connectivity of the network when the locations of the nodes are random. This problem reduces to finding the distribution of the longest edge length in the random Euclidean minimum spanning tree, which is known only asymptotically. The problem can be generalized by requiring a higher degree of connectivity, which measures the robustness of the network topology against node failures. Another, somewhat related, problem is that of coverage of sensor networks, where the aim is to determine the distribution of the fraction of a given target area that is covered by randomly distributed sensors. The problem of full coverage is similar to that of connectivity in that only asymptotic analytical results exist but it can be predicted using statistical models. In addition, a study on the spatial distribution of a node moving according to a well-known mobility model, the Random Waypoint model, was started and a simple expression giving the distribution in an arbitrary geometry was derived (an example is illustrated in Figure 3.3).

### 3.8 Optical Access Networking (OAN)

**Project leader:** Jorma Virtamo, Samuli Aalto **Researchers:** Esa Hyytiä, Laura Nieminen

Optical Access Networking (OAN) was a three year project started in February 2001 and carried out in collaboration between VTT and HUT.

The project was funded by TEKES and industrial partners. The research dealt with all-optical WDM network technologies, especially optical access networks. The research conducted at HUT focussed mainly on network level problems on two areas.

The first one concerned the allocation of network resources, i.e. how to configure lightpaths in a dynamic or static case. In 2002 the main focus was on studying the static case, in particular the logical topology design (LTD) problem. The goal of LTD is to configure lightpaths, which correspond to links on the logical layer, and the routing in the logical layer while minimizing some objective function, e.g. average packet delay. This can be formulated as a mixed integer linear programming problem, for the solution of which, however, heuristic algorithms are needed. Such algorithms were developed.

The second research topic dealt with optical packet switching. The objective is to study traffic related problems emerging in this context and to compare different technical solutions. In 2002 the research focused on optical burst switching (OBS). The performance of one proposed protocol, JET, was evaluated by simulations. It was also demonstrated that fiber delay lines can improve fairness considerably in an OBS network.

### 3.9 TIEVA

**Project leader:** Jorma Jormakka **Researchers:** Marko Luoma, Markus Peuhkuri, Mikko Pitkänen, Ville Jussila, Timo Viipuri, Risto Sarala, Kirsi Willa

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.

During the year 2003 two M.Sc theses were done on the areas of Intruder Detection and Service Level Assurance measurements.

### 4.1 General notes on teaching in 2003

We are responsible for three major subjects in the HUT degree program of Communications Engineering. They are Networking Technology, Teletraffic theory and Telecommunications Management. The last one is produced jointly with the Department of Computer Science and Engineering and the Department of Industrial Engineering and Management.

During 2003 the impact of the Bologna process that is leading to the introduction of an intermediate degree of Bachelor of Science in Engineering was felt. While this big change is being prepared current development of the existing degree programs has slowed down. However, due to initiating the new area of Networking business, Professor Heikki Hämmäinen started new courses into our curriculum. These are Seminar on Mobile operator strategies and games (S-38.042) and Special Assignment on Networking Business (S-38.045).

In the course S-38.001 Telecommunication Forum many visiting lecturers shared their view on evaluation of telecommunications industry. The course was better attended than ever and the collection of presenters formed a very good cross-section of the industry. (See also Figure 2.1).

### 4.2 Course descriptions

This is the full list of courses in our curriculum:

#### **Studia generalia:**

- S-38.001 Telecommunications Forum (Telecommunications Forum)

#### **Basic courses for all students studying telecommunications**

- S-38.105 Principles in Communication Engineering (Tietoliikennetekniikan perusteet)
- S-38.145 Introduction to Teletraffic Theory (Liikenneteorian perusteet)

#### **Courses concerning communications and networks:**

- S-38.115 Signaling Protocols (Televerkon merkinannot)
- S-38.165 Switching Technology (Välitystekniikka)
- S-38.180 Quality of Service in the Internet (Palvelunlaatu Internetissä)
- S-38.188 Communications Networks (Tietoliikenneverkot)
- S-38.192 Network Service Provisioning (Verkkopalvelujen tuotanto)

