Laboratory of Telecommunications Technology

ANNUAL REPORT 1999

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PREFACE

The last year of the 20th century was for the Laboratory of Telecommunications Technology both a year of continuous development and growth but also a year of some important changes.

The laboratory was run by the three year old team of professors Raimo Kantola, Timo Laakso, and Jorma Virtamo. Prof. Timo Laakso, however, took a leave of absence from the office for the second half of the year, and Ramin Baghaie was nominated as an acting professor for that period. Prof. Jorma Jormakka was nominated, starting from January 1, 2000, to the new Chair of Communications Engineering, a shared Chair between the HUT and the National Defense College, with the specific scope of data communication protocols, software, and services.

The internationalization of the laboratory proceeded rapidly. Longer visits took place both by researchers from other countries in our laboratory and by our researchers in Universities abroad. Three Master's theses were completed by students from Spain. The recruitment of foreign staff continued, including a post doc researcher from China. An important milestone was the start of the Master's Programme, with prof. Raimo Kantola acting as the head of the programme. Some 50 students were enrolled in this programme in Fall 1999.

In the area of teaching, other notable events were e.g. the Telecommunications Forum, organized for the third time with an ever increasing success. In the study year 1999-2000, two majors were offered. In addition to the existing Telecommunications Technology major, the major in Teletraffic Theory was created. The courses provided by the laboratory were developed, and one course was given in English as part of the Master's programme. The textbook "Tietoliikenneaapinen" by Seppo Uusitupa and Kirsi Voipio was published early 1999, and was later given the "Textbook of the Year" award by HUT. In addition the booklet "How to write a diploma thesis" by Timo Laakso became ready for a widespread use. The laboratory was actively involved in the development of the two new degree programmes of the department of ECE as well.

At the end of the year, part of the laboratory moved to a temporary location due to the plans to enlarge and renovate the department building. A further partial move is foreseen at the end of 2000, when hopefully the temporary arrangements will be over and the laboratory can continue to work in a stable environment.

An important change took place at the end of the year, when it was decided that the Chair held by Prof. Timo Laakso, and his whole research group, would move to the Laboratory of Signal Processing and Computer Technology in the beginning of year 2000. The decision was motivated by the desire to make the research and teaching profiles of the laboratories clearer. It is our belief that this change, in the long run, will benefit both laboratories and make them better prepared to meet the challenges of the future.

These and other developments in 1999 are described in more detail in this Annual Report.

Jorma Virtamo

1 INTRODUCTION

1.1 General

The process of filling the two new Chairs, which were established in the preceding year, was started early 1999. After an initial round intended to find interested candidates, it was decided to proceed with the process for one of the Chairs, a shared Chair between the HUT and the National Defense College. Finally, this lead to the appointment of prof. Jorma Jormakka, formerly with the Lappeenranta University of Technology, to the Chair of Communications Engineering for a five year term starting from 1.1.2000. The specific scope of the new Chair was defined to be data communication protocols, software and services.

Internationalization of the laboratory continued by visits of outside experts in the laboratory and visits by our researchers in other laboratories abroad. The longer visits by Prof. Vinod Sharma from Bangalore, India, and Mr. Attila Vidács, Ph.D. student form Budapest, Hungary, already started in 1998, continued but took end by the middle of the year. Dr. Zhang Peng from China joined the IPANA project in August to spend a post doc period in the laboratory. Dr. Samuli Aalto made a six months visit to EURANDOM, a new institute at the Eindhoven University of Technology devoted to studies of stochastic phenomena and their applications. Mr. Stefan Werner visited the Signal Processing Laboratory at the Federal University of Rio de Janeiro for a period of 11 months.

In addition, three Master's theses by Spanish students were also de facto completed in the laboratory during the year.

An important restructuring decision of the Laboratory of Telecommunications Technology was taken at the end of the year, when it was agreed that the Chair held by Prof. Timo Laakso, as well as his research group, would move to the Laboratory of Signal Processing and Computer Technology in the beginning of year 2000. This move will make the research and teaching profiles of the laboratories more streamlined and thus better enables the development of the respective laboratories. From the practical point of view, the separation will be gradual, as the research group will for the present stay in the premises of the Laboratory of Telecommunications Technology.

1.2 Research

As to the external framework, this year mostly represented a steady continuation of the projects already in progress in 1998:

The IP/ATM Network Architectures (IPANA) project continued for the third year, with two subprojects: IP Switching and IP Voice. In IP switching, research on traffic classification continued. Important extensions were multi-class classification and using packet interarrival times for classification. We now see the use of traffic classification to be connected with the introduction of Differentiated Services. Class based routing was started as a new topic under IP switching. The first result was the development of a Quality of Service Routing Simulator supporting routing

simulations for the Integrated Services Internet. In IP Voice, the development of the protocols for the Numbering and Routing Infrastructure for the hybrid packet and circuit switching network (SCN) was continued. We have now formulated our goal to be the development of a routing information testbed for the IP/SCN network. In addition we continued building our competence in IP based telephony signalling.

In the area of traffic theory and engineering, the project Mitta, funded by the Academy of Finland was finished at the end of 1998, and a new follow-up project Mi^{2}tta was started in 1999. Otherwise, the work continued in the projects COST 257 and Com^2. Two major achievements in these projects were the development of an algorithm for exact calculation of end-to-end blocking probabilities in multicast networks, and the development of an nearly optimal importance sampling method, which allows a speed-up by several orders of magnitude in the Monte Carlo estimation of the end-to-end blocking probabilities in multiservice networks. Good progress was also made in the studies of optimal routing methods and related problems both in ordinary multiservice networks and in WDM networks. A new approach for analyzing the behavior of RED buffer management scheme was also developed.

The research in signal processing in communications continued in two TEKES funded projects. The VDSL project has concentrated on capacity analysis of practical connections and on network design aspects. The WCDMA research has focused on design of adaptive receiver algorithms for 3rd-generation systems, where cooperation with the Federal University of Rio de Janeiro, Brazil has been active, in the form of mutual visits.

1.3 Teaching

Preparation for the new Master's Programme in Telecommunications was continued and the programme was started in fall 1999 with some 50 students with B.Sc. background enrolled. The programme, jointly organized by the Department of ECE and the Department of Computer Science and Engineering, is the first degree programme at Helsinki University of Technology for English speaking foreign students with the objective of increasing the number of M.Sc. degrees awarded to foreign students. Currently, the programme provides majors in Telecommunications Software and in Radio Communications. The course 38.145, Introduction to Teletraffic Theory, was produced in English specifically for the Master's Programme.

Telecommunications Forum, the Studia Generalia on hot topics in Telecommunications, was organized for the third time. This year the course attracted more students than ever before. The course has firmly established itself as the event of the fall term.

In 1999, the old Telecommunications Technology major, with different paths, was split into two separate majors. The new offspring is the major in Teletraffic Theory, and Jani Lakkakorpi, who worked as a research assistant in the laboratory, was the first student to receive the Master's degree with this major.

The book "Tietoliikenneaapinen" (The ABC of Telecommunications) by Seppo Uusitupa and Kirsi Voipio, was published in the beginning of the year. The book has been a success, and it was later given the "Textbook of the Year" award by HUT.

Timo Laakso's booklet "How to write a diploma thesis" was also finalized and released for a widespread use within the department. The booklet focuses on mastering the writing process of a thesis. It is written in an easy style, giving many useful hints on how to proceed with the work and how to avoid getting stuck in the case of obstacles. It will certainly be found useful by students and supervisors alike.

In addition, efforts were directed in improving the existing material for many of the laboratory's courses.

1.4 Departmental Activities

A decision of dividing the current degree programme of the department of ECE into two separate programmes, one of them being the programme of Telecommunications Technology, was taken and approved by the Ministry of Education towards the end of the year. The new degree programme structure will be adopted already for the admission of new students in 2000. To this end, the planning of the contents and detailed structure of the programme was started.

During the year, it became clear that the plans of the ECE department for the enlargement of the current department building required the removal of part of the laboratory to a temporary location. A further partial move is foreseen at the end of 2000. The process of planning the new premises and the temporary location, as well as planning the removals and relocation of the people, disturbed a steady operation of the laboratory to some extent. We hope, however, that at the end of year 2000, the temporary arrangements will be over, and the laboratory can continue to work in a stable way in ever better premises.

