Since our last report we have received the RAE 2001 results and follow ups which saw Surrey's Electronic Engineering achieve a 5** and come top of the pile. As the biggest of the four Research Centres within EE, we have contributed considerably to this accolade. The Centre is now some 120 strong (12 academics, 34 research assistants, 66 Ph.D students and 9 support staff). Surrey remains the largest Academic Research Centre in Communications in the UK.

We have consolidated our position as a major player in Europe having been involved in 20 IST projects within the Framework 5 research programme. We were invited by the EU to participate in the planning of the sixth framework programme and have been represented on several EU strategy committees and on missions to Japan, Korea and China. Our European programme also includes major roles in the Wireless World Research Forum and the Advanced Satellite Mobile Systems task force. We have also contributed in mobile satellite networking and multimedia areas to ETSI standards. As we go to press the negotiations on the first call for FP6 are taking place and CCSR is represented in 7 IP's and 5 NoE's plus STREPS and so will retain its major European presence.

Our contacts with industry are considerable as evidenced from the separate page listing them. We remain a central partner in the UK Mobile Virtual Centre of Excellence with 23 industrial partners and our EU presence also brings us into contact with all of the major European Communications industry. We encourage many of our Ph.D students to work with industry as part of their doctoral study and this provides them with real life problems to solve as well as a valuable training in industrial related research.

We have a longstanding relationship with Nokia and Ericsson as part of their Global University Networks and in addition have increasingly close collaboration with Alcatel, Thales, Siemens, Motorola, Samsung and Vodafone. Further afield we have on going relationships with CRL in Japan, ETRI in Korea and Tsinghua university in China.

Industry has continued to support our research excellence awards made annually to CCSR researchers for outstanding research with industrial relevance. Vodafone, Nokia, Thales and Inmarsat each contributed to this fund and selected the prizes for research as follows for 2003:

- Inmarsat prize was awarded to Daniel Chew (Mobile Group) for "Size reduced dual-band printed quadrifilar helix antenna"
- Nokia prize was awarded to Nilantha Katugampala (Multimedia Group) for "Secure voice over GSM and other low bit rate systems"
- Thales prize was awarded to Christian Sturt (Multimedia Group) for "Pitch synchronous sinusoidal speech coding"
- Vodafone prize was awarded to Kar-Ann Chew (Mobile Group) for "Route update for IP-based intradomain mobility management"

Work has started this year on the extension of our building to accommodate a new Media lab. Funds of £2.5 m were won from the SRIF initiative to allow us to provide a mobile multimedia lab which we are calling the I-Lab. We will be joined in this initiative by the Digital World Research Centre from the School of Human Sciences who will supply the social scientists to work alongside our engineers to research future systems. This is an exciting initiative to bring together researchers on users and lifestyles with technology that we feel is the way forward for communications.

CCSR staff have contributed to the successful series of MSc courses run by the School in Mobile, Satellite, Multimedia, Networks/ Software and Digital Signal Browsing. A total of 100-150 students per year pass through these courses plus a new MRes course aimed as a research introduction. Some of the students stay on to do research, funded by 6 scholarships given to the very best students from inside and outside the Centre annually.

The CCSR patent portfolio has been extended to 19 and we are starting to see some licence returns flow-in. We are in the process of spinning off a company MULSYS Ltd. which will exploit our speech/vision/security work. There are other areas also in which current ideas could result in future spin offs. In addition to research we have also taken on consultancy work in the communications field and are happy to discuss this with industry.

This report covers three years of activity in CCSR and does not include all of our current work. For further details of up to date research projects, staff and publications please consult our website (http://www.ee.surrey.ac.uk/ccsr/).

We welcome contact from prospective students, sponsors of research and consultancy or potential customer of our spin outs.

Professor Barry Evans
CCSR Highlights 2001-2003

- 20 EU projects in Framework Programme 5
- 5 patents filed (Total 19)
- Industry research excellence awards PhD students from Nokia, Vodafone, Thales, Inmarsat
- 41 PhD's awarded over the period - a record!
- New standards inputs to ETSI, ITF, ITU-T
  - ITU-T study group 13/13 on IP QoS over satellite
  - IETF on IP Multicast security
  - Integrated S/T UMTS controlling system
- Major role in the development of technology roadmaps for wireless world communication systems
- £2.5m from SRIF1 to create a new Mobile Multimedia Lab in conjunction with Digital World Research Centre (Human Sciences)
- IPv6 Wireless Test Bed up and running
- Successful migration to Mobile Virtual Centre of Excellence core 3 research programme
- Development GPRS/EDGE/UMTS network emulators for industrial partners and in-house use
Major Industrial Partners

- VCE (Virtual Centre of Excellence) in Mobile & Personal Communications: 7 Universities and 23 industrial companies. www.mobilevce.com

- Airtel
- Alcatel Espace
- Alenia Spazio
- Astrium
- BBC
- BT
- Cadence Design Group
- Cable and Wireless
- CISCO
- CNET France Telecom
- CRL CSELT
- Dassault Electronique
- DLR
- Ericsson
- ETRI (Korea)
- Fujitsu
- Hispasat
- Hitachi
- Hewlett Packard (Agilent)
- Hughes Network Systems
- IBM
- Italtel
- Imagecom Ltd
- Inmarsat
- Intracom
- Laben Spa
- Logica CMG
- Lucent Technologies
- Matsushita
- Mitsubishi
- Mobile Systems International
- Motorola
- NERA
- Nokia
- Nortel
- NTT
- NTL Cable Telecoms
- O2
- T-Mobile
- Hutchison 3
- Philips
- Roke Manor Research
- Samsung
- Siemens AG
- Space Engineering Spa
- Space Helas
- Sun Microsystems
- Symbionics
- Telenor
- Texas Instruments
- Thales
- TNO
- Toshiba
- Vodafone
**2001-2003 Grants and Contracts**

**Grants**

- DIGIPLAN - Coverage prediction for digital broadcasting services
- Multi-User detection for CDMA
- Air interface studies for multimedia cellular and satellite communication systems
- HAPS - High Altitude Platforms for UMTS service delivery
- Adaptive multiparty audio-visual conferencing over mobile packet networks
- PRONET - Production of broadcast content in an object-oriented IP based network
- Impact of vegetation on wireless communication systems
- Speech enhancement in hands free communication systems
- ROPA - Co-operative channel coding and detection for CDMA
- Wireless Network Test Bed
- A new compression scheme for scaleable video transmission

**European Union**

- VIP-TEN - Validation of IP-Telephony over EuroSkyWay Network
- TEQUILA - Traffic engineering for quality of service in the internet, at large scale
- MANTRIP - Management testing and reconfiguration of IP based networks using mobile software agents
- DRIVE - Dynamic radio for IP-services in vehicular environments
- GEOCAST - Multicast over geo-stationary EHF satellites
- VESPER - Virtual home environment for service personalization and roaming users
- SATIN - Satellite-UMTS IP-based network
- ICEBERGS - IP conferencing with broadband multimedia over geo-stationary satellite
- PRODEMIS - Promotion and dissemination of the mobile information society
- MATRICE - Multi-carrier CDMA transmission techniques for integrated broadband cellular systems

- Radio wave propagation between indoor environments of different buildings for future communication systems
- Receiver-end speaker identification based on coded speech parameters
- Integrated Electronics Portfolio: Wireless, networks and middleware (CCSR); Multimedia and signal processing (I-Lab & CVSSP); Devices, electronics enablers, displays (ATI)
• EVOLUTE - Seamless multimedia services over all IP-based infrastructure
• ASP-NET - Application service providers network
• FULLSPEED - Open and full speed USB smart card
• MUMOR - Multi-mode radio architecture platform for enhanced 3G
• OVERDRIVE - Spectrum efficient uni and multicast services over dynamic multi-radio networks in vehicular environment
• MODIS - Mobile digital broadcast satellite
• NATACHA - Network architecture and technologies for airborne communication of internet high bandwidth
• STRIKE - Spectrally efficient fixed wireless network based on dual standards
• WSI - Wireless Strategic Initiative
• NEXWAY - Network of excellence in wireless applications and technology
• WWRI - Wireless World Research Initiative
• ANWIRE - Academic network on wireless internet research in Europe
• MESCOAL - Management of End-to-end quality of Service Across the internet at Large
• VISNET - Networked audiovisual media technologies

Industrial Contracts

• Influence of possible second generation satellite architectures & interface issues of the terminal
• Optimised air interface for the satellite commensurate with the terrestrial standard
• Propagation models based on multiple diffraction
• Indoor radio propagation
• Low bit rate speech coding
• Development of UMTS traffic/coverage & implementation
• Multi-service traffic dimensioning for GPRS
• Mobile VCE Core 2 research programme
• Practical implementation of the intelligent quadriphilar helix antenna for user terminal applications
• DMB Study
• Multi-carrier transmission technology for high-speed satellite communications
• Hybrid techniques for efficient, accurate, multiple diffraction computations
• Mobile VCE Core 3 research programme
• Secure multicast project
• Intelligent packet scheduling for satellite mobile systems
• Feasibility study on High Altitude Platforms technologies for Mobile and Broadcast Services
• Reliable multicast for satellite mobile communications
• Power control for multi HAP mobile communications
• Sinusoidal speech coding
MOBILE COMMUNICATIONS RESEARCH GROUP

RESEARCH AIMS
To research into innovative techniques, system and deployment concepts for 2G, 3G, 4G cellular systems, W-LAN/MAN, Moving Networks such as Vehicle Area Networks, Personal/Body Area Networks, Mobile AdHoc Networks, and Multihop concept for delivery of Unicast, Multicast and Broadcast services via Terrestrial, Satellite & High Altitude Platforms and the cooperation between them on the network, terminal and services levels. The research also focuses on the optimisation of techniques and algorithms for better capacity, coverage, guaranteed quality of service, seamless and secure access to Internet. The results of the work are useful to both sectors of the industry namely; Network Operators and Equipment Manufacturers.

MAJOR ACHIEVEMENTS
• Breakthrough in fast and reliable Genetic Algorithms
• Fast, adaptive, low complexity near-far resistant multi-user detection for W-CDMA, MC-CDMA
• New channel estimation algorithms for MC-CDMA and OFDMA
• 2 New Soft handover techniques for CDMA-based cellular networks (2 Patents)
• Automatic self-planning and optimisation technique for CDMA (Patent)
• New Multihop concepts developed and tested for both cellular and satellite mobile networks
• New Call Admission Control and packet Scheduling algorithms suitable for TDMA, CDMA Terrestrial and Satellite multimedia Networks (Patent)
• New scheduling technique for OFDMA and MIMO
• New Packet scheduling schemes for reliable multicast services for 3G terrestrial and satellite networks
• New power control algorithms for multicast 3G cellular networks
• Novel dynamic spectrum allocation and band-sharing algorithms
• New dual-mode mobile antenna (2 Patents)
• New Context Transfer Technique for All-IP mobile Networks (Submitted to IETF & Patent)
• New QoS routing algorithm for Mobile AdHoc Networks (submitted to IETF)
• New fast handover/routing algorithm for All-IP cellular Networks
• Developed reconfigurable baseband architecture for TDD and FDD CDMA and HSDPA
• Improved reconfigurable architecture management

RESEARCH AREAS
1. MOBILE NETWORKING
1.1. Routing and Quality of Service in Mobile Ad hoc Networks
Mobile ad hoc networks or MANETs are self-configuring systems that can be established on the fly without any fixed infrastructure. Nodes in a MANET can be mobile, semi-mobile or static and use multi-hop wireless paths to communicate with each other. This research aims to develop efficient and reliable routing and QoS algorithms for ad hoc networks. The Relative Distance Micro-discovery Ad hoc Routing (RDMAR) protocol has been developed in CCSR and was also accepted in the MANET working group of the Internet Engineering Task Force (IETF). RDMAR is a distributed, loop-free, reactive routing algorithm, based on the concept of query localisation. The objective is to reduce the control overhead and it is achieved with the help of a Relative Distance Estimation algorithm. We have incorporated a node-positioning algorithm in the original RDMAR proposal to enhance the performance of the protocol. Further work is currently ongoing with the focus on QoS issues in ad hoc networks.