- S-38.121 Routing in Communication Networks (Reititys tietoliikenneverkoissa)

**Courses on Networking Business:**

- S-38.042 Seminar on Mobile Operator Strategies and Games (Tietoverkkoliiketoiminnan seminaari)
- S-38.045 Special Assignment on Networking Business (Tietoverkkoliiketoiminnan erikoistyö)

**Courses on protocols and services:**

- S-38.153 Security in telecommunications (Tietoliikenteen tietoturva)
- S-38.157 Protocol Design (Protokollasuunnittelu)
- S-38.158 Protocol Design, practical assignment (Protokollasuunnittelun harjoitustyö)

**Seminars, laboratory works, special assignments:**

- S-38.133 Laboratory course on Networking Technology (Tietoverkkotekniikan laboratoriotyöt)
- S-38.138 Networking Technology, special assignment (Tietoverkkotekniikan erikoistyö)
- S-38.203 Project course on Networking Technology (Tietoverkkotekniikan projektityö)
- S-38.310 Thesis Seminar on Networking Technology (Tietoverkkotekniikan diplomityöseminaari)

**Postgraduate courses include:**

- S-38.030 Postgraduate Course on Networking Technology (Tietoverkkotekniikan lisensiaattikurssi)
- S-38.141 Teletraffic Theory (Teleliikenneteoria)
- S-38.143 Queueing Theory (Jonoteoria)
- S-38.149 Postgraduate Course in Teletraffic Theory (Teleliikenneteorian lisensiaattikurssi)
- S-38.205 Individual Course on Networking Technology (Tietoverkkotekniikan yksilöllinen opintojakso)
- S-38.215 Special course on Networking Technology (Tietoverkkotekniikan erikoiskurssi)
- S-38.360 Research Seminar on Networking Technology (Tietoverkkotekniikan tutkijaseminaari)

The key results of teaching in the Networking Laboratory in 2003 can be summarized as

59 Master's theses

2 Doctoral dissertation

The development of thesis production is shown in Figure 4.1

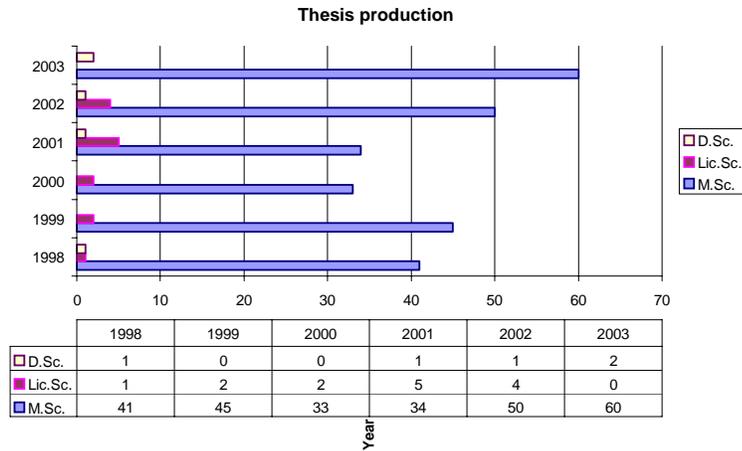


Figure 4.1: Thesis production 1998-2003

#### Doctor of Technology

**Jorma Hirvensalo:** Quality Measurements and the Utilization of Measurement Results in a Software Development Process

**Petteri Mannersalo:** Gaussian and Multifractal Processes in Tele-traffic theory

#### Masters of Science

The employers of our Master's thesis students are shown in Figure 4.2.

