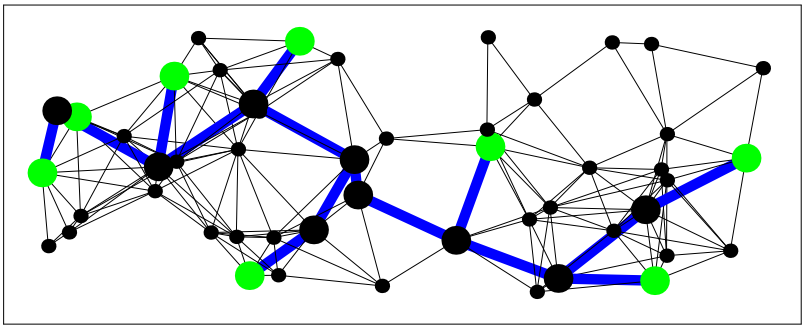
Helsinki University of Technology Networking Laboratory
Teknillinen korkeakoulu Tietoverkkolaboratorio
Espoo 2006

ANNUAL REPORT 2005



TEKNILLINEN KORKEAKOULU
TEKNISKA HÖGSKOLAN
HELSINKI UNIVERSITY OF TECHNOLOGY
TECHNISCHE UNIVERSITÄT HELSINKI
UNIVERSITE DE TECHNOLOGIE D'HELSINKI

Helsinki University of Technology Networking Laboratory
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ANNUAL REPORT 2005

Editors: Raija Halkilahti, Arja Hänninen, Jouni Karvo

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

Teknillinen korkeakoulu
Sähkö- ja tietoliikennetekniikan osasto
Tietoverkkolaboratorio

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ABSTRACT

Research and teaching in the Networking Laboratory focuses on communication networks, in particular the network layer, but also end-to-end issues, teletraffic theory, and network economics. Currently the central research problem of the field is leveraging the Internet into a converged service network. This requires novel approaches in managing service quality, charging, security, and service platforms.

The teaching curriculum of the Networking Laboratory includes three major subjects: Networking Technology, Teletraffic Theory and Telecommunications Management. In the International Master's Programme on Communications Engineering, we provide a combination of these under the name of Network Engineering. In these subjects we run courses on IP technology, circuit-switched networking, teletraffic theory, service and protocol development, and networking business.

During 2005, the new study structure of 3+2 years was introduced and first students were admitted to the new Degree Programs. The new renumeration system for civil servants and government employees was introduced during the year and caused additional administrative burden to all superiors and worry to all of us.

In 2005, a new professor, Dr.-Ing. Jörg Ott joined the laboratory. Our staff published 8 international journal papers and circa 32 papers in international conferences. Publication activity shows a steady increase from last year. One doctoral thesis, 3 licentiate theses and 44 M.Sc. theses were achieved by the students of our laboratory. Seven of the Master's theses were completed by students working directly at Netlab.

In 2005, the laboratory carried on research in several multi-year research projects. The biggest project through the years, the Intelligent Routing Network project (IRoNet), a TEKES NETS spearhead project, was completed during the year.

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1 INTRODUCTION

The highlights of the year 2005 were the joining of a new professor, Dr.-Ing. Jörg Ott with the laboratory, the launch of the new 3+2 degree structure with an intermediate Bachelor degree, the charity donation by Tellabs Foundation to Netlab, the introduction of the civil service renumeration system and the increase in the international activity in the laboratory.

Professor, Dr.-Ing. Jörg Ott joined the laboratory in March, 2005. His area is protocol design, services and telecom software. Professor Ott brings a strong link for us to the work on defining the future Internet at the Internet Engineering Task Force where he chairs one of the Working Groups and participates in several others. The slides Professor Ott used in his inauguration speech November 1st at TKK are attached to this annual report.

The new 3+2 degree structure was launched with the first intake in 2005. We spent a serious amount of work in rethinking our teaching and will have to continue to refine the program in 2006. The 3+2 degree structure consists of a Bachelor degree of 180 ECTS and a Master's degree of 120 ECTS with the total nominal length of 5 years.

We participate in the Bachelor and Master's Programs on Communications Engineering. In the future, it is likely that the dedicated Bachelor Programs on Communications Engineering, Electronics and Electrical Engineering and possibly others will be merged into one program while intake of high school graduates will be to each Master level program on top of the merged graduate program. The section on Teaching provides more information on the study issues.

Mid 2005 we were delighted to be chosen by Tellabs Foundation as the target for its first non-US charity grant. The Tellabs Foundation is a not-for-profit organization under Section 501(c)(3) of the US Internal Revenue Code. The mission of the Tellabs Foundation is to advance specific, strategic endeavors — primarily in education, health and the environment — in communities where Tellabs employees live and work. We promised to use the grant mainly to significantly upgrade our experimental research infrastructure but also to advance our own community activities by participating in running volunteer IT activities at Espoo schools and to continue providing Internet coverage for the Studia Generalia, Telecommunications Forum that focuses the interest of our students and the community on hot topics in telecommunications. We thank the Foundation for the grant and will use it as promised.

All government organizations are bringing into use a new system of renumeration. This involves grading each job onto a level reflecting the level of the job requirements and the involved responsibility and moreover, the grading of each person based on performance. Particulars, such as salary levels were not known but still all superiors had to conduct evaluations of all employees with interviews and filling of forms. This created quite a lot of uncertainty and anxiety besides creating a lot of unproductive administrative work and thus reducing the time available for our main tasks of research and teaching. Unfortunately, based on experience so far, I must

say, that the new system does not help the University in reaching its strategic goals in any way. However, I hope that we learn to live with it before it causes too much damage.

The first intake of international students into the Networking Technology major in 2003 has brought an additional international momentum to our course portfolio in 2004 and 2005. This year, the former International Master's Program in Telecommunications was renamed into Master's School in Information and Communications Engineering with two independent Master's Programs. One in Computer Science and the other in Communications Engineering in our Department of Electrical and Communication Engineering. The MP in CE is aligned with the new 3+2 degree structure and is, in principle, a 120 ECTS full Master's Program. Students with a foreign 4 year Bachelor degree from a renowned university in Electronics, Communications or Computer Science, however, are required to complete only 100 ECTS in the new International Programs, which is well justified because Bachelors from our own programs have studies only for 3 years. The new International Master's Programs are also open for domestic students.

Many researchers of the laboratory achieved academic degrees, including the degree of the Doctor of Science in Technology by Mika Ilvesmäki. The number of M.Sc. theses earned by our students in 2005 was 44, which is high but clearly less than the all-time-high, 60 theses in the previous year. For less than four professor man-years during 2005 the number of supervised M.Sc. theses continues to be excessively high compared to the TKK average of about 5 theses per professor. We expect a high thesis workload per professor to continue even though our plan includes the increase of professor head count and decrease of student intake. The impact of these actions is likely to be felt only in several years.

The development in project financed research activities is shown in the laboratory spending presented in Figures 1.1 and 1.2. Figure 1.1 shows the diversity of sources of research funding and Figure 1.2 the overall development for the past few years. The development shows a decline in 2005 particularly in TEKES funding. During 2005 TEKES did not have a program in the area of Telecommunications.

The laboratory had a development day in May jointly with the TML Laboratory from the department of Computer Science focusing on the new study structure. The purpose of the day was to identify areas of collaboration in the two laboratories.

Two lab-wide social events were organized during the year. The summer trip was to Porvoo, some 40 kilometers away from Helsinki, using roller skates and bicycles on the onward trip and a national heritage ship for the tour back to Helsinki. The traditional Christmas party was this time in the form of a cruise to Tallinn including presentations of the research portfolio and discussions on directions of research on the ship.

1.1 International activities

Internationalization of the laboratory continues steadily. The Networking Technology major is a part of the TKK International Master's program in Telecommunications. In the new 3+2 structure we offer an International

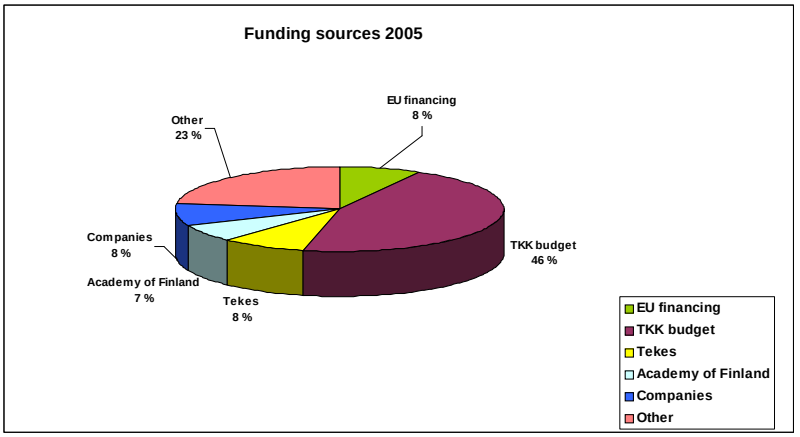


Figure 1.1: Financing of the Networking Laboratory 2005

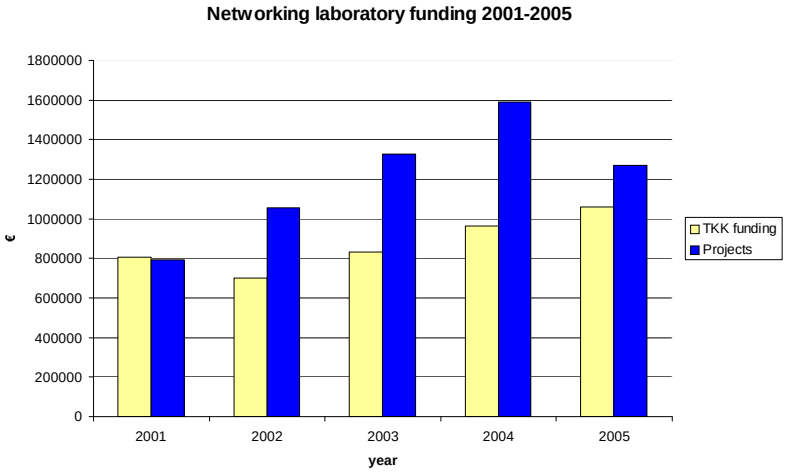


Figure 1.2: Financing of the Networking Laboratory 2001-2005

Network Engineering Major. Roughly 50% of our courses were lectured in English (not including individual assignments and labworks). The courses taught in English include many Ph.D level courses and seminars as well as the Master's level courses needed in the International Major. Many of the courses that are lectured in Finnish can also be taken in English because all material is offered in English. Just above 80 percent of the Master's theses in 2005 were written in English.

