

Helsinki University of Technology Networking Laboratory  
Teknillinen korkeakoulu Tietoverkkolaboratorio  
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## **ANNUAL REPORT 2002**

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Helsinki 2003

## ABSTRACT

The research and teaching area of the Networking laboratory focuses on communication networks, 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 courses on IP technology, circuit-switched networking, teletraffic theory and on service and protocol development.

In 2002, the laboratory staff published two patents, 3 international journal papers and 17 papers in conferences. In 2002, one Doctor dissertation, 4 Licentiate theses and 50 M.Sc theses were achieved by the students of our laboratory.

In August 2002, the Networking Laboratory hosted the 16th Nordic Teletraffic Seminar gathering experts representing twelve nationalities in a three-day meeting.

In 2002, the laboratory obtained several new multi-year research contracts. In the TEKES NETS Future Networks research program the Intelligent Routing Network project group was selected as one of the NETS spear head groups with a three year contract. A group of companies also joined in supporting the initiative. Another example of a multi-year project is the MobileMan Project on ad hoc networking supported by the EU.



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## 1 INTRODUCTION

The results of the year 2002 presented in this Annual Report show that the positive development trend of the previous years continues. Personally for me the year marked an important milestone since on January 22nd I gave my inauguration lecture. This section discusses and evaluates the highlights in the life of the Laboratory during 2002. The rest of the report presents the main facts.

The Laboratory was headed by professor Virtamo until the start of his sabbatical in August. I took the responsibility for the remainder of the year.

D.Sc (Tech) Heikki Hämmäinen was appointed a professor of networking economics for a period of two years, the term starting from Jan 1st 2003. Dr. Pertti Raatikainen, whose main occupation is Research Professor of VTT, was appointed as a docent of switching technology. Dos. Raatikainen will teach a course on switching technology annually for the time being.

Many researchers of the laboratory earned academic degrees, including Jouni Karvo's doctorate and Mika Ilvesmäki's, Eeva Nyberg's and Markus Peuhkuri's licentiates. Eeva Nyberg was also the first female PhD student to receive a licentiate degree in our Laboratory. In addition, two post-graduate students earned licentiate degrees while working for other organizations.

The number of active PhD and licentiate students continued to rise. Among them there are many advanced students who have either completed all their courses or already have their licentiate degrees. We thus expect to see more doctoral theses in the coming years. One of our PhD students was awarded a new position in the GETA graduate school. The number of M.Sc theses earned by our students in 2002 was 50 which is rather high compared to previous years. For two and a half professor man-years during 2002 the number of supervised M.Sc theses continues to be excessive high compared to the HUT average of less than 5 theses per professor. It seems that the high intakes of late 1990's are now in the final stages of the M.Sc studies and we expect a high workload on supervising M.Sc theses during the coming years. 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.

At the beginning of year 2002 we started two large projects: IRoNet and TIEVA. IRoNet, financed by TEKES, is one of TEKES spearhead group projects in the NETS future networks program. TIEVA is a large project studying IP QoS. Both can be considered major milestones for the laboratory.

Another new project started in 2002 is MobileMan on ad hoc networking funded by the EU. In MobileMan we are one of the partners among several European Research and Academic institutions. During 2002 we continued to be active on the traditional European COST cooperation. We joined a Network of Excellence, namely Euro3G. We also participated in the E-Net initiative for preparing a wider multi-year E-Next NoE.

As a result of the multi-year contracts we could recruit new PhD students with much more confidence and foresight than ever before. 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 government budget, the government directed Finnish Academy and TEKES are the largest sources for research funding.

