

## 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 2001, the laboratory staff published five journal papers and 12 papers in conferences. In 2001, one Doctor dissertation, five Licentiate degrees and 34 M.Sc degrees were awarded to the students of our laboratory.

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<b>1</b>	<b>PREFACE.....</b>	<b>3</b>
<b>2</b>	<b>PERSONNEL 2001 .....</b>	<b>5</b>
2.1	LABORATORY STAFF .....	5
2.2	PART-TIME TEACHERS & ASSISTANTS .....	6
2.3	GUEST LECTURERS.....	6
<b>3</b>	<b>RESEARCH PROJECTS.....</b>	<b>9</b>
3.1	MI <sup>2</sup> TTA - MODELS FOR INTEGRATED INTERNET AND TELECOMMUNICATION NETWORKS TRAFFIC AND ARCHITECTURE .....	9
3.2	OPTICAL ACCESS NETWORKING (OAN).....	10
3.3	COST 279 .....	11
3.4	COM <sup>2</sup> - COMPUTATIONAL METHODS FOR THE PERFORMANCE ANALYSIS OF BROADBAND COMMUNICATION NETWORKS .....	11
3.5	ANALYSIS OF INTERNET CONGESTION AND NETWORK CALCULUS .....	12
3.6	FIT - FUTURE INTERNET: TRAFFIC HANDLING AND PERFORMANCE ANALYSIS .....	12
3.7	USETRAM - USER TRAFFIC MODELLING FOR FUTURE MOBILE SYSTEMS .....	13
3.8	IMELIO - INTERNET MECHANISMS FOR QUALITY AND INTEROPERABILITY .....	14
<b>4</b>	<b>TEACHING.....</b>	<b>17</b>
4.1	KEY FACTS 2001 .....	17
4.2	DEVELOPMENT OF TEACHING.....	17
4.3	THESES .....	19
<b>5</b>	<b>ACTIVITIES .....</b>	<b>25</b>
5.1	PARTICIPATION IN CONFERENCES AND MEETINGS.....	25
5.2	FOREIGN VISITORS IN 2001.....	26
<b>6</b>	<b>PARTICIPATION IN BOARDS AND COMMITTEES .....</b>	<b>27</b>
6.1	UNIVERSITY BOARDS AND COMMITTEES .....	27
6.2	OTHER BOARDS AND COMMITTEES.....	27
6.3	REFEREE ACTIVITIES .....	28
<b>7</b>	<b>PUBLICATIONS .....</b>	<b>31</b>
7.1	NUMBER OF PUBLICATIONS.....	31
7.2	LIST OF PUBLICATIONS.....	31

## 1 PREFACE

The results of the year 2001 presented in this Annual Report show that the steady positive development trend of the previous years continues. The main events of the year include the following:

Professor Raimo Kantola was officially appointed to the professorship he has been holding. Dr. Shyam Chakraborty was appointed as a docent of wireless broadband communications. Many researchers of the laboratory earned academic degrees, including one doctorate and two licentiates. We also obtained a post-doctorate position from the Academy of Finland and a post-graduate position from GETA. The degrees earned by students and Ph.D. students in the laboratory are listed in the report.

At the beginning of year 2002 we will start two large projects: IRoNet and TIEVA. IRoNet, financed mainly 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 of strategic importance to the laboratory. There were other new projects started in the year 2001: Academy project FIT and TEKES projects COST279 and OAN, the latter focusing on optical networks.

Three new courses were first time lectured during the year 2001: S-38.157 Protocol Design, S-38.153 Security of Communication Protocols and S-38.180 Quality of Service in the Internet. The two first mentioned were lectured in English, enlarging our course selection for foreign students.

The laboratory had a development day of research in Sjäkulla with visiting lectures by Professor Erkki Oja and Dr.Tech. Pekka Soininen. There were two social events during the year: a summer trip and the traditional Christmas party, with a very amusing Tiernapoika show. There were also several visits to our laboratory, including a 6 month visit of Col. Liet. Savisalo from the National Defense College and short visits by Professor LeBoudec and Mr. Leeuwaarden.

These events, and the results described in this Annual Report, describe some aspect of the achievements. I would like to add other less concrete matters, which were discussed during the year.

One of the main future problems in the laboratory is that the number of students taking one of the majors of the laboratory has grown fast while finding new professors from the field is difficult. In order to address this problem, the laboratory supported a decrease in the number of students to be admitted. Some alleviation to supervision of Master's Thesis was achieved by a more equal distribution of Thesis supervision among the professors. We are still facing the problem of having too few professors in the near future. One way is to find competent people from outside, another is to get them from the inside. These different alternatives result to different requirements for the Ph.D. education in the laboratory, though this is not fully realized yet.

Concerning the education on the M.Sc. level, we can be relatively satisfied with the present courses. With the Ph.D. education there probably is need for additional efforts. One problem is the relatively narrow orientation of research on only few topics. In this context we must consider the development trends of the telecommunication industry. So far there has been a very fast growth in the field. The challenge in Ph.D. education is to guess the important research areas on a longer time frame.

The research areas of the laboratory have become clearer. We have a research group on traffic issues lead by Professor Virtamo, and another research group on IP routing, traffic classification and voice over IP, lead by Professor Kantola. IRoNet, being a project for three years, will focus research on the interplay of QoS issues and routing in IP and create more cooperation between these groups.

Co-operation between the department and the defence forces has been increased. This concerns us especially because of a joint professorship with the National Defence College. This co-operation will have importance to the development of the Laboratory. A new research area, security issues, is motivated by this setting.

In general, I would say that the concrete results of the year 2001 were comparable, while not better, to the results of the previous years, but clarification of the goals and the means for reaching the goals can be seen as positive signs.