We are members of two European Networks of Excellence, Euro-NGI in the area of teletraffic theory, performance analysis and network design, and E-NEXT in the area of networking technology.

We received 14 foreign research visitors to our laboratory and we sent 3 research visitors to foreign laboratories. Particularly, delightful is our deepening relationship in the area of Teletraffic theory with the Budapest University of Technology and Economics and the University of Debrecen (also in Hungary) that was fostered under a two-year bilateral agreement. Close research collaboration continued also with France Telecom R&D and ENST Bretagne in Brest, France. Professor Virtamo and Dr. Pasi Lassila visited both of our Hungarian partner Universities in May and in November respectively. One of our PhD student from the teletraffic group, Ilmari Juva, visited ENST Bretagne for a period of one month in May.

Also in February a Netlab delegation visited our sister Laboratory at KTH headed by professor Gunnar Karlsson. In the autumn we participated in two project proposals with KTH and other Nordic Universities in the Nordunet 3 program jointly financed by the Nordic countries through their Academies of Science.

1.2 Summary

The laboratory has achieved a situation of four full-time professors. New steps are being taken to implement the TKK decision to increase the number of professors in the area of Netlab by two more professors. We hope that the result will be a reasonable student to professor ratio and that as a result our future activity can have a stronger research focus. Steps that are being taken by our sister Laboratory, Comlab at TKK, in filling in new professor posts make us hope that the improvement in the professor to student ratio is going to apply for the whole degree program of Communications Engineering.

The laboratory will continue steadily toward a more international profile, a larger output of high-quality doctoral theses, and a stronger industrial and public funding base. Whether this is realistic depends on the government and TKK maintaining their positive approach to new professorships and resources.

March 31rd, 2006

Raimo Kantola

2 PERSONNEL 2005

Laboratory staff and personnel can be reached by e-mail with address: `firstname.lastname@netlab.tkk.fi`

2.1 Professors and Docents

Hämmäinen, Heikki	D.Sc. (Tech.), Professor
Kantola, Raimo	D.Sc. (Tech.), Professor, head of laboratory (2005)
Ott, Jörg	Dr. Eng, Professor
Virtamo, Jorma	D.Sc. (Tech.), Professor
Chakraborty, Shyam	D.Sc. (Tech.), Docent
Kilkki, Kalevi	D.Sc. (Tech.), Docent
Pirinen, Aulis	Ph.D., Docent
Raatikainen, Pertti	D.Sc. (Tech.), Docent
Rahko, Kauko	D.Sc. (Tech.), Professor emeritus

2.2 Administrative personnel, teachers and assistants

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

2.3 Senior researchers and researchers

Aalto, Samuli	Ph.D.
Hyytiä, Esa	D.Sc. (Tech.)
Ilvesmäki, Mika	D.Sc. (Tech.)
Karvo, Jouni	D.Sc. (Tech.)
Kuusela, Pirkko	Ph.D.
Lassila, Pasi	D.Sc. (Tech.)
Töyli, Juuso	D.Sc. (Tech.)

Beijar, Nicklas	Lic.Sc. (Tech.)
Costa Requena, José	M.Sc.
Gröhn, Antti	M.Sc.
Huttunen, Jari	M.Sc.
Juva, Ilmari	M.Sc.
Kaleelazhicathu, Renjish	M.Sc.
Kalm, Juha	M.Sc.
Kamppari, Sauli	M.Sc.
Kiiski, Annukka	M.Sc.
Koskinen, Henri	M.Sc.
Leino, Juha	M.Sc.
Liu, Shuping	M.Sc.
Luoma, Marko	Lic.Sc. (Tech.)
Matuszewski, Marcin	M.Sc.
Mölsä, Jarmo	Lic.Sc. (Tech.)
Nieminen, Johanna	M.Sc.
Nyberg-Oksanen, Eeva	Lic.Sc. (Tech.)
Penttinen, Aleksi	M.Sc.
Peuhkuri, Markus	Lic.Sc. (Tech.)
Smura, Timo	M.Sc.
Susitaival, Riikka	Lic.Sc. (Tech.)
Töyrylä, Piia	M.Sc.
Viipuri, Timo	M.Sc.

2.4 Research assistants and trainees

Apilo, Olli
Basaure, Arturo
Bovolenta, Gabriel
Hautala, Mikko
Heikkinen, Timo-Pekka
Holopainen, Visa
Huguet Prunera, Josep
Hyyryläinen, Tuomo
Häkkinen, Jarkko
Ivanov, Yavor
Jaskiewicz, Daniel
Järvinen, Juha
Kaikkonen, Sampo
Keränen, Heikki
Kivi, Antero
Lamminen, Olli-Pekka
Lehtinen, Juuso
Luo, Cheng
Mahanen, Petri
Merger, Mikko
Ralli, Timo
Simola, Oskari
Solarmo, Eero
Tallberg, Mathias
Tirronen, Tuomas
Vardar, Tuna
Vermaja, Juha
Zhao, Shushan
Zseni, Peter

2.5 Part-time teachers

Kneckt, Laura	S-38.105 Principles in Communication Engineering
Uusitupa, Seppo	S-38.105 Principles in Communication Engineering
Seppänen, Kari	S-38.165 Switching Technology

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

Figure 2.1: Telecom Forum 2005

3 RESEARCH PROJECTS

3.1 AHRAS

Project leader: Jorma Virtamo **Researchers:** Esa Hyytiä, Henri Koskinen, Pasi Lassila, Aleksi Penttinen

The project AHRAS aims at developing a high level of expertise of the essential teletraffic problems and issues related to effective performance of ad hoc networks. This expertise is utilized in designing methods to improve routing, performance, reliability and robustness of such networks and drawing guidelines for effective network implementation and exploitation in military environment.

During its final year (2005), the project addressed network connectivity and capacity issues, node mobility, multicast routing, and performance analysis in ad hoc networks.

Connectivity and capacity issues of ad hoc networks were studied under a detailed interference model, i.e., the Physical model. In this model a transmission is successful only if the received signal-to-interference ratio is larger than a given threshold. Within the Physical model, the threshold range for connectivity was characterized under two different MAC-layer models; CDMA and Slotted Aloha. Another related topic of research was the probability of successful transmission in a Slotted Aloha network. The existing theoretical results were scrutinized under more realistic assumptions by developing methods for computing the probability.

Study on the effects of node mobility was continued by more thorough analysis of the Random Waypoint model. The node distribution on a unit disk is illustrated in Figure 3.1. The model was further applied to describe the traffic load distribution in dense ad hoc networks.

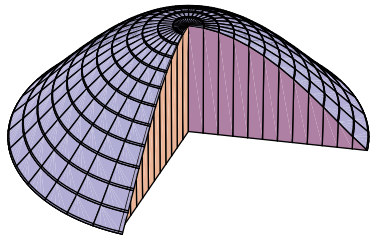


Figure 3.1: Distribution of nodes under Random WayPoint mobility model on a unit disk.

Also the load balancing problem was examined in a similar context. The aim was to minimize the maximum load in the network area by changing the routing paths so that the most heavily loaded areas are avoided. As a result, two lower bounds for the minimum achievable maximum load were derived and different path selections were empirically analyzed. For example, in unit disk with uniform traffic demands we were able to devise

path sets (see Figure 3.2 for one set of paths) which reduce the maximum traffic load considerably when compared to the shortest path routing. In particular, the obtained traffic load level is also quite near the tightest lower bound."

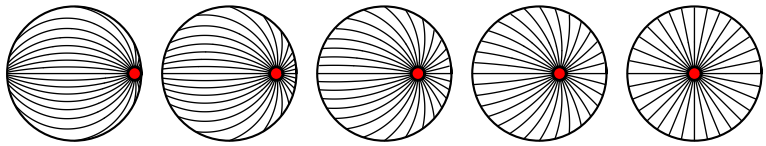


Figure 3.2: A set of circular paths used for load balancing.

The multicast routing problem entails finding a tree consisting of sequential transmissions to connect a source to several destinations. In 2005, a novel routing algorithm was developed in the project. The algorithm utilizes the unicast routing tables to compute efficient multicast trees under arbitrary transmission costs. The algorithm is illustrated in Figure 3.3.

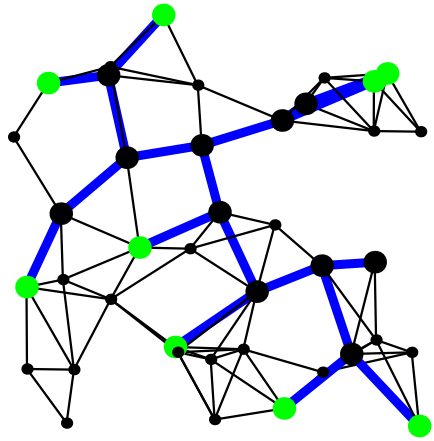


Figure 3.3: A multicast tree minimizing the number of retransmissions in a wireless multihop network.

Finally, the study on flow-level performance of wireless multi-hop networks was continued. Development resulted into efficient approximation schemes and enabled the analysis of complex networks, which had defied previous approaches. The analysis was also extended to models in which the transmission rates can depend on the location of nodes.

3.2 ECOSYS

Project leader: Heikki Hämmäinen, Renjish Kaleelazhicathu **Researchers:** Timo Smura

ECOSYS (Techno-economics for Intergrated Systems and Services) is a 3-year international project (2004-2007) part of the EUREKA/CELTIC program. The project covers a set of operator-centric techno-economic investment issues related to fixed, mobile, and convergent networks. Workpackages include traffic forecasting, development of techno-economic analysis methodology and tools, and application of these on specific business cases. Our team focuses on mobile network related topics.