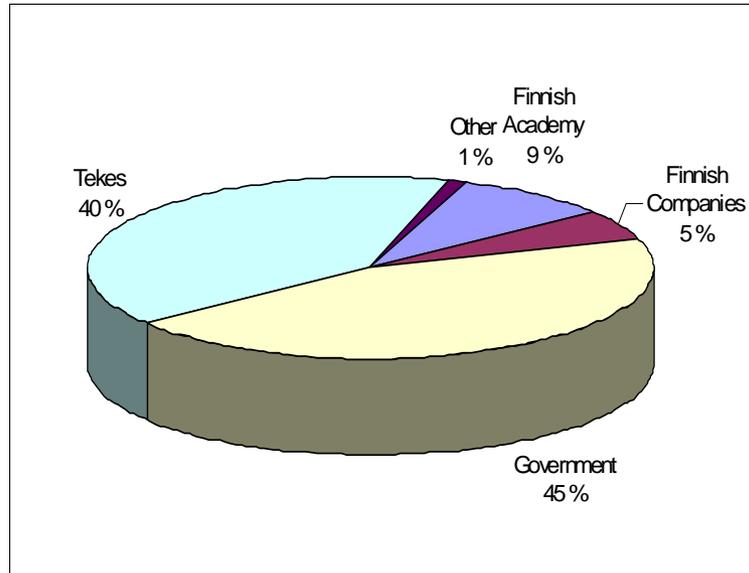


Figure 1.1: Financing of the Networking Laboratory 2002

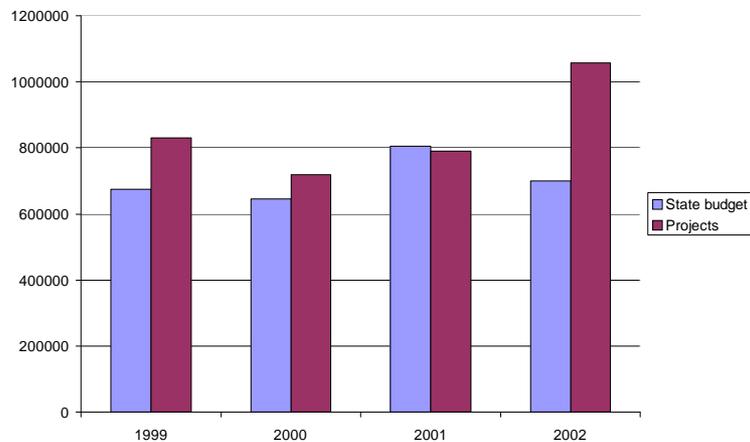


Figure 1.2: Financing of the Networking Laboratory 1998-2002

During the year, I participated in the core IP networking interest area

groupwork in the TEKES NETS program. The idea is to bring people from the academia and the companies closer together to work on goals of mutual interest in the NETS framework. One of the results was a National seminar on Multicast in IP networks organized under the NETS umbrella. D.Sc Jouni Karvo gave a presentation in the seminar based on his D.Sc thesis on Multicast.

In August the Laboratory hosted the 16th Nordic Teletraffic Seminar gathering experts representing twelve nationalities in a three-day meeting. Jorma Virtamo, Pasi Lassila and Eeva Nyberg did a great job in organizing the event and deserve our special thanks on behalf of the Laboratory.

In 2002 we decided to join the Master's programme in Telecommunications by introducing a major in Networking technology. The courses of the major are a subset of our regular courses and will be taught in English from 2003 onwards. In practice already during 2002 we offered many of the courses for the networking major in English. The first intake to the Networking major in the master's programme will be in 2003.

The laboratory had a development day of teaching in Meripuisto, Kivenlahti, Espoo. There were two social events during the year: a summer trip and the traditional Christmas party, this time at the LänsiAuto Arena.

There were also several visits to our laboratory, including a 2 month visit by professor Resing from the Eindhoven University of Technology and short visits by professor Henning Schulzrinne of Columbia University, and by Charles Perkins of NRC.

In June our professors and PhD students experienced a warm welcome visiting our sister laboratory at KTH led by professor Gunnar Karlsson. We had a one day seminar on topics of ongoing research in our laboratories followed by a nice dinner. Seminars like this, alternately at HUT and KTH, have already become a tradition.

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.

April 3rd, 2003

Raimo Kantola



## 2 PERSONNEL 2002

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)
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	Department secretary
Koivisto, Johanna	Student adviser
Kosonen, Vesa	M.Sc., assistant
Lemetyinen, Mirja	Department secretary (on leave 1.10.2001-)
Nupponen, Esko	Senior laboratory supervisor
Pitkäniemi, Kimmo	PC support
Planman, Irma	Department secretary
Uusitupa, Seppo	Lic.Sc.(Tech.) Specialist teacher

### 2.3 Senior Researchers

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

## 2.4 Researchers

Beijar, Nicklas	M.Sc.
Costa Requena, Jose	M.Sc.
Hyytiä, Esa	Lic.Sc. (Tech.)
Ilvesmäki, Mika	Lic.Sc. (Tech.)
Luoma, Marko	Lic.Sc. (Tech.)
Ma, Zhansong	M.Sc.
Mölsä, Jarmo	Lic.Sc. (Tech.)
Nieminen, Laura	M.Sc.
Nyberg, Eeva	Lic.Sc. (Tech.)
Penttinen, Aleksi	M.Sc.
Peuhkuri, Markus	Lic.Sc. (Tech.)
Susitaival, Riikka	M.Sc.
Zhou, Wenpeng	M.Sc.

