RAJIV CHAKRAVORTY

SAN FRANCISCO CA 94102 PHONE: 415-793-8339
rajiv.chakravorty@gmail.com http://www.rajivchakravorty.com
Status: US Permanent Resident (Jan 2007–)

VOCATIONAL

Founder/ Serial Enterprenuer. Researcher. Teacher. Consultant. Investor. Founder of 5 multi-disciplinary silicon valley start-ups. Interests/expertise spans: mobile and wireless systems, applications and services; comparative (computer) architectures; distributed computing; reconfigurable computing; networked sensors/actuators systems; networked Internet appliances; file/storage systems; sensory multimedia and signal processing; real-time OS (especially modular OS'es); Internet protocols and Web services; data mining/AI; nano-electronics; healthcare, HCI and the intersection of bio-cogno-neuro sciences.

PROFESSIONAL PREPARATION

CAMBRIDGE UNIVERSITY UNITED KINGDOM — Oct 2001 – Dec 2007
Ph.D. in Computer Science — *(Sun Microsystems Fellowship)*
Dissertation: Rearchitecting the Internet for Wide-area Wireless Services
Supervisors: Prof. Ian Pratt and Prof. Jon Crowcroft

TECHNICAL UNIVERSITY OF AACHEN GERMANY — May 1998 – Feb 1999
DAAD Scholar, Chair of Communications Networks — *(DAAD Scholarship Award from Germany)*
Research topic: Internet Quality of Service
Supervisor: Prof. Bernhard Walke

INDIAN INSTITUTE OF TECHNOLOGY DELHI INDIA — July 1997 – May 1999
Master of Technology (M.Tech), Computer Technology — *(IIT Graduate Scholarship)*
Supervisor: Prof. Subrat Kar

NAGPUR UNIVERSITY INDIA — Sep 1993 – June 1997
Bachelor of Engineering, Electronics Engineering — *(Ranked 2nd out of more than 1000 students)*

PROFESSIONAL WORK EXPERIENCE

PHILIPS RESEARCH, EINDHOVEN, THE NETHERLANDS — June 2000 - Sep 2001
Member of Technical Staff (Senior Embedded Designer)

Architected, designed and implemented a successful working prototype for a futuristic project named Smart Box Management (SBM). Built and demonstrated a novel prototype of a set-top-box device that can be dynamically reconfigured and remotely managed on-the-fly without requiring explicit manual intervention. Concepts and tools from SBM are now part of all the Internet-enabled STREAMIUM™ devices from Philips. Implemented and participated in the standardization of Digital-to-Digital Copy Protection for DVD-video. Shipped two successive releases of the then Philips led Millennium Watermarking System for digital video. This work spun out the two innovative products – REPLITRACK™ and CINEFENCE™ – available from Philips.

SASKEN COMMUNICATIONS TECHNOLOGIES LTD., BANGALORE, INDIA — May 1999 - June 2000
Software Design Engineer, Mobile Multimedia R&D Group

Designed, implemented and evaluated MPEG-4 standards-based multimedia solutions. Led the design and implementation of an innovative network-aware middleware stack based on ISO/IEC 14496 (Part 6) of the MPEG-4 standard known as DMIF (Delivery Multimedia Integration Framework). This work, now part of Sasken's STRAWBERRA™ applications, is licensed and incorporated into several commercial products.

SELECT HONORS AND AWARDS

- ◇ *Extraordinary Ability* achievements-based classification from the US government for "researchers at the top in their fields of endeavor (Nobel prize or equiv.)" USA (2007)
- ◇ *Visiting Research Fellowship* CS dept. University of Wisconsin-Madison USA (Jan - July 2005)
- ◇ *Sun Microsystems PhD Fellowship Award* Cambridge University UK (2001 - 2005)
- ◇ *Hughes Hall Scholarship Award* Cambridge University UK (2001 - 2004)
- ◇ *DAAD Scholarship Award* from Germany (1998 - 1999). Top 2% in IIT Delhi: based on all round academic merit and research potential .
- ◇ *IIT Graduate Scholarship* Indian Institute of Technology Delhi India (1997 - 1999)
- ◇ *Ranked* 2*nd out of more than* $1,000$ *engineering graduates* Nagpur University India (1997)
- ◇ *Best Paper Award* for undergraduate project and paper presented in a National Conference India (1997)
- ◇ *Second Prize* in the Nationwide Innovative Technical Design Competition, *Second Prize* in the Nationwide Electronics Design Competition, and *Second Prize* in the Nationwide Technical Quiz Competition (1995)
- ◇ *Top* 0.1% *out of over* $1,60,000$ *science students* in Higher Secondary Exam in Maharashtra India (1993)