Espoo 5. February.2002      Jorma Jormakka

## 2 PERSONNEL 2001

### 2.1 Laboratory staff

#### Professors and Docents

Jormakka, Jorma	Ph.D., professor, head of laboratory
Kantola, Raimo	D.Sc. (Tech.), professor
Virtamo, Jorma	D.Sc. (Tech.), professor
Chakraborty, Shyam	D.Sc. (Tech.), docent
Kilkki, Kalevi	D.Sc. (Tech.), docent
Pirinen, Aulis	Ph.D., docent
Rahko, Kauko	D.Sc. (Tech.), professor emeritus

#### 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	Specialist teacher

#### Researchers

Aalto, Samuli	Ph.D.
Costa Requena, Jose	M.Sc.
Hyytiä, Esa	Lic.Sc. (Tech.)
Ilvesmäki, Mika	M.Sc.
Karvo, Jouni	Lic.Sc. (Tech.)
Kuusela, Pirkko	Ph.D.
Lassila, Pasi	D.Sc. (Tech.)
Luoma, Marko	Lic.Sc. (Tech.)
Ma, Zhansong	M.Sc.
Nyberg, Eeva	M.Sc.
Penttinen, Aleksi	M.Sc.
Peuhkuri, Markus	M.Sc.
Zhang, Peng	Ph.D.

#### Research assistants and trainees

Antila, Johanna
Beijar Nicklas
Fan, Tyh-Dar
Huttunen, Jari
Ignacio Gonzalez, Olias

Kaikkonen, Sampo  
 Koski, Marjukka  
 Kuumola, Eemeli  
 Leppänen, Risto  
 Navarro Vaello, Moises  
 Paju, Antti  
 Pedros Porres, Ramiro  
 Pulkkinen, Piia  
 Raminez Yebenes, Julio  
 Redondo Antón, Juan  
 Sirèn, Elena  
 Somerkoski, Pauliina  
 Susitaival, Riikka  
 Timonen, Vesa  
 Ventura Agustina, Juan  
 Viipuri, Timo  
 Villanen, Juha  
 Willa, Kirsi  
 Zhang, ChenXin  
 Zhen, Xiaoling  
 Zhou, Wenpeng

## 2.2 Part-time teachers & assistants

Aarnio, Jaakko	S-38.164	Broadband Switching Technology
Kilpi, Risto	S-38.108	Communication Network Architectures
Kyntäjä, Timo	S-38.157	Protocol Design
Miettinen, Petri	S-38.203	Networking Technology, project course
Nieminen, Klaus	S-38.001	Telecom Forum
Pärssinen, Juha	S-38.158	Protocol Design
Poikola, Antti	S-38.203	Networking Technology, project course
Pietiläinen, Antti	S-38.164	Broadband Switching Technology
Ruutu, Jussi	S-38.164	Broadband Switching Technology
Sainio, Sampo	S-38.147	Simulation of Telecommunication Networks
Sipilä, Mari	S-38.108	Communication Network Architectures
Tervonen, Ari	S-38.164	Broadband Switching Technology

## 2.3 Guest lecturers

### S-38.001 Telecommunications Forum

David Bowes	COO	Riot Entertainment Ltd
Rauni Hagman	Director General	Finnish Communications Regulatory Authority
Heikki Huomo	Director	Nokia Ventures Organization
Liisa Kanniaainen	Vice President	Nordea
Antti Kasvio	Research Director	University of Tampere

Klaus D. Kohrt	Dr., Vice President, Wireless Technologies Access and Radio	Siemens AG, Information and Communication Mobile Networks
Pekka Lundmark	Managing Director	Startupfactory Oy
Arvo Mustonen	CEO	Comptel PASSAGe
Mikael Nyberg	Ministerial Adviser	Ministry of Traffic and Communications
Tero Ojanperä	Dr., Vice President, Research, Standardization & Technology	Ipv6
Peter Peters	Dr.	Nokia Mobile Phones
Pirjo Rautiainen	Researcher	University of Tampere
Juha Rytönen	Director	Jippii Group
Mika Sarén	Technology Manager	Radiolinja
Reijo Svento	Managing Director	Ficom Oy
Markku Taulamo	CEO	Futurice



### 3 RESEARCH PROJECTS

#### 3.1 Mi<sup>2</sup>tta - Models for Integrated Internet and Telecommunication networks Traffic and Architecture

Project leader            Jorma Virtamo  
Researchers              Marko Luoma, Markus Peuhkuri

MI<sup>2</sup>TTA was a part of the Finnish contribution to the European COST 263 Action, in which laboratories and research institutes from 12 countries participated. The project, funded by the Academy of Finland, was completed at the end of year 2001. The focus was on traffic management and measurements in the Internet, in particular in the QoS aware Internet. Our belief was from the early beginning that Internet would benefit from the measurement based control architecture. We have devised, together with researchers in the project IMELIO, a control architecture for the next generation Internet. The architecture is based on continuous measurement and computational intelligence. This architecture forms our framework for the next three years period as one of the leading research groups of the NETS program funded by TEKES.

The main milestones during the project were:

- A licentiate thesis - "*Simulation studies of Differentiated Services Networks*". This thesis describes development cycle of DiffServ architecture along with performance analysis of different class / forwarding behaviour combinations. Performance analyses were made with a simulator that was developed as a library for the commercial simulation tool BONEs.
- A draft version of licentiate thesis that is going to be finished during year 2002 - "*Studies of IP traffic*". The main focus in this thesis is the characterization of the impatience of the web users. The user impatience is an important consideration from the point of view of different congestion management schemes. However, relatively little is known about the users' impatience behaviour. Proper caching may reduce the amount of lost work (partially transmitted objects) which is caused by premature disconnection of impatient users. Caching can be used to reduce the delay from the initial request to the arrival of last packet in particular web page.
- A simulation program for the Differentiated Services based Internet environment. This simulator, built as a library for commercial simulation tool BONEs, is able to simulate Assured Forwarding, Expedited Forwarding and Best Effort per hop behaviours along with rate, application and source based classification mechanisms. PHBs were implemented with different schedulers, such as Weighted Round Robin, Processor Sharing and Priority scheduler, and active queue management algorithms, like Random Early Detection and Random In/Out. Source population for simulations include models for FTP, HTTP and VoIP traffic. Models were developed to characterize the behaviour of single and large population of active clients with real TCP/UDP control in individual flows.
- A measurement system for long time scale continuous measurement of the Internet traffic. This system is based on library functions developed in Cooperative Association for Internet Data Analysis (CAIDA). With the help of library

functions and embedded hardware we have been able to capture and analyse traffic with wire speed of 155Mbps. This system has allowed us to explore the real nature of IP traffic in different levels of aggregation. This systems serves as a base platform for our measurement based network control architecture that we are currently developing.