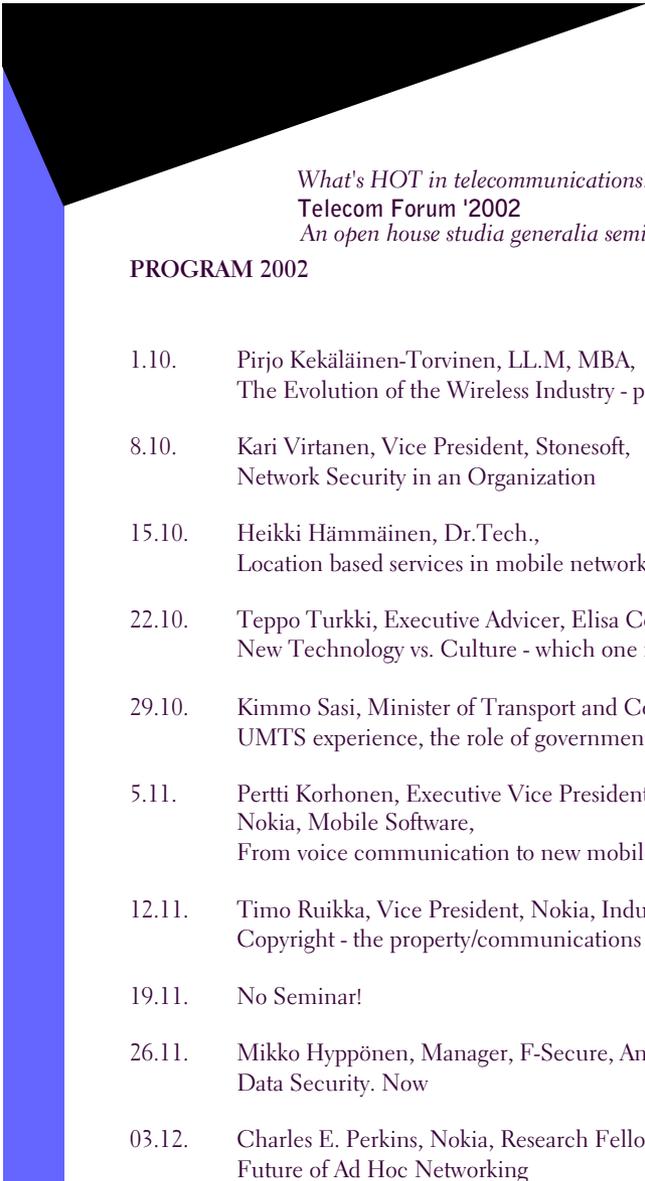
## 2.5 Research assistants and trainees

Antila, Johanna	Bai, Xiaole
Creado, Jarrod	Erkkilä, Antti
Fan, Tyh-Dar	Gonzalez Olias, Ignacio
Huttunen, Jari	Jussila, Ville
Juva, Ilmari	Kaikkonen, Sampo
Kneckt, Laura	Koski, Marjukka
Koskinen, Henri	Kuumola, Eemeli
Leino, Juha	Li, Yaohui
Matinlauri, Anni	Pradas Adán, Jose
Pulkkinen, Piia	Paju, Antti
Redondo Antón, Juan	Salonen, Tuomo
Savolainen, Jussi	Sarala, Risto
Timonen, Vesa	Uchida, Kei
Viipuri, Timo	Willa, Kirsi
Villanen, Juha	Zhang, ChenXin
Zhou, Yi	

## 2.6 Part-time teachers

Aarnio, Jaakko	S-38.164 Broadband Switching Technology
Nieminen, Klaus	S-38.001 Telecom Forum
Poikola, Antti	S-38.203 Networking Technology, project course
Resing, Jacques	S-38.215 Special Course in Networking Technology
Sipilä, Mari	S-38.105 Principles in Communications Engineering
Schulzrinne, Henning	

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



*What's HOT in telecommunications?*

**Telecom Forum '2002**

*An open house studia generalia seminar on telecommunications*

**PROGRAM 2002**

- 1.10. Pirjo Kekäläinen-Torvinen, LL.M, MBA,  
The Evolution of the Wireless Industry - past, present ...and future?
- 8.10. Kari Virtanen, Vice President, Stonesoft,  
Network Security in an Organization
- 15.10. Heikki Hämmäinen, Dr.Tech.,  
Location based services in mobile networks
- 22.10. Teppo Turkki, Executive Adviser, Elisa Communications,  
New Technology vs. Culture - which one is the driver?
- 29.10. Kimmo Sasi, Minister of Transport and Communications, Finland,  
UMTS experience, the role of government
- 5.11. Pertti Korhonen, Executive Vice President,  
Nokia, Mobile Software,  
From voice communication to new mobile applications and services
- 12.11. Timo Ruikka, Vice President, Nokia, Industry Initiatives,  
Copyright - the property/communications battle
- 19.11. No Seminar!
- 26.11. Mikko Hyppönen, Manager, F-Secure, Anti-Virus Research,  
Data Security. Now
- 03.12. Charles E. Perkins, Nokia, Research Fellow,  
Future of Ad Hoc Networking

Figure 2.1: Telecom Forum 2002



## 3 RESEARCH PROJECTS

### 3.1 AHRAS

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

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.

In 2002, studies concerning energy constrained routing for multicast traffic were continued. The related optimisation problem was formulated and an algorithm to solve the problem was generated. The computational complexity of this solution is, however, so demanding that heuristic methods are needed in practice. Such methods were developed. The connectivity and reliability problems were also studied. More precisely, the statistical behaviour of the threshold range for  $k$ -connectivity in a square with uniform node distribution was explored by simulations. In this context, new algorithms to find the corresponding threshold range were developed. The third topic was the development of an ad hoc network simulator (operating at a highly abstract level) for the studies related to routing and connectivity in a mobile environment.

### 3.2 TIEVA

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

TIEVA is a research project for analyzing the network layer operation of a large service provider network in unusual overload and error situations. The project aims to create recommendations for dimensioning and topology modifications for securing the network operations in extreme conditions. The project investigates different quality and traffic control methods and their applicability in increasing the network stability. The project aims to create a simulation program for large scale IP networks with accurate packet level events and protocols. For these purposes, extensive traffic measurements and protocol modelling are done.

### 3.3 InterOperability Mechanisms for IN/IP Telephony (INTERO)

**Project leader:** Raimo Kantola **Researcher:** Nicklas Beijar

The project continued the work started in the IMELIO (Internet MEchanisms for quaLity and InterOperability) project. The project studied protocols for management of routing information necessary in the in-

terconnection of the IP telephony and the circuit switched networks. The purpose of these protocols is to provide routing information to all systems that require it. The protocols for exchanging routing information are required when the IP Telephony network is connected to the circuit switched network following a large-scale peer model. Additionally, the project studied solutions for implementing number portability in the hybrid network formed by the IP telephony and the circuit switched networks.

### 3.4 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 the year we started developing an ad hoc routing testbed which is an integral part of the three year research plan.

### 3.5 FIT and other teletraffic research funded by the Academy of Finland

**Project leader:** Jorma Virtamo **Researchers:** Johanna Antila, Pirkko Kuusela, Vesa Timonen

The acronym FIT stands for Future Internet — Traffic Handling and Performance Analysis. This is a three-year project funded by the Academy of Finland and started in August 2001. Affiliated to this project are a Research Doctor (Pirkko Kuusela) and, for the period from August 2002 to

July 2003, a Senior Research Scientist (Jorma Virtamo). The work in 2002 was mainly concentrated on the topics described below.