FULL PUBLICATIONS LIST

Highly-selective conference papers — 8
ACM MOBICOM: 2; IEEE INFOCOM: 3; ACM MOBISYS: 2; IEEE PERCOM: 1

Widely-circulated journal articles — 6
IEEE JSAC: 2; ACM WINET: 1; ACM MONET: 1; JCN: 1; IEEE Wireless: 1; ACM MC2R: 2

[P-1] R. Chakravorty. "Harnessing Channel Uncertainty with Fuzzy Inferencing for Interactive Cellular Video Transmission". SUBMITTED FOR PEER REVIEW (Manuscript available on request)

[P-2] R. Chakravorty. "Implementation and Applications-driven Handover Evaluation in an Integrated Wireless IPv6 Network". SUBMITTED FOR PEER REVIEW (Manuscript available on request)

[P-3] R. Chakravorty, S. Banerjee, S. Ganguly. "MobiStream: Error-Resilient Video Streaming in Wireless WANs using Virtual Channels". PROCEEDINGS OF IEEE INFOCOM 2006, Barcelona, Spain

[P-4] R. Chakravorty. "MobiCare: A Programmable Service Architecture for Mobile Medical Care". PROCEEDINGS OF IEEE PERCOM WORKSHOP UBICARE 2006: THE FIRST WORKSHOP IN UBIQUITOUS AND PERVASIVE HEALTHCARE, Pisa, Italy

[P-5] R. Chakravorty, S. Agrawal, S. Banerjee and I. Pratt. "MoB: A Mobile Bazaar for Wide-area Wireless Services". PROCEEDINGS OF ACM MOBICOM 2005, Cologne, Germany

[P-6] R. Chakravorty, S. Agarwal, S. Banerjee, I. Pratt. "A Mobile Bazaar for Wide-area Wireless Services". ACM JOURNAL FOR WIRELESS NETWORKS (ACM WINET), Special Issue on selected papers from ACM Mobicom, 2006

[P-7] R. Chakravorty, S. Katti, I. Pratt and J. Crowcroft. "Using TCP Flow Aggregation to Enhance Data Experience of Cellular Wireless Users". IEEE JOURNAL ON SELECTED AREAS OF COMMUNICATIONS (IEEE J-SAC). Special Issue on Mobile Computing and Networking, May 2005

[P-8] R. Chakravorty, A. Clark and I. Pratt. "Optimizing Web Delivery over Wireless Links: Design, Implementation and Experiences". IEEE JOURNAL ON SELECTED AREAS OF COMMUNICATIONS (IEEE J-SAC), Special Issue on Intelligent Services and Applications in Next Generation Networks, Feb 2005

[P-9] T. Pagtzis, R. Chakravorty, J. Crowcroft, S. Hailes and P. Kirstein. "Proactive Mobile IPv6 for Context-aware all-IP Wireless Access Networks". PROCEEDINGS OF THE IEEE CONFERENCE ON WIRELESS COMMUNICATIONS (IEEE WIRELESSCOMM 2005), Hawaii, USA

[P-10] R. Chakravorty and I. Pratt. "Performance Issues with General Packet Radio Service". IEEE JOURNAL OF COMMUNICATIONS AND NETWORKS (IEEE JCN). Special Issue on Evolving from 3G deployment to 4G definition, pages 266-281, Vol. 4, No. 2, December 2002

[P-11] J. Chesterfield, R. Chakravorty, I. Pratt, S. Banerjee, P. Rodriguez. "Exploiting Diversity to Enhance Multimedia Streaming over Cellular Links". PROCEEDINGS OF IEEE INFOCOM 2005, Miami, USA