1.5 International co-operation

Samuli Aalto visited EURANDOM as a Research Fellow for a half-year (1.1.-1.7.1999). EURANDOM is a novel European research institute for the study of stochastic phenomena, located on the campus of Eindhoven University of Technology in the Netherlands. During the visit S. Aalto participated in the Stochastic Networks project led by Professors Boxma and Wessels, continuing the studies on stochastic fluid queues and batch service queueing systems he had started in his PhD Thesis. During his visit S. Aalto gave four presentations (two in EURANDOM, one in CWI, and one in the University of Twente). S. Aalto also attended the 16th International Teletraffic Congress (ITC-16) in Edinburgh in June and three workshops arranged in the Netherland.

Stefan Werner visited the Signal Processing Laboratory at the Federal University of Rio de Janeiro during the period 2.2. - 10.12.1999. The Signal Processing Laboratory is the Centre of Excellence in signal processing accredited by the Brazilian council for research and development. During the visit S. Werner cooperated with Prof. Diniz and Prof. Campos in the area of low-complexity adaptation algorithms.

1.6 Other Laboratory Activities

Development discussions, now recommended for general use within the University, and adopted as a standard practice in the laboratory already three years ago, were continued. A development day, with the participation of the whole laboratory staff, was held in Sjökulla in May. The theme of the day centered around the question of how to make our research work more productive and goal oriented. An invited speaker was Prof. Mikko Paalanen, the head of the Low Temperature Laboratory.

A showcase display of the history and development of the telecommunications technology and telephony was planned and built. The architects behind this demonstration were Kirsi Voipio and Mari Sipilä, a summer trainee. The showcase is placed in the main corridor of the department close to the premises of the laboratory where it continuously attracts the attention of students and visitors.

Some recreational events were also arranged during the year. One of the most memorable ones was the church boat trip made under very favorable weather conditions in June to a nearby island.

Fig. 1. The church boat trip.

1.7 Key facts 1999

Masters thesis	45
Lic.Tech. thesis	2
International journal publications	5
Conference presentations	24
Other publications	16

2 PERSONNEL

2.1 Laboratory staff

Baghaie, Ramin	Lic.Sc. (Tech.), professor
Kantola, Raimo	D.Sc. (Tech.), professor
Kilkki, Kalevi	D.Sc. (Tech.), docent
Laakso, Timo	D.Sc. (Tech.), professor
Pirinen, Aulis	Ph.D., docent
Rahko, Kauko	D.Sc. (Tech.), professor emeritus
Virtamo, Jorma	D.Sc. (Tech.), professor, head of laboratory
Aalto, Samuli	Ph.D., senior researcher
Beijar Nicklas	Research assistant
Brax, Veikko	M.Sc., research scientist
Costa Requena, Jose	M.Sc., research scientist
Erke, Tapio	Laboratory engineer, on leave of absence
Espigares, Inmaculada	M.Sc., research scientist
Gyasi-Agyei, Amoakoh	M.Sc., research scientist
Haapala, Juho	Research assistant
Hietala, Petri	Laboratory technician
Hlinovsky, Jan	Research assistant
Hyytiä, Esa	M.Sc., research scientist
Hänninen, Arja	Department secretary
Ilvesmäki, Mika	M.Sc., senior research scientist
Insa Hernandez, Richardo	research assistant
Kaikkonen, Sampo	research assistant
Karttunen, Petri	M.Sc., research scientist
Kettunen, Kimmo	M.Sc., senior research scientist
Kosonen, Vesa	M.Sc., research scientist
Kuusela, Pirkko	Ph.D., senior research scientist
Lakkakorpi, Jani	M.Sc., research assistant
Lassila, Pasi	Lic.Sc. (Tech.), research scientist
Lindfors, Anna-Kaisa	Research assistant
Lemetyinen, Mirja	Department Secretary
Liu, Yaohui	M.Sc., research scientist
Luoma, Marko	M.Sc., senior research scientist
Ma, Zhangsong	Research assistant
Marjamäki, Harri	Research assistant
Mäntylä, Harri	M.Sc., research scientist
Nieminen, Klaus	Student adviser
Nupponen, Esko	Senior laboratory supervisor
Nyberg, Eeva	M.Sc., research scientist
Peuhkuri, Markus	M.Sc., senior research scientist
Pitkäniemi, Kimmo	Research assistant
Renko, Jari	M.Sc., research scientist
Rummukainen, Hannu	Research assistant

Suominen, Jukka	Research assistant
Sipilä, Mari	Research assistant
Syväsalmi, Sari	Secretary
Uusitupa, Seppo	Lic.Sc. (Tech.), senior engineer
Voipio, Kirsi	Research assistant
Vidács, Attila	M.Sc., research scientist
Werner, Stefan	M.Sc., research scientist
Zhang, Peng	Ph.D., research scientist

Fig. 2: The personnel of the Laboratory of Telecommunications Technology.

2.2 Part-time teachers & assistants

Kati Ahvonen	S-38.202	Telecommunications Engineering Project I
Jaakko Aarnio	S-38.164	Broadband Switching Technology
Reijo Juvonen	S-38.164	Broadband Switching Technology
Jorma Lilleberg	S-38.220	Postgraduate course in Signal Processing in Telecommunication
Petteri Mannersalo	S-38.145	Introduction to Teletraffic Theory
Petteri Mannersalo	S-38.149	Postgraduate Course in Teletraffic Theory
Jukka Mononen	S-38.128	Telecommunications Technology, special assignment
Ilkka Norros	S-38.149	Postgraduate Course in Teletraffic Theory
Antti Pietiläinen	S-38.164	Broadband Switching Technology
Ari Tervonen	S-38.164	Broadband Switching Technology

2.3 Guest lecturers

S-38.001 Telecommunications Forum

Ala-Pietilä, Pekka	President	Nokia
Eloholma, Tero	Director	Siemens Business Services
Johannesdahl, Harri	Managing Director	Saunalahti
Karpakka, Jari	Director	Helsinki Telephone Corporation, Kolumbus services
Keskiivari, Pekka	Director	Sonera Mobile Communications
Kilkki, Kalevi	Principal Scientist	Nokia Research Center
Laaksonen, Tero	President	Telia Finland
Paajanen, Reijo	Senior Vice President	Nokia Wireless Bus Comms
Siilasmaa, Risto	President, CEO	Data Fellows
Valtonen, Mato	General Director	WapIT

S-38.191 Corporate networks

Lars Arnkil	Jukka Hokkanen	Jyrki Laine
Matti Hilli	Heikki P S Leivo	Matti Lahti
Lauri Halme		

3 RESEARCH PROJECTS

3.1 Mi^{2}tta - Models for Integrated Internet and Telecommunication networks Traffic and Architecture

Project leader	Jorma Virtamo
Researchers	Marko Luoma, Markus Peuhkuri

MI^{2}TTA is part of the Finnish contribution to the European COST 263 Action, in which laboratories and research institutes from 12 countries participate. The research is funded by the Academy of Finland. The project focuses on issues of traffic management and measurements in the Internet, particularly in the QoS aware Internet.

The project has so far devised:

- A flexible, non-intrusive, measurement system for a long time scale continuos measurement of Internet traffic. This system has ability to do analysis and to capture traffic for more than a week in a single sample. This has been possible by implementing a novel compression mechanism for data representation, with a minimal amount of lost information.

  The data obtained using this tool has been extensively used in other projects: Com^2, COST257, and IPANA.

- A simulation model for the Differentiated Services based Internet environment. This simulator is able to simulate Assured Forwarding, Expedited Forwarding and Best Effort traffic classes implemented with Weighted Round Robin, Processor Sharing and Priority scheduling. The simulator is build on the commercial simulation tool - BONeS.

3.2 Radio Interface and Network Design Techniques in 3rd-generation radio systems (RAVE)

Project leader	Timo Laakso
Researchers:	Ramin Baghaie, Petri Karttunen, Kimmo Kettunen, Stefan Werner

This is a two-year project of the Institute of Radio Communications (IRC). The IRC was established in 1993 to coordinate research on radio communications by several laboratories of the department. The research is funded by TEKES and industry partners including Nokia, Sonera, and Helsinki Telephone Company. The RAVE project has focused on new mobile communications systems and it divides into several subprojects. Our subproject is Region B: Radio interface and algorithms, which further divides into the following projects of our laboratory:

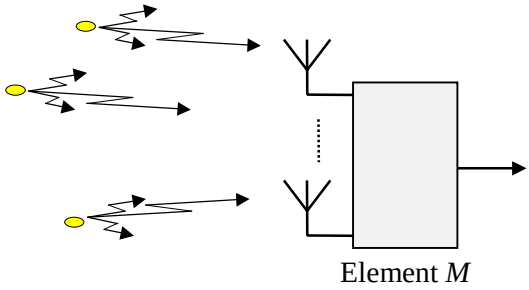

Fig. 3. Multiple antenna-element receiver enables the increase in the system capacity of the future WCDMA telecommunication systems by employing clever adaptive array processing algorithms.