- Abu-Raed, Nael: Network Processor Based Packet Processing in 3G-SGSN, Nokia
- Ahola, Mikko: Machine-to-Machine Communications for Enhancing E-Commerce Logistics, Novo Group plc
- Ahvenainen, Marko: Langattomien lähiverkkojen turvallisuus, HUT, Netlab
- Antila, Johanna: Scheduling and quality differentiation in Differentiated Services, HUT, NetLab

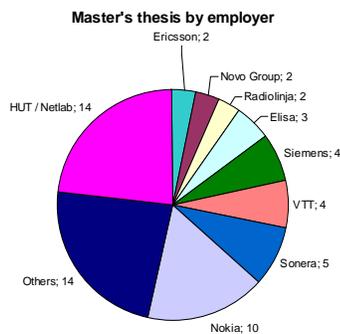


Figure 4.2: Employers of Master's thesis students 2003

- Bai, Xiaole: Investigation and Analysis of Optimal Multi-Class Routing Algorithms for IP Networks, HUT, NetLab
- Erkkilä, Antti: IEEE 802.1x Authentication in Operator's WLAN, Sonera Corporation
- Francke, Juhana: Teknologiastrategia omistaja-asiakkaasta riippuvaiselle uusille markkinoille laajenevalle yritykselle, IT Solicum Oy
- Guiton, Emmanuel: A Rate-Limiting System to Mitigate Denial of Service Attacks
- Gupta, Nidhi: Component-based Modeling of XML Vocabularies using UML, Nokia Research Center
- Haikonen, Jarno: Product Strategy Process in a High-Technology Company
- Hares, Teemu: Adding multimedia resource function processor functionality to Mobile Media Gateway, LMF Ericsson
- Heino, Teemu: Internetprotokollien pääsynvalvonta verkkolaitteissa, Elisa
- Helske, Juhani: Hardware test suite for a scalable router, Nokia Networks
- Honkamaa, Kaarle: Liikkuvuuden- ja paikkatiedon hallinnan yhteentoimivuus ja optimointi pakettikytkentäisessä verkossa, Siemens
- Höijer, Markus: Interoperability of Different Versions of the Session Initiation Protocol, Siemens
- Jussila, Ville: Intrusion Detection Systems - Principles, Architecture and Measurements, HUT, NetLab

- Juva, Ilmari: Analysis of Quality of Service Routing Approaches and Algorithms, HUT, NetLab
- Kalland, Rolf: Charging in Multiservice IP Networks, Comptel Oyj
- Kaulio, Tuomas: Product data management in a Nordic telecommunications operator: A maturity model, TeliaSonera
- Kokko, Juha: Mobile operator business game, HUT, NetLab
- Koskinen, Henri: Connectivity and Reliability in Ad Hoc Networks, HUT, NetLab
- Krigsman, Jani: Wireless Access to Video-based Monitoring Service, Radiolinja
- Kujala, Kalervo: In-Service Performance in Mobile Media Gateway, Ericsson
- Kuosa, Jussi: Automated Test System for Broadband IP Products, Tellabs Oy
- Lallukka, Sami: Programmable logic design for an optical access network, VTT
- Lanu, Heikki: Teleoperaattori yrityksen ICT-ratkaisutoimittajana - prosessinäkökulma
- Leino, Juha: Applications of Game Theory in Ad Hoc Networks, HUT, NetLab
- Lemminkäinen, Riikka: Network monitoring with simple network management protocol in optical feeder network, VTT
- Liu, Ping: Authentication in Mobile Internet Protocol version 6, Nokia
- Luostarinen, Tomi: Implementing Mobile IP into GPRS-WLAN Networks, Sonera Oyj
- Matikainen, Heikki: Tietoliikenteen laadun seuraaminen ja parantaminen yritysverkossa, Kemira
- Mattila, Kimmo: Telecommunications platform productisation for horizontal markets, Nokia Networks
- Mäki, Toni: Lawful Interception in 3G IP Multimedia Subsystem, Nokia Networks
- Mäntysaari, Jani: Downlink Shared Channel in the 3rd Generation Base Station
- Palmén, Krister: Broadband Internet connections for residential housing areas and their business economic effects for network operators, Elisa