During 2005, we participated in the techno-economic modelling and analysis of two types of mobile operators in a small and large country setting. 1) new entrant mobile operator case, where the operator has a UMTS license but no GSM license (acts as a 2G MVNO) and 2) a pure Mobile Virtual Operator (MVNO) case, where the operator has neither UMTS nor GSM license. The results of the new entrant case study shows that such an operator's business in a small country may not be profitable without acquiring substantial number of subscriptions (more than 20% of the market share) which is not an easy task. In the MVNO case, comparison between a pure MVNO and a service provider business shows that MVNO case can be more profitable, mainly as a result of revenue from termination charges. However, MVNO's relationship with Mobile Network Operator (MNO) is key to its success. The competitive potential of WiMax in the broadband market was also studied. Results show its suitability in dense urban and rural areas.

Fixed-mobile convergence was another area of study during 2005. The team was involved in the preliminary studies on convergence such as the identification of key drivers, technology and service realisation and a set of scenarios to be studied further this year. The team has also taken up the leadership of convergence work package in ECOSYS.

3.3 E-NEXT

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

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

A NoE like E-NEXT does not pay for the research work itself, it only has a budget for covering cooperation expenses.

During 2005 we participated in several E-NEXT work group activities, conference organization activities and in the SATIN Doctoral School. We also had a joint research project with our E-NEXT partners on Metropolitan Area Ad hoc Networks (MobileMAN).

3.4 Euro-NGI

Project leader: Jorma Virtamo **Researchers:** Samuli Aalto, Esa Hyytiä, Ilmari Juva, Henri Koskinen, Pasi Lassila, Juha Leino, Aleksi Penttinen, Riikka Susitaival

Euro-NGI is one of the Network of Excellences of the EU Sixth Framework Programme. The purpose of a NoE is to foster, in a broad sense, collaboration between the participating institutions and integration of their research activities. The end of the acronym, NGI, stands for Next Generation Internet. Euro-NGI was started in December 2003 and continues for three years. It is a very large network including 58 partners, mostly from the academia but also a few partners from the industry are involved. After 2006, the network will continue with a follow-up project Euro-FGI, the proposal for which was accepted by the Commission in 2005.

Researchers of the Networking Laboratory have participated in many activities of Euro-NGI. One paper was presented in the first Euro-NGI conference that was held in Rome in April 2005. Two papers were submitted and accepted for the second Euro-NGI conference to be held in Valencia in April 2006. Networking Laboratory was also a partner in two joint research projects within Euro-NGI, namely the Cellular project and the project on estimating the Origin-Destination Demands Matrix. Several meetings of the Cellular project were attended by the researchers from the Netlab. Within the traffic matrix estimation project, I. Juva made a one-month visit to ENST Bretagne, Brest, in May 2005, and Prof. S. Vaton from ENST Bretagne made a two-week visit to TKK in August 2005. Both of these projects were finished at the end of 2005 but a proposal for a follow-up project of the Cellular project was submitted and later approved.

3.5 Fancy

Project leader: Jorma Virtamo **Researchers:** Samuli Aalto, Mika Ilvesmäki, Ilmari Juva, Eeva Nyberg-Oksanen

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

Balanced fairness (BF) is a novel insensitive resource sharing scheme which defines how to share capacity of a network to different flows in such a way that the resulting system is insensitive. The work on this subject, started in FIT project, was continued. The performance of three usual allocations (max-min fairness, proportional fairness and balanced fairness) were compared in a communication network whose resources are shared by a random number of data flows. A recursive formula for evaluating the per-flow throughput in a multirate system with elastic traffic was presented. Dynamic insensitive load balancing in the case of a single arrival process

was explored and an analytic study of the single class case was performed, which allows giving a simple and efficient algorithm for deriving the optimal policy. The behavior of balanced fairness was studied in light and heavy traffic regimes, and it was presented how the corresponding performance results can be used to approximate the flow throughput over the whole load range.

Multilevel Processor-Sharing disciplines (MLPS) were originally introduced by L. Kleinrock but they were forgotten for years. However, due to an application related to the service differentiation between short and long TCP flows in the Internet, they have recently gained new interest. In the project a study was performed where an earlier result, showing that replacing PS discipline with MLPS reduces the mean delay, is generalized to a wider service time distribution class. A previous result from literature about the optimality of foreground background discipline was proved false, but a weaker result of the same hypothesis was proved. Then, an analysis of MLPS was performed to provide a constructive way to prove the optimality of FB.

An important milestone was that the D.Sc. thesis of E. Nyberg-Oksanen was completed in 2005. Though not done strictly within the Fancy project, a central part of the work focussed on the problems just discussed, e.g., MLPS scheduling disciplines. The approval for printing the work was received in November and the defense was scheduled for January 2006.

The knowledge of the current traffic demands between the origin-destination pairs of the network is a necessary input in many traffic engineering and dimensioning tasks. Estimating the traffic matrix on the basis of link load measurements, however, is a strongly under-determined problem and poses a big challenge. In the project, a new estimation method using the link covariances was developed. The characteristics of origin-destination traffic were studied from measurements from the Funet network in order to study the validity of key assumptions involved in traffic matrix estimation. Statistical bounds for efficiency of an estimator were derived. A Licentiate thesis giving a comprehensive overview of current methods was completed within the project.

3.6 IRoNet – Intelligent Routing Network

Project leader: Raimo Kantola **Researchers:** Johanna Antila, Xiaole Bai, Evgenia Daskalova, Antti Gröhn, Jari Huttunen, Mika Ilvesmäki, Ilmari Juva, Renjish Kaleelazhicathu, Pasi Lassila, Marko Luoma, Anni Matinlauri, Marcin Matuszewski, Antti Paju, Timo Smura, Riikka Susitaival, Piia Töyrylä, Yin Wang, Peng Zhang

IRoNet studied the additional intelligence that is needed in the IP network in order to support Quality of Service. IRoNet scope covered the packet forwarding plane, the control plane and the management plane functionality needed in an IP network in order to fulfill the operator's popular vision of All-IP network and to provide a QoS enhanced Internet. In particular, the main areas of interest were traffic classification, modelling of the forwarding plane algorithms, routing and management support for the whole system. The project used mathematical modelling of the for-

warding plane mechanisms and the behavior of traffic streams, simulations of protocols and algorithms, traffic and performance measurements and prototyping of the mechanisms and algorithms particularly in the control and management planes. The project started in 1/2002 and ended in early 2005.

During 2005 we continued refining the methodology of traffic classification and building a large QoS prototype in which we can verify our earlier results on traffic classification and policy based management of QoS. In our prototyping and prototype based controlled measurement research we gained new insights in the capabilities of many new and well-known mechanisms that are used for implementing QoS. Using simulations we studied novel packet scheduling algorithms, in particular delay estimation for adaptive scheduling. In QoS routing the focus was on simulating the potential of Traffic Engineering using routing to allocate traffic onto the network, prototyping the concept of Multi-Class Routing and on prototyping a solution for centralized intra-domain routing. In multi-class routing the idea is that each DiffServ traffic class is routed separately and has its own routing table in each of the routers. Each class may also use a different routing algorithm.

In Ironet in 2005 we continued collecting and processing traffic traces from FUNET in close collaboration with the CSC that runs the Finnish University Network. We now have an abundance of traffic trace material for developing our traffic classification methodology and for doing statistical studies on Internet traffic. The traces pose significant processing requirements due to the data volumes but we believe this a good problem to have.

In IroNet we refined our hardware solution for synchronizing the router clocks in the research prototype. The solution is based on GPS and allows to time stamp events in the prototype with the accuracy of some tens of microseconds. In June 2005 one of the IroNet researcher, Mika Ilvesmäki, defended his Doctoral thesis.

3.7 LATE

Project leader: Markus Peuhkuri **Researchers:** Mikko Hautala, Heikki Keränen and Mikko Merger

LATE project focuses on simulation-based performance evaluation of wireless LANs ja MANs (IEEE 802.11, 802.16) on different usage scenarios. Using Mobile IPv6 on WLAN environment was studied using simulation models built for ns2 and Omnet++ simulators.

3.8 LEAD

Project leader: Heikki Hämmäinen, Sauli Kamppari **Researchers:** Annukka Kiiski, Timo Ralli, Mathias Tallberg, Juuso Töyli, Antero Kivi, Timo Ali-Vehmas

LEAD (Optimal Rules for a Leading Mobile Data Market) was a 2-year national project (2004-2005) funded by TEKES/NETS, Ficora, Nokia, Sonera, Elisa, and DNA. The general plan was to identify, analyze, and

better understand the techno-economic bottlenecks of the Finnish mobile data services market. This research was done together with the key market players. Research methodology was based on literature studies, expert interviews, frequent reviews with partners, technology scenario modelling, and construction of a mobile operator business game.

During 2005 we focused on a small set of issues: handset bundling, national roaming for WLAN, virtual operators, and mobile usage measurements. Handset bundling is a relevant topic because Finland has recently decided to allow it. Our study so far has produced an impact model describing the effects of bundling on mobile data usage. National WLAN hotspot coverage according to our study may happen through access network sharing rather than actual bilateral roaming agreements. Virtual operators together with number portability induced a new level of mobile competition in Finland, but this trend has slowed down because of mergers. Our interview study on virtual operators still continues. Measuring mobile data usage in handsets, routers, and operator databases has produced us uniquely accurate base data on the Finnish market. First analyses have been done, but the data set still allows additional more focused studies.

3.9 MobileMAN

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

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

The main technical outputs expected of this project include:

1. Development, validation, implementation and testing of the architecture, and related protocols, for configuring and managing a MobileMAN. The research is conducted spanning all layers in the networking hierarchy. Our research combines advanced communications and networking research with basic research.

2. Physical implementation of this architecture for lower layers (i.e., wireless technologies). This was done by improving the existing IEEE 802.11 wireless technologies for dealing with bursty access environments as self-organized networks.

3. Integration of applications on top of the self organized network.

4. Validation of the self-organizing paradigm from the social and economic standpoint.

During this year, we continued the development and testing of the ad hoc routing testbed that is an integral part of the three-year research plan. A routing testbed is useful because simulations seem to produce rather arbitrary results for the benefits of each routing protocol being evaluated. Due

to having both proactive and reactive routing protocols in the same testbed, these two routing approaches are easy to compare.

The prototype runs on iPaq palmtops that have Linux OS. The nodes can run several routing protocols. The currently operational routing protocols are AODV, OLSR, and ZRP. The nodes are grouped into ”smart” and ”dummy” nodes. Smart nodes can provide additional services, such as a gateway to a base station or an Access Point. We have implemented service discovery in the prototype and we have implemented and measured sample services on the platform. These are Voice over Ad Hoc and Peer-to-Peer services.