Fairness is an important aspect in bandwidth sharing for elastic traffic in the Internet. A review study was made of the previous research in this area covering all the basic fairness definitions: max-min fairness, proportional fairness, potential delay minimization, and a more general, so-called  $\alpha$ -fairness. Max-min fairness tries to equalize the rate allocation as far as possible at the expense of the total throughput, whereas throughput maximization would discriminate some flows. Proportional fairness penalizes long routes more than max-min fairness, with a tendency to achieve greater total throughput. The static allocations according to various fairness criteria were worked out for some simple network topologies. All these “classical” fair allocation schemes can be formulated as optimisation problems maximizing a given utility function. Another fairness concept, balanced fairness, was recently introduced by Bonald and Proutière. It is not utility based but makes the allocation in such a way that the system obeys detailed balance (or partial balance, in a more general setting) resulting in a flow level performance that is essentially independent of any detailed traffic characteristics. This property makes it very attractive from traffic engineering viewpoint. As an extra bonus, balanced fairness provides, at least in principle, a way to determine the state distribution of a dynamic system and to evaluate the performance parameters. An efficient recursive algorithm for calculating the flow throughputs in tree networks was developed during J. Virtamo’s visit to France Telecom R&D, in fall 2002.

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. The objective of packet scheduling is to share the common resources so that some predefined policy selected by the operator will be met. A study was first made of the quality models an operator can use to support its service approach and on the scheduling disciplines suitable for implementing these models. The focus was on service disciplines designed for capacity and delay differentiation since they are the quality parameters that are most affected by the choice of a scheduling discipline. Besides the qualitative analysis the selected scheduling disciplines were implemented in a simulator. The simulations, along with reporting the whole work in a Master’s thesis, will be completed in 2003.

Other topics studied in this project include the dynamics of the previously developed TCP-RED model. The field has advanced considerably calling for new research approaches. Stochastic network calculus has also been on the research agenda, and new research was being initiated on the control theoretic approach to congestion control in data networks.

### 3.6 COST 279

**Project leader:** Jorma Virtamo, Samuli Aalto **Researchers:** Johanna Antila, Jouni Karvo, Laura Knecht, Eemeli Kuumola, Pirkko Kuusela, Pasi Lassila, Eeva Nyberg, Riikka Susitaival

COST 279, a joint project with VTT, is the Finnish contribution to the European COST 279 Action, "Analysis and Design of Advanced Multi-service Networks Supporting Mobility, Multimedia, and Internetworking". The project started in 2001 and it is funded by Tekes and industrial partners. In 2002, our focus was on the three research areas listed below.

**QoS mechanisms for the Internet: DiffServ packet handling mechanisms** were modelled and analysed at different levels of abstraction (packet and flow levels). The results were published in conference papers and in a Licentiate Thesis. In addition, scheduling based approaches for differentiating short and long TCP flows were studied by simulations. Thirdly, the joint dynamics of instantaneous and exponentially averaged queue lengths, needed e.g. for the analysis of RED queue management, was studied by a Markovian model analogous to those commonly used to analyze fluid queues. Part of the work was done jointly with Professor J. Resing, University of Eindhoven, during his 2 month visit to the Laboratory. The results were published in conference papers and in a Master's Thesis.

**Traffic engineering in IP/MPLS networks: Load balancing and service differentiation by MPLS in differentiated services networks** were studied by optimization models in a Master's Thesis.

**Traffic related issues of multicast connections:** The gain of multicasting compared to unicasting in a single cell of a mobile cellular system was evaluated. The results were published in a conference paper. In addition, a Doctoral Thesis concerning teletraffic problems in multicast networks was completed.

### 3.7 IRoNet – Intelligent Routing Network Intelligent Routing Network

**Project leader:** Raimo Kantola **Researchers:** Samuli Aalto, 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, Jarrod Creado, Xiaole Bai, Kei Uchida

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, constraint based 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 starting from 1/2002.

### 3.8 Optical Access Networking (OAN)

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

Optical Access Networking (OAN) is a three year project started in February 2001 and carried out in collaboration between VTT and HUT. The project is funded by TEKES and industrial partners. The research concerns all-optical WDM network technologies, especially optical access networks. The research conducted at HUT deals mainly with network level problems on two areas.

The first one concerns the allocation of network resources, i.e. how to configure lightpaths in 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 deals 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. The results were published in a conference paper and in a Master's Thesis.



## 4 TEACHING

### 4.1 General notes on teaching in 2002

The Course S-38.133 Laboratory Course on Networking Technology underwent big changes when most of the laboratory assignments were renewed to be more up-to-date.

In spring 2002 professor Jacques Resing visited the laboratory and lectured a special course on fluid queues and their applications in telecommunications. In the course S-38.001 Telecommunication Forum many visiting lecturers shared their view on evaluation of telecommunications industry. Among them were minister of transport and communications Kimmo Sasi (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-38.180 Quality of Service in the Internet (Palvelunlaatu Internetissä)
- S-38.188 Communications Networks (Tietoliikenneverkot)
- S-38.192 Network Service Provisioning (Verkkopalvelujen tuotanto)
- S-38.120 Telecommunications Switching Technology (Tiedonvälitystekniikka)
- S-38.121 Routing in Communication Networks (Reititys tietoliikenneverkoissa)
- S-38.164 Broadband Switching Technology (Laajakaistainen välitystekniikka)

#### **Courses on teletraffic theory:**

- S-38.148 Simulation of Data networks (Tietoverkkojen simulointi)

#### **Courses on protocols and services:**

- S-38.151 Service Creation and Management (Palvelunkehitys ja hallinta)
- 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-38.119 Seminar on Networking Technology (Tietoverkkotekniikan seminaari)
- 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)

### 4.3 Theses

The key results of teaching in the Networking laboratory in 2002 can be summarized as

- 50 Masters' theses,
- 4 Licentiate theses, and
- 1 Doctoral dissertation.