3.2.1 User tracking systems

Researcher: Petri Karttunen

This subproject has focused on the development of fast and robust user tracking algorithms for a base station in the wideband code division multiple access (CDMA) receivers with multiple antenna elements. Methods for mobile user tracking systems should provide fast tracking capability and small parameter estimation errors at low hardware complexity.

The conventional gradient based least mean squared (LMS) adaptive algorithm was employed for the tracking system for which the performance was improved by the developed adaptive step size method. Furthermore, the conjugate gradient based tracking method was analysed, and a simplified gradient based high-resolution noise subspace approach was developed for user tracking.

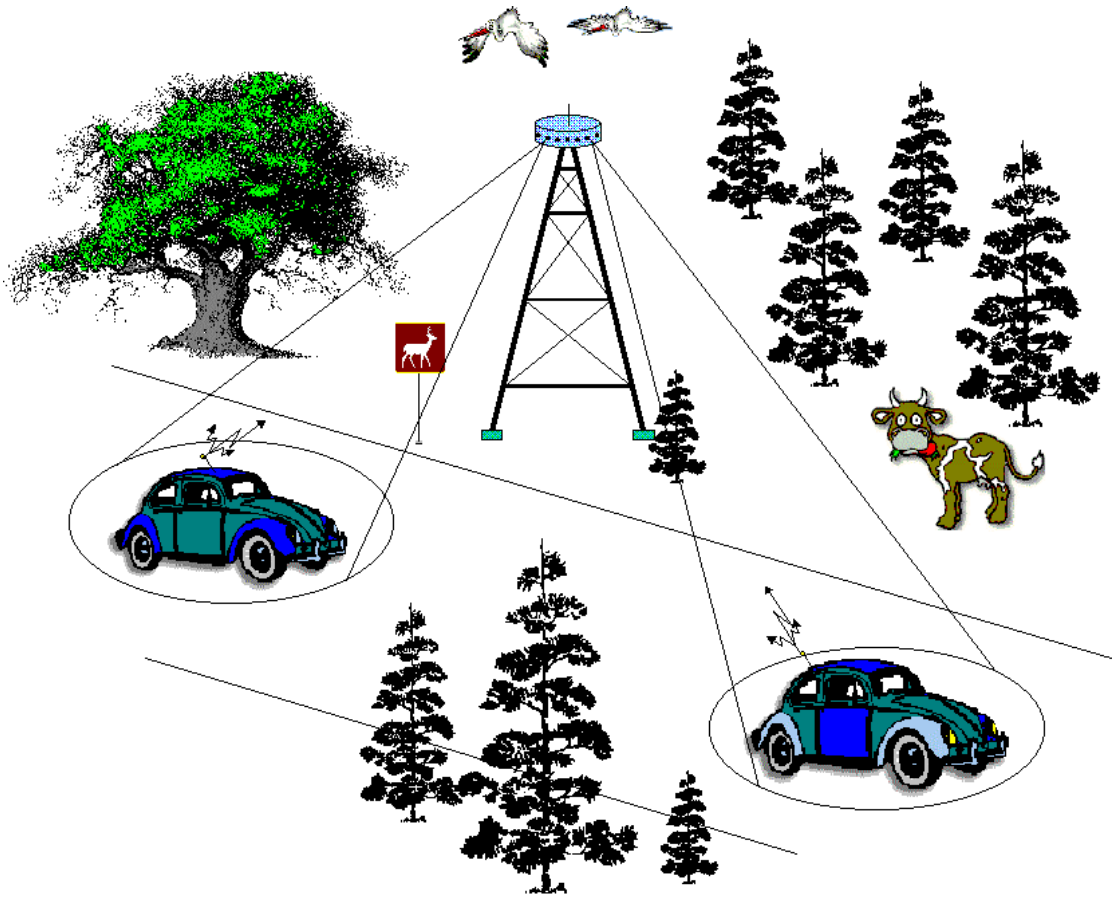

Fig. 4. Illustration of a base station antenna working in the beamforming mode in a rural area.

3.3 Adaptive detection for multiple-antenna CDMA systems

Researchers: Stefan Werner, Paulo Diniz, Jose Apolinario, Marcello de Campos

Adaptive interference suppression is of importance in the wideband CDMA mobile receiver.

The demand on robust and low-complexity algorithms is of interest to reduce the power consumption at the receiver. To speed up the convergence of the standard least means square (LMS) algorithm at low additional complexity, the binormalized data-reuse LMS (BNDR-LMS) algorithm can be used. In addition, low misadjustment error can be attained by utilizing the concept of set-membership filtering (SMF). The SMF only executes a coefficient update when the output estimation error exceeds the specified limits, which requires fewer computations and lower misadjustment error.

This project has been carried out in cooperation with Prof. Paulo Diniz's group at the Federal University of Rio de Janeiro whose expertise is in the field of adaptive algorithms. Prof. Diniz himself as well as his colleagues Jose Apolinario and Marcello de Campos have contributed in the project during their visits to our laboratory in 1998 and 1999.

3.3.1 Implementation of fast algorithms for multiple-antenna CDMA systems

Researcher: Ramin Baghaie

This project addresses the methodologies needed to design VLSI circuits for systems that require higher throughput or lower power consumption. This is of great importance when implementing mobile communication systems. Some of the techniques that are presented in this project are applied to the DSP algorithms needed in the previous subprojects.

The first part of this project considers high-level algorithm transformation techniques such as the look-ahead (LA), relaxed look-ahead (RLA), and strength reduction (SR). For the pipelined implementation of adaptive mobile receiver the LA and RLA techniques have been utilized. As a result, higher throughputs or lower power consumption were achieved. The second part of this project addresses several high-level architectural transformations that can be used to design families of architectures for a given algorithm. These transformations include pipelining, retiming, unfolding, and array processor design. Pipelined DSP algorithms allow us to tradeoff speed, power, and area during the course of VLSI implementation.

3.3.2 Multiuser receivers and channel coding

Researcher: Kimmo Kettunen

The classical multiuser receiver algorithms of Verdu, Varanasi and Aazhang, et al. have been implemented completely without error-correction coding which is assumed to be separate. However, it is known that better results in terms of bit error rate can be obtained by considering them in the same process. This project addresses the problem of joint detection and decoding in a multiuser wideband CDMA receiver. Iterative techniques have been investigated which implement interference cancellation type detection and iterative channel decoding in an alternating manner. Cooperation with prof. Aazhang’s group at the Rice University, Houston, USA, was initiated by Mr. Kettunen’s 3-week visit there in May 1999.

3.4 Fast Digital Subscriber Line (DSL) technologies in broadband transmission

Project leader: Timo Laakso
Researchers: Amoakoh Gyasi-Agyei, Yaohui Liu, Harri Mäntylä

This 3-year project started in 1998 and is carried out together with prof. Markku Renfors' group in the Telecommunications laboratory of Tampere University of Technology. It is funded by TEKES and industrial partners (Nokia Telecommunications, Tellabs, Helsinki Telephone Company, and Tampere Telephone Company). The main objective of the research is to develop technology for the reuse of old copper telephone wiring for multi-megabit transmission using advanced signal processing techniques.

3.4.1 Channel measurements and modelling

Researcher: Yaohui Liu

In this project, the telephone line measurements carried out in Tampere are analysed. The focus is on interference measurements and modelling and in capacity analysis of connections. Special attention has been paid to radio frequency interference (RFI) caused by radio amateur transmissions. RFI has been found to be one of the most problematic disturbances for VDSL transmission, due to its coupling in indoor telephone wirings.

3.4.2 Design of pulse shaping filters

Researcher: Amoakoh Gyasi-Agyei

This subproject focuses on pulse shaping filter design for CAP/QAM type line code. Efficient FIR filter design techniques employing symmetric coefficients have been studied. Furthermore different frequency allocation alternatives for the use in the single-carrier transmission have been investigated.

3.4.3 Design of VDSL networks

Researcher: Harri Mäntylä

Different schemes for implementing the subscriber networks are studied. The basic issue is how close to the subscribers the optical fiber should be brought and what kind of network architectures should be utilized.