- Perttula, Antti: Assessing strategy deployment in service operator business
- Perämäki, Timo: Reaaliaikaisen videon siirto UMTS-verkossa hyödyntäen palvelun laatuluokittelua, VTT, Oulu
- Pietilä, Iiro: Designing Principles for Services using Continuous HTTP Connection
- Rautapää, Miikka: A Speech Processing Solution in a 3G Media Server, Nokia
- Riesen, Simon: The usage of mainstream technologies for public safety and security networks
- Rissanen, Jaakko: Dynamic resource reallocation in cellular networks, VTT
- Ruotsalainen, Toni: IP-tekniikka 3G-tukiaseman rajapinnassa, Nokia
- Salomaa, Ville: Structure of Value Networks in Wireless Telematics Business, Siemens
- Savola, Pekka: Examining Site Multihoming in Finnish Networks, CSC Scientific Computing Ltd.
- Sulander, Heikki: Älyverkko toiminteen testaus kolmannen sukupolven matkapuhelinkeskuspalvelimessa, Siemens
- Suomalainen, Pekka: Public Key Infrastructure Deployment for Mobile Devices, Nokia
- Svahnström, Niclas: QoS Support for Packet Switched Services in UMTS Networks, Sonera
- Talvitie, Ilkka: Kustannustehokas paikkatietomenetelmä matkaviestinverkkoihin: teleoperaattorin näkökulma, Elisa
- Tan, Zhiwei: 3G-Terminal IP Quality of Service Integration in UMTS Network, Nokia Mobile Phone
- Timonen, Vesa: Simulation studies on performance of balanced fairness, HUT Netlab
- Viinikka, Jouni: Statistical analysis techniques to display trends in alert information, France Télécom R&D
- Vuori, Mika: Signaalivoimakkuuden vaikutus EGPRS-palvelun laatuun, Sonera
- Willa, Kirsi: Measuring Service Level and Traffic in a Router Network, HUT NetLab
- Xiao Lei: Design and Implementation of an Ad Hoc Routing Framework, HUT NetLab

- Xiaoling, Zheng: Using the Domain Name System for Telephony Service, HUT NetLab
- Ylhäisi, Teemu: Mobiiliyhteydet yrityksen tietoverkkoon, Radiolinja
- Ylijoki, Mikael: Audit trail model for intermediated business document exchange
- Zhou, Yi: Investigation on the Fish-eye state algorithm in context with QoS routing, HUT NetLab
- Zhu, Haifeng: Comparison between Pre-Computation and On-Demand Computation QoS Routing with Different Link State Update Algorithms, HUT NetLab



### 5.1 Participation in conferences and meetings

- Samuli Aalto
  - Euro3Gi Preliminary Meeting, Paris, France, April 10-12, 2003
  - Cost 279 8th Management Committee Meeting, Warsaw, Poland, September 24-27, 2003
- Johanna Antila
  - International Workshop on Multimedia Interactive Protocols and Systems (MIPS 2003), Naples, Italy, November 18-21, 2003
- Nicklas Beijar
  - MobileMAN Project Meeting, Cambridge, U.K., July 1-4, 2003
- Josè Costa-Requena
  - MobileMAN Project Meeting, Sophia Antipolis, France, March 6-7, 2003
  - MobileMAN Meeting, Brussels, Belgium, October 14-16, 2003
  - MobileMAN Meeting, Pisa, Italy, December 2-5, 2003
- Esa Hyytiä
  - IASTED International Conference, Wireless and Optical Communications, Banff, Alberta, Canada, July 14-16, 2003
- Heikki Hämmäinen
  - 2nd Thinks Meeting, Paris, France, March 25-26, 2003
  - NETS Technology Programme, Tokyo, Japan, November 11-16, 2003
- Mika Ilvesmäki
  - Clobecom 2003 Conference, San Francisco, USA, December 1-5, 2003
- Jorma Jormakka
  - COTS in Defence, Conference, & Exhibition, London, U.K., October 14-16, 2003
  - Nordic Defence Digitization Conference, Stockholm, Sweden, November 2-4, 2003