The development of thesis production is shown in Figure 4.1

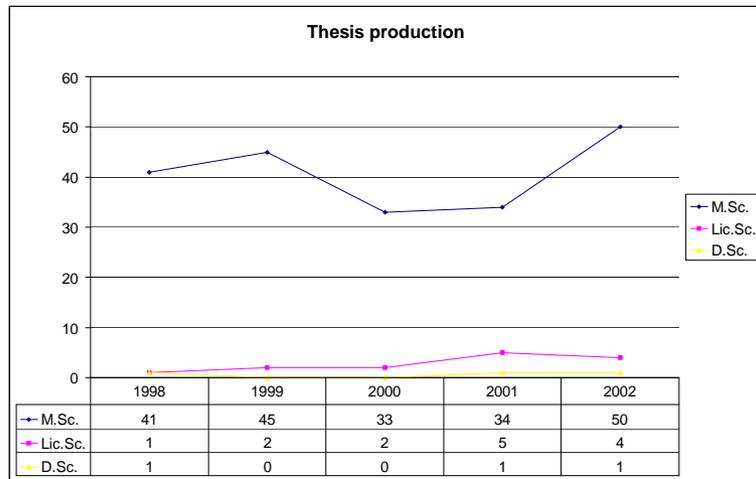


Figure 4.1: Thesis production 1998-2002

### Doctor of Technology

**Jouni Karvo:** A Study Of Teletraffic Problems in Multicast Networks

The dissertation studies teletraffic engineering of dynamic multicast connections. The traditional models in teletraffic engineering do not handle multicast connections properly, since in a dynamic multicast tree, users may join and leave the connection freely, and thus the multicast tree evolves in time.

A model called multicast loss system is used to calculate blocking probabilities in a single link and in tree-type networks. In a single link case, the problem is a generalised Engset problem, and a method for calculating call blocking probabilities for users is presented. Application of the reduced load approximation for multicast connections is studied. Blocking probabilities in a cellular system are studied by means of simulation.

The analysis is mainly concentrated on tree type networks, where convolution-truncation algorithms and simulation methods for solving the

blocking probabilities exactly are derived. Both single layer and hierarchically coded streams are treated. The presented algorithms reduce significantly the computational complexity of the problem, compared to direct calculation from the system state space. An approximative method is given for background traffic.

The simulation method presented is an application of the Inverse Convolution Monte-Carlo method, and it gives a considerable variance reduction, and thus allows simulation with smaller sample sizes than with traditional simulation methods.

Signalling load for dynamic multicast connections in a node depends on the shape of the tree as well as the location of the node in the tree. The dissertation presents a method for calculating the portion of signalling load that is caused by call establishments and tear-downs.

### **Licentiate of Technology**

#### **Veikko Brax:** Scalability Parameters of the Multiservice IP Network

This Licentiate's Thesis presents the scalability of a hypothetical Multiservice IP Network, without proposing an implementation based on any particular technology. We assume, that the Multiservice IP Network will replace small and large local PSTN's in the future.

First we present the development of traffic in the Internet and in the PSTN. The purpose is to find facts to select services and predict the topology of the national Internet and the technologies, which are proposed to improve Quality of Service of the Internet. We assume that the Multiservice IP Network will be based on similar technologies.

We also present results of real traffic measurements from Internet data sessions and from telephone calls in the PSTN. We use these results to define the characteristics of the sessions in our hypothetical Multiservice IP Network. To evaluate the scalability of the Multiservice IP Network, we define a methodology. Then we apply it to a case study, where the Multiservice IP Network replaces a small local PSTN, to find out the scalability factors. Then we continue the evaluation by using each scalability factor as variable. A Multiservice IP Network would use for the telephone calls a half of the bandwidth, what the PSTN does. If it transported the TCP-based services as separate best-effort traffic, the saved bandwidth could transport only a share of the Internet traffic. The best-effort transport does not use efficiently the link bandwidth. If the audio and video delivery data traffic become popular, they may have an essential impact on the scalability of the network.

#### **Matti Koivisto:** From Control to Competition – Changes in Regulator's a Strategic Position in Telecommunications Markets

Regulators have always been interested in the development of the telecommunications industry and infrastructure. In the past, the main role of telecommunications regulation was in protecting customers from the monopoly power of vertically integrated operators. The deregulation of

telecommunications markets has not made regulation redundant but has changed its scope. Today regulators cannot operate only on the borders of the industry but they also have to get involved with the internal operations and structures of the industry.

In this study I develop a theoretical model for describing the regulators strategic position in liberalized telecommunications markets. I call this model the white box regulation model. It shows all interfaces between regulators and other stakeholders of the industry. I use the model for analyzing how deregulation has changed the regulators strategic position and focus in the USA, the UK and Finland. The data were gathered mainly from regulation documents from the period of 1996–2000.

This study shows that deregulation has caused regulators to shift their focus from the borders of the industry to the internal operations. This development which I call the regulatory switch has changed regulators into sector specific competition authorities.

**Eeva Nyberg:** How to achieve fair differentiation: Relating flow level QoS requirements to DiffServ packet level mechanisms

Differentiated Services (DiffServ) is a set of mechanisms aiming at providing scalable differentiation, where quality treatment inside the network is done to aggregates of flows not to individual flows. Quality guarantees can be divided into two service models. In assured services the flow should receive a rate at least equal to the contracted rate, while in relative services the rate of the flow should be proportional to the contracted rate.