Figure 1: Routing in mobile ad-hoc network
1.2. Mobility Management for Internet Protocol-based Cellular Systems

In the future, IP will form the heart of connectionless multimedia communications in the fixed domain. Users will want to enjoy the same service in the mobile network as in the fixed network. Hence, a mobile network that is enhanced with, or integrated into IP technologies is desired. Mobile IP has been optimized for macro-level or inter-network mobility and with the high-density of mobile users in micro- and pico-cell networks. Mobile IP need to be complemented by more distributed mechanisms providing real-time mobility support across a network domain. The objective of this research is to provide a solution for the mobility management, at IP layer in a cellular environment. As such, a routing protocol for handling intra-domain mobility (or micro-mobility) has been developed. In addition, support for inter-working of ad hoc mobile networks and infrastructured mobile networks has also been developed.

1.3. SIP-based end system mobility solution in WLAN all-IP infrastructures

One of the research activities ongoing in the Wireless Network Testbed is investigating the provisioning of terminal mobility using the Session Initiation Protocol (SIP). SIP is a protocol developed by the Internet Engineering Task Force designed to initiate multimedia sessions between users which could be enhanced to support terminal mobility and hence allow a mobile client to maintain any ongoing sessions even when changing subnets. Figure 2 shows the hardware configuration used to support these experiments and together with modified versions of open source implementations configured on the appropriate entities, we are testing SIP as an end system mobility solution for all-IP Networks. The fundamental objective of this work is to investigate ways in which SIP can interwork with other mobility protocols to optimise handover performance resulting to seamless mobility. Currently in the wireless network testbed, terminal mobility is achieved within a WLAN 802.11b using SIP-enhanced mobile terminals and future research will also consider WLAN-to-WLAN and WLAN-to-UMTS handovers. The focus of this research will be on the architectures and algorithms that would be required for SIP based mobile terminals to work successfully in a mobile all-IP product environment, using SIP (based on RFC 3261) and Mobile IPv6 (IPv6 based on RFC 2460) facilities in a variety of mobile and wireless networks.

1.4. Service Discovery and Provision in Personal Area Networks

The aim of this project is to design, implement and evaluate a procedure for service discovery and provision in a Personal Area Network formed around a mobile terminal. The focus of the study will be the investigation on how a mobile terminal can connect to a backbone network and detect wireless devices within its proximity in order to form a Personal Area Network with them. Once the neighbouring devices are discovered by performing a service discovery procedure, the terminal may advertise available services within the network. In such a scenario, the terminal will play a service routing role acting as an interface between backbone and ad hoc network.

Personal Area Networks are formed in an ad hoc manner, which means that their structure can rapidly change due to the mobility of the terminal or of connected devices. Devices participating in this scenario must be equipped with a wireless interface to provide the required connectivity to the terminal. Optionally, they can also keep their own connection to the backbone via other networks such as private networks and Internet.

1.5. Multicast in Mobile and Broadcast networks

The increasing use of high-bandwidth applications in third generation mobile systems requires an efficient information distribution, especially when a large number of users are receiving the same high data rate services. Broadcast networks can provide an extension of the downlink capacity of 3G mobile networks, however additional mechanisms such as Multicast can be adopted to use network resources more efficiently. The benefit of Multicast in a combined network is that data is sent only once on each link, thus decreasing the amount of data sent in the network.

The main objective in this research is to explore mechanisms of how multicast can be efficiently employed in inter-working mobile and broadcast networks. As a first step, a multicast network architecture is being developed. Then further research will focus on how current Multicast Group Management Protocols can be extended to adapt to the network architecture considering the mobility of single users as well as whole groups of users. Further to this, new mechanisms will be studied con-
concerning the Announcement and Discovery of Multicast Services in this hybrid network.

1.6. QoS Provisioning and Mobility Management for IP-Based Wireless LAN

The demand for high-speed Internet access and the emergence of multimedia applications are leading towards a new area of broadband wireless networks. We have investigated, tested and evaluated the HiperLAN2 air-interface standard based on an "all-IP" network architecture. We have proposed an advanced QoS framework for the next generation IP-based Wireless LAN, while studying link adaptation techniques together with synchronisation algorithm enhancements, which optimize the performance WLAN systems PHY layer. We have lately been involved in the investigation of the possible integration of the WLANs with UMTS over an All-IP-based Network Infrastructure where we have investigated and tested mobility management concepts and protocols in order to provide end users with terminal, service and network mobility in a secure manner.

1.7. Locating Services in Hybrid Ad Hoc Cellular Network

The growing applications for mobile location have received wide spread attention in recent years. For instance, the positioning of the mobile user equipment (UE) could provide a range of services like location-based services, location-sensitive billing, fraud detection, cellular network design and resource management, fleet management and intelligent transportation systems. The most immediate motivation for the cellular network to provide UE geo-location is Enhanced-911 (E-911) emergency services. Furthermore, in recent years the mobile communications market has been growing rapidly, and therefore there is a need to provide new services in order to capture larger market share.

The research undertaken here is to investigate UE position- tioning in a hybrid ad hoc cellular network. In the hybrid network, the UEs are able to perform peer-to-peer communications and interoperation with the cellular network. Allowing nearby UEs with geo-location information to function as a positioning element, this will mitigate the visibility problem usually encountered in the fixed infrastructure network-based positioning methods. Moreover, it also improves the accuracy of the estimated UE position. In addition, another objective is to incorporate UE position information for mobility management, such as, handover and relaying algorithms.

2. MOBILE SATELLITE AND HAPS

2.1. Support of TCP traffic over GEO broadband satellite networks

This research is related to the efficient support of TCP traffic over next-generation geostationary satellite networks. It focuses on the interaction of TCP with link layer and Bandwidth on Demand (BoD) mechanisms introduced in these networks to cope with link errors and increase resource utilisation efficiency respectively. It also aims at the identification of those procedures that can constitute the building blocks of different classes of service for TCP traffic. The potential of TCP proxies to assist to this task is investigated as well.

In general, resource management for TCP traffic becomes extremely challenging due to the adaptivity of TCP flows, a feature that differentiates radically this type of traffic from other types of 'free-traffic', e.g. Poissonian or Markovian Arrival Processes, which have been studied quite adequately in the past.

The main bulk of current work is directed towards the interaction of TCP with the MAC layer in these networks. Bandwidth on Demand satellite networks, with transfer capabilities similar to the ones standardized under DVB-RCS, are considered as a reference. The capability to provide different levels of QoS to TCP flows sharing the satellite link, via a number of options available both at transport level as well as the MAC level have been demonstrated.

2.2. Reliable Broadcast and Multicast services via Satellite-UMTS

The most demanding applications in 3G mobile networks is multimedia (or entertainment) services, as they are envisaged today. Terrestrial mobile networks will have to directly address the challenge of handling heavy asymmetric traffic towards large audiences. There is clear evidence that low prices and high quality will be key issues to ensure these services succeed. Satellite systems may offer a complementary solution for terrestrial network operators to provide broadcast and multicast services; Satellite’s broadcast nature and ubiquitous
coverage offer a natural way to broadcast and multicast data over a large geographical area.

A new framework/architecture for the support of Broadcast and Multicast services was introduced within 3GPP, called Multimedia Multicast Broadcast Services (MBMS). Several 3GPP-working groups are working on MBMS. All the issues related to MBMS in terrestrial network are not applicable to satellite networks; this is mainly due to large geographical coverage by satellite. The most crucial issue relating to multicast over satellite is reliability. This is also applicable to terrestrial networks, but satellite channels are uni-directional, therefore reliability techniques are more important in satellite networks than terrestrial networks. This research work has emphasized that Packet Level Adaptive Forward Error Correction (AFEC) is one of the best solutions to provide higher reliability. Currently this research is in the process of developing Satellite-UMTS model by using computer simulation methods.

2.3. Improved turbo coding for mobile satellite systems

This project aims to investigate new turbo coding schemes that can provide high data rates employing high order modulation. Better performance should be achieved at very low BER considering mobile satellite environment characteristics (payload non-linearities, fading received signal). Candidate systems are binary turbo codes, non-binary turbo codes and multilevel coding. Different iterative decoding algorithms (SOVA, Log-MAP) have also to be applied and compared with each other.

2.4. Integrated Satellite/Cellular UMTS systems

Increasing interest in accessing multimedia content while on the move puts pressure on the terrestrial operators due to the limitations on spectrum and the additional requirements for the support of broadcast/multicast traffic. In order to overcome this problem, the satellite industry has defined a complete operational system called satellite digital multimedia broadcasting (S-DMB) relying on the large geographical area coverage of satellites. The idea is based upon integrated satellite/terrestrial system as first proposed by CCSR in the SATIN project.

SATIN is the first ever EU project to be led by UniS, and investigates the broadcast/multicast content delivery to UMTS users; the aim is to achieve this in a cost effective manner, via use of 3G terminals, while increasing the content delivery capacity of the 3G terrestrial network. SATIN proposes a system architecture featuring terrestrial repeaters to cover urban areas as shown in fig. 4, based on a selected service set determined via business analysis. The business analysis has considered both mass and niche markets. The main technical focus of the project is the definition of the radio access scheme (Physical layer, MAC, RLC and RRC) based on the 3GPP UMTS standards and evaluates its performance via simulation (Link level and system level).

2.5. Load balancing in high altitude platform stations

In the future, service customization and personalization will be important features. Different systems and different services are converging. In the area of mobile communication systems, the future generation may have to be able to cope with those differentiations. This leads to very wide variation of traffic behavior. As a consequence, the traffic load coming into a resource within a system may be very high for a period of time that may cause the system to congest or collapse, meaning loss of revenue.

A resource sharing mechanism (i.e. load balancing) could be a solution to this problem. Instead of being limited by a single resource, the system stability is limited by the whole system. The load balancing could also be implemented for different systems (e.g. 2G, 3G, and DVB). In high altitude platform stations (HAPS), this sharing mechanism could be implemented centrally so that it can provide more flexibility, accuracy, and adaptability.

2.6. Satellite Constellation Design

Two main issues related to non-GEO satellite constellations were investigated in recent years in CCSR: automation of satellite constellation design and radio resource management particularly dynamic channel allocation (DCA).

A novel design approach called ‘Genetic Satellite Constellation (GSC)’ was proposed based on the multi-objective genetic algorithms to select an optimal single and hybrid satellite constellation considering total number of satellites, the angle between planes, the angle shift between satellites, the inclination angle, diversity and average elevation angle. The software developed in CCSR can select the constellation automatically based on the input parameters.
A new algorithm was proposed for dynamic channel allocation using a genetic algorithm where traffic load for each spotbeam and interference limited DCA were represented as a chromosome structure. The outcome of the study using this proposal showed that traffic capacity using genetic DCA could be increased and is more efficient under high traffic conditions.

2.7. SIP-based Session Establishment over IP-based Satellite-UMTS Network

Session Initiation Protocol (SIP) has been selected by the Third Generation Partnership Project (3GPP) as the official end-to-end IP signalling protocol for establishing multimedia sessions in the IP-based Universal Mobile Telecommunication Systems (UMTS) network for Release 5 and beyond. Since a satellite component has been identified within UMTS, there is a need to support SIP-based session establishment over Satellite-UMTS (S-UMTS) as well as to achieve an end-to-end seamless IP-based terrestrial/satellite network integration. However, due to the inherent characteristics of SIP being transactional-based and generous in size, the transport of SIP signalling packets over the radio interface is not efficient and when transversing over the error-prone wireless links, the session establishment delay can be rather large. Hence, this research aims at evaluating the performance of SIP-based session establishment over the S-UMTS, taking into account not only the larger propagation delay over the satellite but also the impact of the UMTS radio interface. It also addresses the issue of incorporating a link layer retransmission based on the Radio Link Control acknowledgement mode (RLC-AM) mechanisms and examines variations of the RLC parameters and retransmission options and its implications on the SIP session establishment performance.

2.8. Mobile Telecommunication CDMA Power Control for S-UMTS

UMTS is a new technology under the IMT-2000 framework aimed at providing multimedia services on a global scale. In this framework, the satellite component of the UMTS (S-UMTS) plays a complementary role to the terrestrial component (T-UMTS) with the main objective of achieving very close integration between S-UMTS and T-UMTS. As such, both are going to use wideband Code Division Multiple Access (WCDMA). However, in order to realise full potential of the CDMA systems, transmit power control (TPC) is indispensable.

Accordingly, motivated by the need to achieve very close integration between S-UMTS and T-UMTS, the S-UMTS is going to use both open-loop and closed-loop power control. However, closed-loop power control has been considered less effective in satellite environments because of long propagation delays. Therefore, closed-loop TPC for S-UMTS should be modified to take into account features associated with satellite environment.