The European COST 263 Action started a new series of workshops, "*International workshop on Quality of Future Internet Services (QoFIS)*". Several members of the Laboratory have served as members of its Technical Program Committee.

### **3.2 Optical access networking (OAN)**

Project leader: Jorma Virtamo  
Researchers: Esa Hyytiä, Elena Sirén

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 industry. 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 light path requests in order to minimize the expected blocking probabilities. During year 2001 methods were developed to obtain quick estimates how different routing and wavelength assignment (RWA) decisions affect the future costs. The consecutive RWA decisions are made using some standard policy. The knowledge of the relative costs of the states allows a policy improvement step but never results on a worse policy. The problem was solved in the Markov decision process framework where importance sampling technique was used to speed up the decision process.

The other research topic focused on optical packet switching. The objective was to study traffic problems emerging in this context and to compare different technical solutions. During year 2001 the optical burst switching (OBS) was given special attention. In OBS the transmitted unit is a short burst of packets. There are many open parameters (e.g. burst length) which can have crucial effect on the final performance. Numerical simulations were used to optimize these parameters and evaluate the performance of OBS network.

### 3.3 COST 279

Project leader: Jorma Virtamo  
Researchers: Jouni Karvo; Pirkko Kuusela; Eeva Nyberg; Riikka Susitaival;  
Eemeli Kuumola; Arijit Ganguly; Johanna Antila; Vesa Timonen

Internet QoS mechanisms are being studied in the project. In particular, attention is paid on the performance of so called SIMA mechanism both at packet and the flow levels. The performance of active queue management (AQM) mechanisms is studied as well. At the network level, the capability of MPLS for traffic engineering is assessed. New computational methods are developed for traffic analysis of multicast networks. Specific research tasks have been the following:

- Analysis of TCP and AQM methods. Simulation based studies have been conducted to validate an analytical model for a population of TCP sources sharing a congested buffer that uses the RED queue management algorithm. As a part of the work, an easy to use simulator has been developed with the ns2 simulation tool for simulating various scenarios. Additionally, ns2 based simulation studies have been conducted to investigate the accuracy of some well-known analytical TCP throughput results.
- Multicast networks. Application of Markov decision processes in the case of dynamic multicast connections has been considered.
- Internet QoS. The project focused on studying Internet QoS through modelling of differentiation mechanisms implemented in DiffServ architectures. More precisely, models were constructed for metering and marking mechanisms at the DiffServ boundary node and forwarding and discarding mechanisms inside the DiffServ node. With these models we were able to study the performance of end-to-end DiffServ proposals such as Assured Forwarding (AF) and Simple Integrated Media Access (SIMA). As performance measure we used fairness of bandwidth division as a function of number of TCP and non-TCP flows.

### 3.4 Com<sup>2</sup> - Computational Methods for the Performance Analysis of Broadband Communication Networks

Project leader: Jorma Virtamo  
Researchers: Samuli Aalto, Jouni Karvo, Pirkko Kuusela, Pasi Lassila,  
Aleksi Penttinen, Elena Siren

Project Com<sup>2</sup> (funded by the Academy of Finland and started in 1998) was completed at the end of year 2001. The aim of the project was to develop computational methods for the performance analysis of broadband communication networks. A program library of the algorithms resulting from the project was also created and maintained. Specifically, the milestones in 2001 were:

- The studies concerning the performance of the TCP congestion control mechanism together with RED buffer management were completed, becoming an essential part of a doctoral thesis.
- The research of multicast networks with dynamic membership was continued. New algorithms using the convolution-truncation approach for calculating blocking probabilities of multi-layer multicast streams were developed. Multi-layer here refers to hierarchical coding of the multicast information streams. In addition, an efficient sampling method for the Monte Carlo simulation of these multi-layer multicast networks was developed using the inverse-convolution approach.
- As a new research topic, packet marking algorithms for congestion pricing were studied. A new marking mechanism based on the expected shadow price was developed.

### **3.5 Analysis of Internet Congestion and Network Calculus**

Project leader: Jorma Virtamo  
Researchers: Pirkko Kuusela

This is a post doc research project funded by the Academy of Finland and started in August 2001. The aim is to utilize mathematical models to analyze common mechanisms used in data transmission and congestion control. As a first research activity the dynamics of a TCP-RED congestion control has been explored to investigate if chaotic elements or behaviour are present.

### **3.6 FIT - Future Internet: Traffic Handling and Performance Analysis**

Project leader: Jorma Virtamo  
Researchers: Vesa Timonen, Johan van Leeuwen

FIT is a 3-year project (2001-2003) funded by the Academy of Finland. The main goal of the project is to deepen the understanding of and to develop new methods for the Internet traffic handling through mathematical modelling and performance analysis of current and future Internet technologies. The first research activities were:

- As a continuation of earlier activities in developing efficient methods to calculate blocking probabilities (that partly characterize the grade of service in networks) inverse convolution method was applied to a Banyan net. In a variance comparison to a static Monte Carlo method, inverse convolution was found to be up to 6700 times more effective.

- Johan van Leeuwen made a 2 month visit during which he studied load balancing in cellular networks. Mobility is a new research area in the laboratory that will be focused more in the future. The study compared the performance of both static and dynamic allocation policies for a simple model of two base stations with overlapping cells.
- Professor Jean-Yves Le Boudec from EPFL Lausanne, Switzerland made a 3 day visit during which network calculus was discussed.