The thesis models QoS mechanisms used and proposed for use in DiffServ networks. The modelling concentrates on the interaction between various differentiation mechanisms and traffic flows using a given transport protocol. This type of closed loop modelling of the dependency of the flow sending rate on the metering, marking, dropping and scheduling mechanisms has not been done before. The mechanisms are modelled and analyzed on two levels: flow level and packet level. Furthermore detailed simulations of the packet level are performed. The correspondence between the models is good, and each modeling approach is able to illustrate a different aspect of mechanism design, either through the choice of parameter values or through the choice between two complementary mechanisms. Based on the models, we study how well relative services can be achieved, i.e. in what proportion network bandwidth is divided, using DiffServ without admission control.

**Markus Peuhkuri:** Internet traffic measurements — aims, methodology, and discoveries

Traffic measurements are performed for a variety of reasons. These include traffic and network characterization, network monitoring and network control. Internet was instrumented from the beginning to support extensive measurement data collection, but at the later phases in 1990s large scale measurements were not in focus of commercial network operators. The thesis develop tools and methodology for the internet traffic measurements

and introduce discoveries based on these.

A method to compress Internet traffic packet traces, utilising similarities between packets within a connection, was developed. Along with compression, packet address fields can be anonymised while maintaining topology information and uniqueness of end hosts.

Internet traffic traces were collected over an 18 month period. This data has been analysed in order to identify basic properties of network traffic. Traffic properties of different application protocols were studied based on specifications and examples.

A flow, built up from a train of IP packets, can be defined by various criteria of which the most important are address granularity and packet interarrival time. Counts of flows were studied based on these criteria. It was found that some of application protocols were very sensitive to the threshold selection.

User impatience may result in useless traffic being carried in the network. The most important factors for impatience turned out to be a transfer time exceeding 10 seconds and a low transfer rate. Available bandwidth between hosts was found variable even over short time scales. It was concluded that using test traffic probes does not guarantee quality of connection.

### Masters of Science in Telecommunication technology

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

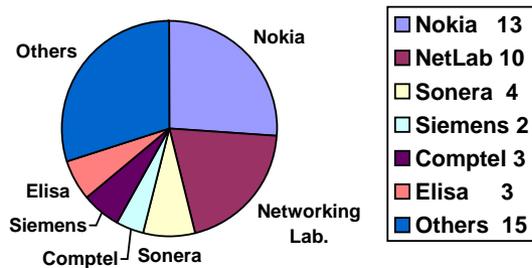


Figure 4.2: Employers of Masters' thesis students 2002

- Ahonen, Annukka: E-operability in professional mobile radio networks, Nokia
- Altonen, Marko: IP -pohjaisen puheratkaisun käyttöönotto vaihdeverkossa, Kapiteeli Oy
- Annala, Raino: Broadband video strategy: Effects of television broadcasting digitalization, Elisa

- Arjas-Rodrigues, Ivan: Stream control transmission protocol, the design of a new reliable transport protocol for IP networks, Nokia
- Beijar, Nicklas: Distribution of numbering information in interconnected circuit and packet switched networks, HUT, NetLab
- Gonzalez Olias, Ignacio: Security and auto-configuration of location Servers for IP Telephony, HUT, NetLab
- Davidsainen, Sanna: Pankkitoimen asiakkuiden hallintajärjestelmien vertailu ja valinta, Samlink Oy Ab
- Fan Tyh-Dar: Policy management, its relationship to QoS mechanisms and case studies, HUT, NetLab
- Gerdt, Janne: Management service providers — Analysis of and opportunities of IT infrastructure management services, Cygate
- Grech, Sandro: Optimizing mobility management in future Ipv6 mobile networks, Nokia
- Heino, Arto: ENUM Service in 3G networks
- Helenius, Ville: Datalys of EF and AF service classes of differentiated services, Sonera
- Hiisilä, Jani: Automation in 3rd generation radio access network system testing, Nokia
- Hjelt, Björn: Evaluation of Java 2 micro edition based service creation for mobile devices, Sonera
- Huang, Taotao: Analysis of Push Initiator tool used for wireless application protocol
- Häkkinen, Ville: Maintainability of a telecommunication software system, Comptel Oyj
- Jalava, Teemu: Service routing in 3GPP IP multimedia subsystem, Nokia
- Kiiskinen, Lasse: QoS in IP based broadband access network providing TV content delivery, Siemens
- Kneckt, Jarkko: Point-to-point and point-to-multipoint calls over IP, Nokia
- Krooks, Ville: Controlling customer premises equipment auto-configuration using digital subscriber line access multiplexer, Nokia
- Kornatowski, Maciej: Service development using the SPIRITS protocol
- Kukko, Eero: Distribution of client security policies, Nokia