- Ilmari Juva
  - COST 279, Second European Summer School 2003, Darmstadt, Germany, September 8-12, 2003
- Raimo Kantola
  - E-NEXT Meeting, Paris, France, March 24-25, 2003
  - COST 263 International Workshop on Quality of Future Internet Services, Stockholm, Sweden, October 1-3, 2003
  - 'Cooperation between Russian and Finnish Higher Education Institutions', Seminar and Exhibition arranged by CIMO, St Petersburg, Russia, October 20-22, 2003
- Jouni Karvo
  - COST 279 Management Committee Meeting, Karlskrona, Sweden, May 21-24, 2003
- Henri Koskinen
  - INOC 2003 Conference, Paris, France, October 27-29, 2003
- Pasi Lassila
  - ITC 18 - International Teletraffic Congress, Berlin, Germany, August 31 - September 5, 2003
- Marko Luoma
  - E-NEXT Meeting, Paris, France, March 24-25, 2003
- Laura Nieminen
  - 7th IFIP Working Conference (ONDM2003), Budapest, Hungary, February 3-5, 2003
- Eeva Nyberg
  - Art-QoS'2003 Conference, Warsaw, Poland, March 23-26, 2003
- Aleksi Penttinen
  - Workshop on Wireless Local Networks (WLN 2003), Bonn, Germany, October 20-24, 2003
- Riikka Susitaival
  - COST 279 6th Management Committee Meeting, Dubrovnik, Croatia, January 23-24, 2003
  - Art-QoS'2003 Conference, Warsaw, Poland, March 23-26, 2003
  - COST 279 European Summer School 2003, Frankfurt, Germany, September 8-12, 2003

- Jorma Virtamo
  - INTIMATE 2003 Workshop (INternet Traffic MATrices Estimation), Paris, France, June 16-17, 2003
  - ITC 18th International Teletraffic Congress, Berlin, Germany, August 31 - September 5, 2003
  - Euro-NGI Kick-off Meeting, Paris, France, December 8-10, 2003
  - ML Institute; Program Committee Meeting, Stockholm, Sweden, December 11, 2003
- Peng Zhang
  - HSNMC'2003 Conference, Coimbra, Portugal, July 21-27, 2003

## 5.2 Academic activities

- Samuli Aalto
  - Opponent, Lund Institute of Technology, Lund, Sweden, March 14, 2003
- Ingemar Kaj
  - Visiting opponent from Uppsala University, Dept. of Mathematics, Sweden, April 24-26, 2003
- Jorma Virtamo
  - External Examiner of Doctoral Thesis, Olav Østerbø, NTNU, Norwegian University of Science and Technology, Trondheim, Norway, 2003

## 5.3 Visits abroad

- Heikki Hämmäinen
  - Tekes co-operation seminars with Keio University, Waseda University, and Tokyo Institute of Technology, Finnish Embassy, Tokyo, Japan, November 12-14, 2003
  - Company visit to YRP Ubiquitous Networking Laboratory, Tokyo, Japan, November 14, 2003
  - Company visits to NTT DoCoMo, KDDI and CRL, Yokosuka, Japan, November 13, 2003
- Raimo Kantola
  - Visits to National e-Science Centre and to EPCC (Edinburgh Parallel Computing Centre), the University of Edinburgh, Edinburgh, U.K., May 6-9, 2003
  - University visits to ETU and LPI, St Petersburg, Russia, October 19-22, 2003

- Eeva Nyberg
  - Visiting researcher, Institut National de Recherche en Informatique et en Automatique (INRIA), Sophia-Antipolis, France, January 20-26, 2003
- Jorma Virtamo
  - Visiting researcher, Cambridge University, Computer laboratory/Microsoft Research, London, U.K., February 3 - April 11, 2003