### **3.7 UseTram - User Traffic Modelling for Future Mobile Systems**

Project leader: Jorma Virtamo  
Other researchers: Moisés Navarro Vaello

In the sub-project of the UseTram project, energy constrained routing for multicast traffic in wireless ad hoc networks has been studied. The problem arises, e.g., in the case of a battery powered sensor network. The Flow Augmentation (FA) algorithm, applied by Tassiulas et al. for the unicast problem, was adapted for the multicast case. A new sub-problem is encountered with this approach: one has to determine the minimum cost multicast tree, when the sending costs of the nodes as a function of the transmission power are given. The problem is related to the well-known Steiner tree problem in fixed networks but is, however, different due to the broadcast nature of wireless transmissions. A new algorithm has been developed to find a nearly optimal, low-cost tree. The algorithm uses incremental optimisation. First, one creates a connection along the shortest path from the origin to one of the destination nodes. When this path has been established the cost matrix is modified to reflect the incremental costs, i.e. from each link cost the cost of the already used power level of the sending end of the link is subtracted. With the modified matrix one then finds the shortest path to some other of the destination nodes. This is repeated until all the destination nodes are included in the tree. The algorithm was implemented with Mathematica. Experiments showed that in adding branches to the tree it is most advantageous to proceed in the order of the shortest path distances, starting with the node that is farthest, then adding the path to the one of the remaining nodes that is farthest according to the incremental path cost, and proceeding in similar manner.

### 3.8 IMELIO - Internet MEchanisms for quaLity and InterOperability

Project leader: Raimo Kantola  
Researchers: Mika Ilvesmäki, Peng Zhang, Zhangsong Ma, Sampo Kaikkonen, Piia Pulkkinen, Pauliina Somerkoski, Nicklas Beijar, Jose Costa Requena, Julio Ramirez Yebenes, Wenpeng Zhou, Xiaoling Zhen; Tyh-Dar Fan, Ignacio Gonzalez Olias

It has become a widely accepted vision that the Internet is the future all services networking technology. To realise this vision, we believe that the IP technology has to be enhanced. In September 2000, we started a new project, IMELIO – Internet Mechanisms for quaLity and InterOperability to work on improving the Internet technology and to carry on the work started in IPANA.

Differentiated Services seem to be the most promising way to introduce improved Quality of Service Mechanisms into the Internet. The idea of Differentiated Services has two main implementations: the DiffServ architecture and Multi-Protocol Label Switching with priority bits on the “shim” layer. The architectures allow carrying high quality voice and video among data over the network. DiffServ introduces per hop behaviours (PHBs) - essentially priorities for classes of packets. Based on PHBs the packets are treated differently in the network nodes. This changes the service paradigm of the network and will have wide business implications. Intermediate steps may be needed before DiffServ can be widely deployed.

The Architectures of DiffServ and MPLS are, however, by no means ready. Additional mechanisms for improving quality and network performance need to be studied and introduced. A candidate improvement to the Architecture of quality aware Internet is traffic classification - the idea that all or some of the traffic is classified by the network into background best-effort, interactive and real-time and that each of these classes are assigned different PHBs. This can be seen as a first short step in changing the service paradigm or a basis for assigning traffic to different PHBs per se in the ingress nodes or used as an additional mechanism in a highly loaded DiffServ network to avoid eventual or intermittent quality degradation in the network. Our recent research shows that if users are allowed to arbitrarily map their traffic streams to classes, other users and network efficiency will suffer. If on the contrary, the network makes an intelligent choice in mapping the user traffic to classes, each traffic type can be treated in a similar and efficient manner and as a result, a more fair behaviour and improved efficiency of the network can be achieved. This is a promising indication that network based traffic classification will have a role in production networks in the future.

Another candidate improvement is Class or constrained based routing - the idea that each class or some of the classes could be routed differently from others for the purpose of improving service quality and network performance. A particular problem that could be addressed by routing is avoiding starvation of the lower priority classes on highly loaded links while the amount of high priority traffic increases. The new routing could be applied to flows or classes or be introduced as another background process. In any case, this would change the current shortest path internet routing paradigm. We need to understand what are the potential gains under different conditions and how this could be implemented - a particular complication in implementing alternative routing in the Internet is that currently there is no route pin-down mechanism. MPLS (Multi Protocol Label Switching) is now proposed as a means to retain the existing traffic on the original shortest path while additional network load is diverted to an alternative path - i.e. to achieve route pin-down. Alternative route pin-down mechanisms may also be studied.

While Internet grows in importance and starts to carry voice, before it can replace the Switched Circuit Network in a large scale, it has to become a peer network to the Switched Circuit Network. The SCN does not disappear overnight, maybe it never will - we need to be prepared for a long period of coexistence of the two peer networks. This means that we need to identify the interoperability and service management issues in the hybrid network and solve them before they become problems. In IPANA we identified Numbering and number portability as a key interoperability issue in the hybrid network. IPANA has produced a draft solution to this problem based on loosely synchronised reachability information across multiple administrative domains. In IMELIO we have refined the solution and studied its scalability properties. More specifically, in IMELIO we have specified a new protocol and an architecture for distributing routing information across the hybrid IN/IP telephony network.

Telephony over Internet introduces a new environment for call signaling. New approaches are being introduced, specified and prototyped. At the moment the most important developments are ISUP over IP, Megaco and SIP. We have followed this development, identified and evaluated the fundamental changes in signalling in as much as they may have an impact on the technology base and the business conditions in the industry.

The main results of the project during the year included a Licentiate thesis on traffic classification, six conference papers on routing and traffic classification and an invited talk on Interoperability. A number of thesis works were still ongoing at the end of the year (and are finished at the time of writing this report).



## 4 TEACHING

### 4.1 Key facts 2001

Masters thesis	34
Licentiate thesis	5
Dissertations	1

### 4.2 Development of teaching

A new post graduate research field, Teletraffic Theory, was introduced to the post graduate studies supported by the laboratory.

A new course S-38.180 (Quality of Service in the Internet) was lectured first time. It belongs to the path Computer Networks in the major Telecommunication technologies.

The lecture material of the courses S-38.120 (Telecommunication Switching Technology) and S-38.121 (Routing in Communication Networks) is now available in English.

Problem Based Learning was used on the course S-38.108 (Communication Network Architectures). The name of this course was changed due to co-ordination with a similar course at Department of Computer Science and Engineering.