- Kuosmanen, Petteri: Choosing routing protocol for military ad hoc networks based on network structure and dynamics, Finnish Defence Forces
- Kuumola, Eemeli: Modelling the joint dynamics of instantaneous and exponentially averaged queue lengths, HUT, NetLab
- Laamanen, Aleksander: Developing text message based community services, Iobox Oy
- Lehtinen, Kati: Analysis of the charging protocols in the all IP Network, Nokia
- Lopez, Daniel: Intrusion detection systems in the computer security model, HUT NetLab
- Lönnfors, Mikko: Service provisioning using parlay in hybrid network environment, Nokia
- Martelius, Kari: Implementation and analysis of quality self-assessment, Visual Systems Oy
- Miettinen, Natalia: Analysing dynamic differentiated services architectures, Elisa
- Määttänen, Mikko: Using SNMP in charging of IP traffic, Comptel Oyj
- Nieminen, Klaus: Service provisioning in future network environment, Comptel Oyj
- Ollikainen, Sami: CAMEL phase 3 in UMTS, Nokia
- Paju, Antti: Tilaaanumeron siirrettävyys yhdistetyssä piiri- ja pakettikytkentäisessä verkossa, HUT, NetLab
- Pättö, Toni: Tehokas asiakastarpeeseen vastaaminen: suuret yritykset tietoliikennetoimittajan haastavina asiakkaina, Elisa
- Rantanen, Santtu: The administrative process of a cluster
- Redondo Anton, J.F: Ad Hoc networks — Design and performance issues, HUT, NetLab
- Rostela, Tuomo: Numbering and routing in a carrier class hybrid network
- Seppänen, Anssi: Tuotekehitysprosessin yhtenäistäminen yritysfuusion jälkeen
- Sirén, Elena: Optical Packet Switching, HUT, NetLab
- Somerkoski, Pauliina: The Reuse of Software in Design of Intelligent Networking Technology, Siemens

- Susitaival, Riikka: Load balancing by MPLS in differentiated services networks, HUT, NetLab
- Talvitie, Jukka: Feasibility study to adapt Lifebelt ideology to object oriented world, TietoEnator
- Tullila, Anssi: Problems in the idea — invention — patent application process in companies in view of applying a patent, Papula Oy
- Tuomaala, Eero: Dynamic frequency allocation with smart antennas in future GSM networks — concepts and performance, Nokia
- Tähtinen, Sami: Communication security of process-oriented integration software, FRIENDS Technology Inc.
- Wu, Kai: Performance study of a SMPP Traffic Generator Tool, Nokia
- Välimäki, Harri: Leimakytkentää hyödyntävien virtuaaliverkkojen vertailu, Sonera
- Väänänen, Kai: Roaming in SIP based UMTS network, Sonera
- Zhou, Wenpeng: Provision and route optimization in differentiated services Networks, HUT, NetLab



## 5 ACTIVITIES

### 5.1 Participation in conferences and meetings

- Nicklas Beijar
  - Med-Hoc-Net 2002 Conference Sardegna, Italy, September 4–6, 2002
- Josè Costa-Requena
  - MobileMan project meeting Pisa, Italy, January 22–24, 2002
  - Interworking 2002 Symposium, Perth, Australia October 13–16
  - 2002 MobileMan project meeting, Pisa, Italy, November 2–6, 2002
- Jorma Jormakka
  - IFIP World Computer Congress, Montreal, Canada, August 23–30, 2002
- Raimo Kantola
  - Opponent in the Dr.Tech. dissertation of Timo Hämäläinen, Jyväskylä University
  - Visit to MacGill University in Montreal and a talk in meeting on Student exchange organized by CIMO and AUCC (Association of Universities and Collages of Canada) Ottawa, Canada, September 22–27, 2002
  - ESF Conference, Al Mare-La Spezia, Italy, October 10–12, 2002
  - EECS Seminar, Berkley, San Francisco, USA, October 16–20, 2002
- Jouni Karvo
  - Networking 2002 Conference, Pisa, Italy, May 19–24, 2002
  - High Performance Switching and Routing 2002 Conference, Kobe, Japan, May 27–31, 2002
  - SPECTS 2002 The Society of Modeling and Simulation International Symposium on Performance Evaluation of Computer and Telecommunications Systems, San Diego, California, USA, July 14–18, 2002
  - WoWMoM 2002, Atlanta, USA, September 23–28, 2002
- Vesa Kosonen
  - SEFI Conference, Firenze, Italia, September 8–11, 2002

- Pasi Lassila
  - Queueing Seminar CWI, Amsterdam, The Netherlands, May 15, 2002
  - EECS Seminar, Berkley, San Francisco, USA, October 16–20, 2002
- Marko Luoma
  - ICQT 2002 International Workshop, Zürich, Switzerland, October 16-18, 2002
  - ENET, Kick-off meeting, Madrid, Spain, October 26–30, 2002
- Eeva Nyberg
  - International Seminar, Telecommunication Networks and Teletraffic Theory, LONIIS, Saint -Petersburg, Russia, January 29 – February 1, 2002
  - GETA Conference, Stockholm, Sweden, January 16–18, 2002
  - Networking 2002 Conference, Pisa, Italy, May 19–24, 2002
- Aleksi Penttinen
  - SPECTS 2002 International Symposium on Performance Evaluation of Computer and Telecommunications Systems, San Diego, California, USA, July 14–18, 2002
  - COST 279 summer school, Darmstadt, Germany, August 24–30, 2002
- Riikka Susitaival
  - COST 279 5th Management committee meeting, Lyngby, Denmark, September 18–22, 2002
- Jorma Virtamo
  - Networking 2002 Conference, Pisa, Italy, May 19–24, 2002

## 5.2 Visits abroad

Professors Raimo Kantola and Jorma Virtamo and senior researchers of Networking Laboratory visited Kungliga Tekniska Högskolan in Stockholm on June 14th.

