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The Radio Communication Systems (RCS) laboratory was founded in 1989 with the mission to advance mobile communications through both education and research. The group has been growing since and has now reached a comfortable size of four faculty members and 14 PhD students. Seong Lyun Kim from ETRI, Korea, joined the faculty as assistent professor after spending a year with the group 1996/97 as post-doc research fellow. Magnus Almgren from Ericsson Radio, Stockholm, Sweden continues to visit the group on a part time basis. Excellent progress was made by the graduate students. After having 4 PhD graduations and 1 licenciate degree passed in 1997, there were no thesis defenses during 1998. However, five licenciate and two doctoral defenses are planned in 1999. 25 Master thesis projects were supervised by the group, 2 within the group and the rest at the industry.

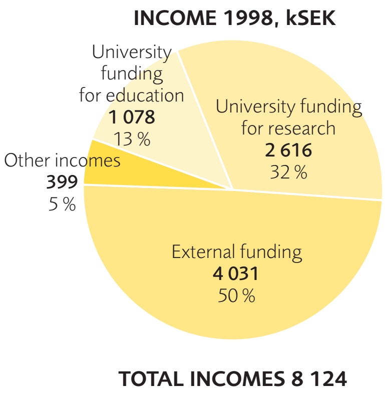
Research is mainly in the area of mobile and personal communication systems with special emphasis on capacity analysis, multimedia traffic modeling, a resource management. A large part of these activities have taken place within the framework of the European Community ACTS program FRAMES, targeted at proposing radio interfaces for 3rd generation Universal Mobile Communication Systems (UMTS). The participation of the group has this year mainly been focused on radio network concepts and radio resource management issues.

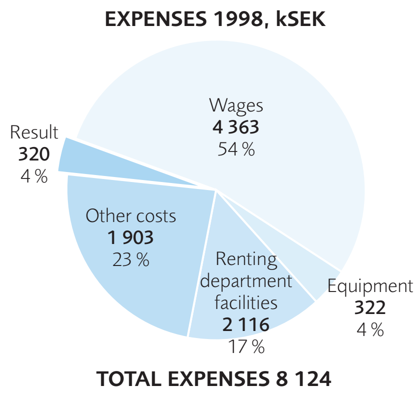
During the year the Strategic Science Foundation (SSF) national research program "Personal Computing & Communication" (PCC) has picked up speed. The group participates in the 4th Generation Wireless Infrastructure project (4GW, c.f. below).

Digital broadcasting is also a significant part of our research activities with focus on frequency planning and network design issues. The work on autonomous radio systems, has been focused on multihop packet radio networks, both for civilian rural applications, as well as for military use.

Education continues to be an important activity of the RCS group. During the year, a total of two graduate courses and two undergraduate courses in Radio Communication and Radio Networks. Some twelve introductory courses in radio communication, simulation methods and CDMA networks for practicing engineers in industry, ranging from 2-3 days were offered. The number of sponsors of the group this year remains at seven.

Picture of the RST group: Agnes, Marvin, Matthias, Jens, Magnus, Lise-Lotte, Robert, Inger, Carl-Gustav, Ben, Fredrik, Seong-Lyun.





PROJECTS

Mobile and Personal Communications

Faculty: Jens Zander, principal investigator, S-L Kim, assistant professor Zvi Rosberg, visiting professor.

Graduate Students: Miguel Berg, Robert Karlsson, Magnus Lindström, Carl-Gustav Löf, Stefan Pettersson, Kai-Erik Sunell

Wireless personal communication systems will attract large user population with various QoS requirements, demanding new design methods that are quite different from those for conventional wide area cellular telephone systems. Dense radio infrastructures will allow high data rates and low transmission power. However, the scarce radio spectrum imposes hard limitations on the design of wireless systems. To provide future wireless communication services with higher capacity as well as better quality necessitates powerful and robust methods to reuse the radio spectrum in the most efficient way, efficient multiple access methods, and efficient coding and modulations schemes. Flexibility will be also very important for future services, requiring easy frequency/cell planning, operation at different environments, and possibility of providing various services to different subscribers at different cell types.

Transmitter Power Control: The transmitter power control has been extensively studied at the Department from different perspectives. As an effort for combining power control with handoff, a two-mode uplink power control algorithm was suggested, in which mobiles maintain two modes, normal and congestion. Under the normal mode, mobiles continue power control with a given base station assignment. On the contrary, under the congestion mode, mobiles executes power control and base station assignment (handoff decision) simultaneously. It has been demonstrated that the algorithm substantially enhances the radio network capacity with a very small amount of extra effort[r3].

A new distributed power control algorithm has been also proposed, where the algorithm uses, for power update, power levels of both current and previous iterations. The gain from such a second-order algorithm is in faster convergence. Computational results have shown that the algorithm significantly enhances convergence speed. In addition, a practical version of the algorithm has been studied and compared with the power control algorithm in IS-95 and WCDMA systems. The results showed that the proposed algorithm also has a high potential for increasing the radio network capacity [r12].