#### 5.4 Foreign visitors in 2003

The laboratory had the honor to enjoy the following visitors:

- Akira, Sano Sano from Keio University, Japan
- Ayesta, Urtzi from Institut National de Recherche en Informatique et en Automatique (INRIA), France
- Berndt, Hendrik from DoCoMo Communications Laboratories Europe, Germany
- Tricarico, Francesco from Politecnico di Bari, Italy
- Guiton, Emmanuel from Ecole Française d'Electronique et d'Informatique (EFREI), France
- Gutiérrez, Juan from Universidad Politecnica de Madrid, Spain
- Iwao, Sasase from Keio University, Japan
- Kaj, Ingemar from Uppsala University, Sweden
- Künzle, Stefan from University of Applied Sciences, Switzerland
- Marsh, Ian from Kungliga Tekniska Högskolan, Sweden
- Nanevski, Ivan from Ss. Cyril and Methodius, Macedonia
- Pradas Adán, Jose Luis from Universidad Politecnica de Valencia, Spain
- Yukitoshi, Sanada from Keio University, Japan

In addition professor Gunnar Karlsson, director of the Laboratory for Communication Networks of Kungliga Tekniska Högskolan, Sweden held a seminar in the Networking Laboratory with the following researchers:

Andersson, Anders	Koudoridis, Giorgios
Dan, Gyorgy	Lindh, Thomas
Fu, Jing	Lundqvist, Henrik
Gonzalez, Alberto	Marsh, Ian
Grob, Daniel	Ossipov, Evgeni
Hagsand, Olof	Sjödin, Peter
Hidell, Marcus	Stadler, Rolf
Ivars, Ignacio	Velayos, Hector

### 6.1 University boards and committees

- Raimo Kantola
  - Director of the Master's 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 Faculty Council at the Department of Electrical and Communications Engineering
  - Several memberships in nomination committees for the appointment of professors in Computer Science
- Markus Peuhkuri
  - Member of Committee of Post Graduate School at Department of Electrical and Communications Engineering
- Kirsi Willa
  - Member of Committee for Qualitative Development of Teaching at Department of Electrical and Communications Engineering

### 6.2 Other boards and committees

- Heikki Hämmäinen
  - Member of Board, NETS Future Networks Program, TEKES
  - Member of Local Organizing Committee, Information Technology, World Championships in Athletics, Helsinki 2005
  - Member of Technical Program Committee, International Conference on Information & Communication Technologies: From Theory to Applications, ICTTA'04
  - Member of Program Committee, International Telecommunication Society, Biennial Conference 2004
  - Chairman of the International Review Group, Midterm review of NETS program, TEKES
- Jorma Jormakka
  - Member of the scientific council of the National Defence College

- Pirkko Kuusela
  - Member of Doctoral Defence Committee at Uppsala University, Department of Mathematics, Sweden
- Marko Luoma
  - Member of the Technical Program Committee of the workshop on Quality of Future Internet Services, QoFIS'03, Stockholm, Sweden
  - Member of the Board of Creanord Oy
- Jorma Virtamo
  - Member of IFIP Working Group 6.3, Performance of Communication Systems
  - Member of the Board of the Finnish Graduate School in Stochastics
  - Member of the Board of the Research Foundation of Helsinki Telephone Company
  - Member of the Technical Program Committee of 18th International Teletraffic Congress ITC-18, Berlin, August 31 - September 5, 2003
  - Member of the Technical Program Committee of Fourth International Workshop on Quality of Future Internet Services (QoFIS'03), Stockholm, October 1-3, 2003
  - Member of the Technical Program Committee of Networking 2004, Athens, Greece, May 9-14, 2004
  - Member of the Technical Program Committee of ITC Specialist Seminar on Performance Evaluation of Wireless and Mobile Systems, Antwerp, Belgium, August 31 - September 2, 2004
  - Member of the Scientific Steering Committee of Institut Mittag-Leffler, The Royal Swedish Academy of Sciences, Program in Queueing Theory and Teletraffic Theory, Fall 2004