[P-12] J. Chesterfield, R. Chakravorty, I. Pratt, S. Banerjee, P. Rodriguez. "Transport Level Optimisations for Interactive Streaming Multimedia over Wide-area Wireless Links". ACM MONET JOURNAL, 2004

[P-13] R. Chakravorty, S. Banerjee, P. Rodriguez, J. Chesterfield, I. Pratt. "Performance Optimizations for Wireless Wide-Area Networks: Comparative Study and Experimental Evaluation". PROCEEDINGS OF ACM MOBICOM 2004, Philadelphia, USA

[P-14] P. Rodriguez, R. Chakravorty, J. Chesterfield, I. Pratt, S. Banerjee. "MAR: A Commuter Router Infrastructure for the Mobile Internet". PROCEEDINGS OF ACM SECOND MOBILE SYSTEMS, APPLICATIONS, AND SERVICES CONFERENCE (ACM MOBISYS 2004), Boston, USA

[P-15] R. Chakravorty, A. Clark and I. Pratt. GPRSWEB: OPTIMIZING THE WEB FOR GPRS LINKS. PROCEEDINGS OF ACM FIRST MOBILE SYSTEMS, APPLICATIONS, AND SERVICES CONFERENCE (ACM MOBISYS 2003), San Francisco, USA

[P-16] R. Chakravorty, S. Katti, J. Crowcroft and I. Pratt. "Flow Aggregation for Enhanced TCP over Wide-Area Wireless". PROCEEDINGS OF IEEE INFOCOM 2003, San Francisco, USA

[P-17] R. Chakravorty, P. Vidales, K. Subramanian, I. Pratt and J. Crowcroft. "Performance Issues with Vertical Handovers: Experiences from GPRS Cellular and WLAN hot-spots Integration". PROCEEDINGS OF THE IEEE PERVASIVE COMMUNICATIONS AND COMPUTING CONFERENCE (IEEE PERCOM 2004), Orlando, USA

[P-18] R. Chakravorty, M. D'Arienzo, I. Pratt, J. Crowcroft. "A Framework for Dynamic SLA-based QoS control for UMTS". IEEE WIRELESS COMMUNICATIONS, Special Issue on Merging IP with Wireless Networks, Vol. 10, No. 5, October 2003

[P-19] R. Chakravorty, P. Vidales, K. Subramanian, I. Pratt, J. Crowcroft. "Practical Experience with Wireless Networks Integration using Mobile IPv6". ACM MOBILE COMPUTING AND COMMUNICATIONS REVIEW (ACM MC2R), Vol. 3, No. 4, October 2003

[P-20] R. Chakravorty and I. Pratt. "Practical Experience with HTTP and TCP over GPRS". ACM MOBILE COMPUTING AND COMMUNICATIONS REVIEW (ACM MC2R), Vol. 7, No. 1, January 2003

[P-21] J. Chesterfield, R. Chakravorty, J. Crowcroft, P. Rodriguez and S. Banerjee. "Experiences with multimedia streaming over 2.5G and 3G Networks". PROCEEDINGS OF BROADWIM: WORKSHOP ON BROADBAND WIRELESS MULTIMEDIA: ALGORITHMS, Architectures and Applications, 2004, San Jose, USA
(Invited Paper)

[P-22] R. Chakravorty, J. Chesterfield, P. Rodriguez and S. Banerjee. "Measurement Approaches to Evaluate Performance Optimizations over Wide-Area Wireless Networks". PROCEEDINGS OF FIFTH PASSIVE AND ACTIVE MEASUREMENT WORKSHOP (PAM 2004), Antibes Juan-les-Pins, France

[P-23] J. Chesterfield, R. Chakravorty, P. Rodriguez, S. Banerjee, I. Pratt and J. Crowcroft. "Transport Level optimizations for Interactive streaming media over wide-area wireless networks", PROCEEDINGS OF MODELING AND OPT. IN MOBILE, AD HOC AND WIRELESS NETWORKS (WIOPT 2003), Cambridge, UK

[P-24] P. Vidales, R. Chakravorty and C. Policroniades. "PROTON: A Policy-based Solution for Future 4G devices". PROCEEDINGS OF THE 5TH IEEE INTERNATIONAL WORKSHOP ON POLICIES FOR DISTRIBUTED SYSTEMS AND NETWORKS (IEEE POLICY 2004), June, New York, USA