3.5 Adaptive signal processing algorithms for 3rd-generation mobile communication technology (ASPA)

Project leader: Ramin Baghaie
Researchers: Ricardo Insa Hernandez, Kimmo Kettunen

In this project, practical implementations of the Gram-Schmidt Conjugate Direction and Conjugate Gradient algorithms were studied and compared. We illustrated that although theoretically the CG algorithm must converge in at most N steps, in practice for large $\mathbf{R}$ it may not happen. As a result, due to round-off errors different resetting schemes and more iterations were required. On the other hand, we demonstrated that the GSCD method always converges at most in N steps. Furthermore, the fixed-point implementation of the above mentioned algorithms were studied and presented. For more realistic results, the algorithms were applied to a multiuser detection scheme in a DS-CDMA system. In these simulations, for different number of users, different number of iterations and different wordlengths the MSE errors were calculated.

3.6 Implementation of real-valued discrete transforms via algebraic integers quantization

Researchers: Ramin Baghaie, Vassil Dimitrov

In this project, we have focused on a novel approach for computing real-valued discrete transforms such as the discrete cosine transform (DCT) and the discrete Hartley transform (DHT). The approach is based on the algebraic integers encoding scheme. With the aid of this scheme, an error-free representation of the *cos*, *sin*, and *cas* functions becomes possible. For further complexity reduction, different approximation methods were presented. Furthermore, for the implementation of these algorithms a fully pipelined systolic architecture with $O(N)$ throughput was proposed.

3.7 COST 257

Project leader: Jorma Virtamo
Researchers: Samuli Aalto, Esa Hyytiä, Eeva Nyberg, Jari Renko

COST 257 is a joint project between the Laboratory of Telecommunications Technology at HUT and VTT Information Technology. It represents the Finnish contribution to the European COST 257 Action, in which laboratories and research institutes from 18 countries participate. The research is mainly funded by TEKES with the support of Nokia Telecommunications and Sonera. The research focuses on developing models and methods for the performance analysis of telecommunication systems. The following problem areas have been addressed:

- Calculation of end-to-end blocking probabilities in a multicast network, where an originating node sends several transmissions, "programs", via separate dynamic multicast trees, which the users can join and leave. An exact algorithm has been developed for the solution of this problem. The algorithm is based on alternatingly applying a new mathematical construction, OR-convolution, and truncation on the channel state distributions. The algorithm was extended to cover also the case of Poissonian background traffic. Dimensioning aspects of a multicast network were examined.
- Routing and wavelength allocation in WDM networks without wavelength conversion at the nodes. Heuristic algorithms for optimal solution of the static problem have been refined and tested. The dynamic case, where connection requests arrive according to a Poisson process has been studied. A new approach based on the Markov Decision Theory has been developed. Any heuristic policy can be improved by so-called policy iteration, where the relative costs of states are estimated on-the-fly by simulations.
- Multiprotocol Label Switching, MPLS. A technology report on the current status and prospects of the MPLS concept has been compiled.

3.8 Com^2 - Computational Methods for the Performance Analysis of Broadband Communication Networks

Project leader: Jorma Virtamo
Researchers: Samuli Aalto, Jan Hlinovsky,Pirkko Kuusela Jani Lakkakorpi, Pasi Lassila, Aleksi Penttinen, Vinod Sharma, Hannu Rummukainen Attila Vidács

The aim of the project is to develop computational methods for the performance analysis of broadband communication networks. The scope of the project encompasses: 1) Development of queueing models applicable to communication networks and methods for the solution of these models as well as the related optimization problems. 2) Development of variance reduction techniques for the speed-up of simulations. 3) Development of models for long-range dependent traffic and methods for the estimation of the parameters of the models. A program library is being created and maintained of the algorithms resulting from the project. Specifically, the milestones in 1999 were:

- The work on effective simulation of multiservice loss systems (such as an ATM network considered at the call level) has been continued. A nearly ideal importance sampling method has been developed by which speed-up factors in the range of 10^3-10^5 can be achieved. In this method, the problem is first broken down into independent one-link problems. Then, in each subproblem, samples are generated directly from the conditional distribution in the set on blocking states of the link. This is possible to do exactly by a method called inverse convolution. The method is fast but requires storage of large tables. The storage requirements can be avoided by another method, called Gaussian method, but this requires more computation per sample and leads, due to some unavoidable approximations, to less optimal results, though even these are far better than anything reported in the literature before. The developed method leaves virtually no room for further improvement.

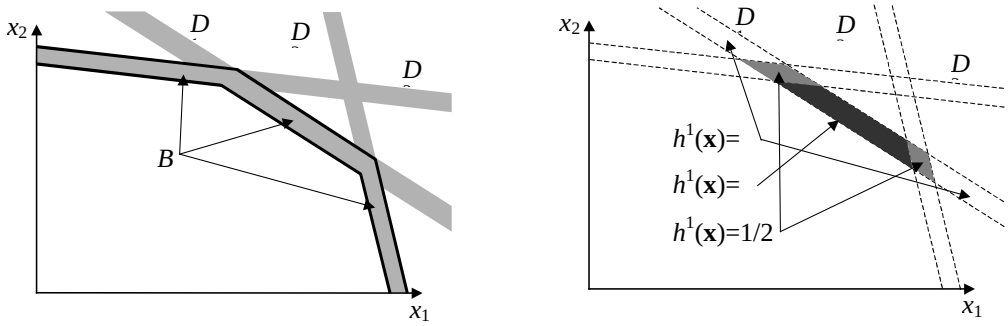

Fig. 5. Decomposition of the set B into three subsets (D^1, D^2, D^3) and the possible values of h^1(x) in different parts of D^1.

- The performance of RED algorithm has been studied (RED is a buffer management scheme proposed for routers in the Internet). A new approach has been developed by which the transient behaviour of a RED controlled buffer can be analyzed. The analysis focuses on the evolution of the expectations of the

exponentially averaged queue length and the instantaneous queue length. An ordinary differential equation (ODE) has been derived for the expected exponentially averaged queue length. In a simpler scheme, where quasi-stationarity assumption is made, an autonomous ODE is obtained. In a more refined scheme, capable of explaining the oscillatory behaviour of the system, this is augmented with another ODE describing the expected instantaneous queue length. A fairly good agreement with simulation results has been observed. The dependence of the mean queue lengths on the traffic parameters has also been examined for a multi traffic class system.

- A method has been developed for the estimation of the Hurst parameter of data traffic obeying the fractional Brownian motion process. The aim of this new method is to reduce the number of sample points required for a given accuracy. This is obtained by using a geometric sampling grid. Intuitively, such a grid a) being "self-similar" fits neatly to the scheme b) removes redundant points c) sees many time scales with fewer samples. The maximum likelihood principle is applied for the estimation. This requires the calculation of the inverse covariance matrix. Based on the observation that the covariance function is nearly linear, approximations for the inverse covariance matrix have been derived. Numerical experiments show that the method, indeed, works well and outperforms wavelet based methods, which have recently become popular.
- Optimal routing in circuit switched multi bitrate networks has been studied. Under the assumption of link independence the problem breaks down into separate single link problems. The Markov Decision Process approach has been applied, calls for the calculation of link shadow prices. Though these can, in principle, be solved from Howard equations the size of the state space of a realistic system is prohibitive. The approximate approach by Krishnan and Hübner has been used as a starting point. The method has been viewed from new angles and has enabled introducing improvements. The KH method can been seen as the aggregation step in the aggregation-disaggregation method, which suggests applying the disaggregation step as well. On the other hand, the KH method can be viewed as a way of approximating the state value function. Better approximations can be obtained by other piecewise polynomial base functions. New recursive algorithms have been devised for calculating the matrix elements needed in the normal equations with such base functions. Most promising results were obtained with piecewise linear base functions.

3.9 UseTraM - User Traffic Modelling for Future Mobile Systems

Project leader: Jorma Virtamo
Researchers: Jani Lakkakorpi

This project is a task in a larger project managed by the Telecommunications Laboratory. A hierarchical model for the WWW traffic has been created based on the extensive measurements by T. Nieminen. The model has been implemented for the Network Simulator (ns-2) and has been used to analyse the performance of the

wireless GPRS system. Latency times for page retrieval and end-to-end IP packet delays with different loads have been studied by simulations.

3.10 Studies in queuing theory

Project leader: Samuli Aalto

One topic was stochastic fluid queues, used in the modelling and performance analysis of various telecommunication systems (such as ATM networks). The research related to this topic was done in cooperation with W. Scheinhardt, a postdoc reasearcher in Prof. Boxma's group. In particular, S. Aalto and W. Scheinhardt considered a tandem fluid queue system with multiple consecutive buffers. As a result, they were able to characterize the marginal content distribution of any buffer. In addition, they managed to determine the correlation between two buffer contents. The results were reported in EURANDOM's report series. A manuscript based on this report was also submitted to a journal (OR Letters).