CDMA power control for S-UMTS has been studied, focusing on closed-loop power control schemes, with the aim of compensating slow fading. In this regard, an analytical model that describes the dynamic behaviour of the closed-loop power control taking into account the effects of delay has been developed. The results have shown that the effects of delay can be modelled as a stochastic process; implying that the effects of delays could be compensated through statistical methods. Consequently, predictive TPC schemes using adaptive filters have been investigated. First, standard recursive algorithms: RLS and LMS have been used in predictive TPC schemes and then a modified version of LMS algorithm that exploits prior knowledge of the mobile satellite channel fading characteristics has been proposed. The results have demonstrated that more accurate TPC schemes can be realised using predictive schemes. Finally, the link-capacity of a power-controlled S-UMTS has been evaluated highlighting the impact of imperfect TPC.

2.9. Adaptive Physical layer for S-UMTS

Satellite resource management efficiency has been identified as one of the key factors in the commercial success of mobile satellite systems due to the limited bandwidth and power. The compensation techniques used in order to overcome the fading effects experienced in the link are generally applied by considering the worst-case channel conditions. This results in inefficient utilization of resources and not taking advantage of favorable conditions. There is no dynamic control adaptation used in current mobile satellite systems except simple power control. In addition, a single scheme is capable neither of providing an optimum solution for fade mitigation nor of closing the link budget at all times. Hence, we propose an adaptive modulation and coding system applicable to 3G mobile satellite systems based on the Rice factor variation. The novelty of this research work is also centred on the switching mechanism used for the adaptation of coding and modulation schemes. With this technique, the data rate is varied according to the channel conditions hence improving efficiency and, in addition, implementation complexity is reduced.
3. MOBILE ACCESS SYSTEMS

3.1. A Low Complexity Equalizer for Enhanced Data Rates for GSM Evolution

In order to meet the requirements of 3G, the EDGE standard is defined based on the evolution of the existing TDMA systems - GSM and IS-136. The evolution of GSM (GSM/EDGE) is the main focus of this project. In EDGE, the high gross bit rate on the interface is increased with the introduction of 8-PSK while maintaining the same symbol rate of 270.833kHz as in the current GSM. Additionally, the LGMSK filter is employed to fit within the 200kHz bandwidth. With this technique a gross bit rate of 69.2kbps per time slot (compared with current 22.8kbps) can be achieved while still fulfilling the GSM spectrum masks and leaving the time slot duration and framing structure unchanged. Although there is high bit rate and efficient spectrum efficiency in EDGE, there is a significant impact on the design of the transceiver, in particular to the equalizer. The 8-PSK is more prone to errors as it has smaller Euclidean distance between symbols as compared to GSM's GMSK. Also, the LGMSK introduces ISI and the effects become more severe due the fast-time-varying frequency selective fading in the mobile environment. A robust equalizer is therefore required. The optimum equalizer structure based on the MLSE is implemented in the GSM system known as the Viterbi Equalizer offers an optimum solution but is too complex for practical implementation in EDGE. The complexity of the Viterbi equalizer increases exponentially with channel memory. In EDGE the number of trellis states required is $8^5 = 32768$ as compared to $2^5 = 32$ in GSM. Reducing the complexity while maintaining the required performance remains the priority of a trellis-based equalizer. The trade-off between complexity and performance is unavoidable and the aim is to seek an optimum solution that compromise both. This project looks into the design of a reduced trellis-based equalizer that is suitable for equalization in EDGE.

3.2. Power Control for Multicast in UMTS

GSM, GPRS and UMTS only permit point-to-point links between mobile terminal and access system external network infrastructure. This is highly inefficient for dense populated multicast groups, as a copy of each multicast packet must be delivered to each receiver. Though efficiency concerns may be neglected in an access system's core network, the overhead on the air interface is enormous. Hence, it would be advantageous to exploit the broadcast properties of the radio signals, which are used to propagate the data to achieve multicasting. Research work is concentrated on the mechanisms required for efficient power control in multicast transmissions, to achieve a reliable QoS to the multicast group and minimise interference to the network.

3.3. Pre Rake Receiver using TDD for UMTS

Inspired by rapid development of wireless communications to produce the smallest mobile unit possible and the need of better propagation channel data to combat multipath propagation, the Pre Rake Receiver is introduced with the solution to overcome the problems and at the same time minimizing mobile size and the receiver complexity. Pre Rake Receiver uses the same methodology as the Rake Receiver. The distinction between them is that the diversity combination is performed before the transmission in the Pre Rake Receiver. By this method the size and complexity of the mobile unit can be minimized, and the unit is made simpler as a non-combining single path receiver.

The figure below describes both the combination processes for Rake and Pre Rake:

![Figure 6: W-CDMA demodulator (up-normal RAKE Rx; down-Pre RAKE Rx)](image)

The power and relative phase of multipath components can be estimated and the above mentioned multiplexation can be carried out at the transmitter side. The received signal will then be equivalent to the Rake combined signal since the same linear operation is performed in both systems, although in a different order. Simulations proved that the Pre-Rake Receiver performance is as good as the Rake Receiver in many conditions. There are some impairments detected in the Pre Rake design that are due to Multiuser Interference and Doppler fading, that caused the channel estimation to be less valid and a difference in BER for Rake and Pre-RAKE receivers.

As of date, more simulations and mitigation methods to overcome the problems mentioned above planned and underway for example by interference cancellations to further prove that the Pre Rake system is a versatile system.

3.4. Dynamic Spectrum Allocation Between Cellular and Broadcast Networks

Future mobile multimedia services are faced with the reality of scarce and economically valuable radio spectrum resources. This research looks into the potential for improving the spectrum efficiency in a future mobile radio
environment where differing networks, such as cellular and broadcast systems, are utilised to deliver a variety of mobile multimedia services to users. This research is approached on two levels. Firstly, the potential for sharing radio spectrum between these different networks is considered, according to their time-varying demands for the spectrum.

Secondly, methods of traffic control are investigated that allow the sharing of traffic between heterogeneous radio networks, in order to optimise the available capacity. The goal of this research is to evaluate the possible increases in the spectrum efficiency that can be gained in a heterogeneous multi-radio environment through the application of the developed schemes.

3.5. Multiuser Detection for WCDMA and joint Interference Cancellation and Turbo decoding

Multiuser detection for WCDMA is an approach using sophisticated signal processing methods for suppressing the interference level and hence improving performance. As UMTS uses CDMA for its access method, application of MUD for third generation of mobile cellular phones has absorbed a lot of research communities' efforts. The work undertaken on this project focuses on different aspects of these methods and the direction of the research is based on the following areas:

1- Systematic comparison of different well known methods to achieve a fair starting point toward the rest of the project
2- Introducing and implementing an iterative method
3- An analytical analysis of the iterative method in synchronous and asynchronous scenarios
4- Proposing modifications on the method (3) based on mathematical analysis on (4)
5- Using optimum criteria of MUD and proposing a fair algorithm to solve it.
6- Several modifications on (5) for simplification
7- Considering the Turbo coding in conjunction with Multiuser detection, which ends up with some modifications to the conventional turbo decoder
8- Proposing different structures to achieve (7) and comparing their performances

Figure 8 covers the issues addressed on items (2-4) mentioned above

3.6. Power Control For Ad-Hoc Networks

In traditional mobile networks, it is inevitable that some users will be located near the boundary of the cell due to a strong shadow effect, and will not be able to communicate with the Base Station. The aim of this research is to use the concept of Ad-Hoc Networks to enable these users to be served by the Base Station. This concept is called Relaying, which means using other existing terminals located between the original terminal and the Base Station for the purpose of retransmitting the original packet, which necessitates the usage of user equipments as relay stations. The aim of this project is to compare the performance between conventional Cellular Networks and Multi-hop Cellular Networks.
3.7. Radio Resource Management for Personal Area Networks

The vision of high speed Personal Area Networks (PANs) for communications for business and personal use, as personal electronic equipment, office IT equipment or home appliances will require adaptable and efficient Radio Resource Management (RRM) algorithms. Devices are linked in their immediate vicinity by a PAN and transparently via a Personal Distributed Environment (PDE), thus to enable remote access of services and information.

The challenge is to develop RRM algorithms that efficiently manage resources within a PAN and across adjacent PANs, as well as consider other services operating in the same frequency band (e.g. unlicensed bands 2.4 and 5GHz).

The RRM algorithm has to be adaptable to progress with the changing spectral conditions, for example changing multipath or spectral occupancy of parallel communication systems. It has to be fair to all users, to avoid greedy users occupying resources permanently, and to be spectrally efficient.

Different waveforms and Medium Access Control protocols are considered to investigate the performance of centralised and distributed multidimensional RRM for best effort and QoS guaranteed transmission.

3.8. Link-Level UMTS Simulator Development

Description:
We have developed a general purpose link-level UMTS simulator complying with the 3GPP specifications, in Visual C++. Its main characteristics are

- Simulates UMTS Downlink and Uplink
- Ability to multiplex up to five Transport Channels
- Power Control
- Various Channel Models: Basic, UMTS, and 3GPP Multipath Models
- Antenna Correlation
- Handover: Soft and Softer handover
- Space-Time Transmit Diversity (Downlink)
- Receive Antenna Diversity
- Channel Estimation through C-PICH or Dedicated Pilot in the DPCCH
- Geometry Factor (Downlink)
- Multi Code Transmission
- The main outputs are BER and BLER values for each Transport Channel
- Saving / Exporting the Results

The simulation is used in a number of the research projects.

3.9. Adaptive RAKE receiver for CDMA systems

The introduction of data services, and the need for higher rate applications have lead to the evolution of 3G systems that can support up to 2 Mb/s in indoor environments. The CDMA multiple access scheme has been adopted as the new air-interface, that makes use of inherent multi-path delay in the channel profile to provide a diversity gain, employing RAKE combining. This has lead to the design and validation of a simulation platform to measure the performance of the RAKE receiver based in the scenarios defined by UMTS UTRA. The RAKE receiver assumes perfect delay and channel estimation. In this project, we measure the impact of delay and channel estimation on the RAKE performance. Moreover, we evaluate the performance of enhanced estimation techniques to provide improved channel throughput based on vector array subspace estimation techniques, and Kalman.

3.10. Load Balancing in an Integrated Heterogeneous Network

This research area has focused in balancing the diverse traffic load in an integrated cellular heterogeneous networks (i.e. GSM/GPRS/UMTS). With the time varying mixed traffic and different sets of QoS demanded by the diverse sets of services provided by the service providers, a quantitative analysis or dimensioning...
methodology for capacity planning in an integrated heterogeneous network is crucial.

The research aims of this project are to derive a threshold level for the packet switched session for different sets of QoS. The data session threshold prediction is particularly useful for network operators and network designers. This novel idea can be used to improve the resource allocation and the call admission procedures in wireless networks. The aim is to provide an insight into the adaptive and optimal usage of available bandwidth according to the actual load and application requirements.

3.11. Traffic Characterisation and Optimisation of Admission CAC and Scheduling Algorithms

Several recent studies show that network traffic is self similar, or exhibits long range dependent (LRD) characteristics. Self similarity is problematic for routing and congestion control algorithms because self similar traffic is very different from conventionally considered traffic such as Poisson or Markovian. Therefore self similarity behaviour must be thoroughly understood if appropriate call admission controls, scheduling algorithms and congestion control mechanisms are to be designed.

This research involves understanding and investigation of the traffic behaviour in terms of aggregate traffic and as well as source traffic consisting of popular data services such as Email, WWW browsing and FTP along with voice traffic load. Investigation of call admission control and scheduling algorithms for diverse service classes is also studied in this research. A novel admission control and scheduling algorithm based on genetic algorithms is proposed and the superior performance of the proposed technique over the state of the art mechanisms is demonstrated on an example GPRS system.

Figure 12: Resource assignment using GA techniques

3.12. Space-Time Coding and MIMO communication systems

The demand for capacity on mobile telecommunication systems is continually increasing. This situation is further accelerated by advances in mobile computing and the plethora of multi-media rich services planned for wireless communication systems of the future. In order to provide the capacity in the air interface to support this demand, multiple-element antennas are viewed as a promising choice. This follows the results from information theoretic research, promising that the use of multi-element antennas at both ends of a radio link can increase the link capacity immensely. To exploit this capacity to the greatest possible extent, channel coding techniques that take advantage of time and space dimensions, and hence called Space-Time Codes (STC) are being investigated.

This project has the objective of investigating the various STC techniques in real-world channel conditions that exhibit non-ideal behaviour. Correlation between fading profiles experienced at the elements of an antenna array is one particular problem that is investigated and robust techniques are designed. Indoor channel measurements were also analysed to gain insights into the spatial fading characteristics of such channels.