During the year 2005 we have performed additional field testing with several nodes and routing protocols. We have also refined and tested SIP and VoIP on top of the routing package.

3.10 NAPS

Project leader: Jorma Virtamo **Researchers:** Olli Apilo, Pasi Lassila, Juha Leino, Shuping Liu

NAPS (Networking and Architecture for Proactive Systems) was a 3-year project (2003-2005) funded by the Academy of Finland. It was part of the research programme on Proactive Computing (PROACT). The research consortium of NAPS was coordinated by Helsinki Institute for Information Technology, Basic Research Unit, with sub-projects conducted at the Networking Laboratory (TKK) and the Laboratory for Theoretical Computer Science (TKK). Our work in the NAPS project was presented also in the Proact Colloquium held at the Helsinki University in Spring 2005. During the final year (2005) of the project, the following topics were addressed:

We extended a model presented in the literature to account for the effect of mobility on the performance of a cellular system, specifically considering the finiteness of the user population. In its full generality, the problem is difficult, and the paper studies the performance in two extreme regimes which are amenable to analysis and also give bounds for the performance in intermediate cases. The regimes are those of a very slow motion and a very fast motion, and these are analyzed using so-called quasi stationary and fluid approximations, respectively.

Traditional reactive and proactive routing protocols do not scale well to large ad hoc networks. If geographic location information is readily available, so called geographic routing can be used to achieve better scalability. Geographic routing in large ad hoc network can be decoupled into a macroscopic and a microscopic level. At the macroscopic level, the network can be considered as a continuous medium, and the problem is to define the geometric properties of the routes according to a given routing metric, for example shortest path routes correspond to straight lines. At the microscopic level, the direction of packet flow is given by the macroscopic level routing algorithm, and the task of the microscopic level forwarding method is to maximise the flow of packets in the given direction.

In a Master’s thesis work we considered a model under which the performance of microscopic forwarding methods can be compared under a minimal set of parameters assuming a slotted ALOHA type protocol. The

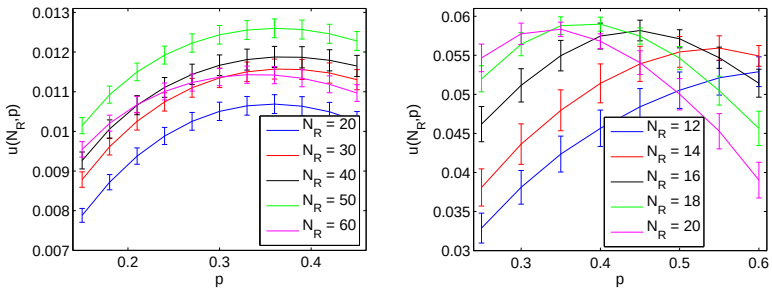


Figure 3.4: The maximum packet flow for deterministic forwarding (left) and opportunistic forwarding (right).

maximum sustainable packet flow intensity of a random network was studied by simulations with respect to the free parameters and the performances of four different forwarding methods, namely one deterministic, two randomised forwarding methods, and one locally coordinated opportunistic scheme were compared. Figure 3.4 which depicts the normalised mean packet flow as a function of the ALOHA transmission probability p for various values of the network density parameter N_R for the deterministic and opportunistic forwarding methods.

As in fixed networks, also in wireless multi-hop networks the performance perceived by the users sending elastic traffic mainly manifests itself on the flow level. A flow of elastic traffic typically comprises of a transfer of a document, file or message. The transmission can use all the bandwidth that is available but can also adapt the transmission speed to share the bandwidth with other concurrent flows. The performance depends on the dynamic behavior of the system and on how the bandwidth is shared between different flows. Thus it is necessary to study the system in a dynamic setting where new flows arrive at the network, are transferred across the network, and upon completion depart from the system.

In general, performance evaluation of dynamic networks is difficult. Balanced fairness (BF) is a new resource sharing concept recently introduced by Bonald and Proutière as a means to approximately evaluate the performance of fair allocations like max-min fairness and proportional fairness in wired networks. We have extended the use of this notion to wireless multi-hop networks, e.g., ad hoc networks, where the link capacities at the flow level are not fixed but depend on lower layer issues such as scheduling and interference. Different physical and access layer configurations are described by a linear constraint model and an efficient computational scheme is devised for solving the system.

We have specifically applied the concept of balanced fairness to study a scenario where two base stations with link adaptation serve in a coordinated fashion downloading users on a road or street between the stations. The performance of the system under balanced fairness is compared to that with other allocation schemes such as maximum throughput and max-min fairness. To facilitate the analysis of the alternative allocation schemes, a novel approximation method referred to as value extrapolation was in-

troduced. This idea is formulated within the setting of Markov decision Processes (MDP) and it is generally applicable to approximate any performance measure expressed as the expected value of a random variable which is a function of the system state. Our experiments indicate that the method is efficient yielding surprisingly accurate results even with radically truncated state spaces.

In another study of intercell co-ordination for interference avoidance the objective was to find the capacity limit of a multicell cellular system. To this end, one has to find the optimal division of each cell into sub-areas each of which is to be served in a given transmission mode (a set of base stations simultaneously serving their respective cells). The work covers the general case where the traffic load is inhomogeneous. A complete characterization of the optimum in two-cell and three-cell systems was found in terms of a set of necessary conditions. An example of a three-cell system was numerically worked out and the resulting optimal division is shown in Figure 3.5.

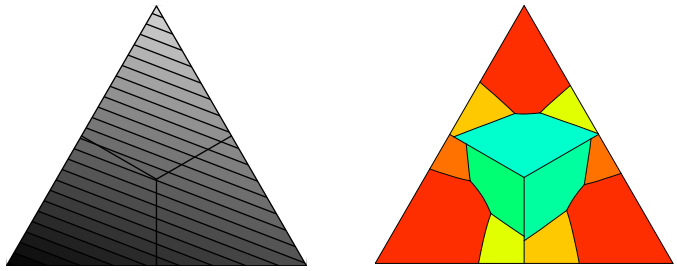


Figure 3.5: Example of inhomogeneous traffic distribution in a cellular system with three base stations (left) and optimal division of the area into sub-areas to be served in different transmission modes (right).

Network resources are utilised more efficiently, if traffic load is balanced dynamically between different routes. We generalised balanced fairness to networks, whose traffic flows can be split between several routes. Traffic splitting corresponds to packet level load balancing. The problem can be solved recursively. In each state, the amount of allocated capacity is maximised while satisfying the capacity constraints and the constraints required for insensitivity. The maximisation problem can be formulated and solved as an LP problem. In another work, we compared insensitive traffic splitting with insensitive load balancing executed at flow level. Insensitive flow level balancing can be optimised using LP formulation of the theory of Markov Decision Processes. Packet level load balancing outperforms flow level balancing. Packet level balancing is also significantly easier to analyze as the computation can be executed recursively.

3.11 PAN-NET

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

PAN-NET is a joint project with VTT Information Technology. The project is funded by TEKES and it was started in 2004. In 2005, the indus-

trial partners in the project were Nokia and ROMMON. The project will be continued in 2006 with a new TEKES funded project ABI, which is one of the strategic projects in the new GIGA Technology Programme. In 2005, the main areas of research in the project were p2p networks, dimensioning of radio access networks and Fountain codes.

The use of wireless links to provide Internet access is rapidly increasing, e.g., via the use of WiMAX technology, and methods for dimensioning of such wireless multihop networks were developed. The main idea was to apply recent analytical results on flow-level models that allow the dimensioning to be based on a natural flow-level QoS metric, such as the average throughput, and to combine this with models capturing the impact of interference on the wireless links.

Peer-to-peer applications have emerged as new communications paradigm that has already had considerable impact on, e.g., the traffic in the operator's networks. The work concentrated on analyzing and modeling the dynamics of the distribution of a document by a peer-to-peer system. Relevant issues concern both stationary and dynamic behavior of the system, e.g., with respect to the number of copies of the document in the system and the number of downloaders. An example of this is shown in Figure 3.6, where left figure depicts the temporal evolution for the number of documents in the system and the right figure the number of downloaders. Solid continuous lines correspond to the fluid model and the grey lines to simulated realizations of the random process.

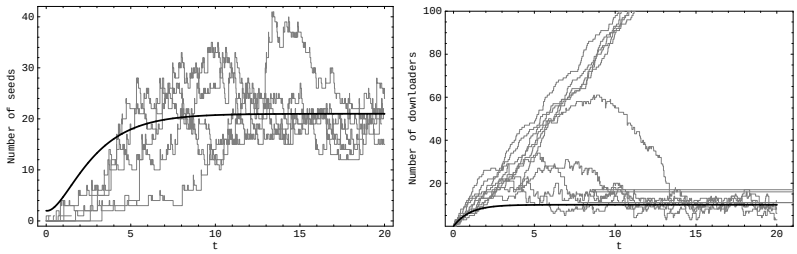


Figure 3.6: Temporal evolution of number of documents (left) and number of downloaders (right) in a peer-to-peer system.

Fountain codes represent a new paradigm for forward error correcting codes (FEC), recently invented by M. Luby. They are specifically designed for an erasure channel where entire packets may be lost (as opposed just bit errors occurring) but received packets are assumed error-free. The basic idea is to form from a set of source packets, by a certain simple stochastic algorithm, a virtually endless supply (like droplets in a fountain) of encoded packets that are sprayed into the network. For a recipient it is sufficient to collect a certain number of encoded packets – no matter exactly which – to decode the original message, as if he were holding a bucket under the fountain in order to get it filled with water. This coding scheme opens interesting new application possibilities. In the PAN-NET project we have addressed the problem of optimizing the so-called degree distribution used in the coding process in order to minimize, e.g., the mean number of encoded packets needed for full decoding. The central idea was borrowed

from the importance sampling, providing a way to estimate the objective function under any degree distribution based on a sample of simulated results obtained under a given degree distribution. In particular, one can estimate the gradient of the objective function with respect to parameters of the degree distribution and thus allows one to use efficient gradient-based optimization algorithms. Extensive simulation experiments were conducted and improved degree distributions were found. A master's thesis on the topic was well underway, though the work was not finalized in 2005.