The other topic was the optimal control of batch service queueing systems. During the visit, S. Aalto (partly) generalized the results that he had presented in his PhD Thesis. The generalization related to the inclusion of the service costs: the former results were merely based on the holding costs of customers. The results of these studies were also reported in EURANDOM's report series. Moreover, the manuscript based on this report has been accepted for publication in a journal (Mathematical Methods of Operations Research).

3.11 IPANA / IP voice

Project leader: Raimo Kantola
Researcher: Jose Costa Requeña, Juho Haapala, Harri Marjamäki, Nicklas Beijar, Inmaculada Espigares, Julio Raminez Yebenez

Voice over IP studies the transmission, switching and routing of voice in IP networks and service interoperability of such networks with PSTN/ISDN. The project was initiated in April 1997 and is planned to continue for three years. The project is mainly funded by a TEKES grant, and it has four industrial partners (Nokia Research Center, Nokia Telecommunications, Sonera Oy and Omnitele/Helsinki Telephone Research).

Results for the second year include Jose Costa Requeña's M.Sc. thesis and conference paper on the implementation of SCSP. Also Ms. Espigares finished her M.Sc. thesis. In addition, one conference paper, internal reports and student papers were produced. We also started the implementation of a routing testbed for the hybrid IP Voice - Circuit switched network (SCN). The testbed uses the SCSP as a means to distribute and synchronise routing information in Location Servers that may reside either on the IP Voice network side or on the SCN side. The implementation is based on the MySQL database and uses Python scripting for mapping data from the SCSP payload to MySQL. The purpose of the testbed is to study the feasibility of automating service management in the hybrid network and provide seamless number portability as a by-product.

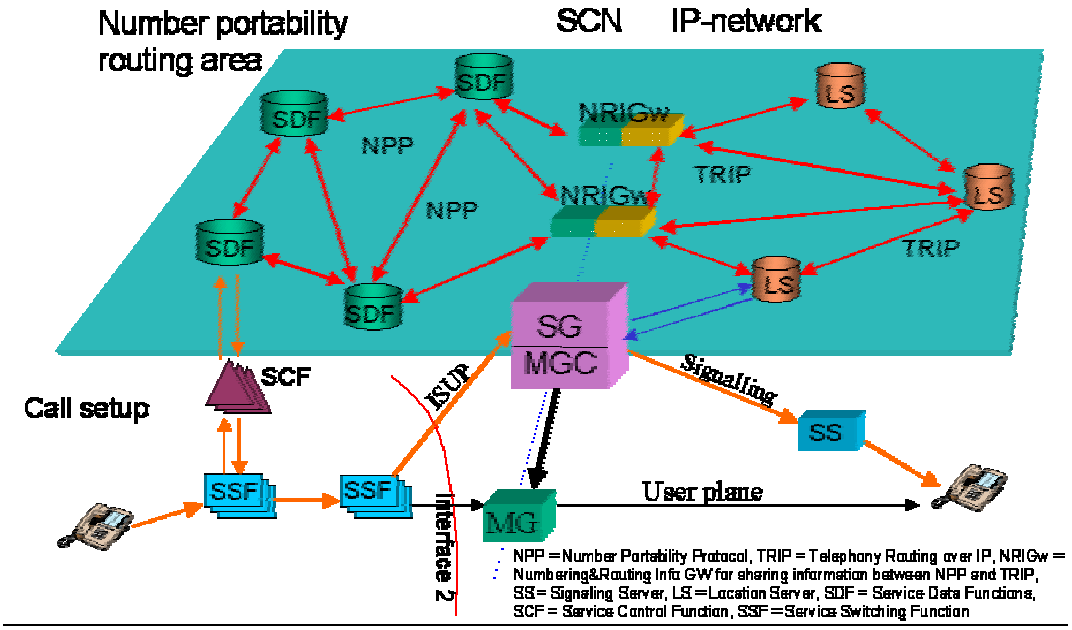

Fig. 6. Routing Information protocols in the hybrid IP/SCN network.

3.12 IPANA / IP switching

Project leader: Raimo Kantola
Researchers: Mika Ilvesmäki, Veikko Brax, Anna-Kaisa Lindfors, Kimmo Pitkäniemi, Peng Zhang, Zhangsong Ma, Sampo Kaikkonen

The project was initiated in April 1997 and is planned to continue for 3 years ending in summer 2000. The project is mainly funded by a TEKES grant; it has four industrial partners (Nokia Telecommunications, Sonera Oy and Omnitele/Helsinki Telephone Research).

Although viewed as the prototype of the future Information Superhighway, the current Internet technology has a number of drawbacks, including: limited transmission and routing capacity, limited speed, long and variable transmission delays and no support for quality of service. The project is aimed at helping to solve some of these problems by focusing on issues of deployment of ATM to increase the performance of the Internet and to improve the quality of service available to the user.

Besides technology evaluation the most important results in the project are based on using neural algorithms for Internet traffic classification and applying the classification results for boosting the network performance and perceived quality of service.

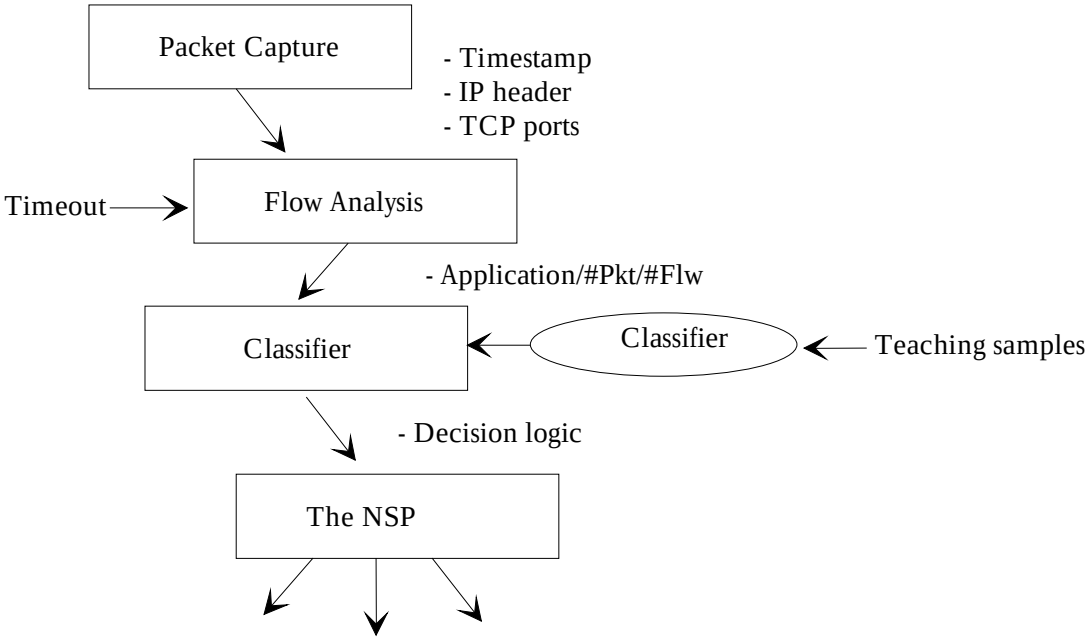

Fig. 7: Methodology to analyse and classify traffic measurements in the Internet.

A new topic of class based routing was started in the IP switching subproject. The purpose is to study the feasibility and usefulness of using constrained based or class based routing in an IP switched network built using Multiprotocol Label Switching and Differentiated Services. The first results were an internal report on the subject and the development of the first version of a Quality of Service Routing Simulator. This simulator supports the analysis of routing concepts in a flow based IP network.

4 TEACHING

4.1 Development of teaching

The major in Telecommunications Technology was split in two parts, resulting in a new major in Teletraffic Theory.

The course “Introduction to teletraffic theory” (S-38.145) was given both in Finnish (spring term) and in English (fall term). The English version of the course was produced specifically for the Master’s Programme started in fall 1999.

The book "Tietoliikenneaapinen" (The ABC of Telecommunications) by Seppo Uusitupa and Kirsi Voipio was published in the beginning of year 1999. This book is being used as the basis for the course “Principles in communication engineering” (S-38.105).