[P-25] R. Chakravorty, P. Vidales, L. Patanapongpibul, B. Dragovic and C. Policroniades. "A Testbed for Ubiquitous Networking". PROCEEDINGS OF THE UBIQUITOUS COMPUTING (UBICOMP 2003) CONFERENCE, Seattle, USA

[P-26] P. Vidales, L. Patanapongpibul and R. Chakravorty. "Ubiquitous Networking in Heterogeneous Environments". PROCEEDINGS OF THE IEEE WORKSHOP ON MOBILE MULTIMEDIA COMMUNICATIONS (IEEE MOMUC 2003). Munich, Germany

[P-27] C. Policroniades, R. Chakravorty, P. Vidales. "A Data Repository for Fine-Grained Adaptation in Heterogeneous Environments". PROCEEDINGS OF THE 3RD ACM WORKSHOP ON DATA ENGINEERING FOR WIRELESS AND MOBILE ACCESS (ACM MOBIDE 2003), San Diego, USA

[P-28] R. Chakravorty, M. D'Arienzo, J. Crowcroft and I. Pratt. "Dynamic SLA-based QoS Control for Third Generation Wireless: The CADENUS Extension". PROCEEDINGS OF IEEE CONFERENCE ON COMMUNICATIONS (IEEE ICC 2003), Alaska, USA

[P-29] R. Chakravorty, J. Cartwright, I. Pratt. "Practical Experience with TCP over GPRS". PROCEEDINGS OF IEEE GLOBAL COMMUNICATIONS CONFERENCE (IEEE GLOBECOM 2002), Taipei, Taiwan

[P-30] R. Chakravorty and I. Pratt. "Engineering Mobile Proxy Design for Wide-Area Wireless". PROCEEDINGS OF THE 7TH CABERNET EUROPEAN WORKSHOP 2002, Bertinoro, Italy

[P-31] R. Chakravorty. "Making GPRS perform better!". PROCEEDINGS OF THE MULTISERVICE NETWORKS WORKSHOP 2002, July, Oxford, UK

[P-32] R. Chakravorty and I. Pratt. "WWW Performance over GPRS". PROCEEDINGS OF IEEE INTERNATIONAL CONFERENCE ON MOBILE AND WIRELESS COMMUNICATION NETWORKS (IEEE MWCN 2002), Stockholm, Sweden

[P-33] R. Chakravorty and H. Ottevanger. "SBM: Enabling Remote Management Services for Dynamically Reconfigurable Devices". PROCEEDINGS IEEE INTERNATIONAL CONFERENCE ON WIRELESS LANS AND HOME NETWORKING (IEEE ICWLHN 2002), Atlanta, USA

[P-34] R. Chakravorty and H. Ottevanger. "Architecture and Implementation of a Remote Management Framework for Dynamically Reconfigurable Devices". PROCEEDINGS OF IEEE INTERNATIONAL CONFERENCE ON NETWORKS (IEEE ICON 2002), Singapore

[P-35] R. Chakravorty, D. Jaiswal and R. Babu. "Design, Implementation and Performance Evaluation of a QoS Aware Middleware for MPEG-4 Applications". PROCEEDINGS OF THE IEEE INTERNATIONAL CONFERENCE ON SOFTWARE, TELECOMMUNICATIONS AND COMPUTER NETWORKS (IEEE SOFTCOM 2000), Venice/Trieste, Italy

[P-36] R. Chakravorty and D. Jaiswal. "Streaming-based Visual Surveillance System". PROCEEDINGS OF THE IEEE NATIONAL SYMPOSIUM ON INTERNET AND TELECOM TECHNOLOGIES FOR THE NET ECONOMY 2000, Bangalore, India

[P-37] R. Chakravorty and R. Babu. "A QoS-aware middleware for MPEG-4 applications". PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON ADVANCED COMPUTING AND COMMUNICATIONS (ADCOM 2000), Cochin, India