This is the full list of courses in our curriculum:

#### 4.2.1 *Studia generalia*

S-38.001 Telecommunications Forum (Telecommunications Forum)

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

S-38.105 Principles in Communication Engineering (Tietoliikennetekniikan perusteet)

S-38.108 Communication Network Architectures (Tietoliikenneverkkojen arkkitehtuuri)

#### 4.2.3 *Courses concerning communications and networks*

S-38.180 Quality of Service in Internet (Palvelunlaatu Internetissä)

S-38.191 Corporate Networks (Televerkot yrityksissä)

#### 4.2.4 *Courses on switching and ATM*

S-38.110 Telecommunication Switching Technology I (Tiedonvälitystekniikka I)

S-38.121 Routing in Communication Networks (Reititys tietoliikenneverkoissa)

S-38.164 Broadband Switching Technology (Laajakaistainen välitystekniikka)

#### **4.2.5 Courses on teletraffic theory**

S-38.145 Introduction to Teletraffic Theory (Liikenneteorian perusteet)

#### **4.2.6 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)

#### **4.2.7 Seminars, laboratory works, special assignments**

S-38.117 Seminar on Telecommunications Technology (Teletekniikan seminaari)

S-38.128 Telecommunications Technology, special assignment  
(Teletekniikan erikoistyö)

S-38.133 Laboratory course on Networking Technology (Tietoverkkotekniikan  
laboratoriotyöt)

S-38.138 Networking Technology, special assignment (Tietoverkkotekniikan erikoistyö)

S-38.202 Telecommunications Engineering Project (Teletekniikan projektityö)

S-38.203 Project course on Networking Technology (Tietoverkkotekniikan projektityö)

S-38.300 Thesis Seminar on Telecommunications Technology  
(Teletekniikan diplomityöseminaari)

S-38.310 Thesis Seminar on Networking Technology (Tietoverkkotekniikan  
diplomityöseminaari)

#### **4.2.8 Postgraduate courses**

S-38.030 Postgraduate Course on Networking Technology (Tietoverkkotekniikan  
lisensiaattikurssi)

S-38.130 Postgraduate Course in Telecommunications (Teletekniikan lisensiaattikurssi)

S-38.141 Teletraffic Theory (Teleliikenneteoria)

S-38.143 Queueing Theory (Jonoteoria)

S-38.149 Postgraduate Course in Teletraffic Theory (Teleliikenneteorian lisensiaattikurssi)

S-38.200 Individual Course in Telecommunications (Teletekniikan yksilöllinen opintojakso)

S-38.205 Individual Course on Networking Technology (Tietoverkkotekniikan yksilöllinen  
opintojakso)

S-38.210 Special course in Telecommunications Technology (Teletekniikan erikoiskurssi)

S-38.215 Special course on Networking Technology (Tietoverkkotekniikan  
erikoiskurssi)

S-38.350 Research Seminar on Telecommunications Technology (Teletekniikan  
tutkijaseminaari)

S-38.360 Research Seminar on Networking Technology (Tietoverkkotekniikan  
tutkijaseminaari)

## 4.3 Theses

### 4.3.1 Doctor of Technology

*Pasi Lassila: Methods for performance evaluation of networks: Fast simulation of loss systems and analysis of Internet congestion control*

Performance evaluation of complex modern networks by means of mathematical modelling often results in a situation, where an exact analytical solution poses a hard difficult problem in terms of computational evaluation. In this thesis, two such problems have been studied and a different approach for easing the computational burden has been developed in each case.

The first part of the thesis considers the problem of evaluating blocking probabilities in loss systems, which are often used as models for the call scale behaviour of modern networks. Exact computation of the blocking probabilities is not possible due to the prohibitive size of the state space. Then, one can use simulation to obtain estimates of the blocking probabilities. In the thesis, several importance sampling based methods are presented, of which the inverse convolution approach provides variance reductions surpassing all previously reported results in the literature.

In the second part of the thesis, the problem of congestion control in the Internet is studied. By using various analytical approximations, a novel dynamic model is derived for describing the interaction of between an idealized TCP source population and a RED controlled buffer. Ultimately, the model consists of a set of coupled (delay) differential equations governing the time dependent expectations of the stochastic system state variables. This model is used to explore the dependency of the equilibrium of the system on the parameters of the physical system. Additionally, methods are derived allowing the stability of the system to be analyzed.

### 4.3.2 Licentiate of Technology

*Ilkka Korkiamäki: Assessing the potential of TETRA-system for military use (TETRA järjestelmän sotilaalliset käyttömahdollisuudet) in Finnish*

Military requirements and features of the TETRA-system are studied. The subject is studied from the following points of view: Offered services, technical performance, integration, network management, variability and expandability of the network, tolerance against electronic attack, tolerance against physical attack, information security and availability performance. Military threat is an essential issue in the evaluation.

Results of the thesis show that the TETRA-system is an optimal choice for different kinds of military voice and data applications used in peace time and low level crises including peace support operations and other international activities.

*Esa Hyytiä: Dynamic Control of All-Optical WDM Networks*

In the first part of the thesis a brief introduction to all-optical WDM networks is given. The second part contains a survey of the static routing and wavelength assignment problem, where the problem is described together with some heuristic RWA algorithms. Then in the third part the dynamic routing and wavelength assignment problem (D-RWA) is considered. The problem is approached in the framework of the Markov Decision Process theory. In practice the optimal policy cannot be exactly calculated due to the huge size of the state space, but heuristic algorithms can come still quite close to the optimal policy. The work contains, among other things, a description how the first policy iteration can be applied to D-RWA problem, together with some simulation results. Finally, the fourth part contains a brief survey of the important restoration and protection aspects in all-optical networks.

*Sauli Savisalo: The impact of Information Threat on Information Systems in the Information Society (Informaatiouhan vaikutus tietoyhteiskunnan tietotekniisiin järjestelmiin) in Finnish*

Information threat directs towards business enterprises, research and development, industry, production, political system and even common people. The object can be a financial, a political or a social benefit. It is totally possible, that warfare has also been prepared.

The basis of the taxonomy for attacker and attacks is built in this thesis. Attackers are classified into four groups from the national security's point of view: attackers threatening national security, insiders threatening business enterprise, outsiders threatening business enterprise and hackers. Attacks are classified into three groups; an attack over a network, a local attack and a combined attack over a network and locally. Different features of an attack and attackers have been described in the thesis and classes of attacks and attackers have been associated.