The concept of multi-rate power control has been studied for the emerging wireless multimedia services [r32]. The joint optimization of rate and power control has been formulated into a linear constrained problem with continuous and integer variables. A distributed algorithm for joint rate and power control has been developed by applying the Lagrangian relaxation technique [r8, r29],

Hierarchical Cell Structures Traffic demands in future personal communication systems are expected to vary significantly over both time and space. In particular in densely populated business districts, local traffic peaks are likely to occur. To provide sufficient capacity at such "hot spots", small micro cells are needed to complement macro cells providing low cost large area coverage. These problems can be solved by using a mixed cell structure, with macro cells for coverage and micro cells for capacity. To avoid a large number of handoffs for fast moving terminals, it is an advantage if the traffic can be controlled between the layers. Such a scenario, where coverage is provided from both macro and micro cells in a large part of the service area, is often referred to as HCS (Hierarchical Cell Structure).

The key problem in these scenarios is that due to the large dynamic range of received signals, the suppression of inter-layer interference may not be sufficient to provide adequate signal-to-interference ratios at all times. A particularly difficult situation is when one fast moving mobile connected to a distant macro cell base station, enters a micro cell. The unwanted radiation of this high power terminal into the micro cell band may cause severe difficulties to the micro cell base station receivers, tuned to the low power microcell terminals [r14].

Within the FRAMES project, special emphasis was placed on a novel concept for hiearchical structures, the "Bunch concept". In such a system "Bunch"-basestations, i.e. a collection hot spot cells, utilize the same central controller allowing for synchronous, centralized channel allocation. The bunch-cells are protected from outside interference by frequency hopping. Preliminary results are very promising, in particular in scenarios with mixed (multimedia) traffic [r21, r31, r33, r34, r35].

OFDM for fading channels

Faculty: Ben Slimane, principal investigator

Graduate Students: (PhD):

Multi-carrier transmission techniques are considered as effective techniques in digital transmission under severe multipath fading. Its appeal has existed for some time, but it is only recently that its implementation has become technically feasible and costly competitive. Both transmitter and receiver can be implemented by DSP using efficient IDFT/DFT techniques. Multi-carrier allows high data rate transmission and the possibility of maximizing its efficiency by adapting its variables to the transmission channel. Orthogonal Frequecy Division Multiplexing (OFDM) is a special case of multi-carrier systems where the different subacrriers are orthogonal within each multi-carrier block. However, without coding OFDM suffers from flat fading. By relaxing the orthogonality condition and using smooth time waveforms instead of the regular rectangular, multi-carrier systems can exploit the frequency diversity gain introduced by multipath fading channels without any efficiency loss. Considerable performance gain can be achieved with moderate complexity increase [r9, r16, r23, r24]. Design of optimum sets of time waveforms for multi-carrier systems is ongoing. We are also investigating combined coding and multi-carrier systems. This study includes both convolutional coding and trellis-coded modulation techniques and aims at combining the coding memory with that of the multi-carrier system and the design of the corresponding MLSE detector.

Multi-carrier-CDMA is another system that we are investigating. In this system a CDMA component is added to the OFDM scheme. Here we are concerned with detector design and possible reduction of multi-user interference. The use of quadrature spreading codes with OFDM is a possible solution to reduce multiple access interference due to multipath radio channels [r5]. Presently, we are looking at design and performance analysis of detectors with reduced complexity for the case of single spreading codes.

Digital Broadcasting

Faculty: Jens Zander, principal investigator

Graduate Students: (PhD): Magnus Eriksson, Agnes Ligeti, Christer Frank

In OFDM based digital audio broadcasting (DAB) and digital video broadcasting (DVB) systems, identical signals can be transmitted by many transmitters simultaneously in the same frequency. In such single frequency networks (SFNs) a large diversity gain is obtained yielding better coverage and frequency economy than in conventional multi frequency networks (MFNs). Besides the signal quality improvement a new range of personal services can also be introduced in DAB and DVB systems. By combining the broadcasting network with a bidirectional access method, such as PSTN, GSM, interactive personal services can be implemented, e.g., mobile Internet access and video-on-demand.

These properties impose new demands on the network architecture of broadcasting networks. The total capacity demand of the user population and its spatial distribution have to be taken into account when planning the radio coverage. One of the project goals this year is to develop design methods for DAB/DVB networks with broadcasting, personal and mixed services and to analyze the resulted network architectures in terms of resource usage – such as required number of frequencies, total emitted power etc. – and application of MFNs and SFNs. For personal services we propose schemes for downlink radio resource management, including channel reservation schemes, power control and packet scheduling. We evaluate them in terms of area coverage, packet delay, maximum throughput and computational complexity [r7, r25, r26, r38].