Other visits:

- Pasi Lassila
  - Visiting researcher, University of Twente, March 1 – July 31, 2002
- Eeva Nyberg

- Visiting researcher, Institut National de Recherche en Informatique et en Automatique - INRIA, France, October 1 – November 30, 2002
- Jorma Virtamo
  - Visiting researcher, France Telecom R&D, Paris, September 16 – November 22, 2002

### 5.3 Foreign visitors in 2002

The laboratory had the honor to enjoy the following visitors:

- Resing, Jacques from The Eindhoven University of Technology, Netherland
- Morozov, Evsey from Russian Academy of Sciences, Petrozavodsk University and Institute of Applied Mathematical Research
- Schulzrinne, Henning from Internet Real-Time Laboratory, Columbia University, USA
- Iversen, Villy B. from Technical University of Denmark, Denmark
- Perkins, Charles from Nokia USA
- Hassan, Mohammad from Indian Institute of Technology, Guwahati, India
- Raman, Shree from Indian Institute of Technology, Guwahati, India
- Gutiérrez, Juan from Universidad Politecnica de Madrid - UPM
- Tormo Mas, Ricardo from Universidad Politecnica de Valencia, Spain
- Lopez, Daniel from EFREI, Paris, France
- Ewers, Frank from Technical University of Berlin, Germany



## 6 PARTICIPATION IN BOARDS AND COMMITTEES

### 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

- Jorma Jormakka
  - Member of the scientific council of the National Defence College
- Jorma Virtamo
  - Member of IFIP Working Group 6.3, Performance of Communication Systems
  - Member of the Technical Program Committee of the International Seminar on Telecommunication Network and Teletraffic Theory, Saint Petersburg, January 29 – February 1, 2002
  - Member of the Technical Program Committee of Networking 2002, Pisa, May 19–24, 2002
  - Member of the Technical Program Committee of the ITC Specialist Seminar on Internet Traffic Engineering and Traffic Management, Würzburg, Germany, July 22–24, 2002

- Chairman of the Organizing Committee for the Sixteenth Nordic Teletraffic Seminar NTS-16, Espoo, Finland, August 21–23, 2002
- Member of the Technical Program Committee of the workshop Quality of Future Internet Services, QoFIS'02, Zürich, October 16–18, 2002
- Member of the Technical Program Committee of Internet Performance Symposium, IPS 2002, Taipei, Taiwan, November 17–21, 2002
- Member of the Board of the Research Foundation of Helsinki Telephone Company

### 6.3 Referee activities

- Samuli Aalto
  - Reviewer for the journal Computer Networks
  - Reviewer for the following conferences: Networking 2002, QoFIS 2002, Infocom 2003, 15th ITC Specialist Seminar (ITCSS-15)
- Esa Hyytiä
  - Reviewer for journal European Transactions on Telecommunications (ETT)
  - Reviewer for the Networking 2002 conference
- Jorma Jormakka
  - Reviewer for the following scientific journals: Transaction on Vehicular Technology, Wireless Personal Communications
- Raimo Kantola
  - Reviewer for journal Computer Communications
- Jouni Karvo
  - Reviewer for the Networking 2002 conference
- Pirkko Kuusela
  - Reviewer for the following conferences: Networking 2002, Infocom 2003
- Pasi Lassila
  - Reviewer for following conferences: Infocom 2003, QoFIS 2002, Networking 2002, 15th ITC Specialist Seminar
- Marko Luoma

- Reviewer for following scientific journals: Elsevier Computer Communications, Electronic Letters
  - Reviewer for following conferences: Infocom 2003, ICC'2003, QofIS'2002
- Eva Nyberg
  - Reviewer for the Networking 2002 conference
- Jorma Virtamo
  - Reviewer for the following scientific journals: IEEE/ACM Transactions on Networking, Performance Evaluation
  - Reviewer for the following conferences: QofIS 2002, IFIP Working Conference on Performance Modelling and Evaluation, IPS2002, Networking 2002 conference



## PUBLICATIONS

- [1] Samuli Aalto, Jouni Karvo, and Jorma Virtamo. Calculating blocking probabilities in multicast loss systems. In *Proc. SPECTS 2002*, pages 833–842, San Diego, CA, July 2002.
- [2] Samuli Aalto and Eeva Nyberg. Flow level models of DiffServ packet level mechanisms. In *Proceedings of the Sixteenth Nordic Teletraffic Seminar, NTS 16*, pages 194–205, August 2002.
- [3] Janne Aaltonen, Jouni Karvo, and Samuli Aalto. Multicasting vs. unicasting in mobile communication systems. In *Proc. WoWMoM 2002*, pages 104–108, Atlanta, GA, September 2002.
- [4] J. F. Redondo Antón. Ad hoc networks — design and performance issues. *Master's thesis*, Helsinki University of Technology, Networking Laboratory series 2002, 2002. Master's Thesis.
- [5] José Costa-Requena, Nicklas Beijar, and Raimo Kantola. Mobility and network management in ad hoc networks. In *IASTED International conference*, Málaga, Spain, 2002.
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- [7] José Costa-Requena, Ignacio Olias Gonzalez, Raimo Kantola, and Nicklas Beijar. Autoconfiguration mechanism for IP telephony location servers. In *6th International Symposium on Communication Networking*, Perth, Australia, 2002.
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- [14] Raimo Kantola. Tutkintojen uudistaminen, näpertelyä. *Statement of opinion*, Helsingin sanomat, 8.9.2002.
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- [16] Jouni Karvo. A study of teletraffic problems in multicast networks. *Doctoral thesis*, Helsinki University of Technology, Networking Laboratory series 2002, October 2002.
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- [21] Eemeli Kuumola, Jacques Resing, and Jorma Virtamo. Joint distribution of instantaneous and averaged queue length in an M/M/1/K system. Technical Report TD(02)22, COST279, May 2002.
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- [36] Riikka Susitaival, Jorma Virtamo, and Samuli Aalto. Load balancing by MPLS in differentiated services networks. Technical Report TD(02)041, COST279, October 2002.
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