*Mika Ilvesmäki: On the behavior and performance of the packet count flow classifier*

Flow classification is used in the Internet to find and detect flows of packets that can be handled separately from the rest of the traffic. The packet flows may receive different service levels or they may be treated differently in the network. This work studies a flow classification method where the flows are detected by counting packets on flow candidates.

Results show that the number of packets outside of any active flows is relatively small thus reducing the workload of conventional packet forwarding. However, the classified flows are from a large number of different applications and it is doubtful that packet count flow classification may be used to support the introduction of quality of service in the Internet. Furthermore, the candidate table, an essential part of the packet count classifier implementation, forms a significant performance bottleneck because of the size and frequent changes in it.

*Tommi Koistinen: Media processing in Third Generation Mobile Networks*

The thesis presents the current state of IP telephony related signal processing in the 2G and 3G networks. The IP Multimedia Subsystem (IMS) of Third Generation Partnership Project (3GPP) is used as an example of the future development. The media processing elements and the most relevant protocols of the IMS subsystem are overviewed and several new enhancements for the current signal processing applications are proposed. These include a method for exchanging coding capability information over packet based links, an adaptive rate matching scheme for modem handling in gateways, a delay estimation method for echo cancellers operating within packet based interfaces, and a speech enhancement device operating in parameter domain.

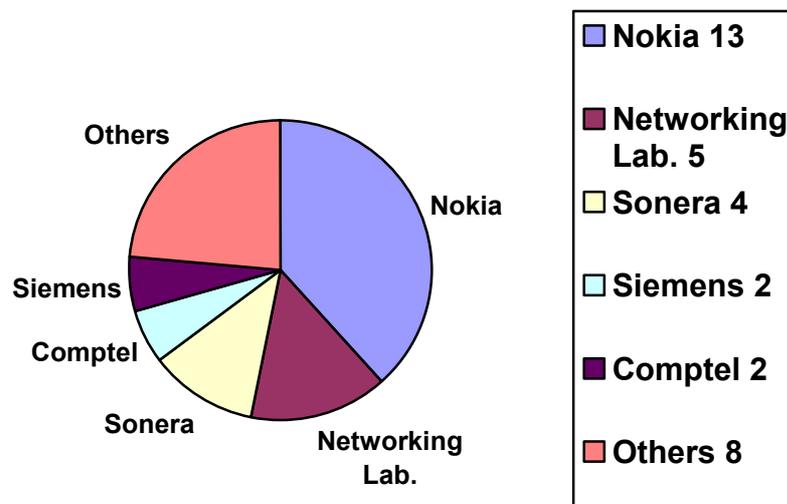
The thesis also identifies new signal processing application areas especially for the network side. The potential of each new application area is assessed in the conclusion. Content adaptation and streaming services are evaluated to offer most of the new signal processing opportunities for the future core network.

**4.3.3 Masters of Science in Telecommunication technology**

J. Seppänen Cygate ESM Oy	Management tools in large scale IP networks, in Finnish (Laajojen IP-verkkojen hallintatyökalut)
M. Mäki Elisa Communications Oyj	Using IP multicast in TV content delivery
J. Selin Nokia Research Center	Media management in IP telephony systems
J. Haapala Nokia Networks	Differentiated services in 3 <sup>rd</sup> generation mobile networks
R. Meres-Wuori Nokia Networks	Techno-economic study on using DSL and wireless routers in an Internet access network
J. Wang Nokia Research Center	WLAN radio access to GPRS network-study of feasible alternatives and a prototype implementation
A.-K. Lindfors Nokia Networks	XML in network management
V. Kuokkanen Nokia Networks	Integration of adaptive message-based master-slave synchronization networks
P. Ginzboorg Nokia Networks	Policy-based route selection in a telephone exchange

P. Niemelä Nokia Networks	Regression testing process in functional testing area
P. Naukkarinen Nokia Networks	Automating the installation of an external specialized resource point in an intelligent networks
T. Rissanen Siemens	Testing of the advanced speech call items in mobile network
R. José Pedrós Porres HUT/Networking lab.	Application of mobile agents in IP QoS networks management
J. Ramírez Yébenes HUT/Networking Lab.	A scalability analysis of the server cache synchronization protocol (SCSP)
M. Nykyri Nokia	Analytical modeling of TCP in software environment
M. Lybeck Nokia Networks	Interworking of multimedia services in third generation mobile networks
T. Mikkonen SSH Comm. Security Corp.	Analysis and deployment of IPSec&PKI environment
H. Luukas Oy L M Ericsson Ab	Hybrid ARQ in WCDMA
A. Penttinen HUT/Networking Lab.	Mathematical models for marking in congestion pricing
S. Paavola Siemens	Project specific modifications in V5.2 interface, in Finnish (Projektikohtaisten muutosten toteuttaminen V5.2-rajapinnassa)
J. Haapala Tecnomen	A video transcoding system
S. Lähde Sonera Oy	GPRS gateway GPRS support node performance measurements and their utilisation in a production network for planning purposes
T. Oikkonen Comptel	Broker platforms in mobile commerce
A.J. Rönkä Sonera Oy	Competitive environment in providing business-to-business mobil value-added services, in Finnish (Liikeasiakkaiden mobiili-lisäarvopalveluiden tarjonnan kilpailu-ympäristö)

J. Ventura Augustina HUT/Networking Lab.	Impact of GPRS on existing GSM services
M. Aroharju Technical Research Center of Finland (VTT)	Service provision in virtual home environment
P. Lahtinen Sonera Oyj	Access transparent personal mobile service
J. Halonen Comptel	Service activation in IP networks - requirements for provisioning mediation system
B. Hjelt Sonera Zed ltd.	Evaluation of Java 2 micro edition based service creation for mobile devices
H. Waris Nokia	Ipv6 provider based auto configuration
A.V. Borrego Nokia	Transporting signalling connection control part messages over IP networks
S. Jormalainen	An architecture for spontaneous networking
J. Mattila TietoEnator	Data warehousing in customer relationship management, in Finnish (Tietovarastointi asiakassuhteiden hallinnassa)
M. Kornatowski HUT / Networking Lab.	Service development using the SPIRITS protocol