A typical link model in this context is shown in the diagram below with a transmitter and receiver both having antennas with multiple elements. Transmitter array of size N elements and a receiver array of size M elements, together with the resulting matrix channel are shown.

Figure 13: Typical MIMO system

The following graph shows the variation, along the measurement path in an indoor foyer, of correlation coefficient between the antenna elements of an 8-element Uniform Linear Array (ULA).

Figure 14: Multiple antenna elements cor.coef.
4. MOBILE RADIO ENVIRONMENT

4.1. In-building Cellular Radio System Design and Optimisation using Measurements

A novel technique has been created for designing and optimising indoor cellular wireless networks using measurements. The research has examined different aspects of the indoor radio propagation environment, including current path loss modelling, so that the challenges of the indoor propagation channel and key benefits of the proposed methodology are highlighted. Capacity has also been considered as a key element for optimum network performance, for which Traffic Collection and a novel Traffic Mapping methodology have been created to assist in the correct dimensioning of capacity resources. A measurement-based prediction approach to predict path loss and signal strength has been created for use indoors, for which the elements affecting the accuracy of the predictions have been investigated and mitigated whenever possible. It is demonstrated as part of this research that the measurement-based approach is more accurate than existing standard path loss models, making use of extensive measurement campaigns for different environments and system deployments. The Distributed Antenna Optimiser has been proposed, which is an algorithm for system optimisation for distributed antenna systems, and its use is demonstrated in various real deployments. This technique has allowed design and optimisation of UMTS networks to be performed quickly and effectively with the use of measurements*.

4.2. Antenna Diversity for Mobile Terminals

Antenna diversity has, for many years, been used to mitigate multipath fading in mobile communications at the base station. In recent days this has been used at the mobile and it is likely to increase in the future. Modelling diversity at the mobile has, however been understudied and there is little indication as to how the designer can determine why mobile antennas have diversity, if any, and how to optimise the performance. This research has therefore developed new techniques to model the diversity of antennas and determine from these models how the performance might be improved or optimised.

4.3. Intelligent Quadrifilar Helix Antenna

The Intelligent Quadrifilar Helix Antenna (IQHA), which CCSR pioneered over the years, has been developed further on the generic issues of the IQHA antenna technology and the user terminal application. Recent work has made the IQHA antenna work at a reduced size and multi-frequencies for mobile terminal applications.

4.4. Impact of Vegetation on Wireless Communication Systems

The impact of vegetation on wireless communication systems emphasizing the dynamic effects of vegetation scattering under the influence of wind is the main focus of this work. It is an attempt to study and model the characteristics of radio channels in these adverse conditions. Series of indoor (inside an anechoic chamber) and outdoor measurement campaigns had been conducted. As a complement to the measurements, physical-statistical modelling of these effects is currently undertaken. The ultimate goal is to design a model that is able to describe the correlation between wind speed and fading statistics in a vegetation environment for system performance prediction.

4.5. Measurement and Prediction of the Indoor Wideband Infrared and Radio Channels

This study is focused on modeling and measurement of the indoor radio and infrared channels. Both channels have been studied, compared and their vital differences identified. An infrared channel model was developed that
The wireless diffuse infrared channel is only used indoors and is usually confined within a room. Conventional channel models are described, but their disadvantage is time consuming and processor requirements. Hence, a new model is introduced, in which the approach is different from the traditional methods in the way that it discretises the delay range instead of the physical characteristics of the environment. The new model offers accurate results without the increased time and processor requirements compared with traditional techniques. A radio channel model was then implemented, which shares the principles of the infrared model. The radio channel prediction benefits from the accuracy of the infrared model, where a very high accuracy is necessary in order to predict the effect of scattering. A simple measurement campaign has been introduced in order to validate the results of the simulation tool and a comparison with the most important wideband channel models has been performed, along with higher frequency measurements where scattering is more important. The results present a good fit to the measurements and models presented in the literature, and empirical conclusions relative to the scattering characteristics of the radio channel are drawn from these comparisons.

### 4.6. Wideband Channel Measurements at 5.4GHz

A wideband radio propagation campaign has been performed for indoor office type scenarios, and has taken place in two different buildings. This measurement campaign has allowed valuable insight into the mobile radio channel, especially for WLAN type system planning. Time domain analysis of the measurement results allowed the careful study of the radio channel and produced interesting results as far as RMS delay spread and Power Delay Statistics are concerned. Various conclusions on the time domain characteristics of the channel have been presented, with the most important being that the RMS delay spread is not always dependent on antenna separation, while it was found to be highly dependent on the clutter present on the measurement environment. The measurement results were also compared with sample scenarios from the Saleh-Valenzuela model, and good correlation was found.

### 4.7. Distributed Antenna Architectures for Indoor Coverage and Capacity

This project investigates the performance of the distributed antenna system (DAS) radio architecture and also more flexible implementations of this (e.g. Zoning and Switching), in order to provide coverage and capacity for in-building hot spot areas. It was found that the conventional DAS architecture is very efficient in meeting the high coverage and capacity requirements of the W-CDMA system, as well as minimising the transmit power levels in both the uplink and the downlink. Capacity limitations, however, were present as this is limited by the pole capacity of the W-CDMA system. In order to overcome these limitations the deployment of Zoning and Switching was investigated. It was observed that the capacity with Zoning is doubled compared with the conventional DAS implementation. However, it was seen that additional AEs do not result in significantly higher number of users, due to the fact that pole capacity limitations are again present in a common 3-sector Node B system. Implementing Switching to the closest antenna element, overcame these limitations and a linear increase of capacity with the number of AEs was obtained.

Further implementations of the DAS architecture are studied for further user capacity and signal quality enhancements. These are based on time delay diversity and RAKE combining, adaptive antenna technology and further investigation of the concept of the Intelligent Picocell, which was developed in CCSR. Synergies of DAS with Multiple-Input-Multiple-Output (MIMO) systems are planned for further research.
4.8. Comparison of terrain propagation models in terms of computational speed and accuracy.

In propagation models, prediction accuracy is sacrificed at the expense of computational speed and vice-versa. Hence there is always a trade-off between speed and accuracy depending on the requirements of the radio planning engineer. Existing models have been modified so as to improve their accuracy or their speed. The modification has been essentially based on the terrain selection approach. The performance of the modified models is compared to the original models by running simulations over some terrain databases. In cases where the terrain profile has distinctive peaks, a gain in performance due to the modified models is obtained. This gain in performance is shown in Figure 21 by comparing the results of the SE-UTD model (modified model) against the extended STD-UTD model (original model). However, this has not been achieved for generally flat profiles.

4.9. Building to building radio wave propagation

The goal of this project is to understand the radio wave propagation in building-rich environments based on deterministic models. An indoor/outdoor propagation model based on 3D ray-tracing method has been developed. This model is used to study the impact of environment variation on co-channel interference in WLAN. The work presented in this research investigates the variation in the geometry of the scenario and the constitutive parameters of the materials, for the case of interest and how this can influence interference planning decisions, based on signal strength predictions. Future research will aim to extend an existing outdoor to indoor propagation model taking into account all possible radio propagation mechanisms.

Figure 22 shows the signal strength variation on each floor reflected from a neighboring building as the distance between the two buildings increases (Tx is on the ground floor of the original building and the building is 10 floors high). The dashed line depicts the variation of the received signal power of the single reflection from the nearby building on the 3rd, 6th and 9th floor. It shows that the abrupt increase of signal power at a certain distance is due to a single reflection becoming the dominant mechanism.

4.10. Advanced Planning & Optimisation techniques for Cellular Radio Networks

The shift of focus from voice-centered services to multiple high data rate services, and the advent of the new WCDMA based air-interface, have necessitated review of existing Cell Planning techniques, so that radio networks can be planned for high coverage & capacity, at minimum infrastructure cost. In 3G systems, due to the increase in number of RF parameters and due to their complex interdependency, efficient optimisation algorithms are required to derive the optimum RF configuration in terms of number of sites, their locations, antenna parameters or transmit powers, whether we consider an
indoor picocell or an urban macrocell environment. This work aims at implementing combinatorial optimisation techniques, such as Simulated Annealing, which can handle large number of multivariate data, as in case of a realistic UMTS network. However, automatic optimisation would require performance evaluation of hundreds or thousands of network configurations, before the optimum solution can be obtained. These performance evaluations are generally done in a 3G simulator (planning tool), which runs complex power control algorithms, repeated for several snapshots of user locations. The underlying simulations make the planning process too time consuming for practical applications. We will look into the various steps involved in UMTS planning, with an aim to develop simpler modeling rules and simulation techniques, and incorporate intelligent optimisation algorithm in the planning tool, which can then be used for efficient roll-out of UMTS systems, or for their subsequent reconfiguration.

Figure 23: UMTS optimisation
MULTIMEDIA SYSTEMS RESEARCH GROUP

RESEARCH AIMS

The main focus of the group is on multimedia communications and signal processing. The group conducts research in the areas of coding and compression of speech, audio and video, with the aim of providing high quality of service (QoS) over fixed (wired) and mobile (wireless) communication networks. Robust packetisation, networking, security, forward error correction, echo cancellation, noise suppression and QoS optimisation by way of link adaptation are also areas of investigation. Recently, the group has begun to extend its focus to cover the design of augmented reality (AR) technologies this permits improved performance in scenarios such as location-based services and virtual teleconferencing. Furthermore, human-computer interfaces, such as speaker recognition and verification, are also current under investigation.

MAJOR ACHIEVEMENTS

- Candidate speech coders for standardisation efforts (NATO, ETSI, etc.)
- Patents in the fields of video communications, secure speech transmission over wireless networks, and efficient IP-based multimedia communication
- 2.5G and 3G channel emulation models for testing multimedia software
- New techniques for model-based coding, including real-time software
- Formation of industrial links to aid the introduction of wireless multimedia messaging
- Real-time video transcoding algorithms
- Multi-rate scalable audio coding techniques
- Real-time error-resilient MPEG-4 video coder
- Coordination of EU Network of Excellence (VISNET), bringing together some of Europe’s best visual net working experts.

I-LAB

CCSR has obtained £3.5 million funding to construct an exciting new research facility called the I-Lab. The I-Lab is a joint project involving CCSR and the Digital World Research Centre (DWRC). This combination will bring together the expertise of researchers in the fields of human factors (sociologists, psychologists, economists), and telecommunications. Within the multi-disciplinary environment, the researchers will investigate new forms of multimedia. The I-Lab will provide the following facilities:

- StudioLab - Space for capture of 3-D video and audio
- VisLab - Experimentation into immersive visualisation systems using a high-end graphics manipulation server, and 3D audio system
- UseLab - Usability testing of new systems and methods
- WirelessLab - Research in mobile/wireless access systems
- BuildLab - Equipment prototyping
- Link to external facilities
- Wireless testbed, Sun E10000

The research areas to be investigated include mobility, presence, ubiquity, personalisation, security, and navigation of multimedia environments.

RESEARCH AREAS

1. AUDIO AND SPEECH

1.1. Secure Voice over GSM and Other Low Bit Rate Systems

The GSM system ensures confidentiality of subscriber identity and authentication as well as confidentiality of user traffic and signalling. The ciphering algorithms used in GSM have proved to be effective in ensuring traffic confidentiality. However, the traffic confidentiality is only ensured across the radio access channel. Voice traffic is transmitted across the core circuit-switched networks ‘in clear’ in the form of PCM or ADPCM speech which opens up the possibility of unauthorised access to GSM-to-GSM or GSM-to-PSTN conversations. For end-to-end security, the speech signal must be encrypted to prevent access by unauthorised users. Moreover, the security over the GSM speech channel is controlled by the network operator, not the end user. User control is preferable in some applications.

Although the GSM data channel can be used for encrypted speech transmission, this approach suffers from a number of disadvantages. The GSM data channel typically requires 28–31 seconds to establish a connection, of which approximately 18 seconds are taken up by the GSM modem handshaking time. In addition, the round-trip time of the GSM data channel is around 1 to 2 seconds for the 95th percentile. Although the proposed 3GPP standards specify the provision of low-latency data bearer channels, which could be used for end-to-end secure communications or telemetry operations, the deployment dates of such systems are as yet uncertain, and it will be quite some time before 3G mobile systems will be ubiquitously available.
On the other hand, the use of encryption on the speech channel is not straightforward. The GSM terminal has a speech compression/decompression process for efficient use of the bandwidth. This is heavily based on the assumption that the input signal will be speech. It uses the usual speech production model parameters such as pitch, vocal tract model, etc to efficiently compress the input speech. If the speech signal is encrypted before feeding into the speech encoder, it will not comply with the expected speech characteristics. The encryption process will randomise the speech signal, thus the encrypted signal will fail to go through the GSM compression/decompression process with sufficient accuracy. Therefore, after the encryption process, the resultant bits are modulated onto speech-like waveforms which possess the required speech characteristics. The modulation scheme achieves a bit rate of 3 kb/s with bit error rates of 0.5%. Using a punctured 1/2-rate convolutional coder, a 1.8 kb/s-channel is available with a bit error rate less than 4x10^-4. The resulting frame error rate is less than 2x10^-4, low enough for conventional error resilience techniques to ensure that there is no noticeable degradation in the quality of speech. A modern 1.8 kb/s-speech coder is used at the front end.