3.12 TIEVA

Project leader: Marko Luoma **Researchers:** Markus Peuhkuri, Timo-Pekka Heikkinen, Juha Järvinen, Yavor Ivanov

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

3.13 WIDENS – Wireless DEployable Network System

Project leader: Raimo Kantola **Researchers:** Daniel Jaskiewicz, Jouni Karvo, Shushan Zhao

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

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

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

The project will support the strong on-going European involvement in the joint ETSI/TIA standardization initiative MESA (Mobile Broadband for Emergency and Safety Applications). The design and prototype devel-

opments will be contributed to the MESA standardization process and will shape the future of private mobile communication systems.

During 2005 the project produced two Master's theses and three conference papers.

4 TEACHING

4.1 General notes on teaching in 2005

The department continues to run the Degree Program in Communications Engineering initiated in 2000 until 2010. In this Program Netlab is responsible for three major subjects. They are Networking Technology, Teletraffic theory and Telecommunications Management. In addition, we have the Network technology major in the International Master's Programme in Telecommunications. The Telecommunications Management major is produced jointly with the Department of Computer Science and Engineering and the Department of Industrial Engineering and Management.

In 2005, TKK introduced the new study structure following the Bologna principles. In the new structure, the number of Master level major subjects is reduced to about 60 for the whole TKK. The whole degree program is organized into modules and all courses are dimensioned in ECTS rather than the old credit units. While the new program was designed all courses were evaluated in terms of core content and ECTS dimensioning was based on a system of work estimation.

The new study structure differs from the old one significantly. The structure consists of modules, most of 20 ECTS. Particularly, the 3rd and 4th year programs changed towards reducing compulsory material and giving the student more decision power in compiling his or her degree from reasonable chunks of knowledge. These chunks are called modules. Major subject in a masters program consists of three consecutive modules two of which can be taken already in the Bachelor degree. Minor is a slightly looser set of two modules but is not compulsory meaning that a degree at minimum will have a major and a set of modules giving the total volume of 300 ECTS.

In the new 3+2 structure, Netlab is now responsible for the Bachelor level Major in Networking Technology and the Master level Major in Networks containing three alternative modules in Network Technology, in Teletraffic Theory and in Networking Business. In addition we provide a Special module or C module in Networks that can be taken to deepen one's studies in the area. Teletraffic theory is available in the master level major called Mathematical methods in Communications Engineering as well.

The International Master's Programme is now fully integrated with the study structure for domestic students. Administratively the programs in Computer Science and Communications Engineering are separated. Due to this administrative separation and remodeling of the International Programs to conform with the 3+2 Bologna structure, new names for the Programs were adopted from 2005. The Program run by the Department of Electrical and Communications Engineering is now called the International Master's Programme in Communications Engineering and we continue to provide a Major in that program with the title Network Engineering. This is a combination of the courses from all fields provided by the laboratory. The modules are designed in such a way that a student from

a slightly different program than our own B.Sc program can still take our master's program.

In the new study structure all master level degrees include a compulsory module of 10 ECTS on research methodology. For this module we introduced a new course on IP network measurements and measurement analysis that applies statistical analysis to IP network traffic.

The modules in the new study structure Netlab is responsible for are presented in Figure 4.1.

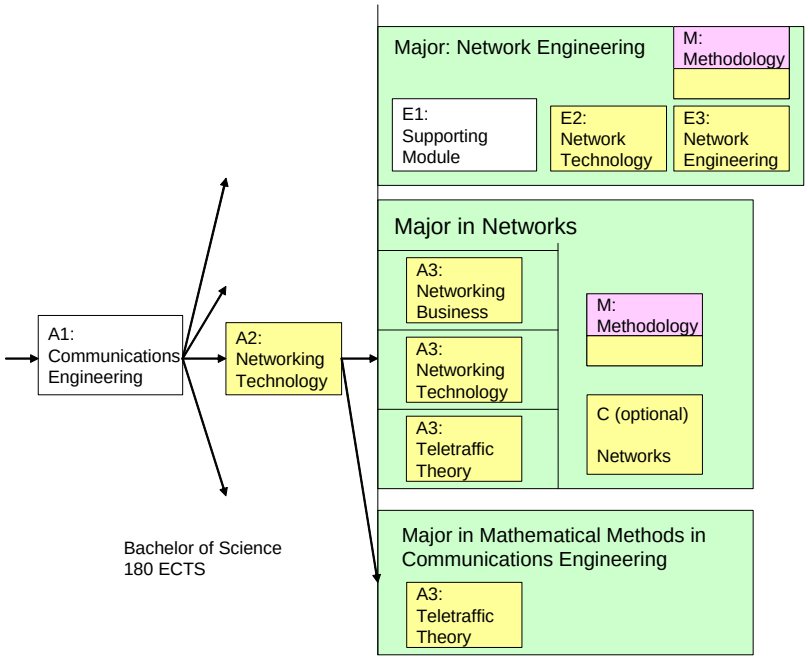


Figure 4.1: Netlab modules in the new study structure.

A new thing in the 3+2 degree structure is the existence of the intermediate degree of Bachelor of Science. Bachelors that have specialized in Network technology will have actually taken only an introductory course in telecommunications, a course in telecommunications systems, an introduction to teletraffic theory, a course in Computer Networks, course in Routing in telecommunication networks and a short hands-on laboratory course. Otherwise the degree gives a strong background in mathematics, physics, circuits and electronics, software engineering and in fundamentals of communications theory.

A diploma engineer majoring in Networks will have to take at least one of the A3 modules in the Figure. By taking the C-module one can deepen the specialization in the area of the major. Taking the C-module is possible within the minimum frame of 300 ECTS for the degree but the student has many other choices as well.

In the course S-38.3001 Telecommunication Forum many visiting lecturers shared their views on the evolution of telecommunications industry.

4.2 Course descriptions

This is the full list of courses in our curriculum:

Studia generalia:

- S-38.3001 Telecommunications Forum (Telecommunications Forum)

Basic courses for all students studying telecommunications:

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

Courses concerning communications and networks:

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

Courses on Networking Business:

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

Courses on Teletraffic Theory:

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

Courses on protocols and services:

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

- S-38.3157 Protocol Design (Protokollasuunnittelu)

Seminars, laboratory works, special assignments:

- S-38.2132 Laboratory course on Networking Technology A (Tietoverkkotekniikan laboratoriotyöt A)
- S-38.3133 Laboratory course on Networking Technology B (Tietoverkkotekniikan laboratoriotyöt B)
- S-38.3138 Networking Technology, special assignment (Tietoverkkotekniikan erikoistyö)
- S-38.1203 Project course on Networking Technology (Tietoverkkotekniikan projektityö)
- S-38.3310 Thesis Seminar on Networking Technology (Tietoverkkotekniikan diplomityöseminaari)

Postgraduate courses include:

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

4.3 Theses

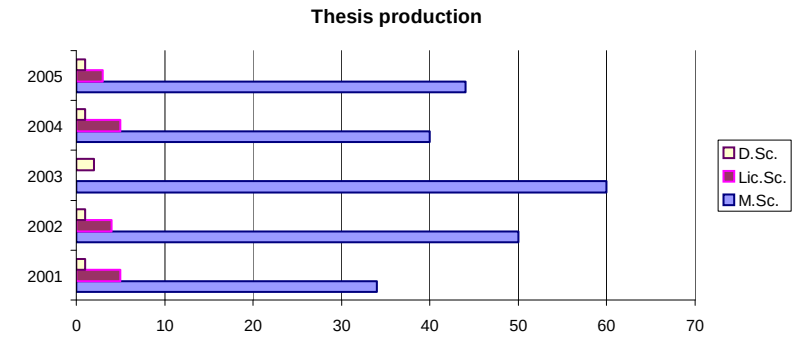
The key results of teaching in the Networking Laboratory in 2005 can be summarized as

44 Master's theses

3 Licentiate theses, and

1 Doctoral dissertation

The development of thesis production is shown in Figure 4.2



Year	2001	2002	2003	2004	2005
D.Sc.	1	1	2	1	1
Lic.Sc.	5	4	0	5	3
M.Sc.	34	50	60	40	44

Figure 4.2: Thesis production 2001-2005

Doctor of Technology

Mika Ilvesmäki On traffic classification and its applications in the Internet

In this work, the methods and applications of traffic classification in the Internet are examined in detail. First, we define and discuss the conceptual environment of traffic classification. We then discuss the performance issues of traffic classification and define a method of visualization to compare the performance of traffic classification implementations.

Previously introduced methods of traffic classification: the static applications, the packet count and the list classifiers are compared with each other. We find these methods to perform quite well when analyzed as performing in an IP router, but to be rather ambiguous as to the effect they cause to the user.

We introduce an implementation of dynamic traffic classification to two classes using learning vector quantization (LVQ) for flow analysis data and find it to perform well in a simulated environment using flow analysis made on traffic measurements. In comparison to the previous methods of traffic classification, we see that the LVQ classifier has adequate performance. We also study a method of traffic classification using consecutive flow analysis with varying values of the parameters of the flow and find that we are able to classify traffic to 2 or 3 different classes. Within the classes the applications are similar in measured behavior and thus may provide help in realizing some advanced Internet service architectures.

Finally, we also observe the application of the dynamic classifier in an Internet router and in the Internet itself. We argue that the im-

plementation of the dynamic classification method is feasible in the network.

Licentiate of Technology

Guoyou He Inter-operation between RADIUS and Diameter Protocols

Authentication, Authorization and Accounting (AAA) protocols such as Terminal Access Control System (TACACS) and Remote Authentication Dial-In User Service (RADIUS) were initially deployed to provide dial-up Point-to-Point Protocol (PPP) and terminal server access.

This thesis reviews the main AAA protocols, the widely used RADIUS protocol and the newly proposed Diameter protocol, and examines the current situation of defining the inter-operation between these two protocols. The problems on the definition and specifications of RADIUS and Diameter inter-operation up to date are investigated and described.

Ilmari Juva Traffic Matrix Estimation

The thesis studies the problem of traffic matrix estimation. Validity of common assumptions is studied and a comprehensive overview of methods proposed in literature is given. The methods are divided into two main groups: The methods based on the gravity model and Maximum likelihood methods.