[P-38] R. Chakravorty, S. Kar and P. Farjami. "Performance Evaluation of the Scalability Effects on Control-Plane Signaling in Resource Reservation Protocol (RSVP)". PROCEEDINGS OF THE SECOND INTERNATIONAL CONFERENCE ON ADVANCED COMMUNICATIONS TECHNOLOGY (ICACT-2000), Muju, Korea

[P-39] R. Chakravorty, S. Kar and P. Farjami. "Internet Quality of Service: Issues, Architecture and Frameworks", PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON INFORMATION TECHNOLOGY (ICIT-2000), Bhuvaneshwar, India. (Invited paper)

[P-40] R. Chakravorty and S. Kar. "How to enable Quality of Service in the Internet?". PROCEEDINGS OF THE NATIONAL CONFERENCE ON COMMUNICATIONS (NCC-2000), Delhi, India

PUBLICITY POSTERS AND REPORTS

- ◇ "Practical Experience with TCP and HTTP over GPRS", poster, *ACM MOBICOM 2002*
- ◇ "Ubiquitous Networking in Heterogeneous Environments", poster, *UBICOMP 2003*
- ◇ "Practical Experience with Wireless Integration using Mobile IPv6", poster, *ACM MOBICOM 2003*
- ◇ "Performance Optimization for Wireless Wide-area Networks", poster, *ACM MOBISYS 2004*
- ◇ "Exploiting Diversity in MARS– A Mobile Access Router System", unpublished paper, August 2003.
- ◇ "On Inter-network Handover Performance using Mobile IPv6", unpublished paper, June 2003.
- ◇ "A Case for Proxy-based Adaptation for Wireless Networks", unpublished paper, May 2002.

SERVICE, RESEARCH IMPACT AND OTHER ACTIVITIES

- ◇ OFFICIAL REVIEWER – IEEE Journal of Selected Areas in Communications (IEEE JSAC), IEEE Transactions on Mobile Computing (IEEE TMC), IEEE Transactions on Wireless Communications (IEEE TWC), IEEE Transactions on Computers (IEEE TC), IEEE Transactions on Parrallel and Distributed Systems (IEEE TPDS), ACM Monet Journal, European Transactions on Telecommunications (ETT), Elsevier Computer Networks Journal, ACM Mobile Computing and Communications Review (ACM MC2R), IEEE Network, IEEE Wireless Communications, IEEE Infocom (2003, 2004, 2005, 2006)

- ◇ EXTERNAL REVIEWER – ACM Mobisys (2004), ACM Mobicom (2005), SOSP (2003).

- ◇ RESEARCH IMPACT – Systems that I architected or designed in the industry are now incorporated into several commercial products (e.g. NEC N902i/Panasonic P902i 3G phones, SHARP VN-EZ1 Viewcam, PHILIPS products for digital copy protection, etc.). Top CS/EE departments worldwide have taught my research papers including MIT, Berkeley, CMU, Cornell, UIUC, UT Austin, UW-Madison, Georgia Tech, Maryland, Rutgers, UNAM-Mexico, TU Berlin, Helsinki, UCL, IITs in India, UNSW/Australia, UT-Canada, Moratuwa Sri Lanka, NTU Taiwan, LUMS/Pakistan, KAIST Korea, USTC China, etc.

- ◇ CONSULTING SERVICES – I have offered consulting and support of my research to several companies worldwide these include cellular network operators, brand product vendors and start-ups such as T-Mobile Germany, Vodafone UK, Orange Switzerland, Ericsson The Netherlands, Alohanetworks Inc. USA, Netcontinuum Inc. USA, Flashnetworks Israel, are some of them for mention. Details on request.

- ◇ RESEARCH CONSULTANT – I worked as a research consultant full-time to the Japanese conglomerate, NEC Laboratories America Inc. USA during summer 2005. I invented the two innovative concepts of *Virtual Channels* and *Perceptual slice-structured video coding* for error-resilient video streaming over 3G cellular links. This work is also published in Infocom 2006.