1.2. Pre-Processing of Speech for Smooth Pitch Evolution

Irregular pitch variations in speech signals can lead to inaccurate estimation of speech parameters within a speech coder. Fig. 25 shows the effect of irregular variations on the estimated pitch values. This can cause severe quality degradation of the synthesized speech. The aim of this project is to modify the speech signal such that the pitch evolves smoothly during a frame. The modification is performed in LPC residual domain and the resulting speech is more regular, and therefore not only pitch but also other speech parameters (such as voicing strengths, harmonic magnitudes) can effectively be estimated. Since the pre-processor maintains the perceptual speech quality, it can be used in combination with any low bit rate speech coder. Our experiments have shown that the proposed pre-processor in combination with the standard MELP 2.4 kb/s provides better quality than the MELP alone.

1.3. LP Filter Factorisation for Post-Filtering of Synthetic Speech Signals

In conventional post-filtering, there is no prioritisation between formants. Since the largest formant plays the main role on perceptual speech quality, this project aims at shaping the main formant in order to narrow its band-width, obtain smooth inter- and intra-frame magnitude variations, more attenuation in valleys and maintain other formant information. The LP filter is factorised using formants and valleys information to determine the polynomials representing the formants. The values for the poles of the polynomial representing the main formant and shaping constants are then optimised to maximise the perceptual speech quality.

1.4. Low Bit Rate Speech Coding (below 4 kb/s)

The aim of this project is to provide high quality speech at low bit rates, mainly for communication purposes. The Split-Band LPC Vocoder (SB-LPC) is a speech coding algorithm which has been developed for several years in the Multimedia Group. It is designed to operate at low to very low bit rates, and is based on a sinusoidal speech model, with advanced parameter extraction and quantisation techniques.

The project consists of improving the baseline algorithm and the different versions: 4 kb/s for near-toll quality speech, 2.4 kb/s for communications quality speech and a 1.2 kb/s mode that retains most of the intelligibility of the higher rate versions. During the course of this project, systems based on this coder have been developed and submitted as candidates to several standardisation
efforts. These include the ETSI GSM-AMR and NATO STANAG 1.2/2.4 kb/s competitions.

1.5. Pitch-Synchronous Speech Coding

Traditional speech coders analyse speech using fixed duration windows placed sequentially. For the purpose of analysis, the speech is considered to be stationary during the analysis window. Whilst this assumption holds true during regular voiced speech, it fails during transitions. This leads to a smearing of speech parameters extracted from an area of speech that varies significantly within an analysis window. In order to remove this problem, the pitch synchronous speech coder segments the speech into pitch cycle blocks, and each cycle of speech is analysed individually. The speech parameters are then jointly quantised to produce a fixed-rate coder. At the decoder, the speech is synthesised as a series of pitch cycles. The effect of removing the window smearing is seen in crisper more accurate speech transitions.

1.6. Speaker Identification and Verification

Biometric recognition methods such as iris, retinal, fingerprint and speaker recognition use peoples physiological or behavioural characteristics to recognise individuals. Speaker recognition is a process of recognising who is speaking by using characteristics of the speaker's voice. It can be used for either identification or verification purposes. The most common application areas are law enforcement, access control to buildings or databases, transaction authentication, and prisoner monitoring tasks. Speaker identification is the process of identifying the unknown speaker from a set of known speakers, and speaker verification is a process of determining if the person is who he or she claims to be. These processes are depicted in Fig. 26.

In this project, a text-independent speaker recognition system has been developed. This system employs Gaussian Mixture Models to model peoples voices, where Gaussian components can reflect some unique speaker spectral shapes and perform robust speaker recognition. The system works satisfactorily with a high speaker identification performance (99.2%) on the 630-speaker TIMIT speech database.

High demand for mobile communications brings the need for speaker recognition techniques to increase security through mobile cellular networks. GSM transcoding modifies the speech signal and reduces the speaker recognition performance. Research now focuses on solving this problem.

1.7. Echo-Canceller and Noise-Suppressor

This work is related to finding a solution to the double talk problem in the existing echo canceller systems. A method has been proposed such that the dependence on an accurate Voice Activity Detector (VAD) is removed. The method has a soft-decision based adaptive step size which enables continuous filter coefficient adaptation even during periods of double talks. The removal of the need for a VAD and the continuous filter coefficients adaptation present a revolution in the way echo cancellers should be designed to overcome the double talk problems.

A noise suppressor has also been added to the system so as to improve the overall system performance when used in high noise contamination environments. It is also used to remove the residual echo signal after convergence has been achieved in order to reduce its volume for the far end speaker.

The results of the developed echo canceller systems and the added noise suppressor have confirmed the superiority of the proposed systems as compared to existing methods. Convergence has been achieved even at SNR as low as 0 dB.

1.8. Robust Statistics-Based Pitch Post-Processing System

In this study, the objective is to improve the reliability of the pitch (or fundamental frequency) estimates when used in high noise contaminated environments. Sinusoidal model-based speech coders strongly depend on an accurate pitch estimate in predicting the remaining
model parameters. In general, pitch estimators degrade in performance when background noise is present in addition to speech.

The robust statistics-based pitch post-processing technique is used to overcome the current robustness issues of pitch estimators and to improve the reliability of the pitch estimates. The proposed pitch post-processing system is based on robust statistics, i.e. M-estimators. Two systems are proposed: The first being the unweighted M-estimator and the second being the weighted M-estimator. The weighting function is related to the confidence of the current pitch estimate. An iterative algorithm is used to find the optimum statistical mean that represents the pitch estimate of the current frame.

1.9. Improved Line Spectral Frequencies (LSF) and Spectral Amplitudes (SA) Estimation through Anti-Aliasing Filtering

In this study, LSF extraction is examined from an oversampling and decimation perspective. It has been noticed that a considerable amount of high frequency energy is present in all LSF tracks when LSF extraction is performed every sample over a 20-25 ms analysis window. This high frequency variation (or energy) present in the over-sampled LSF tracks is a source of spectral overlapping leading to aliasing. The presence of the high frequency variation is related to the stationary assumption made for speech within the analysis window length. As the information above the LSF cut-off frequency of the coding system is of no benefit when decimating the over-sampled signal to the required rate, we propose an anti-aliasing filter with a cut-off dependent on the LSF transmission rate. The proposed anti-aliasing filter removes all of the unnecessary information while maintaining the quality of the overall signal. This leads to significant bit rate reduction in predictive coding of LSFs as well as reduction in large outliers.

Spectral Amplitudes (SA) are the frequency magnitude spectrum of the linear prediction residual. They have also been studied from an oversampling and decimation perspective in the same manner as for LSFs. LSFs are used in calculating the spectral amplitudes. When calculating the SA every sample, a similar high frequency variation, as is present in the LSF, is also present for SA. This is related to the weak stationary assumptions within the analysis window, through its effect on LSFs, and on the analysis window position and size. As the frequency variations above the systems cut-off frequency for the SA calculation is not beneficial, and since its presence is the reason for aliasing distortions, its removal is of great importance. Therefore, an anti-aliasing filtering is also proposed for the SA so as to remove the unnecessary (or redundant) information whilst preserving the signal quality intact. It has been noted from the LSF and SA quantisation results that 10-15% of quantisation bit saving is possible for LSF whilst 10% quantisation bit saving is possible for SA using the proposed anti-aliasing method.

Figure 27: 2 dB outlier percentage Vs VQ Codebook bits. f: original LSF; g: low pass filtered LSF.

2. VIDEO CODING

2.1. VISNET

The Multimedia group has been successful in securing a multi-million EU-funded Network of Excellence (NoE) project called VISNET, which was ranked the first proposal in the FP6 strategic objective on Networked audiovisual systems and home platforms. This project aims to create a sustainable world force of leading research groups in the field of networked audiovisual (AV) media technologies with a clear vision for integration, research and dissemination plans for 5 years and beyond.

This project is led by UniS as the NoE coordinator and integrates over 100 researchers from 15 European institutions leading in the field of AV communication technologies. VISNET activities cover several disciplines related to networked AV systems and home platforms:

- Creation/coding of AV content for immersive platforms
- Storage and transport of AV information over heterogeneous networks
- AV analysis techniques for immersive communications
- Security of AV content and transmissions

For more information on this project, contact Visnet coordinator Dr A. H. Sadka (a.sadka@eim.surrey.ac.uk)
2.2. Multi-Rate Adaptive Error Resilience for Video over a Mobile Channel

The highly variable nature of mobile links means that particular attention must be paid to error resilience in order to obtain optimal quality at the receiver. Optimal quality can be obtained by adapting the video coding to the channel conditions. To this end, a real-time MPEG-4 encoder and decoder have been developed. RTP is used to link the two applications, thus basic information on packet loss is fed back to the encoder using RTCP. This allows protection to be varied as the channel conditions change. However, given that it will not be possible to vary the protection until losses are detected, it is important to ensure that recovery from errors is swift. The data that is fed back can be extended to include more detailed information on losses. Using this it is possible to ensure that the video quality is quickly improved upon encountering errors.

Figure 28: (a) Real-time MPEG-4 decoding

Other fixed-rate solutions can be employed to increase error robustness. Prioritisation has been attempted, using the data partition option provided by MPEG-4. The more important first partition is transmitted on a channel featuring greater error protection than the one used for the second partition. At similar source-channel ratios this achieves noticeable quality improvements over non-prioritised transmission. Simulations of this technique over GPRS have shown it to be a viable proposition. It has been found that MPEG-4 video is particularly sensitive to errors when shape coding is used. In fact, its sensitivity is so great that it is only feasible to use shape coding in channels with very high signal to noise ratios. It will therefore be necessary to develop schemes to considerably improve upon this situation.

Figure 28: (b) Effects of GPRS channel on MPEG-4 bitstream: (left) normal; (right) using prioritised streams

2.3. Video Transcoding for Heterogeneous Multimedia Networking

Video transcoding is a technique that enables the interoperability of different video networks. The objective of video transcoding therefore consists of changing the format, size, transmission rate and/or syntax of an input compressed video stream without fully decoding and re-encoding the video information. Thus, a high transfer rate, high resolution compressed video stream can be converted into lower rates and resolutions whilst also complying with the syntax requirements. This is particularly needed for video content adaptation (the realisation of personalisation and customisation), and hence successful delivery of rich multimedia data across a wide range of end-client terminals (from small and lightweight PDAs to large-scale immersive displays) and user preferences. Content adaptation is necessary when there is a significant mismatch between the supply and demand of resources, and this problem can thus be overcome by the solutions provided by video transcoding technologies. Moreover, video transcoding can also be used to inject error resilience into an already compressed and transmitted video stream at an intermediate location, such as at a video gateway at the edge of different networks. As a result, the complexity, processing power and the delay incurred by this process are minimised whilst achieving improved QoS levels even in highly error-prone environments, such as wireless communication networks.

Figure 29: Video transcoding scenario

Figure 30: GPRS network simulation results of bit rate (from 87 down to 47 kb/s) and error-resilient (AIR) transcoded Foreman at 25 fr/s. (a) Objective results with 3 CSs; (b) Subjective results demonstrating the 200th frames
2.4. Object-Oriented Multiparty Communications

MPEG-4 allows different components of a composite video scene to be represented as logically-distinct audio-visual objects (AVOs). This project exploits these AVO coding techniques to provide scene prioritisation. These experiments are carried out in the environment provided by the H.323 centralised multiparty-topology in which a central Multipoint Processor (MP) acts on the different MPEG-4 audio-visual (AV) data to implement stream prioritisation policies. Representing the scenes from different participants in an AV conference as different AVOs provides several advantages. It allows for a single decoder implementation to handle multiple scenes, thereby providing for simple terminal implementations. It also enables the transmission of the most important scene at greater quality than the other scenes, thereby increasing the perceptual quality of the received video. In addition, it allows for improved statistical multiplexing over bandwidth-limited channels.