The course ”Broadband switching technology” (S-38.164) was partly renewed; besides the section on ATM technology, sections on IP switching and optical networking technology were included in the course. The latter part was lectured by a group of experts from Nokia Research Center.

Efforts were directed to improve the material of many other courses and to increase the amount of material available through the web.

4.2 Courses

The laboratory has given education in 26 courses. The courses can be divided into 7 groups:

4.2.1 Basic courses for all students studying telecommunications

S-38.105 Principles in Communication Engineering (Tietoliikennetekniikan perusteet)
S-38.118 Principles in Telecommunications Technology (Teletekniikan perusteet)

4.2.2 Courses concerning communications and networks

S-38.188 Telecommunication Networks (Tietoliikenneverkot)
S-38.191 Corporate Networks (Televerkot yrityksissä)

4.2.3 Courses on switching and ATM

S-38.110 Telecommunication Switching Technology I (Tiedonvälitystekniikka I)
S-38.122 Telecommunication Switching Technology II (Tiedonvälitystekniikka II)
S-38.164 Broadband Switching Technology (Laajakaistainen välitystekniikka)
S-38.166 Programming of Telecommunication Switching Systems
(Televälitysjärjestelmien ohjelmointi)

4.2.4 Courses on signal processing

S-38.211 Signal Processing in Telecommunications I
(Signaalinkäsittely tietoliikenteessä I)
S-38.212 Signal Processing in Telecommunications II
(Signaalinkäsittely tietoliikenteessä II)

4.2.5 Postgraduate courses

S-38.001 Telecommunications Forum (Telecommunications Forum)
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-38.220 Licentiate Course in Signal Processing in Communications
(Tietoliikenteen signaalinkäsittelyn lisensiaattikurssi)
S-38.350 Research Seminar on Telecommunications Technology
(Teletekniikan tutkijaseminaari)

4.2.6 Courses on teletraffic theory

S-38.145 Introduction to Teletraffic Theory (Liikenneteorian perusteet)
S-38.147 Simulation of Telecommunication networks (Televerkkojen simulointi)

4.2.7 Other courses

S-38.117 Seminar on Telecommunications Technology (Teletekniikan seminaari)
S-38.123 Telecommunications Technology, laboratory course I
(Teletekniikan laboratoriotyöt I)
S-38.124 Telecommunications Technology, laboratory course II (Teletekniikan laboratoriotyöt II)
S-38.128 Telecommunications Technology, special assignment
(Teletekniikan erikoistyö)
S-38.202 Telecommunications Engineering Project (Teletekniikan projektityö)
S-38.300 Thesis Seminar on Telecommunications Technology
(Teletekniikan diplomityöseminaari)

4.3 Degrees

4.3.1 Licentiate of Technology

Pasi Lassila: Efficient simulation techniques for multiservice loss systems

On the call scale, the process describing the number of calls present in a network can be modeled by a loss system. In principle, loss systems are mathematically simple and well understood, and one is able to write down exact expressions for such variables as the blocking probability of a call belonging to a given class. However, for systems of realistic size such analytical expressions defy a direct evaluation because of the huge size of the state space.

In such situations, one has to resort to simulations in order to obtain estimates of the performance measures of interest. To this end, some basic simulation methods (traditional MC, process simulation, Gibbs sampler) are considered and it is shown how they are applied for generating samples in the simulation of loss systems. Then the problem of increasing the efficiency of the simulations is addressed by using so called variance reduction techniques. In particular, two different methods for estimating the blocking probabilities in a multiservice loss system are presented. The first method is based on the importance sampling method and utilizes some large deviation results for multidimensional random variables. The second method is based on another known method called conditional expectations method, where the idea is to utilize known analytical results to the maximum `degree`.

Petri Karttunen. Adaptive algorithms for tracking direction-of-arrival in mobile communications systems

One way to significantly increase the capacity of the third-generation mobile communications systems is to employ adaptive antenna array technologies together with sophisticated signal processing algorithms. For the Direction-of-Arrival (DOA) based applications the classical beamformers and spatial spectrum estimation methods can be utilized for the estimation of DOA of mobile users mainly in stationary signal scenarios. Due to the time-varying nature of communications channels the focus of this licentiate thesis was directed towards the development of adaptive DOA tracking methods targeting at non-stationary signal scenarios.

4.3.2 Masters of Science in Telecommunication technology

Alden, B.	Producing test applications to fulfil the test requirements of internal services in a telecommunication systems, in Finnish (Testisovellusten tuottaminen televälitysjärjestelmän sisäisten palvelujen testaustarpeisiin)	NTC
Autere, V.	Charging data collection of subscriber generated IP traffic, in Finnish (Tilaajaliittymien IP-liikenteen laskenta)	SIE
Borgström, M.	Application of the charging procedure in Finland's	SIE

	telecommunication network , in Finnish (Veloitusprotokollan soveltaminen Suomen televerkkoon)	
Espigares del Pozo, I.	An Implementation of the Internet Call Waiting Service using SIP	HUT
Gerdt, L.	Quality of service in fast Ethernet networks, in Finnish (Palvelunlaatu nopeassa Ethernet-verkossa)	Compaq
Haapasaari, M	Charging of VoIP services, in Finnish (IP-puhepalvelun laskenta)	NTC
Halme, M.	Feasibility of ip transport in universal terrestrial radio access network	NTC
Holmberg, M.	An open application environment for a vehicle computer, in Finnish (Avoin sovellusympäristö ajoneuvo-tietokoneissa)	Commit
Höneisen, B.	Convergence of Internet and Intelligent Networks: Interaction of services using PINT	NRC
Insa Hernàndez, R.	Implementation of Gram-Schmidt Conjugate Directions and Conjugate Gradients Algorithms	HUT
Jantunen, T.	Impacts of Internet protocol on PBX evolution and corporate remote access	SIE
Jussila, J.	Applying object oriented methods in building layered software, in Finnish (Oliomenetelmien soveltaminen kerroksellisen ohjelmiston koonnissa)	NTC
Kaikkonen, J.	Role of measurements in process improvement – An internet tool for tracking progress of software development projects	TE
Kaplas, M.	The use of narrowband network tests in broadband network testing, in Finnish (Kapeakaistaverkon testien soveltaminen laajakaistaverkon testauksessa)	SON
Kyheröinen, P.	Transition to Internet Protocol version 6: Teleoperator´s view	HPY
Kyrönaho, J.	Interworking in an IP telephony gateway	NTC
Lakkakorpi, J.	Traffic Modeling and Simulation in Wireless Environment	HUT
Mahkonen, M.	Handover in Actionet, in Finnish (Solujen välinen kanavanvaihto Actionet-järjestelmässä)	HUT
Mattila, T.	Applying the CAMEL architecture to the international GSM network, in Finnish (CAMEL-ominaisuuden sovitus kansainväliseen GSM-verkkoon)	SON
Mikkola, M.	An ISDN based DECT nurse call system, in Finnish (ISDN-tekniikalla toteutettu DECT-hoitajakutsujärjestelmä)	Sondi
Myöhänen, J.	Planning of field validation for an SDH cross-connect system	TE
Mäittälä, M.	Voice over IP in ADSL Access Networks	Nokia Networks
Mäntylä, H.	Design of Very high speed Digital Subscriber Line (VDSL) networks	HUT
Niemi, T.	Application development methods for Interactive Voice Response, in Finnish (Ääniautomatiikka-sovellusten ohjelmointimenetelmien kehittäminen)	Arts & Minds