- ◇ PROGRAM COMMITTEE MEMBER: IEEE WoWMoM 2006 Symposium, Buffalo, New York, June 2006
  IEEE WoWMoM 2007 Symposium, Helsinki, Finland, June 2007

- ◇ LOCAL ARRANGEMENTS CO-CHAIR, REGISTRATION CHAIR AND STUDENT TRAVEL CHAIR – for **WiOpt 2004** (*Workshop on Modelling and Optimization in Mobile, Ad Hoc and Wireless Networks held on 24th-26th March 2004 in Cambridge UK*)

- ◇ FELLOW – Cambridge Philosophical Society, Cambridge Scientific Society

- ◇ STUDENT MEMBER – IEEE, ACM, ACM SIGMOBILE, IEEE COMSOC

RECENT CONFERENCES AND OTHER PRESENTATIONS

[1] "Two Systems to (fundamentally) Restructure Wide-area Wireless Services", 2007 Presentation at various forums: Columbia University, Purdue University, Microsoft Research Redmond, Qualcomm/Flarion Technologies, XEROX Palo Alto Research Center, NTT DoCoMo USA Labs, and various silicon valley startups.

[2] "MobiStream: Error-Resilient Video Streaming in WWANs using Virtual Channels", *IEEE INFOCOM 2006*

[3] "MobiCare: A Programmable Service Architecture for Mobile Medical Care", *IEEE PERCOM: UBICARE 2006*

[4] "MoB: A Mobile Bazaar for Wide-area Wireless Services", *ACM MOBICOM 2005*

[5] "Performance Optimizations of Wireless Wide-area Networks: Comparative Study and Experimental Evaluation", *ACM MOBICOM 2004*

[6] "Performance Issues with Vertical Handovers: Experiences from GPRS Cellular and WLAN hotspots Integration", *IEEE PERCOM 2004*

[7] "Measurement Approaches for Performance Optimizations over Wide-area Wireless Networks", *PAM 2004*

[8] "GPRSWeb: Optimizing the Web for GPRS Links", *ACM MOBISYS 2003*

[9] "Flow Aggregation for Enhanced TCP over Wide-area Wireless", *IEEE INFOCOM 2003*

[10] "Practical Experience with TCP over GPRS", *IEEE GLOBECOM 2002*

[11] "SBM: Enabling Remote Management Services for Dynamically Reconfigurable Devices", *IEEE ICN 2002*

[12] "Optimizing WWW traffic for GPRS links", *Universitat Politechnica de Catalunya (UPC)*, Barcelona, Spain, March, 2003
(*Host: Prof. Josep Paradells as part of WIU253 invitation*)

[13] "Engineering Mobile Proxy Design for Wide-area Wireless", *7th European Cabernet*, Bologna, Italy, October, 2002

[14] "Making GPRS perform better!", *Multiservice Networks Workshop*, Oxford, UK, July, 2002 (*MSN2002 workshop invitation*)

[15] "Performance Optimizations for Wireless Wide-area Networks", *CS dept., University of Wisconsin-Madison*, USA, September, 2004 (*Host: Prof. Suman Banerjee*)

[16] "The Cambridge Open Mobile System Initiative", *IBM T J Watson Research Center*, NY, USA, June 2004 (*Host: Dr. Chandra Narayanaswami, Senior Manager, Pervasive and Wearable Computing Group*)

[17] "Performance Optimizations for Wireless Wide-area Networks", *Bell Labs Research*, Holmdel, NJ, USA, June 2004 (*Host: Dr. Milind Buddikot, Networking Research*)

MENTORING EXPERIENCE

- Extensive undergraduate mentoring experience. I am fortunate to have worked with the following Cambridge University undergraduates, sponsored IIT summer undergraduate interns, and postgraduate (called diploma) students during my PhD. More than six important conference and journal articles resulted from the work.

  - Joel Cartwright, B.A., 2002, Cambridge University (now at Edinburgh)
    (A part of his work contributed to a paper in IEEE GLOBECOM 2002)
  - Sachin Katti, B.Tech, 2003, IIT Bombay (now at MIT)
    (A part of his work contributed to a paper in IEEE INFOCOM 2003 and IEEE J-SAC Journal)
  - Andrew Clark, B.A., 2002, Cambridge University (Cambridge start-up)
    (Contribution to the work in ACM MOBISYS 2003 and IEEE J-SAC Journal)
  - Kavitha Subramanian, B.Tech+M.Tech, 2004, IIT Bombay (now at McKinsey & Co.)
    (A part of her work contributed to a paper in IEEE PerCom 2004)
  - Daniel Shane, Diploma (Postgraduate) Student, 2003, Cambridge University
    (Diploma Thesis on Implementation of Mobile Agents for Mesh Networks)