2.5. 2-D Scalable Model-Based Video Coding

In the recent decade, research has focused on 3-D model-based video coding. As only the analysis data needs to be transmitted to the decoder, very low bit rate video coding can be achieved. However, the scalability and generality of 3-D model based video coding methods are very poor, and their computational complexity is very heavy. In order to overcome the disadvantages of 3-D model-based video coding, 2-D scalable model-based video coding technique has been conducted in our research. The research has shown that 2-D model-based coding with perspective transformation and triangular mesh models can simulate almost all capabilities of 3-D model-based approaches at a fraction of the computational cost. The aim of this project is to achieve scalable very low bit rate video coding, mainly for wireless video communications, and to facilitate future video manipulation. The target bit rate is 5 kb/s. The main tasks involved are video analysis and segmentation, scalable model design and coding and progressive texture coding.

2.6. 3-D Model-Based Video Coding

3-D model-based video coding techniques can achieve transmissions at very low bit rates over traditional communication channels. For a set of head-and-shoulder frames, the 3-D model-based coding technique is based on the estimation of head motion in 2-D images, instead of transmitting the video information as pixel-oriented waveform coding. With a pre-defined 3-D mimic, this technique can achieve very low bit rates by sending only a few motion parameters and variations of the background to the decoder. 3-D model-based video coding is a challenging research area, and demands more robust solutions for problems with the generality of the 3-D model, the impact of illumination, etc. A large number of aspects are being expected to improve. Facial feature extraction plays a crucial role in such a video coding system. The figure shows the extracted facial features using the proposed algorithm.

3. MULTIMEDIA NETWORKING

3.1. NEWCOM

CCSR is participating in NEWCOM, which is an EU funded Network of Excellence targeted at wireless networks beyond 3G. The network brings together all of Europe's top research institutions, and a number of major industrial partners. CCSR is playing a major role in investigating multimedia transmission over mobile networks, and in developing new traffic modelling techniques for compressed video.
3.2. Active Services QoS Architecture for Real-Time Multimedia

QoS architectures for IP networks have not been specifically targeted for real-time multimedia transmission and do not provide exclusive treatment for such traffic. An active Networks approach enables user-defined computations to take place inside the network. These computations are called active services and can dynamically alter the way that the network behaves in order to meet the changing conditions in the transmission medium or the user requirements. This research deals with the problem of designing active services that can enhance the IP-QoS architectures for supporting real-time multimedia communications. Such services are essential for content adaptation, personalisation, mobility, presence and ubiquity of multimedia applications. The figure shows our vision of the active network domain as a part of differentiated services.

![Figure 34: Active networking scenario](image)

3.3. QoS Control for WCDMA video Communications

This project focuses on QoS improvement of WCDMA video communications using the newest video coding standard---H.264. QoS control in mobile networks is more complex than fixed networks due to spatial movement of the user terminal. To combat the problems caused by the use of wireless channels, a number of error resilience tools are introduced in the video encoder. This project investigates these error resilience techniques in order to provide the best possible quality for video transmitted over a WCDMA environment.

![Figure 35: UMTS Emulator Architecture](image)

3.4. Multimedia Communications over UTRAN

A physical link layer model of UMTS forward link has been implemented using Signal Processing Work System (SPW) software simulation tools. The model has been developed in a generic manner that includes all the forward link radio configurations, channel structures, channel coding/decoding, spreading/de-spreading, modulation parameters, transmission modelling and their corresponding data rates according to the UMTS specifications. A UMTS radio interface protocol model, which represents the data flow across the UMTS protocol layers, is designed and integrated with the physical link-layer model to emulate the actual radio interface as experienced by users. This allows for the interactive testing of the effects of different parameter settings of the UTRAN upon the received multimedia quality. Furthermore, UMTS link level performance is enhanced by implementing a closed loop power control and a space-time transmission diversity technique.

![Figure 36: Flow diagram of the proposed link adaptation scheme](image)

3.5. Link Adaptation for Video Communications in Mobile Networks

The provision of video communication services over wireless mobile links is a challenging task due to the poor performance of video compression algorithms in time-varying error-prone environments. This research is targeted at performance enhancement methods for real-time video communications by employing link adaptation. A novel link adaptation algorithm, which is based on feedback channel information including Block Error Rate (BLER), Received Signal Strength (RSS) and the first order statistic of the RSS, has been designed and analysed.
Two approaches for link adaptation are investigated: First, the effects of a link adaptation scheme at the video frame level, which aims to optimise video quality by varying the channel-protection scheme and video source rate for a fixed bandwidth allocation is studied. Second, a link adaptation algorithm with the goal of maximising the overall access network throughput is developed at the EGPRS radio block level. The algorithms are tested for MPEG-4 coded video transmissions over EGPRS networks. The schemes provide significant improvements in quality.

3.6. Mobile Multimedia Streaming Services

This research focuses on the delivery of streaming audio and video services over 2.5G/3G mobile access networks. Typical application scenarios include streaming high-quality mobile Internet radio services, news events and highlights of sporting events to a capable mobile terminal regardless of its location. Two main research areas are investigated: Firstly, the radio bearer is developed and optimised for streaming applications. A backward error correction scheme is designed to exploit the characteristics of streaming media services. This selective retransmission technique exploits the error resilience properties of compressed audio and video streams to increase the throughput across the radio interface at the expense of a small residual error. Secondly, a performance enhancement technique for streaming video that makes use of link adaptation is investigated. In general, link adaptation is not considered suitable for multi-user streaming applications, because it usually requires interaction between the link-layer protocol and the source encoder. The proposed technique requires no such interaction with the encoder, thereby significantly simplifying the link adaptation system. A significant performance improvement has been demonstrated for MPEG-4 coded video streaming over simulated EGPRS networks.

This follows the success of Internet-based communications, which uses packet-switched technology, as well as the success of 2G voice-only mobile communications. 3G networks are designed to support IP over the air interface. IP-based networks grant very high service flexibility and application independence, facilitating a multitude of real-time and interactive services. IP-based multimedia services generally require the use of the Real-time Transport Protocol (RTP), which is typically deployed on top of UDP/IP. RTP provides end-to-end network transport functions, which are suitable for transporting real-time applications, such as audio, video and/or data in multicast and unicast scenarios. However, the main drawback of using RTP/UDP/IP protocol stacks is the relatively large overhead imposed by these protocols, which are at least 40/60 bytes in total, for each transmitted packet depending on whether IPv4 or IPv6 is used. Such significantly large overheads cause the transmission to be inefficient in mobile networks, due to the limited bandwidth and the behaviour of the cellular link. The research concentrates on improving the performance of existing header compression algorithms, and a new adaptive-robust and efficient header compression/stripping scheme is introduced, which:

- Minimises the complexity, processing delay and required memory on mobile terminals as well as reducing the packet loss rate over error-prone channels and the required feedback information due to lost data.
- Improves the QoS of multimedia transmissions and efficiency performance.
- Allows packets to be independent of each other over wireless links.

Within this scheme, Application Defined Packets and Smart Packets are introduced, which improve the robustness. Application Defined Time-Windowing and Smart-Adaptive Buffering techniques are established, which have a significant impact on spectrum allocation.
3.8. Multimedia Security

The Full Speed project takes advantage of a 32-bit multi-
protocol chip card of the same name to support multi-
media applications requiring high cryptographic calcula-
tion capacities on such platforms as PC, interactive TV
and GSM. The tasks are:

• Creation of a secure signed document: The docu-
ment must be hidden from outside attackers. There
must be no possibility for repudiation, meaning that
the user must be authenticated and the content
must be guaranteed the same as seen on screen.
The document to be encrypted/decrypted and
signed, using the card functions.
• Streaming for secure online e-commerce applica-
tion: Provide a way using the processing and data
flow capabilities of the Full Speed card to create an
SSL connection between card and server for access
to web sites for e-commerce purposes. There must
be authentication of the user and non-repudiation of
the transaction.

Common to both applications is a need for user authentica-
tion. This will be provided for, not by a PIN but by an image-
based secret using combinations of different concepts.

3.9. Multilevel Turbo Codes

Multilevel turbo codes are constructed by using multi-
level turbo coding and iterative multistage turbo decod-
ing. Due to the near Shannon limit of good performance
of turbo codes, it can be assumed that there is negligi-
ble error propagation between the modulation levels.
This means the multistage turbo decoding leads to the
optimum result. Because multilevel turbo codes have
both high performance and high flexibility, they can wide-
ly be used in practical communication systems. For
example, in multimedia communications, huge data
source can be first divided into different subsets accord-
ing to their importance, and then coded employing
asymmetric codes in different coding levels. In this way,
a limited channel capacity can be more efficiently utilised.
RESEARCH AIMS

The research activities of the Networks Research Group are in Internet networking, network management and service management, programmable networks, grid computing, satellite networking, network security, and mobile and ad-hoc networks. In this context, some of our research encompasses Quality of Service (QoS) frameworks in IP, traffic engineering, multicast, application and network security, and policy-based management and adaptive services for 3rd generation mobile networks and beyond.

MAJOR ACHIEVEMENTS

• Developed algorithms for traffic engineering routing optimisation and capacity allocation.
• Defined policies for offline network dimensioning and for online dynamic resource management of network devices based on actual network state and load utilisation.
• Developed algorithms for offline and dynamic traffic engineering for production broadcast content.
• Developed network management applications based on mobile agent technology.
• Developed a QoS-enabled testbed with DiffServ and MPLS capabilities for development and validation of network management applications and traffic engineering approaches.
• Made contributions to the standardisation activities of ETSI for broadband satellite systems and ITU-T QoS evaluation of IP over satellite.
• Built a satellite network emulator to study satellite network conditions in a reproducible and controlled manner.
• Developed network architecture for IP multicast over satellite.
• Developed security key exchange protocol and management mechanisms for satellite multicast networks.
• Developed testbed for secure multimedia delivery using IP multicast over satellite.
• Evaluated QoS of VoIP and multiparty multimedia conferencing over satellite.
• Developed security component of architecture for application service providers (ASPs).
• Developed and validated frameworks for adaptive services in mobile networks beyond the 3rd generation.
• Developed prototype for experimenting with context-aware, adaptable services.
• Developed enabling mechanisms for the realisation of Personal Distributed Environments (PDE) based on the Grid Computing paradigm.

RESEARCH AREAS

1. INTERNET NETWORKING

1.1. MESCAL

MESCAL (Management of End-to-end Quality of Service Across the Internet at Large) is an EU IST project which aims to propose and validate scalable, incremental solutions that enable the flexible deployment and delivery of inter-domain Quality of Service (QoS) across the Internet. This involves developing templates, protocols and algorithms for establishing Service Level Specifications (SLS) between Internet Service Providers (ISPs) and their customers, including their peers. Scalable solutions for inter-domain Traffic Engineering (TE) will also be developed based on enhancements to the existing Border Gateway Protocol (BGP) routing protocol and associated route selection logic. MESCAL will consider both unicast- and multicast-based services and ensure that the proposed solutions are applicable to both IPv4 and IPv6.

Figure 40: MESCAL: domain interfaces

1.2. PRONET

PROduction of Broadcast Content in an Object-Oriented IP-based NETwork (PRONET) is a UK LINK/EPSRC project. The project work has been divided into two principal areas that involved partner pairings. The first area involved the University of Surrey and Thales Research; the work concerned the evaluation of the suitability of Internet IP with emerging Quality of Service (QoS) guarantees for the transportation of broadcast production network traffic in terms of video, audio, control and management flows.
We were mainly responsible for the development and evaluation of algorithms for offline and dynamic traffic engineering, and for a contribution towards a prototype and demonstrator. Work in the second area, conducted by the University of Bristol and Sony Broadcast Europe, involved management and control of broadcast content resources through emerging distributed object technologies such as CORBA/Java and the use of the World Wide Web, including the synchronisation of composite objects.

1.3. TEQUILA

The EU IST TEQUILA project (Traffic Engineering for Quality of Service in the Internet at Large Scale) has studied, specified and validated through prototype implementation a complete solution for providing QoS-based services in MPLS/DiffServ IP networks. Starting from a standard Service Level Specification (SLS) template that has been defined to describe QoS-based IP connectivity services, the work combines service management, traffic engineering and monitoring functions, all interworking together in a hierarchical architecture, at different timescales and levels of abstraction. The service management functions cater for the establishment and admission of SLS-based service requests, with the objective of not overloading the network, while distinguishing between service subscriptions and invocations. A two-level traffic engineering approach has been adopted. First, by means of offline traffic engineering functions the network is appropriately dimensioned based on estimates of anticipated traffic demand. Subsequently, dynamic traffic engineering functions aim to optimise resource utilisation while meeting the QoS guarantees of the transported traffic, using as guidelines the network dimensioning output. The impact of different policy settings on the service management and traffic engineering functions has also been investigated, and an architecture has been designed for conveying policies.