*Figure 1. Employers of Masters students 2001*



## **5 ACTIVITIES**

### **5.1 Participation in conferences and meetings**

#### **Samuli Aalto**

Seventeenth International Teletraffic Congress ITC17, Salvador da Bahia Brazil, September 24-28, 2001

#### **Esa Hyytiä**

IASTED International Conference Applied Simulation and Modelling, Marbella Spain, September 4-7, 2001

#### **Mika Ilvesmäki**

ICC2001, Helsinki, Finland, June 11-14, 2001

SPIE's International Symposium ITCOM, Denver Colorado USA, August 19-24, 2001

LCN 2001, Tampa, Florida USA, November 14-16, 2001

#### **Raimo Kantola**

2001 IEEE Workshop on High Performance Switching and Routing (HPSR 2001), 28 May – 1 June 2001, Dallas USA

ICC2001, Helsinki, Finland, June 11-14, 2001

Intelligent Networks 2001, Moscow, Russia, November 20-22, 2001

COST 263 Management Committee Technical Meeting, Namur, Belgium, December 17-18, 2001

#### **Pirkko Kuusela**

Ninth IFIP Working Conference on Performance Modelling and Evaluation of ATM & IP Networks, Budapest, June 27-29, 2001

IFAC Workshop Preprints of Adaptation and Learning in Control and Signal Processing, ALCOSP2001, Cernobbio-Como Italy, August 29-31, 2001

COST 279 Management committee meeting, Lissabon, Portugal, October 8-9, 2001

#### **Pasi Lassila**

Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies, IEEE INFOCOM 2001, Anchorage, Alaska USA, April 22-26, 2001

#### **Marko Luoma**

SPIE's International Symposium ITCOM, Denver Colorado USA, August 19-24, 2001

**Eeva Nyberg**

COST 279 Management committee meeting, Lissabon, Portugal, October 8-9, 2001

**Markus Peuhkuri**

ACM SigCOMM Internet Measurement Workshop, San Francisco USA, November 1-2, 2001

**Jorma Virtamo**

Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies, IEEE INFOCOM 2001, Anchorage, Alaska USA, April 22-26, 2001

Seventeenth International Teletraffic Congress ITC17, Salvador da Bahia Brazil, September 24-28, 2001

**5.2 Foreign visitors in 2001**

Jaroslav Chrvstoliecki, Warsaw University of Technology, Poland, March–May 2001

Grzegorz Grabowski, Warsaw University of Technology, Poland, March–May 2001

Kazi Ahmad, Dr. Ass. Prof. Asian Institute of Technology, Thailand, Sept.14, 2001

Jean-Yves Le Boudec, Professor EPFL-ICA, INN(Ecublens), Switzerland, September 11-13, 2001

Johan van Leeuwen, Eindhoven, Netherlands, October 1 – November 30, 2001

Michel Mandjes, Professor, University of Twente, Netherlands, October 10-13, 2001

Mikael Prytz, Kungliga Tekniska Högskolan, Sweden, October 23, 2001

## **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
- Several memberships in nomination committees for the appointment of professors in Computer Science.

#### **Jorma Virtamo**

- Chairman of the Committee for the nomination proposal for the appointment of the professorship in Telecommunications Engineering (Virantäyttötoimikunta)
- Chairman of the Telecommunications Institute (YVA)

#### **Markus Peuhkuri**

- Member of Committee of Post Graduate School at Department of Electrical and Communications Engineering (Tohtorikoulutoimikunta)

#### **Kirsi Willa**

- Member of Committee for Qualitative Development of teaching at Department of Electrical and Communications Engineering (Opetuksen laatutoimikunta)

### **6.2 Other boards and committees**

#### **Jorma Jormakka**

- Member of the teaching council of the National Defence College
- Member of the scientific council of the National Defence College
- Member of the Program Committee of the Second International Workshop on Quality of Future Internet Services, QofIS 2001, Coimbra, Portugal, September 24-26, 2001
- Member of the Program Committee of IFIP WG 6.7 Smartnet`2002

#### **Raimo Kantola**

- Member of the Supervisory Council in Sonera Oyj until April 2001.

### **Jorma Virtamo**

- Member of IFIP Working Group 6.3, Performance of Communication Systems
- Member of the Program Committee of the Second International Workshop on Quality of Future Internet Services, QofIS 2001, Coimbra, Portugal, September 24-26, 2001
- Member of the Program Committee of the Ninth IFIP Working Conference on Performance Modelling and Evaluation of ATM & IP Networks, Budapest, June 27-29, 2001
- Member of the Technical Program Committee of the Seventeenth International Teletraffic Congress, ITC-17, Salvador da Bahia, Brazil, September 27-29, 2001
- Member of Technical Program Committee of the Internet Performance Symposium, IPS 2001, associated with Globecom 2001, San Antonio, Texas, November 25-29, 2001
- 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
- Chairman of the Organizing Committee for the Sixteenth Nordic Teletraffic Seminar NTS-16, Espoo, Finland, August 21-23, 2002
- Member of the Board of the Research Foundation of Helsinki Telephone Company

### **6.3 Referee activities**

#### **Jorma Jormakka**

- Reviewer for the following scientific journals: IEEE Transactions on Vehicular Technology, IEEE Wireless Personal Communications
- Reviewer for the following conferences: QofIS 2001, IFIP WG 6.7. Smartnet 2002

#### **Raimo Kantola**

- Reviewer for journal Computer Communications

**Jorma Virtamo**

- Reviewer for the following scientific journals: IEEE Journal on Selected Areas in Communications, IEEE/ACM Transactions on Networking, Performance Evaluation
- Reviewer for the following conferences: QofIS 2001, IFIP Working Conference on Performance Modelling and Evaluation, ITC-17, IPS2002, Networking 2002



## 7 Publications

### 7.1 Number of publications

International journal publications	5
Conference presentations	12
Other publications	11