A novel method is proposed for the problem: The Quick method based on link count covariances, which yields an analytical expression for the estimate and is thus computationally light-weight. The accuracy of the method is compared with that of other methods by simulation under synthetic traffic scenarios.

Johanna Nieminen Simulation and Measurements of a Delay-Adaptive Scheduling Algorithm

In this thesis a new delay-bounded Hybrid Proportional Delay (DBHPD) adaptive scheduling algorithm was implemented and evaluated with both simulations and measurements in a prototype router. The objective of the experiments was to investigate what kind of performance advantage can be achieved with adaptive scheduling compared to conventional or pseudo-adaptive scheduling algorithms and to find out whether the DBHPD algorithm can be implemented with reasonable complexity. Another major goal was to compare the measurement results with simulation results in order to see how well real implementations of the selected algorithms correspond to the theoretical simulation models of these algorithms.

Masters of Science

The employers of our Master's thesis students are shown in Figure 4.3.

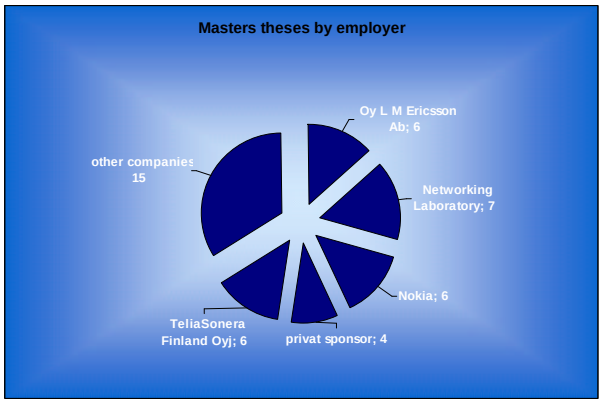


Figure 4.3: Employers of Master's thesis students 2005

- Aarnio, Markus: WLAN-teknologian rooli Suomen laajakaista-markkinoilla
- Basaure, Arturo: Cost Analysis of Mobile Charging and Billing, TKK, Netlab
- Bloigu, Minna: Network attendant service in 3G networks
- Grönlund, Jani: Langattoman lähiverkon tilaus-toimitusprosessi, TeliaSonera Finland Oyj
- Harjama, Esko: Investigation and Evaluation of Systems for Generating Automatic Alerts Using Honeynet Data, F-Secure Corporation
- Heiskanen, Hanna: Quality of Person-to-Person Services in the Third Generation Partnership Project Architecture, TeliaSonera Finland Oyj
- Hietanen, Jari: Validating the Resilience Mechanisms for the Packet Switched Domain in 3G Networks, Nokia Networks
- Huopaniemi, Antti: Implementing Universal Serial Bus over Wireless Local Area Networks
- Huttunen, Jari: Measurements on Differentiation of Internet Traffic, TKK, Netlab
- Hämäläinen, Anssi: Measuring Online Game Application Performance in Wireless Packet Networks
- Isosaari, Mika: Static Call Admission Control and Dimensioning of Media Gateways in IP based Mobile Core Networks, Oy L M Ericsson Ab, Finland

- Joki, Heidi: Modeling of DVB-H Link Layer, Nokia
- Kaikkonen, Sampo: Using a Routing Simulator to Calculate Routes in a Network, TKK, Netlab
- Karvonen, Tuukka: Design of Push to Talk Client for Performance Measurements, Celtius Ltd
- Koivisto, Mikko: Traffic analysis and optimization of a management network, Nokia Networks
- Korhonen, Hanna-Riina: TV-kanavien jakeluoikeuksien soveltaminen suljetussa laajakaistaisessa IP-jakeluverkossa, TeliaSonera Finland Oyj
- Koski, Jani: Verkkoprosessin mikro-ohjelmiston kehityksen prosessimalli, Nokia Networks
- Lagerström, Heidi: Analysis of Service Quality in 3G Mobile Networks, Omnitele
- Lavanti, Heikki: Implementing End-to-End Security in TETRA, Nokia Networks
- Lehtinen, Mika: Session Border Controller and IP Multimedia Standards, TeliaSonera Finland Oyj
- Lehtonen, Kristo: Enhancing Information-Sharing Culture in New Product Development, Nokia
- Lehtonen, Mikko: Hierarchial approach for spotting keywords from an acoustic stream, Eurecom
- Li, Yaohui: Implementing Integrated Services in Network Simulator, TKK, Netlab
- Lindfors, Erno: Investigating the Structure of Integrated Biological Networks, VTT
- Mattila, Marcus: Existing Alternatives for Pushing Content to Mobile Devices - an Analysis and an Implementation, SysOpen Digia Plc
- Mikkola, Lauri: Realization of the Interworking Function in the Layered Architecture Based CDMA2000 Core Network, Oy L M Ericsson Ab, Finland
- Mäenpää, Jouni: Performance of Signalling Compression in the Third Generation Mobile Network, Oy L M Ericsson Ab Finland
- Neuvo, Pekka: IT Network Outsourcing Process
- Ojala, Mikael: Model of Business Intelligence Maturity Levels for Mobile Operators, AffectoGenimap

- Pätynen, Erik: Etäopetusjärjestelmän toteutus ja käyttöönotto, EVTEK
- Rintamaa, Pasi: Telecom Implementation Costs and Cost Drivers of Mobile Network Site, Nokia
- Saikkonen, Toni: Analysis of Electronic Payment Systems for Network Gaming, Sulake Corporation
- Sorvari, Simo: Erään teleoperaattorin laajakaistatoimitusprosessin kustannustehokkuus
- Suorsa, Ying: Comparison of Mobile Communications Service Industry: Finland vs. China
- Tallberg, Mathias: Functional Extensions to Mobile Operator Business Game, TKK, Netlab,
- Tiihonen, Sanna: SIP-pohjaisen kuluttajapalvelun kannattavuus
- Verkasalo, Hannu: Handset-Based Monitoring of Mobile Customer Behavior, Nokia Corporation
- Vermaja, Juha: Applicability of instant messaging in military command and control systems, TKK, Netlab
- Viitanen, Mikko: Measuring Media Gateway Software Efficiency Using Performance Monitor Counters, Oy L M Ericsson Ab, Finland
- Virtanen, Tuija: Avoimen lähdekoodin SIP-toteutusten testaus TTCN-3-kieltä käyttäen, TietoEnator
- Wu, Kaiyuan: Load balancing of elastic data streams in cellular networks, TKK, Netlab
- Vuorensola, Jaakko: Intelligent Network Functions with Call Processing Language and Common Gateway Interface, Sonera Carrier Networks
- Väisänen, Mika: Frame Header Based Speech Quality Analysis Method in a Circuit-Switched Media Gateway, Oy LM Ericsson Ab, Finland
- Xing, Jing: Economic Study on Deployment of Wireless Local Area Network in Finland, Bonito Research Oy

5 ACTIVITIES

5.1 Participation in conferences and meetings

- Samuli Aalto
  - COST 279 Management Committee Meeting, Antalya, Turkey, February 24-25, 2005
- Mohammad A Ayyash
  - MobileMAN Meeting, Pisa, Italy, May 15-18, 2005
  - ICPS'05 Conference, Santorini, Greece, July 11-14, 2005
- Nicklas Beijar
  - MobileMAN Meeting, Sophia Antipolis, Nice, France, June 6-7, 2005
  - Med-Hoc-Net 2005 Conference, Île de Porquerolles, France, June 21-24, 2005
  - Workshop on peer-to-peer networking, Nokia Research Center, Tampere, October 10, 2005
  - ICTSM 2005 International Conference on Telecommunication Systems, Modeling and Analysis, Dallas, USA, November 17-20, 2005
- Jose Costa-Requena
  - Plenary of ARENA Project, Brussels, Belgium, February 16-18, 2005
  - IEEE International Conference on Networking and Systems (ICN2005), Papeete, French Polynesia, October 23-28, 2005
- Evgenia Daskalova
  - EuroIMSA 2005 Conference, Grindelwald, Switzerland, February 21-23, 2005
- Jari Huttunen
  - MSAN 2005 Conference, Orlando, USA, June 12-15, 2005
- Esa Hyytiä
  - EuroNGI Plenary, Barcelona, Spain, February 28 - March 2, 2005
  - COST 279 Final Seminar, Lisbon, Portugal, June 27-29, 2005
  - MSWiM 2005 Workshop, Montreal, Canada, October 10-13, 2005

- Jarkko Häkkinen
  - MobileMAN Meeting, Pisa, Italy, May 15-18, 2005
- Heikki Hämmäinen
  - ECOSYS Meeting, Saariselkä, March 8-11, 2005
  - Networking 2005 Conference, Waterloo, Canada, May 2-7, 2005
- Mika Ilvesmäki
  - E-NEXT Plenary, Naples, Italy, March 30-31, 2005
- Ilmari Juva
  - NGI 2005, 1st EuroNGI Conference on Next Generation Internet Design and Engineering, Rome, Italy, April 18-20, 2005
  - EURO NGI Workshop on Traffic Engineering, Protection and Restoration, Rome, Italy, April 21-22, 2005
  - EuroNGI Specific research project on Traffic Matrix Estimation, Project meeting. Paris, France, December 6, 2005
- Renjish Kaleelazhicathu
  - ECOSYS Meeting, Paris, France, January 31 - February 2, 2005
  - ECOSYS Meeting, Saariselkä, March 8-11, 2005
  - ECOSYS Meeting, Rhodos, Greece, May 23-26, 2005
  - ECOSYS Meeting, Madrid, Spain, June 27-30, 2005
  - ECOSYS Meeting, Berlin, Germany, July 11-13, 2005
  - ECOSYS Meeting, Riva del Garda, Italy, October 3-6, 2005
  - ICTSM 2005 International Conference on Telecommunication Systems, Modeling and Analysis, Dallas, USA, November 17-20, 2005
  - ECOSYS Meeting, Athens, Greece, December 5-8, 2005
- Raimo Kantola
  - TERENA Conference, Poznan, Poland, June 6-8, 2005
  - ICW'2005 Conference, Montreal, Canada, August 15-17, 2005
  - Bi- and Multilingual Education Conference, Helsinki, Finland, September 1-3, 2005
  - Workshop on peer-to-peer networking, Nokia Research Center, Tampere, October 10, 2005
  - CoNext 2005 Conference, October 24-27, 2005
- Jouni Karvo
  - Plenary of ARENA Project, Brussels, Belgium, February 16-18, 2005