1.4. QoS testbed

The QoS testbed is maintained by the Networks Research Group and has been used for a number of research activities. It consists of six Linux-based software routers, realising a small-scale network topology. The main purpose of the QoS testbed is to accommodate and validate research activities carried out by the Networks Group as well as to assist MSc students with their projects. Two examples of projects which have used the testbed are as follows:

- The implementation of an experimental network dimensioning algorithm applied to DiffServ over MPLS-enabled networks that has been part of the research work carried out in the TEQUILA project;
- The implementation and validation of a QoS configuration, auditing and monitoring application based on the PARLAY specifications, for the MANTRIP project.

1.5. IP multicast deployment in differentiated services networks

This project focuses on the provisioning of multi-service group communications in a Differentiated Services (DiffServ) environment. Specifically, we propose a QoS-Source Specific Multicast (QSSM) framework that is based on the promising Source Specific Multicast (SSM) architecture. From a routing point of view, the project involves constructing QoS-aware source specific multicast trees on a per-class-of-service basis inside DiffServ domains. Both intra-domain multicast routing protocols (e.g., PIM-SSM) and inter-domain multicast routing protocols (e.g., MBGP) have been investigated and extended so as to achieve group data delivery with the required end-to-end QoS guarantees. From a scalability point of view, the proposed scheme avoids imposing additional overhead for QoS state maintenance at DiffServ core routers. In effect, the most distinct advantage of QSSM is that it needs no extensions to the underlying multicast routing/forwarding table structure for the inclusion of heterogeneous QoS requirements from end users, and this is an important requirement for practical deployment at large scale. Meanwhile, we also address IP-level multicast traffic engineering issues, e.g., how to balance multicast traffic inside the network so as to achieve optimised flow distribution. Interoperability of unicast and multicast traffic aggregation in DiffServ-based traffic engineering will also be investigated in this project.
2. NETWORK AND SERVICE MANAGEMENT

2.1. MANTRIP

The MANTRIP project (Management Testing and Reconfiguration of IP-based Networks using Mobile Software Agents) is an EU IST project under the Fifth Framework Programme. The main goal of the project was to design, develop, test, validate and provide a set of novel network management applications based on Mobile Agent Technology (MAT) for managing IP-based networks, and to evaluate MAT in the context of Network Management. The project produced three network management applications based on MAT technology. These were: (a) an application for configuration and alarm management of systems for the access network, (b) an application for configuring, auditing and monitoring QoS parameters within an IP-based administrative domain and (c) an application for conformance testing of network elements and mobile agents. The MANTRIP project has exploited the unique features of mobile agent technology in order to provide novel toolkits, responding to the urgent need for efficient IP network management.

![Figure 44: MANTRIP architecture](image)

2.2. POLYMICS: policy-based middleware for context-aware services

The imminent introduction of the 3rd generation of mobile communication networks (3G) will provide service developers and providers with new tools, such as the Open Service Access (OSA) framework and the Mobile Execution Environment (MExE), to facilitate the creation of advanced services. Of the various types of services planned for 3G users, context-aware services are generating large amounts of interest from industry and research communities. These services adapt their behaviour according to a particular context, e.g. user location, thus providing greater added value and multiple levels of customisation for users. Managing such services to meet both the user's and the service's requirements, however, presents new problems for network operators. The POLYMICS project aims to explore and tackle such problems through a policy-based middleware approach that will effectively and efficiently manage service adaptation strategies and the deployment of such services for future network operators.

2.3. Grid computing for enhanced mobile Personal Distributed Environments

Grid computing has emerged as a paradigm for co-ordinated resource sharing and complex problem solving in dynamic, multi-institutional virtual organisations. Thanks to their ability to support the creation of integrated computing environments, Grid frameworks are being widely adopted in the areas of e-science and e-business. Current Grids are, however, mainly composed of high-spec workstations connected by wire-line inter-networks. The inclusion of wireless terminals provides new challenges and opportunities. Issues such as resource heterogeneity, efficient handling of temporary disconnections, power consumption and resource requirements must be taken into account to provide efficient GRID resource management in the context of a hybrid fixed and mobile environment. In the context of M-VCE core 3 (IoN work area) we are looking at methods, architectures and protocols for the realisation of Mobile Wireless Grids as a means to create mobile virtual organisations that are more complex, flexible and powerful than the Personal Distributed Environments studied elsewhere.

2.4. VESPER: virtual home environment for service personalisation and roaming users

The Virtual Home Environment (VHE) is a concept that foresees users who are consistently provided with any personalised service aspects, irrespective of the terminal or network they are using, or their geographic location. The aim of the VESPER project is to define, demonstrate, validate and promote a service architecture for the provision of a VHE across a multi-provider, heterogeneous network and system infrastructure. More specifically, VESPER applies distributed object-oriented principles to VHE service control and management, using TINA principles, agent technology and other innovative approaches in order to effectively support roaming users with service portability, session mobility and service scalability. The VHE architecture has been assessed both theoretically and practically through experimentation. An important contribution of VESPER is the identification of migration paths from current architectures towards the realisation of the VHE. In this direction, CCSR has contributed to the network performance management aspects of a VHE that support the process of service adaptation based on changing network conditions. In addition, we have successfully demonstrated the exploitation of software agent mobility and autonomy in order to address VHE requirements for self-configurable and programmable operation over a heterogeneous network infrastructure.
2.5. Network performance management using mobile agents

In recent years software mobile agents have been considered to be a promising line of inquiry in the area of network management. The research conducted here aims to present a clear direction for the practical exploitation of mobile agents for network management tasks. Three different case studies of network performance management have been examined in order to evaluate the effectiveness of the agent mobility strategy and autonomous behaviour applied within the specific context. The mobile agent benefits identified relate primarily to their easy support for programmability of network elements and the autonomous, self-configurable and fault tolerant agent operation. An important drawback however is that the advanced capabilities of modern mobile agent frameworks typically incur significant performance overheads, and these have been confirmed through a detailed performance evaluation comparing mobile agents with distributed object and mobile code approaches. To address this drawback, we propose network management solutions based on specially formulated execution environments that retain important mobile agent benefits while reducing performance overheads.

2.6. Policy-based management in QoS-enabled IP networks

Policy-based management can guide the behaviour of a network or distributed system. This is achieved through high-level declarative directives that are dynamically introduced, checked for consistency, and refined and evaluated, resulting typically in a series of low-level actions. In this research we view policies as a means of extending the functionality of management systems dynamically, in conjunction with pre-existing “hard-wired” management logic. Inconsistencies in policy-based systems are quite likely since management logic is dynamically being added, changed and removed without the rigid development cycle of “hard-wired” long-term logic. Our work addresses the policy management aspects of architecture for managing IP DiffServ networks, focusing on the resource management part of the architecture. We have defined policies that drive the behaviour of an off-line network dimensioning component, as well as policies that can dynamically manage the resource reservations of the network devices based on actual network state and load utilisation. Finally, we have studied the hierarchical relation between these two types of policies, and we intend to specify conflict detection and resolution mechanisms specific to our problem domain.

2.7. Service management for 3G networks and beyond

The introduction of 3rd generation mobile communications networks (3G) will herald the widespread deployment of a new generation of mobile services (m-services). The distinct boundary between data and telecommunication networks, and similarly m-services, will become indistinguishable as mobile networks evolve towards a high bandwidth all-IP infrastructure. Future services are expected to be accessible through heterogeneous networks, with IP being deployed as the common network layer across multiple network domains. Furthermore, advanced service frameworks, such as the Virtual Home Environment (VHE) will allow users to access their services regardless of network used, terminal type or user location, particularly when roaming between such networks. These new developments require greater emphasis on service management in 3G networks and beyond. Of particular importance are new algorithms for service control, strategies and techniques for dynamic service adaptation, management frameworks for service configurability and service aggregation, and well-defined interfaces and platforms for service portability and accessibility during user roaming. This research will attempt to explore these issues fully with the aim of influencing the development of new management strategies and middleware in the future.

2.8. Resource management for agent-based services

When advanced services are implemented for a mobile wireless context they require more complex management systems than the ones currently available. Therefore, with the increase of dynamic behaviour of networks such as ad-hoc and mobile networks, advanced services for next generation of communication systems need to be designed in a configurable way. In this research we are looking at services in which the individual components are realised with Mobile Agents (MAs). We present therefore a system which aims to manage those service constituents to meet issues such as:

- User requirements (including user profile and terminal profile);
- Service profile in terms of computational capability needed;
• Network QoS.

The main challenges of this research can be illustrated by summarising the work’s objectives. Some of them have been addressed and some need further investigation:

• Investigate services and applications that are realised through the mobile agent paradigm;
• Study dynamic resource management algorithms for advanced adaptable services;
• Study the problem of evaluating such services and management algorithms and develop a suitable simulation methodology and environment for this purpose.

3. INTEGRATED SATELLITE NETWORKING

3.1. ICEBERGS: IP conferencing with broadband multimedia over satellites

The goal of the ICEBERGS Project is to design and validate an integrated broadband communication infrastructure for IP-based multiparty, QoS-sensitive conversation-al services for fixed terminal topologies, for both business users and consumers, based on the EuroSkyWay satellite network. This represents a challenge for next generation networks, and requires studying optimal satellite routing techniques, end-to-end delay control mechanisms and specific service support functionality.

The study has proposed an integrated routing architecture that supports both unicast and multicast to minimise the satellite bandwidth requirement as well as easing the handling of multicast media streams. Unicast end users with simple terminals can join a multiple conference using the multiple MCU infrastructure architecture. In addition, multicast end users are completely compatible with the designed system. A PIM-SM/MSDP/MBGP multicast solution has been demonstrated among all MCUs and multicast enabled users, with a centralised signalling and distributed multicast media conference model.

A demonstrator has been set up and configured: real satellite links and an ESW emulator were used to simulate the real ESW network. Federated ISP domains and a satellite domain were used in this demonstrator. One-to-one and also one-to-many parameters have been defined for ICEBERGS and will be measured in several key scenarios. The measured results will be analysed at both network level and user level.

3.2. Reliable multicast IP protocols over satellite

Multicast IP applications over satellite provide the potential to deliver services effectively at a large scale (in terms of both numbers of users and their geographic spread). We have considered the behaviour of reliable multicast protocols over satellites, looking in particular at one protocol, PGM (Pragmatic General Multicast), which has recently become a experimental Internet RFC standard (RFC3208). We have developed two separate analytical models: the first describes the IP datagram loss rate over a satellite ATM link; the second describes the multicast protocol error performance for each of PGM’s three different error correction mechanisms and quantifies the forward and reverse link traffic volumes for file transfer using each mechanism. These models were confirmed by simulation using the OPNET event-driven simulation package. We have developed a novel algorithm for traffic minimisation, showing how to optimise the traffic by varying the application packet size.

3.3. QoS multicast in satellite IP networks

After almost half a century since the launch of first artificial satellite, satellites are an integral part of modern communication systems. The space environment provides a whole new spectrum of challenges to communications and networking, and the need to understand the impact of satellite networks on Internet applications and services is essential. As an initial part of this research, a testbed has been constructed to enable the evaluation of the effect of satellites in a multicast multiparty videoconference environment. In addition, a Satellite IP Network Emulator has been developed to study satellite network conditions in a reproducible and controlled manner, emulating satellite propagation delays and errors. These two parameters are the most prominent characteristics of satellite links that are different from terrestrial networks. The testbed and emulator will be used as a foundation for devising new algorithms to achieve QoS in a multicast satellite environment, and thus contribute to the next generation Internet.
4. TRAFFIC ENGINEERING AND MODELLING

4.1. Service-driven traffic engineering for the Internet

Internet traffic engineering is defined as that aspect of Internet network engineering that deals with the issues of performance evaluation and performance optimisation of operational IP networks. The Internet exists in order to transfer information from source nodes to destination nodes. Accordingly, one of the most significant functions performed by the Internet is the routing of traffic from ingress nodes to egress nodes, and therefore an important function of Internet traffic engineering is the control and optimisation of routing, so as to steer traffic through the network in the most effective way. The optimisation aspects of traffic engineering can be achieved through capacity management and traffic management. In this work we look into how to control capacity management and routing in order to achieve both network operational and service-oriented objectives. We assume the Differentiated Services service model, and we seek to accommodate customer contracts as defined in Service Level Specifications. The work has resulted in a holistic architecture for service-driven traffic engineering, with the associated algorithms for routing optimisation and capacity allocation. These algorithms have been evaluated through simulations (using Network Simulator – NS2), and we are in the process of validating the results on the Linux-based QoS testbed which is maintained by the Networks Group.