Nurmi, P.	Computer telephony application programming interface technologies and their evolution, in Finnish (Tietokone-puhelinsovellusrajapintateknologiat ja niiden kehitys)	NTC
Nyberg, E.	Calculation of Blocking Probabilities and Dimensioning of Multicast Networks	HUT
Nyberg, S.	An infrastructure for administration of information technology in enterprises, in Swedish (En infrastruktur för administration av informationsteknologi I företag)	AB
Ohtonen, P.	Management of UMTS –radio access transmission, in Finnish (UMTS-liityntäverkon siirtoverkon hallinta)	NTC
Pajakkala, M.	Core processors in networking asics	TE
Pyyhtiä, M.	Differentiated Qos in heterogenous IP networks, in Finnish (Palvelun laatu heterogeenisissä IP-verkoissa)	HPY
Pyyppönen, M.	Technical implementation of the GPS to the existing GSM cellular network, in Finnish (GPRS:n tekninen toteutus olemassa olevaan GSM-solukkoverkkoon)	HPY
Rainola, R.	Comparison of Synchronization Methods in Synchronous Digital Hierarchy (SDH)	NTC
Roine, T.	The performance model of an IN prepay solution	ICL
Romppanen, A.	End-to-end Quality of Service in Internet Telephony	Nokia Networks
Räsänen, M.	Integration of the broadband UDSL-subscriber access in the switching system, in Finnish (Laajakaistaisten USDL-tilaajaliittymien integrointi puhelinkeskusjärjestelmään)	SIE
Saunamäki, J.	Implementation of user and network signalling for an ATM-switch, in Finnish (Tilaaja- ja verkkomerkinannon toteuttaminen ATM-kytkimeen)	NRC
Sipilä, J.	Application of external intelligent peripherals to mobile networks	SIE
Solehmainen, K.	Transfering the remote patient monitoring data in real-time in a packet-switched network, in Finnish (Potilaan etämonitorointitiedon reaaliaikainen välitys pakettiverkossa)	Datex-Ohmeda
Suni, M.	Measurement-based connection admission control	NTC
Sytelä, T.	Management of Subscriber specific intelligent network services, in Finnish (Tilaajakohtaisten älyverkkopalveluiden hallinta)	SON
Toppila, P.	Quality of Service in UMTS Based Internet Access	LME
Torpo, J.	Accuracy of Charging in a Fixed Switching Center	NTC
Wall; J.	Java Based Agents as Secure Proxies	LME
Wallenius, N.	Secure communication between corporate networks and mobile users gprs packet radio network	SON
Visti, H.	Re-engineering of network in Helsinki Stock Exchange, in Finnish (Helsingin Pörssin tietoliikenneverkon uudistaminen)	HEX Oy

AB	Alfred Berg Finland
HPY	Helsinki Telephone Company
HUT	Helsinki Univ. of Technology/ Lab. of Telecom. Technology
ICL	Fujitsu-ICL Computers
LME	Oy L M Ericsson Ab
NRC	Nokia Research Center
NTC	Nokia Telecommunications
NTW	Nokia Networks
SIE	Siemens Finland
SON	Sonera
TE	Tellabs Oy

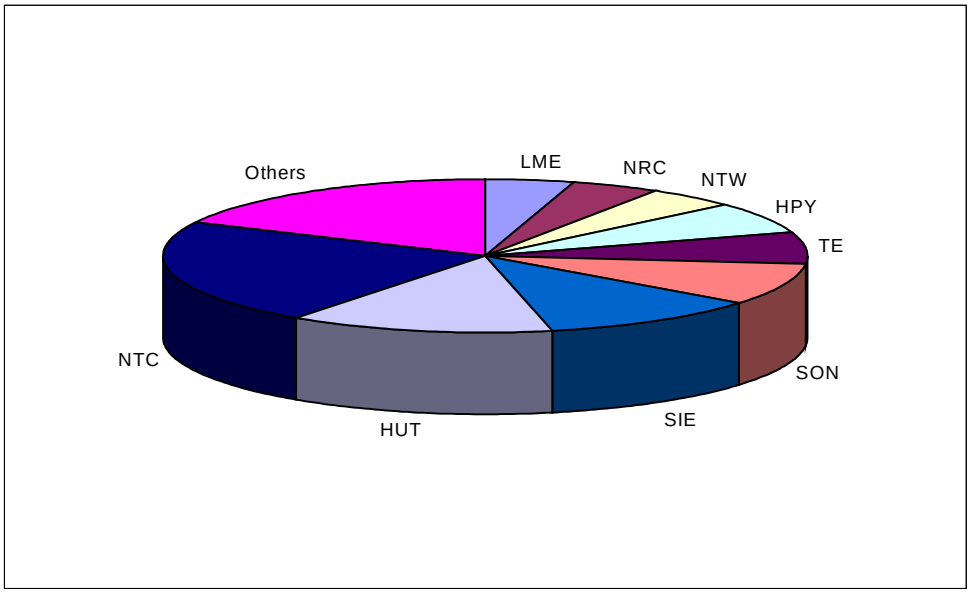

Fig. 8. Employers of Masters students.

5 ACTIVITIES

5.1 International conferences and meetings

- COST 257 Mid-term Seminar and Management Committee meeting, January 20-22, 1999, Vilamoura (Lassila, Virtamo)
- COST 263 Management Committee meeting, January 29-31, 1999, Brussels, Belgium (Luoma)
- IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP`99), March 15-19, Phoenix, Arizona, USA (Laakso)
- COST 263 Management Committee meeting, April 15-18, 1999, Naples, Italy (Peuhkuri)
- Vehicular Technology Conference, May 16-19, 1999, Houston, Texas (Kettunen)
- IEEE Finnish Signal Processing Symposium, FINSIG`99, May 1999, Oulu (Baghaie, Insa, Karttunen, Liu, Mäntylä)
- Pallas Fractal Symposium, May 5-7, 1999, Muonio (Sharma, Vidács, Virtamo)
- Master's Programme in Telecommunications visit to China May 9-17, 1999, (Kantola)
- COST 257 Management Committee meeting, May 17-18, 1999, Warsaw (Virtamo)
- VON Conference, June 22 - 24, 1999, Helsinki (Kantola, Costa Requena)
- 16th International Teletraffic Congress, June 7-11, 1999, Edinburgh, United Kingdom (Aalto, Lassila, Virtamo)
- International Conference on Communications, June 6-10, 1999, Vancouver, Canada (Laakso)
- 45th IETF Meeting, 11-16 July, 1999, Oslo, Norway (Luoma)
- 42nd Midwest Symposium on Circuits and Systems, August 8-11, 1999, New Mexico, USA (Baghaie)
- Lappenranta Summer School on Telecommunications, August 11, 1999 (Kantola - invited talk on Voice over IP)
- IFIP WG6.3 Workshop, August 30 - September 1, 1999 Rethymnon, Greece (Virtamo)
- Sigcomm´99 Conference, August 30 – September 4, 1999, Boston, USA (Peuhkuri)
- 5th Bayona Workshop on Emerging Technologies in Telecommunications, 6-8 September, 1999, Bayona, Spain (Liu)
- The 10th International Symposium on Personal, Indoor and Mobile Radio Communications, September 12-15, 1999, Osaka, Japan (Karttunen)

- COST 257 Management Committee meeting, Larnaca, Cyprus (Aalto)
- International Conference on Voice, Video and Data Communications, September 21-22, 1999, Boston, USA (Ilvesmäki, Kantola, Luoma, Requena)
- COST 263 Management Committee meeting, October 5-6, 1999, Barcelona, Spain (Luoma)
- Asilomar Conference on Signals, Systems and Computers, October, 1999, Pacific Grove, CA, USA (Baghaie)
- IEEE Globecom`99, December 5-9, 1999, Rio de Janeiro, Brazil (Baghaie, Laakso, Werner)
- Erasmus student exchange experience meeting at Ecole Francaise D`Electronique et D`Informatique (EFREI) , Paris (Kantola)
- Visit to Universidade Federal do Rio de Janeiro, Brazil, December 10, 1999 (Baghaie, Laakso)
- Media Gateway Control Conference 99, December 15-17, 1999, Paris, France (Kantola – invited talk on Voice over IP)

5.2 Foreign visitors in 1999

The following persons have visited the Laboratory of Telecommunications Technology during the year 1999:

- Professor Paulo Diniz from Universidade Federal do Rio de Janeiro, Brazil (July - September 1999)
- Ms. Inmaculada Espigares from Universidad Politecnica de Valencia
- Mr. Ricardo Insa Hernandez from Universidad Politecnica de Valencia (October 1998 - July 1999)
- Mr. Attila Vidács from Technical University of Budapest (September 1998 – May 1999)
- Professor Vinod Sharma from Indian Institute of Science, Bangalore (September 1998 - July 1999)
- Dr. Oliver Rose from University of Wuerzburg (August, 1999)
- Mr. Julio Raminez Yebenes from Spain (from November 1999)
- Professor Gerald D. Cain from University of Westminster London, (November, 1999)
- Ph.D. Izzet Kale from University of Westminster London (November, 1999)

6 PARTICIPATION IN BOARDS AND COMMITTEES

6.1 University boards and committees

- **Raimo Kantola**
  - Director of the Master's Programme in Telecommunications
  - Member of Council of Degree Programme
  - Member of the working group on the new structure of basic and option studies.
- **Timo Laakso**
  - Chairman of the Library Committee of the Department of Electrical and Communications Engineering
- **Jorma Virtamo**
  - Vice chairman of the Committee for the International Affairs