- WIDENS Project meeting, Madrid, Spain, May 8-11, 2005
- 14th IST Mobile and Wireless Communication Summit, Dresden, Germany, June 19-23, 2005
- WIDENS Project meeting, Mons, Belgium, July 12-13, 2005
- WIDENS WP3 Meeting, Paris, France, August 31 - September 1, 2005
- WIDENS Meeting, Sophia Antipolis, Nice, France, October 17-21, 2005

• Henri Koskinen

- Med-Hoc-Net 2005 Conference, Île de Porquerolles, France, June 21-24, 2005
- ACM MSWiM 2005 Montreal, Canada, October 10-13, 2005
- IASTED International Conference on Communications and Computer Networks (CCN'2005), Marina del Rey, CA, USA, October 24-26, 2005

• Pasi Lassila

- EuroNGI Cellular project meeting, Paris, France, May 26-27, 2005
- The 19th International Teletraffic Congress (ITC 19), Peking, China, August 29 - September 2, 2005

• Juha Leino

- QoS-IP 2005 Conference, Catania, Italy, February 2-4, 2005
- The 19th International Teletraffic Congress (ITC 19), Peking, China, August 29 - September 2, 2005

• Marko Luoma

- E-NEXT Plenary, Naples, Italy, March 30-31, 2005
- Juniper Networks Conference, Amsterdam, The Netherlands, September 5-7, 2005

• Marcin Matuszewski

- 2005 International Conference on Computer Networks and Mobile Computing (ICCNMC'05), Zhangjiajie, China, 2-4 August, 2005
- IASTED International Conference on Communications and Computer Networks (CCN'20005), Marina del Rey, CA, USA, October 24-26, 2005

• Johanna Nieminen

- QoS-IP 2005 Conference, Catania, Italy, February 2-4, 2005

  - The 2nd IFIP WG6 International Workshop on Autonomic Communication (WAC2005), Athens, Greece, October 3-5, 2005
  - CoNext 2005 Conference, October 24-27, 2005 and E-Next Plenary, October 27-28, 2005, Toulouse, France

- Jörg Ott
  - Upperside WiFi Voice Conference, Paris, May 10-13, 2005
  - VON Europe 2005 Conference, Stockholm, Sweden, May 23-25, 2005
  - 14th IST Mobile and Wireless Communication Summit, Dresden, Germany, June 20-23, 2005
  - RealMAN workshop, Santorini, Greece, July 14, 2005
  - Workshop on Video Coding Applications (VICA), Geneva, July 22-23, 2005
  - 63rd IETF, Paris, July 31 - August 5, 2005
  - ACM SIGCOMM 2005 Conference, Philadelphia, Pennsylvania, USA, August 22-26, 2005
  - Contact negotiation meeting for the VIVALDI Project, Brussels, Belgium, September 13-14, 2005
  - The 2005 IEEE Fall Vehicular Technology Conference, Dallas, USA, September 25-28, 2005
  - Infocom 2006 TPC Meeting, New York, USA, October 13-17, 2005
  - The 64th IETF, Vancouver, Canada, November 6-11, 2005

- Aleksi Penttinen
  - RAWNET, WiOpt & SPASWIN Conferences, Riva del Garda, Italy, April 3-6, 2005
  - EuroNGI Cellular Project meeting, INRIA, Sophia Antipolis, Nice, France, July 4-5, 2005

- Markus Peuhkuri
  - Juniper Networks Conference, Amsterdam, The Netherlands, September 5-7, 2005
  - CoNext 2005 Conference, October 24-27, 2005 and E-Next Plenary, October 27-28, 2005, Toulouse, France

- Mikko Pitkänen
  - HPSR 2005 Conference, Hong Kong, China, May 11-16, 2005

- Timo Smura
  - ECOSYS Meeting, Paris, France, January 31 - February 2, 2005
  - ECOSYS Meeting, Saariselkä, March 8-11, 2005

- ECOSYS Meeting, Berlin, Germany, July 11-13, 2005
- EARIE 2005 Conference, September 1-4, 2005 and ITS 16th Biennial Conference September 4-6, 2005, Porto, Portugal
- ECOSYS Meeting, Riva del Garda, Italy, October 3-6, 2005

- Riikka Susitaival
  - EuroNGI Plenary, Barcelona, Spain, February 28 - March 2, 2005
  - COST 279 Final Seminar, Lisbon, Portugal, June 27-29, 2005
  - Workshop on peer-to-peer networking, Nokia Research Center, Tampere, October 10, 2005

- Tuomas Tirronen
  - Workshop on peer-to-peer networking, Nokia Research Center, Tampere, October 10, 2005

- Timo Viipuri
  - Summer Simulation Multi-conference 2005, Philadelphia, USA, July 24-28, 2005

- Jorma Virtamo
  - Sigmetrics 2005, Banff, Canada, June 6-10, 2005
  - ITC-19, Beijing, China, August 29 - September 2, 2005
  - Performance 2005, Juan-les-Pins, France, October 3-7, 2005
  - Workshop on peer-to-peer networking, Nokia Research Center, Tampere, October 10, 2005

5.2 Academic activities

- Samuli Aalto
  - Member of the evaluation committee of doctoral dissertation: Roland Zander, Lund University, Lund, Sweden, 2005
  - Pre-examiner of doctoral dissertation: Dmitri Moltchanov, Tampere University of Technology, Tampere, Finland, 2005

- Heikki Hämmäinen
  - External Examiner of Doctoral Thesis,Andrey Krendzel, University of Jyväskylä, Jyväskylä, Finland, 2005
  - Opponent to Andrey Krendzel, University of Jyväskylä, 2005

- Mika Ilvesmäki
  - Opponent to Oleksandr Sayenko, University of Jyväskylä, Jyväskylä, Finland, 2005

- Raimo Kantola
  - Evaluation of Scientific Qualification for the position of Docent in Computer Science, Jukka Manner, University of Helsinki, Finland, 2005
  - Evaluation of Scientific Qualification for the position of Professor in Command and Control, Jorma Jormakka, Military Academy, Helsinki, Finland, 2005
- Jörg Ott
  - PhD Grading committee, Hector Velayos: Autonomic Wireless Networking KTH, Stockholm, 2005
- Jorma Virtamo
  - External Examiner of Doctoral Thesis, Balakrishna Prabhu, Universidade de Nice - Sophia Antipolis /INRIA, Nice, France, 2005
  - Opponent to Balakrishna Prabhu Ph.D. dissertation, Universide de Nice - Sophia Antipolis /INRIA, Nice, France, October 11, 2005

5.3 Visits abroad

- The following professors and senior researchers of Networking Laboratory paid a visit to Kungliga Tekniska Högskolan, Stockholm on February 14, 2005

Hämmäinen, Heikki	Aalto, Samuli
Kantola, Raimo	Karvo, Jouni
Ott, Jörg	Luoma, Marko
Virtamo, Jorma	Peuhkuri, Markus

- Other visits:
- Ilmari Juva
  - Visiting researcher, ENST Bretagne, France, May 2005
- Pasi Lassila
  - Visiting researcher, University of Debrecen and Budapest University of Technology and Economics, October 31 - November 6, 2005
- Timo Smura
  - Visiting lecturer, IFRA Conference, Amsterdam, The Netherlands, May 2-5 ,2005
- Jorma Virtamo
  - Visiting researcher, University of Debrecen and Budapest University of Technology and Economics, May 16-20, 2005

5.4 Foreign visitors in 2005

The laboratory had the honor to host the following visits:

- Albarran Gonzalez, Leonardo from Universidad Politechnica de Madrid, Spain
- Bovolenta, Gabriel from Aigle Business School, Suisse
- Diaz, Pedro from Universidad politechnica de Madrid, Spain
- Hijas Carretero, Jesus from Tecnical University of Madrid (UPM), Spain
- Motshidisi, Kagiso from University of Kent, United Kingdom
- Nelson, Priscilla from New Jersey Institute of Technology, the U.S.
- Roszik, Janos from University of Debrecen, Hungary
- Sebastian, Donald H. from New Jersey Institute of Technology, the U.S.
- Sztrik, János from University of Debrecen, Hungary
- Vaton, Sandrine from École Nationale Supérieure des Télécommunications de Bretagne, France
- Ventre, Giorgio from Consorzio Interuniversitario Nazionale per Informatica, Italy
- Vidács, Attila from Budapest University of Technology and Economics, Hungary
- Zseni, Peter from Gollege of Dunaujvaros, Hungary

6 PARTICIPATION IN BOARDS AND COMMITTEES

6.1 University boards and committees

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

6.2 Other boards and committees

- Heikki Hämmäinen
  - Member of Board, NETS Future Networks Program, TEKES
  - Member of Local Organizing Committee, Information Technology, World Championships in Athletics, Helsinki 2005
  - Member of the Board of the Research Foundation of Helsinki Telephone Company
- Raimo Kantola
  - Technology Advisor to the Board of CSC Scientific Computing Ltd
  - Member of the Broadband Networks Thematic Group in the TEKES NETS program

  - Member of the Board of the Graduate School on Networks for Information Society
  - Member of initial Steering Group for the TEKES GIGA research Program.