4.2. Inter-domain traffic engineering

Traffic Engineering (TE) techniques have emerged over the last decade in an attempt to optimise operational IP networks. To date, the primary use of TE has been focused within a domain (intra-domain TE). However, lack of incentives and support for traffic engineering between domains (inter-domain TE) results in poor management of inter-domain resources, which in turn can significantly affect the end-to-end performance. Network operators now recognise that the management of inter-domain traffic is part of their operation costs that should be optimised. In other words, traffic engineering not only needs to be considered within a domain, but also between domains. The current de factor inter-domain routing protocol is Border Gateway Protocol (BGP) which provides policies to select the best path in the global Internet. As TE concerns how to route packets efficiently, we consider modifying and optimising BGP routing as a primary goal of inter-domain TE. We are also investigating how to make quality-of-service and TE work together between administratively distinct domains with different capabilities and policies.

4.3. Traffic measurement and modelling

In order to monitor, evaluate and verify network performance it is important to understand the network traffic characteristics. Consequently, in this work we have initially modelled a single node Ethernet workstation’s performance in terms of an analysis of its traffic measurements (packet size and inter-arrival time for each of WWW, FTP and Telnet traffic). We have compared measured results with theoretical mathematical distributions in order to understand the network traffic’s characteristics. This work will be linked later in the study with network routing and queuing theories in order to explore the network’s ability to support QoS.

A major research topic in IP traffic engineering is the development of traffic source models that are consistent with empirical data obtained from operational networks, as described above. Such models should also be tractable and amenable to analysis. This research is therefore also studying the nature of IP traffic in some network models (classic traffic model and self-similar traffic) developed in JavaSim. The results and their analysis show the characteristics of the IP traffic.

4.4. Admission control and bandwidth management in IP differentiated services networks

Differentiated Services are seen as an important technology that can support QoS in the Internet without the scalability problems of Integrated Services. The fact that in Differentiated Services per-flow information is kept only at edge and not at core routers allows for more efficient utilisation of bandwidth and buffering resources in the core network, but on the other hand makes supporting strict QoS guarantees on a per-flow basis a more difficult task. In this research we have considered bandwidth management and admission control. In the former, the
traffic demands of aggregated traffic in terms of both bandwidth and buffering have been investigated and some implications for traditional traffic engineering techniques have been deduced. As regards admission control, a measurement-based approach has been employed with an attempt to be as non-heuristic as possible so as to be generic and not dependent on individual traffic sources’ characteristics. All cases have been validated through extensive simulations.

5. NETWORK SECURITY

5.1. Application service provider network (ASP-NET) Security

Many application software packages are expensive and are resource-demanding (support, maintenance, software upgrades). These factors put pressure on small-to-medium sized enterprises that have limited managerial and technical staff and limited capital for investment in software and hardware infrastructure. Application Service Providers (ASPs) offer a very promising solution to this kind of SMEs’ problems: ASPs are third party entities that manage and distribute software-based services and solutions to customers across a wide area network from a central data centre.

The objective of ASP-NET is to develop and set-up three example product-service (PS) systems that address the technological needs of modern organisations for e-messaging, enterprise project management and human resources management services. The project is intended to demonstrate the increased efficiency of the ASP model over the traditional software sales model, and illustrate the integration, interoperability, and service provision automation of these PS systems.

As a relatively new development, ASP networks inevitably give rise to many new security concerns, as well as reviving some of the old ones associated with mainframe technology. CCSR’s main responsibility is to investigate the security threats and needs in ASP-NET, and implement security functions for the three PS systems. We will:

- Address security issues related to the ASP network: identify the potential risks and risk management guidelines and procedures, and provide formal security policies for the three chosen PS systems.
• Build, demonstrate and validate a security system for the ASP network using standards such as SOAP, XKMS, XML Digital and XML encryption. This will enable secure transactions between the diversity of actors that interact with the system as well as provide the safe representation of application service data taking into account data ownership and remote storage issues.

5.2. GEOCAST: multicast over geostationary EHF satellites

The objective of the GEOCAST project is to define a multicast satellite system. This definition comprises protocol definitions (for network, medium access and physical layers) in order to ensure that multicast applications can be efficiently carried over the satellite. Three satellite platforms have been considered: ATM on-board processing (OBP), DVB OBP, and a transparent satellite with no OBP. The GEOCAST architecture will also be demonstrated using a satellite emulator. As with many unicast applications, most of the multi-party applications will only be successful if the privacy and authenticity of the participants can be efficiently provided. CCSR’s contribution to the project is to consider the satellite security requirements, both in the satellite core (uplinks and downlinks) and end-to-end. As two examples of the latter, we have built a secure multicast module that is part of a secure file transfer using a file transfer protocol optimised for satellite environments, SAT-RMTP; we have also built an early implementation of LKH, a key management technique that is an Internet Draft and is scalable to the large number of receivers that are expected in satellite multicast.

We have also recommended changes to the DVB-RCS-RCS security specifications in order to support multicast services effectively.

5.3. IP multicast security systems testbed for satellite broadcast networks

The main aim of this project, performed in collaboration with Logica and ESA, is to develop a secure multicast IP system for use over satellite information dissemination systems. More specifically CCSR is developing a secure multicast key management system based on the Group Secure Association Key Management Protocol (GSACKMP) with key distribution optimised by using Logical Key Hierarchy (LKH). This key management will work in the application layer and will interface with IPSec (IP Security, usually implemented in the Unix kernel) to provide seamless IP multicast security. This work will then further be integrated with a multimedia multicast framework developed by Logica to create an integrated secure IP multicast infrastructure for satellite broadcast networks.

5.4. Satellite IP multicast security

Today there is an increasing need for multicast services over satellite: these can take advantage of satellites’ wide geographical spread to deliver multicast services to areas where broadband services (or indeed any telecommunication services) do not exist. Multicast can be served in an efficient manner in a satellite environment due to the broadcast nature of satellites. But there are different security issues involved regarding multicast as opposed to unicast. Unicast security is relatively well understood and standardised, whereas multicast security is still in a research stage, even though in recent years significant research has been conducted in the IETF MSEC (Multicast Security) and IRTF GSEC (Group Security) groups.

We are currently looking into multicast key management and distribution with particular reference to satellite networks. Scalability and reliability issues for IP multicast over satellites will also be investigated. We are currently in the process of implementing a multicast key management and distribution protocol, GSACKMP, which is currently an Internet Draft. This work will help in pushing the IETF Draft document towards RFC status.
6. MOBILE AND AD-HOC NETWORKS AND SERVICES

6.1. Mobile VCE: mobile agents for software-based services beyond 3G

The Networks Research Group has been involved in the Mobile Virtual Centre of Excellence. The purpose of our work is to evaluate the use of Mobile Agents (MAs) for the next generation of mobile communications. The benefit of this technology is as an aid towards reducing network traffic, a fundamental goal in network management. This reduction in network traffic is pursued through appropriate service management. Below are the main objectives of the integrity analysis and performance analysis of Management Systems for Mobile Agent systems:

- Analyse the integrity of the management protocol at a data collection level;
- Analyse the requirements & functionality of the management system;
- Carry out a viability assessment of the management system;
- Design and gradually implement a modular simulation environment, where different distributed management techniques could be evaluated;
- Design and implement the management system;
- Analyse the performance of the management system in the network simulation environment.

6.2. Mobile VCE: personal distributed environment beyond 3G

This project is a further contribution by the Networks Research Group to the Mobile Virtual Centre of Excellence. The Personal Distributed Environment (PDE) targets the expectation that as users move around they interact dynamically with different devices, with differing capabilities, through which they are able to access their services, some delivered via mobile and fixed phone networks, some via wireless and fixed broadcast networks, and some supported by more than one network.

Our interest focuses on Personal Access Management. This involves identifying the distributed device features that need to be discovered in mobile/broadcast for tailoring service delivery to the recipient. This is expected to lead to the development of protocols for feature discovery in mobile/broadcast based PDEs, with the emphasis on the characteristics of the distributed terminals themselves. A standardised representation of the capabilities of individual devices will be developed with a procedure for the dynamic maintenance of these capabilities to facilitate the optimal delivery of services using the elements within the PDE. The key issues to be covered are:

- Identification of the device characteristics & parameters which are required to manage a distributed environment supporting converged broadcast & mobile services;
- Development of a hierarchical, distributed database structure which can be used to represent the capabilities and configuration of the PDE, the devices within the PDE, and the components within each device;
- Algorithms & heuristics for intelligent management of the PDE topology & QoS based on complex cost models.

6.3. ANWIRE: academic network for wireless Internet research in Europe

The ANWIRE project provides an open framework for the exchange of ideas and results between organisations within Europe in the areas of reconfigurability and adaptability in mobile systems, and disseminates results by providing a forum for the exchange of knowledge and ideas in these areas. In order to effectively achieve this goal, a reference point is established for promoting the European effort and research achievements in the fields of reconfigurability and adaptability, thus enhancing the visibility of research in the EU. ANWIRE also facilitates the training of researchers and integration of knowledge and results related to the respective research activities.

6.4. PAN: Programmable ad-hoc networking

PAN is an EPSRC project whose main objective is to consider programmable ad-hoc networks as an important emerging type of network infrastructure that will complement 3G+ mobile and fixed network infrastructures. PAN will investigate solutions for a Quality of Service (QoS) framework, context-aware QoS support and a middleware-based programmable infrastructure. This will allow mobile devices to download and activate required protocols and service software dynamically so as to align themselves with the current requirements of the ad-hoc environment. PAN aims to investigate QoS routing and an overall QoS support framework for bandwidth-only guarantees in mobile ad-hoc networks. PAN will also investigate mechanisms for context-aware QoS support and enhancements, taking into account location, connectivity, received QoS and application requirements.

6.5. QoS support for multimedia applications in mobile ad-hoc networks

A Mobile Ad-Hoc Network (MANET) is defined as an autonomous system of mobile routers connected by wireless links, the union of which forms an arbitrary graph. MANETs are self-creating, self-organising, and self-administrating. Since MANETs will be required to
support real-time applications, effort has been made to support Quality of Service (QoS) in such networks. However, supporting QoS in a dynamic ad-hoc network is still an open challenge. The QoS mechanisms developed for conventional wired networks cannot be applied directly to an ad-hoc network due to its dynamic nature. The objective of this research, therefore, is to find a mechanism that can support QoS for multimedia applications in MANETs. The first task in this process is to devise a scalable routing protocol that can efficiently conserve the scarce channel bandwidth and transmission power in ad hoc networks. The work will then build a flexible QoS model on top of the devised routing mechanism.
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RAGUSA, Carmelo  
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SALLEH, Mohd Noah  
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SHENG, Yun  
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AWARDED PhDs OVER 2001-2003

2001

Maria Farrugia “Combined Speech and Audio Coding with Bit Rate and Bandwidth Scalability”, March 2001
Simon Fabri, “Multimedia Communications over Mobile Packet Networks”, July 2001
Tzaras Constantinos, “Physical and Statistical Modelling of Radiowave Propagation”, July 2001
Klaus Moessner, “Reconfigurable Mobile Communication Networks”, July 2001
Nilantha Katugampala, “Multimode Speech Coding Below 6 Kbps”, October 2001
Safak Dogan, “Video Transcoding for Multimedia Communication Networks”, October 2001
Stephane Villette, “Sinusoidal Speech Coding for Low and Very Low Bit Rate Applications” October 2001
Kanagasabapathy Narenthiran “Optimisation of Mobility Management Resources and Link Emulation for Mobile Satellite Systems” October 2001

2002

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Stamatis Kourtis “Quality-of-service-based approach for dimensioning & optimization of mobile cellular networks”, October 2002
Dimitrios Mavrakis “Measurement & prediction of the Wideband Indoor Radio & Infrared channels”, October 2002
Woo Lip Lim, “Handover for High Altitude Platform Station UMTS”, October 2002
Yu Chiann Foo, “Call Admission Control for High Altitude Platform Station UMTS”, October 2002
Tim Brown, “Antenna Diversity for Mobile Terminals”, December 2002

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Alejandro Aragon, “In building design and optimisation using measurements”, February 2003
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Nasser Neda, “Code Acquisition Techniques for CDMA Based Networks”, August 2003
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