TEACHING EXPERIENCE

- **Cambridge University –** More than 100 hours of teaching experience also called supervisions to Cambridge University undergraduates spanning 3 years (2001-2004). Cambridge-style supervisions consists of teaching multiple small groups (usually 3-5 students in a group) of mostly senior undergraduate students, giving lectures that are not covered or lectured, taking recitations, designing and grading exams, and assisting them in the subject matter.

  In Cambridge University I have supervised the following courses:

  - Digital Communications II (Michealmas/Fall Term: 2001-02, 2002-03, 2003-04)
    (Instructor: Prof. Jon Crowcroft)
  - Comparative Architectures (Lent/Spring Term: 2001-02, 2002-03)
    (Instructor: Prof. Ian Pratt)
  - Introduction to Security (Lent/Spring Term: 2003-04)
    (Instructor: Prof. Ross Anderson/Dr. Markus Kuhn)

- **Indian Institute of Technology Delhi –** Worked as a teaching assistant for two semesters to Prof. Subrat Kar for the computer networks course. Took quizzes, graded assignments and exams. Other responsibilities included maintenance and administration of more than 25 application servers and terminals in IIT Delhi's Computer Technology (CTech) Laboratory.

CITIZENSHIP AND STATUS

- US Permanent Resident
- Citizen of India

Select Paper Abstracts

MobiStream: Error-Resilient Video Streaming in Wireless WANs using Virtual Channels

Rajiv Chakravorty, Suman Banerjee and Samrat Ganguly
IEEE INFOCOM 2006

We present MobiStream – a video streaming system that exploits the perceptual value in the video content and the characteristics of link layer and physical layer channels to enable error-resilient video streaming over wireless wide-area networks (WWANs).

The key building block in MobiStream is the use of link layer based, but application-controlled, *virtual channels* abstraction. Each virtual channel in MobiStream offers a different level of reliability and statistical loss gaurantee using awareness of the link and physical layer channels. Video applications can dynamically instantiate new virtual channels, control their loss behavior, and/or flexibly switch video transmission across channels. MobiStream achieves fine-grained error-resilience by partitioning video frames into number of small, independently decodable, blocks of data (called slices) and assigns priority to each such individual slice based on its perceptual usefulness. MobiStream augments a number of other enhancements for error-resilience: multiple description video coding, perceptual slice-structured coding, low-delay inter-frame and intra-frame slice interleaving, dynamic unequal error protection, and priority-based video-data scheduling to enable efficient and error-resilient video streaming over wireless wide-area links.

MobiStream has been implemented and evaluated using loss distributions from tests conducted over a commercial wide-area wireless (CDMA2000 3G) network. Results show that, even in stationary conditions, MobiStream, in the face of burst packet losses can improve video picture quality by at least 4 dB. We conclude that significant benefits to end-user experience can be obtained by deploying such a system.

A Programmable Service Architecture for Mobile Medical Care

Rajiv Chakravorty
IEEE PERCOM – UbiCare 2006: First Workshop on Ubiquitous and Pervasive Healthcare 2006

This paper introduces MobiCare – a novel service architecture that enables a wide range of health-related services for efficient and mobile patient care. These services include: (1) health-related services in medical devices and sensors to remotely install, self-activate, reconfigure or even self-repair with new health services and applications, (2) secure and reliable dynamic software upgrade or update services applied to the native code of the clinical device, and, (3) remote registration and (re)configuration of body sensors as well as remote health-data services such as patient health report downloads and diagnosis data uploads with provider servers. Collectively these services address a range of patient medical monitoring needs by accelerating deployment of new health-related services, thus reducing medical costs and improving the quality of patient care. We are currently implementing a proof-of-concept prototype. Early experiences with MobiCare do show that it has the potential to become a feasible and a useful infrastructure paradigm for the next generation healthcare.