- Marko Luoma
  - Member of the Board of Creanord Oy

- Jorma Virtamo
  - Member of IFIP Working Group 6.3, Performance of Communication Systems
  - Member of the Board of the Finnish Graduate School in Stochastics
  - Member of the Technical Program Committee of 19th International Teletraffic Congress ITC-19, Beijing, China, August 29 - September 2, 2005
  - Member of the Technical Program Committee of the EuroNGI 2006 Conference, Valencia, Spain, April 3-5, 2006
  - Member of the Technical Program Committee of HET-NETs'05, Ilkley, U.K., July 18-20, 2005
  - Member of the Technical Program Committee of RAWNET 2006, Second Workshop on Resource Allocation in Wireless Networks

6.3 Referee activities

- Samuli Aalto
  - Reviewer of the following scientific journals: European Journal of Operational Research, Queueing Systems
  - Reviewer for the following conferences: HET-NETs'05, IEEE Infocom 2006

- Nicklas Beijar
  - Reviewer for IEEE Communications Magazine
  - Reviewer for ACM WINET Journal
  - Reviewer for the following conferences: HET-NETs'05, IEEE Infocom 2006

- Esa Hyytiä
  - Reviewer for the ACM MSWiM 2005 conference
  - Reviewer for the Optical Switching and Networking journal

- Heikki Hämmäinen

  - Reviewer for the following conferences: ICTTA 2005, 10th IEEE Symposium on Computers and Communications, IEEE Globecom'06
  - Reviewer for the following journals: IEEE Network Magazine, Engineering Applications of Artificial Intelligence

- Mika Ilvesmäki
  - Reviewer for 7th International Conference on Data Warehousing and Knowledge Discovery, , DaWaK 2005

- Raimo Kantola
  - Reviewer for Journal of Wireless Communications and Mobile Computing, VLSI Journal, Computer Communications, IEEE ICPS REALMAN workshop

- Jouni Karvo
  - Reviewer for the following journals: Computer Communications, IEEE Network

- Henri Koskinen
  - Reviewer for Elsevier Computer Networks Journal

- Pasi Lassila
  - Reviewer for the following scientific journals: IEEE Transactions on Wireless Communications, IEE Electronics Letters
  - Reviewer for the following conferences: 10th IEEE Symposium on Computers and Communications

- Marko Luoma
  - Reviewer for the following scientific journals: IEE Electronics Letters, IEE Proceedings in Communications
  - Reviewer for CoNext'2005 conference

- Johanna Nieminen
  - Reviewer for IEEE/ACM Transactions on Networking

- Jörg Ott
  - TPCs: Infocom 2006, VTC Fall 2005
  - Reviewer for the following scientific journals: IEEE Communications Magazine, ACM Transactions on Multimedia, IEEE Network Magazine, misc. Book proposal review for Wiley & Sons Project proposal review for IWT Flanders

- Aleksi Penttinen
  - Reviewer for Wireless Ad Hoc and Sensor Networks Symposium at IEEE ICC 2006 conference

- Markus Peuhkuri
  - Reviewer for SIGCOMM 2006 conference
  - Reviewer for ACM Computer Communication Review journal
- Timo Smura
  - Reviewer for the following scientific journal: Telecommunications Policy
- Riikka Susitaival
  - Reviewer for NGI 2006, Infocom 2006
- Jorma Virtamo
  - Reviewer for the following scientific journals: Queueing Systems, European Transactions on Telecommunications, Computer Journal
  - Reviewer for the following conferences: ISCC 2005, 10th IEEE Symposium on Computers and Communications, LSNI 2005, 1st Large Scale Network Inference Workshop, HET-NETs 2005, Euro-NGI 2006, RAWNET 2006,

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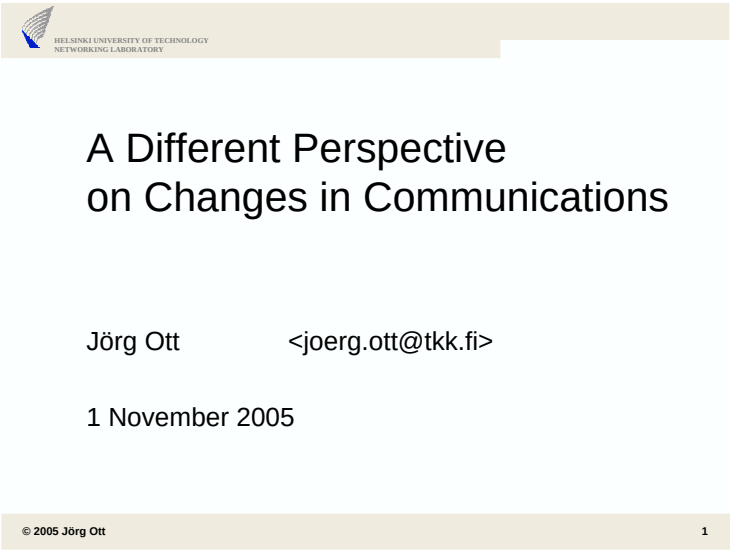
HELSINKI UNIVERSITY OF TECHNOLOGY
NETWORKING LABORATORY
A Different Perspective
on Changes in Communications
Jörg Ott <joerg.ott@tkk.fi>
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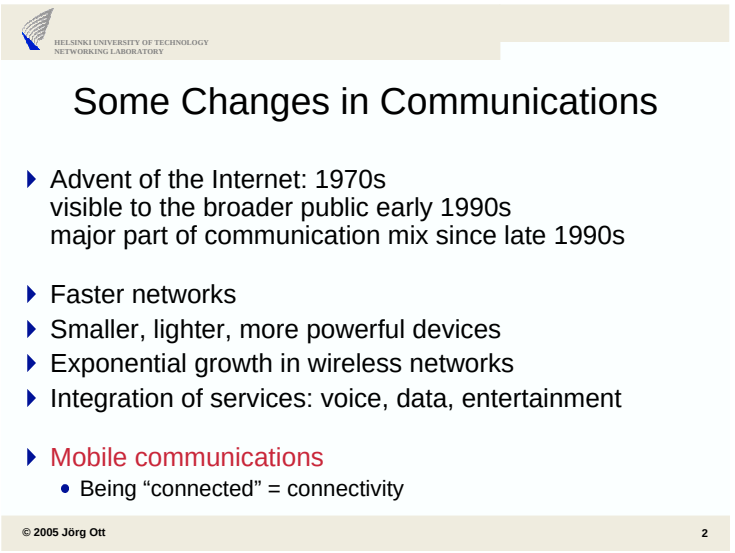
HELSINKI UNIVERSITY OF TECHNOLOGY
NETWORKING LABORATORY
Some Changes in Communications
Advent of the Internet: 1970s
visible to the broader public early 1990s
major part of communication mix since late 1990s
Faster networks
Smaller, lighter, more powerful devices
Exponential growth in wireless networks
Integration of services: voice, data, entertainment
Mobile communications
Being "connected" = connectivity
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Mobility Changes Everything

- Wireless technologies and mobile devices
  - Heterogeneity, new tradeoffs and constraints
- User motion and environment
- User behavior
- What does not change: Applications
- Common goal: Minimize the “visible” changes
  - Ubiquitous networks and seamless access

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Debunking The Myth of the Need for Seamless Connectivity

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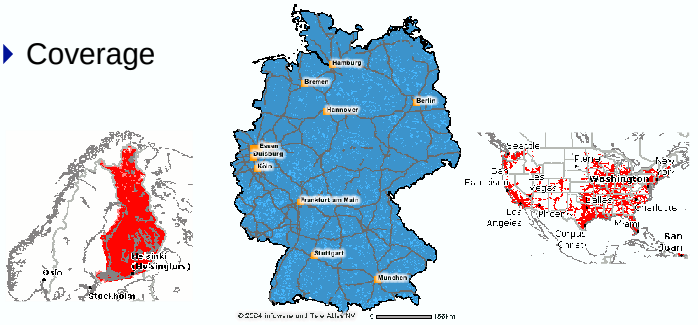
(Today) Connectivity is neither Seamless nor Ubiquitous

- Coverage



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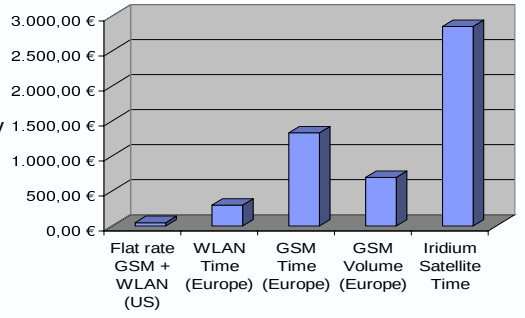
(Today) Connectivity is neither Seamless nor Ubiquitous

- Coverage
- Cost
  - 16h per day
  - 10% usage



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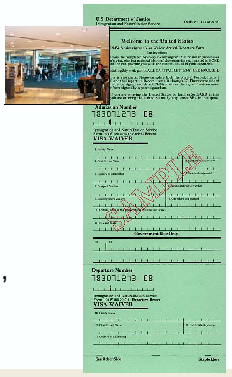
(Today) Connectivity is neither Seamless nor Ubiquitous

- Coverage
- Cost
- Environment
  - Legal, social, personal



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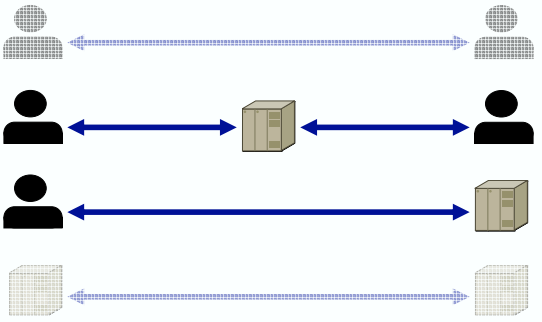
Connectivity need not always be Seamless or Ubiquitous



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Connectivity need not always be Seamless or Ubiquitous

- Applications don't communicate most of the time
  - Examples: web, email, calendar, chat, presence, …
- Applications can use checkpoints and retry automatically
  - Examples: email, file transfer, peer-to-peer, …
- Users don't have to perform "busy waiting"
  - Examples: downloads, tabbed browsing, email, …
- Applications can fall back to asynchronous operation
  - Examples: voice mail, short/instant messaging, …

…regardless of whether mobile or not.

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Designing Applications for Change

- Enabling ubiquitous services – seamless to use
  - Irrespective of changes (mobility, user, environment)
  - Disruption tolerance is just one aspect
- Informed users – change in interaction paradigms
- Drive-thru Internet: Twofold approach
  - Coming from the past: fixing legacy applications
  - Looking into the future: new application designs
- Challenges also in integration and deployment

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Broader Applicability

- Disruption is default
  - Quiet working day in the office?
  - Moving around with scattered time fragments
  - Many tasks, task switches
- Silence is golden
  - Too much connectivity may inhibit productivity
  - Deliberately disconnecting should not cause hassle
- Enhancing a laptop's suspend/resume feature

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Conclusion

- Operating in an ever-changing (mobile) environment
- Need to take the user perspective
  - Applications – actually: their services – are key
  - But nobody cares about how they work and communicate
- Design for change (beyond what you anticipate)
  - Don't try to conceal but actively deal with change
- Looking forward to many research challenges ahead…