6.2 Other boards and committees

- **Ramin Baghaie**
  - Member of Technical Committee of European Signal Processing Conference, EUSIPCO`00, Tampere, Finland
  - Session chairman, IEEE Finnish Signal Processing Symposium, FINSIG´99, Oulu, Finland, May 1999
  - Session Chairman, IEEE Midwest Symposium on Circuits and Systems, Las Cruces, New Mexico, USA, August 1999
  - Member of Technical Program Committee of IEEE Finnish Signal Processing Symposium, FINSIG`99, Oulu, Finland, May 1999
  - Treasurer of IEEE Finland Section
- **Raimo Kantola**
  - Member of the Supervisory Council in Sonera Oyj
  - Session chairman at the International Conference on Voice, Video and Data Communications, Boston, USA, September 1999
- **Timo Laakso**
  - Member of the Digital Signal Processing Technical Committee of the IEEE Circuits and Systems Society
  - Member of the editorial board of Applied Signal Processing (Journal by Springer Verlag)

- **Jorma Virtamo**
  - Vice Chairman of the action COST 257 “Impacts of new services on the architecture and performance of broadband networks”
  - Member of the Technical Program Committee of the 16th International Teletraffic Congress ITC-16, in Edinburgh, June 7-11, 1999
  - Member of Technical Committee of the Conference Networking 2000 (IFIP-TC6), Paris, France, May 14-19, 2000
  - Member of Technical Committee of ITC Specialist Seminar on Mobile Systems and Mobility, Lillehammer, Norway, March 22-24, 2000
  - Member of Technical Committee of 1st International Workshop on Quality of Future Internet Services, QofIS, Berlin, Germany, September 15-16, 2000
  - Member of the Board of the Research Foundation of Helsinki Telephone Company

6.3 Referee activities

- **Timo Laakso**
  - Reviewer for the following scientific journals: IEEE Transactions on Signal Processing, IEEE Trans. on Circuits and Systems, IEEE Trans. on Communications, Signal Processing, Applied Signal Processing, IEE Electronic Letters
  - External evaluator of the Dr.Tech. dissertation of Z. Hang, Tampere University of Technology
- **Jorma Virtamo**
  - Evaluation of associate professor Vinod Sharma for the position of professor, Indian Institute of Science, Bangalore, India
  - 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: Infocom 2000, ITC Specialist Seminar on Mobile Systems and Mobility, Networking 2000

7 Publications

1. Aalto, S. Optimal control of batch service queues with finite service capacity and linear holding costs. Eindhoven University of Technology: EURANDOM, European Institute for Statistics, Probability, Operations Research and their Applications, 1999. 18 p. (Eurandom Report 99-021).
2. Aalto, S. & Scheinhardt, W. Tandem fluid queues fed by homogeneous on-off sources. Eindhoven University of Technology: EURANDOM, European Institute for Statistics, Probability, Operations Research and their Applications, 1999. 13 p. (Eurandom Report 99-022).
3. Baghaie, R. Application of transformation techniques in CDMA receivers. IEEE Midwest Symposium on Circuits and Systems, Las Cruces, New Mexico, August 1999.
4. Baghaie, R. Systolic implementation of sample-by-sample conjugate gradient algorithm. IEEE Finnish Signal Processing Symposium FINSIG´99, Oulu, Finland, May 1999. Oulu, Finland 1999, University of Oulu, s. 252-256.
5. Baghaie, R. Transformation techniques in CDMA receivers, IEEE Finnish Signal Processing Symposium FINSIGé99, Oulu, Finland, May 1999. Oulu, Finland 1999, University of Oulu, s. 10-15.
6. Baghaie, R.& Dimitrov, V. DHT algorithm based on encoding algebraic integers. Electronics Letters, 1999. Vol. 35, nro 16, s. 1303-1305.
7. Baghaie, R. & Karttunen, P. Implementation of mobile user tracking system. Global Telecommunications Conference GLOBECOM´99, Rio de Janeiro, Brazil, December 5-9. s.2127-2131.
8. Baghaie, R. & Karttunen, P. VLSI implementation of CG based mobile user tracking system. IEEE Midwest Symposium on Circuits and Systems, Las Cruces, New Mexico, August 1999.
9. Costa Requena, J. & Kantola, R. Server Cache Synchronization Protocol (SCSP): component for directory enabled networks. Internet II: Quality of Service and Future Directions, Boston USA, 20-21 September. 1999, SPIE, s. 174-182.
10. Dimitrov, V. & Baghaie, R. Computing discrete Hartley transform using algebraic integers. 33rd Asilomar Conference on Signals, Systems and Computers, Pacific Grove, CA, October 1999.
11. Helenius, J. & Liu, Y. & Renfors, M. & Laakso, T. Analysis of VDSL capacity based on channel measurements. Broadband Access Conference BAC´99, Cracow, Poland, October 11-13. s.160-166.
12. Hyytiä, E. & Virtamo J. Wavelength Assignment in multifiber networks. COST257, 1999. 14 s.
13. Hänninen, A. Annual Report 1998. Espoo: Teknillinen korkeakoulu, 1999. 34 s. (Teletekniikan laboratorion raporttisarja).

14. Ilvesmäki, M. & Luoma, M. Performance Analysis of Multi-Class Internet Traffic Classifier in a Connection Oriented Router Environment. Internet II: Quality of Service and Future Directions, Boston, USA 20-21 September. 1999, SPIE, s. 70-81.

15. Insa Hernandez, R., Baghaie, R. & Kettunen, K. Implementation of Gram-Schmidt conjugate direction and conjugate gradient algorithms. IEEE Finnish Signal Processing Symposium FINSIG´99, Oulu, Finland, May 1999. Oulu, Finland 1999, University of Oulu, s.165-169.

16. Karttunen, P. An algorithm for noise subspace based mobile user tracking. International Symposium on Personal, Indoor and Mobile Radio Communications, Osaka, Japan, September 1999. s. 651-655.

17. Karttunen, P. & Baghaie, R. Conjugate gradient based signal subspace mobile user tracking. IEEE Vehicular Technology Conference, Houston, Texas, USA, May 1999. s. 1172-1176.

18. Karvo, J. & Aalto, S. Average Signalling Load for Multicast Group Management. International Teletraffic Congress - ITC-16, United Kingdom, 7-11 June, 1999. Elsevier 1999, pp. 509-518.

19. Kettunen, K. Iterative multiuser receiver/decoders with enhanced variance estimation. IEEE 49th Vehicular Technology Conference, Houston, Texas, USA, May 1999. pp 2318-2322.

20. Kettunen, K. Iterative multiuser receivers in coded CDMA systems. IEEE Finnish Signal Processing Symposium FINSIG´99, Oulu, Finland, May 1999. Oulu 1999, University of Oulu, s. 15-19.

21. Kettunen, K. & Laakso, T. Iterative multiuser receiver utilizing soft decoding information. IEEE International Communications Conference, Vancouver, BC, Canada, June 1999. s. 942-946.

22. Kilkki, K. Differentiated Services for the Internet. Indianapolis, USA 1999, Macmillan Technical Publishing. 356 s.

23. Laakso, T. How to write a diploma thesis. Espoo 1999, Teknillinen korkeakoulu. 27 s.

24. Laakso, T. Näin kirjoitan diplomityön. Espoo 1999 , Teknillinen korkeakoulu. 27 s.

25. Laakso, T. & Välimäki, V. Energy-based effective length of the impulse response of a recursive filter. IEEE Transactions on Instrumentation and Measurement, 1999. Vol. 48, nro 1, ss.7-17.

26. Lassila, P. Efficient simulation techniques for multiservice loss systems. Espoo: Teknillinen korkeakoulu, Teletekniikan laboratorio, 1999. 97 s. (Teletekniikan laboratorion raporttisarja 1/99).

27. Lassila, P. & Virtamo, J. Efficient Importance Sampling for Monte Carlo Simulation of Loss Systems. International Teletraffic Congress - ITC-16, United Kingdom, 7-11 June, 1999. Elsevier 1999, p. 787-796.

28. Liu, Y., Helenius, J., Laakso, T. & Renfors, M Capacity estimation of VDSL Connections based on channel measurements. 1999 Finnish signal processing symposium FINSIG´99, Oulu Finland, 31 May 1999. Oulu 1999, University of Oulu, s.262-266.

29. Liu, Y., Laakso, T., Helenius. J. & Renfors, M. VDSL capacity estimation based on in-field measurements. Fifth Baiona Workshop on Emerging Technologies in Telecommunications, Baiona, Spain, September 1999. s. 37-41.

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