### 7.2 List of Publications

1. Aalto, S., Required Work in the M/M/1 Queue, with Application in IP Packet Processing. *Telecommunication Systems*, 2001. Vol. 16, No. 3-4, pp. 555-560.
2. Hyytiä, E., Dynamic Control of All-Optical WDM Networks. Espoo: Teknillinen korkeakoulu Tietoverkkolaboratorio, 2001, 123 p. (Tietoverkkolaboratorion raporttisarja 1/2001).
3. Hyytiä, E. and Virtamo, J., Optimal Importance Sampling in Markov Process Simulation. *Applied Simulation and Modelling*, Marbella Spain, September 4-7, 2001, pp. 67-72.
4. Hänninen, A., Annual Report 2000. Espoo: Teknillinen korkeakoulu / Tietoverkkolaboratorio, 2001, 27 p. (Tietoverkkolaboratorion raporttisarja).
5. Ilvesmäki, M. and Kaikkonen, S., The Length of Measurement Period to Determine the Application Profile for Traffic Classification in the Internet. The IEEE International Conference on Communications, ICC2001, Helsinki Finland, June 11-14, 2001, pp. 1851-1855.
6. Ilvesmäki, M. and Luoma, M., On the capabilities of application level traffic measurements to differentiate and classify traffic. SPIE's International Symposium ITCOM, Denver Colorado USA, 19-24 August, 2001, pp. 233-242.
7. Ilvesmäki M., On the behaviour and performance of the packet count flow classifier. Espoo: Teknillinen korkeakoulu Tietoverkkolaboratorio, 2001, 56 p. (Teknillinen korkeakoulu Tietoverkkolaboratorion raporttisarja 4/2001).
8. Jormakka, J. Grgic, I. and Sirus, V., Methods for Monitoring, Controlling and Charging QoS in IP Networks. *Teletronikk*, Special Issue on Internet Traffic Engineering, 2001, No. 2/3, pp. 269-286.
9. Kantola, R., IP Telephony protocols, architectures and issues. Espoo: Teknillinen korkeakoulu Tietoverkkolaboratorio, 2001, 115 p. (Teknillinen korkeakoulu Tietoverkkolaboratorio 2/2001).
10. Kantola, R. Costa Requena, J. and Beijar, N., Interoperable routing for IN and IP Telephony. *Computer Networks*, 2001. Vol. 35, pp. 597-609.
11. Kantola, R., Laajakaistaverkko jokaiseen kotiin. *Helsingin Sanomat*, 2001. No. 21.11., p. 3.

12. Karvo, J., Martikainen, O., Virtamo, J. and Aalto, S., Blocking of Dynamic Multicast Connections. *Telecommunication Systems*, 2001, Vol. 16, No. 3-4, pp. 467-481.
13. Karvo, J., Aalto, S., Virtamo, J., Blocking probabilities of two-layer statistically indistinguishable multicast streams. *Seventeenth International Teletraffic Congress ITC17*, Salvador da Bahia Brazil, September 24-28, 2001, pp. 769-779.
14. Kuusela, P., Lassila, P., Virtamo, J. and Key, P., Modelling RED with Idealized TCP Sources. *9th IFIP Working Conference on Performance Modelling and Evaluation of ATM & IP Networks (IFIP ATM & IP 2001)*, Budapest, Hungary June 27-29, 2001, pp. 155-166.
15. Kuusela, P., Lassila, P. and Virtamo, J., Stability of TCP-RED Congestion Control. *Seventeenth International Teletraffic Congress*, Salvador da Bahia Brazil, December 2-7, 2001, pp. 655-666.
16. Kuusela, P., Ocone, D. and Sontag, E.D., Remarks on the sample complexity for linear control systems identification. *Adaptation and Learning in Control and Signal Processing, ALCOSP2001*, Cernobbio-Como Italy, 29-31 August, 2001, pp. 431-436.
17. Lassila, P., Karvo, J. and Virtamo, J., Efficient Importance Sampling for Monte Carlo Simulation of Multicast Networks. *Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies, IEEE INFOCOM 2001*, Anchorage, Alaska USA, 22-26 April, 2001, pp. 432-439.
18. Lassila, P., *Methods for Performance Evaluation of Networks: fast Simulation of Loss Systems and Analysis of Internet Congestion Control*. Espoo: 2001. 196 s. (Teknillinen korkeakoulu, Tietoverkkolaboratorio Tietoverkkolaboratorion raporttisarja 3/2001).
19. Leewaarden, J., Aalto, S. and Virtamo, J., Load balancing in cellular networks using first policy iteration. Espoo: Teknillinen korkeakoulu, Tietoverkkolaboratorio, 2001, 18 p.
20. Luoma, M. and Ilvesmäki, M., Measurement based traffic classification in Differentiated Services. *SPIE's International Symposium ITCOM*, Denver Colorado USA, 19-24 August, 2001, pp. 79-90.
21. Ma, Z., Zhang, P. and Kantola, R., Influence of Link State Updating on the Performance and Cost of QoS Routing in an Intranet. *2001 IEEE Workshop on High Performance Switching and Routing (HPSR2001)*, Dallas USA, May 29-31, 2001, pp. 375-379.
22. Nyberg, E., Aalto, S. and Virtamo, J., Relating flow level requirements to DiffServ packet level mechanisms. Espoo: 2001, 15 p (COST279 TD(01)04).
23. Penttinen, A. and Virtamo, J., Robust Adaptive Capacity Allocation Algorithm. *Seventeenth International Teletraffic Congress ITC17*, Salvador da Bahia Brazil, September 24-28, 2001, pp. 223-231.
24. Peuhkuri, M., A Method to Compress and Anonymize Packet Traces. *First ACM Sigcomm Internet Measurement Workshop*, San Francisco, USA, November 1-2, 2001. San Francisco, USA 2001, pp. 257-260.

25. Rummukainen, H. and Virtamo, J., Polynomial Cost Approximations in Markov Decision Theory Based Call Admission Control, IEEE Transactions on Networking, Vol. 9, No. 6 (2001), pp. 769-779.
26. Ventura A., Impact of GPRS on Existing GSM Services. Espoo: Teknillinen korkeakoulu Tietoverkkolaboratorio, 2001, 89 p. (Tietoverkkolaboratorion raporttisarja 5).
27. Willa, K., Sähkö ja data samasta töpselistä. Tietokone, 2001, No. 9, p. 30.
28. Willa, K., Uusitupa, Seppo Tietoliikenneaapinen, Teletekniikkaa ymmärrettävästi. (4). Espoo 2001, Otatieto, 216 p.