### 6.3 Referee activities

- Samuli Aalto
  - Reviewer for the the following scientific journals: Performance Evaluation, IEEE Transactions on Automatic Control, European Journal of Operational Research
  - Reviewer for the following conferences: ITC-18, QoFIS 2003, ICC 2004
- Esa Hyytiä
  - Reviewer for the following conferences: QoFIS 2003, ITC-18, ISCC 2004

- Heikki Hämmäinen
  - Reviewer for the Expert statement for fulfillment of professorship, Networking technology, VTT
- Jorma Jormakka
  - Reviewer for the following scientific journals: Networking 2004 (cont.), EPMCC'03 (cont.)
  - Reviewer for the following conferences: QofIS 2002, Smartnet 2002
- Raimo Kantola
  - Reviewer for journal Computer Communications
- Jouni Karvo
  - Reviewer for the following conferences: QoFIS 2003, ITC-18
- Henri Koskinen
  - Reviewer for the 18th International Teletraffic Congress (ITC-18)
- Pirkko Kuusela
  - Reviewer for the following conferences: ITC 2003, QoFIS 2003, IEE Electronics Letters
- Pasi Lassila
  - Reviewer for Computer Networks Journal
  - Reviewer for the following conferences: ITC-18, Networking 2004, QoFIS 2003
- Marko Luoma
  - Reviewer for the following scientific journals: Elsevier Computer Communications, Electronic Letters
  - Reviewer for the QoFIS'2003 conference
- Eeva Nyberg
  - Reviewer for the following conferences: ITC-18, Networking 2004
- Aleks Penttinen
  - Reviewer for the 18th International Teletraffic Congress (ITC-18)

- Jorma Virtamo

- Reviewer for the following scientific journals: IEEE/ACM Transactions on Networking, Performance Evaluation, European Transactions on Telecommunications, Computer Communications
- Reviewer for the following conferences: ITC-18, QoFIS 2003, Networking 2004, Infocom'04

- [1] Johanna Antila. Scheduling and quality differentiation in differentiated services. Master's thesis, Helsinki University of Technology, 2003.
- [2] Johanna Antila and Jani Lakkakorpi. On the effect of reduced quality of service in multiplayer online games. *International Journal of Intelligent Gaming and Simulation*, 2(2):electronic publication, 2003.
- [3] Johanna Antila and Marko Luoma. Scheduling and quality differentiation in differentiated services. In *Proc. MIPS*, pages 119 – 130, November 2003.
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- [6] Jorma Hirvensalo. *Quality Measurement and the Utilisation of Measurement Results in a Software Development Process*. Ph.d. thesis, laboratory report series, Networking Laboratory, 2003.
- [7] Esa Hyttiä. Maximization of single hop traffic with greedy heuristics. In *Wireless and Optical Communications, WOC*, pages 289–294, Banff, Alberta, Canada, July 2003.
- [8] Mika Ilvesmäki, Raimo Kantola, and Marko Luoma. Traffic differentiability based on packet and flow per application –analysis. In *Proc. Globecom 2003*. IEEE, November-December 2003.
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- [10] Jorma Jormakka. Combinatorial decision theory with applications in hacker warfare modelling, part 2. National Defence College, Department of Technology, Publication Series, 2003.
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- [14] Jorma Jormakka and A. Rissanen. The call for digitization, working towards digitally-networked defence force. In *2nd Nordic Defence Digitization Conference*, Stockholm, Sweden, November 2003.
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- [19] H. Koskinen. A simulation-based method for predicting connectivity in ad hoc networks. In *Proc. INOC 2003*, pages 355–360, October 2003.
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