Overall design of 4th Generation Wireless Infrastructures

Faculty: Jens Zander, principal investigator

Graduate Students: Olav Queseth, Matthias Unbehaun, Richard Stridh

Tomorrow's consumers of telecommunication services will expect to receive the same services in a wireless fashion as they receive from a fixed network. These services require (at least instantaneously) high bandwidths. It is not expected that future users will be willing either to sacrifice functionality for the added value of mobility, or to pay more for it-mainly because they will hardly be using any other stationary telecommunication devices.

By mainly extending second-generation technologies, higher data-rates, up to 2 Mbit/s will be available, but only to a limited number of users at one time, and only in certain areas. In rural areas, only marginally higher bandwidths will be provided. In order to enable the use of truly new and innovative multimedia services, even higher bandwidths must be provided at a lower cost that can be provided by second- and third-generation systems. Studying alternative technologies and architectures for such wireless access infrastructures is the aim of this project.

Spectrum shortage, power consumption, and infrastructure costs have been identified as key limiting factors. Spectrum shortage is mainly due to interference from other users, but is also due to regulation and coordination with existing services. Device power supply technology is not expected to make substantial progress (i.e., only 1-2 orders of magnitude) in the next decade, thus power consumption must be limited.

The project aims at proposing an overall architecture for a fourth-generation wireless access infrastructure. The architectural design must take both technical as well as regulatory and economical factors in to account, and analyze services, cost structures and marketing issues.

The objectives (and output) of the project is therefore twofold:

- A sequence of annual position papers outlining the proposed architecture, covering all these aspect mentioned above. Particular emphasis should be on identifying fundamental problems and challenging (possibly modifying) the current working assumptions for the PCC program.
- Five PhD student studies of key bottleneck problems. The problems should represent new angles derived from the interdisciplinary interaction in the project.

The project is run in cooperation with the department of Industrial Economics and Management and the department of Teleinformatics at KTH and with the department of Information Theory at Chalmers University of Technology. During the first year, a number of scenarios for wireless communication in 2010-2015 have been derived [r18, r19] and key research question for further study in the project have been derived [r15, r17].

Autonomous Communication Systems

Faculty: Jens Zander, principal investigator

Graduate Students: Oscar Somarriba, Marvin Sanchez, Peter Stenumgaard

In many situation one cannot rely on an existing telecommunication infrastructures. Examples of such applications are military and emergency/rescue operations in rural terrains or over oceans. Here, autonomous communication systems are needed. The project studies two main applications: Tactical radio area networks (TRAN) and rural data networks. In both cases, low cost, reliable, rapid deployment systems are the objective of the investigation.

Integration with a fixed telecom-infrastructure based on civilian standards is of paramount importance. VHF/UHF terrestrial networks is the main focus of the project. Studying design principles and evaluating the performance of Store &forward packet networks with adaptive antennas using topological terrain models has been the key focus of the project.

In autonomous networks, ad-hoc co-location of transmitters for different radio networks at central sites may cause severe EMC problems. The effect of these problems on communication network performance is also studied in this project. New techniques for assessing the impact of Information Technology equipment (ITE) interference on the performance of military wireless communication systems [r13, r28].

The project is run in cooperation with the National Defense Research Establishment (FOA), and the Swedish International Development Agency (SIDA).

Contacts and Funding

Industrial Sponsors (*) and International Contacts

WINLAB, Rudgers University, New Jersey, USA
Faculty of Electrical Engineering, Technical University, Delft, The Netherlands.
Ecole National Superieur de Telecommunication, ENST, Paris, France.
National Defense Research Establishment (FOA), Linköping, Sweden.
Defense Procurement Agency (FMV), Stockholm, Sweden.
National University of Engineering (UNI), Managua, Nicaragua.
TERACOM, Svensk Rundradio AB, Sweden (*).
Ericsson Radio Systems AB, Sweden. (*).
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Celsius Tech Electronics AB, Sweden (*).
NEC, Japan (*).
ENATOR AB, Sweden (*).
Telia Research AB, Sweden (*).

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NUTEK: ACTS/FRAMES 557 kSEK.
FOA (Dnr 92-3986), 194 kSEK.
FMV (Ref. no 21850-93-000-00-092), 317 kSEK.
SAREC/SIDA (Ref. no BIL-NIC NTI-10A-K), 325 kSEK.
INDUSTRIAL SPONSORSHIP PROGRAM, 1136 kSEK.

Education

The following courses were given by the Radio Communication Systems Laboratorygroup during 1998.

Graduate (PhD) Education

Introduction to Radio Resource Management
Packet Radio & Queuing Theory
Error Control Coding
Stochastic Modelling and Simulation

Continuing Education

Mobile Radio Communications, Introductory Course
Mobile Radio Communications, Advanced Course
CDMA
Spread Spectrum Communication