MoB: A Mobile Bazaar for Wide-area Wireless Services
Rajiv Chakravorty, Sulabh Agarwal, Suman Banerjee, Ian Pratt
ACM MOBICOM 2005 (Top Picks for ACM/Springer WINET Journal)

We introduce MoB, an infrastructure for collaborative wide-area wireless data services. MoB proposes to change the current model of data services in the following fundamental ways: (1) it decouples infrastructure providers from services providers and enables fine-grained competition, (2) it allows service interactions on arbitrary timescales, and, (3) it promotes flexible composition of these fine-grained service interactions based on user and application needs.

At the heart of MoB is an open market architecture in which mobile users can opportunistically trade various services with each other in a flexible manner. In this paper we first describe the overall architecture of MoB including various enablers like user reputation management, incentive management, and accounting services. We next present our experience from both simulations as well as our prototype implementation of MoB in enhancing application performance in multiple different scenarios — file transfers, web browsing, media streaming, and location-enhanced services.

Exploiting Diversity to Enhance Multimedia Streaming over Cellular Links
Julian Chesterfield, Rajiv Chakravorty, Ian Pratt, Suman Banerjee and Pablo Rodriguez
IEEE INFOCOM 2005

Wireless Wide Area Networks (WWANs) utilising technologies such as GPRS, UMTS and CDMA2000 are becoming ubiquitous across most geographic regions, enabling simultaneous coverage from multiple providers. WWAN channels exhibit both uncorrelated and correlated behaviour on a variety of levels. In this paper we examine the statistical properties of WWAN links, and illustrate the benefits in heterogeneity that can be exploited to improve statistical throughput and Multimedia quality. Our results are based on real network measurements. We describe the design and implementation of a high quality multimedia streaming application that implements WWAN streaming optimisations utilising Unequal Error Protection coding techniques, and we evaluate the performance over an operational WWAN network.

Performance Optimizations for Wireless Wide-area Networks
Rajiv Chakravorty, Suman Banerjee, Pablo Rodriguez, Julian Chesterfield, Ian Pratt
ACM MOBICOM 2004

We present a comparative performance study of a wide selection of optimization techniques to enhance application performance in the context of wide-area wireless networks (WWANs). Unlike in traditional wired and wireless IP-based networks, applications running over WWAN cellular environments are significantly affected by the vagaries of the cellular wireless medium. Prior research has proposed and analyzed optimizations at individual layers of the protocol stack. In contrast, we introduce the first detailed experiment-based evaluation and comparison of all such optimization techniques in a commercial WWAN testbed. This paper, therefore, summarizes our experience in implementing and deploying an infrastructure to improve WWAN performance.

The goals of this paper are: (1) to perform an accurate benchmark of application performance over such commercially deployed WWAN environments, (2) to implement and characterize the impact of various optimization techniques across different layers of the protocol stack, and (3) to quantify their interdependencies in realistic scenarios. Additionally, we also discuss measurement pitfalls that we experienced and provide guidelines that may be useful for future experimentation in WWAN environments.

MAR: A Commuter Router Infrastructure for the Mobile Internet

Pablo Rodriguez, Rajiv Chakravorty, Julian Chesterfield, Ian Pratt, Suman Banerjee
ACM MOBISYS 2004

We introduce MAR, a commuter mobile access router infrastructure that exploits wireless diversity (e.g. channel diversity, network diversity, and technology diversity) to provide improved data performance for wireless data users. Our system design stems from the observation that rather than choosing a single wireless service provider (e.g. Sprint, AT&T, BT, Vodafone), a single technology (e.g. GPRS, UMTS, CDMA, 802.11), or a single wireless channel, users can obtain significant benefits by using the multiplicity of choices available to the user. MAR is a wireless multi-homed device that can be placed in moving vehicles (e.g. car, bus, train) to enable high-speed data access. MAR dynamically instantiates new channels based on traffic demand, aggregates the bandwidth and dynamically shifts load from poor quality channels to better quality ones, thus, providing a faster, more stable, and reliable communication channel to mobile users.

We have implemented and tested the MAR system in our testbed which spans the networks of three different cellular providers. Through our experiments we have performed a detailed evaluation to quantify the benefits of MAR for different protocols and applications. For example, even in highly mobile environments, MAR, on average, improves the end-user experience of web-browsing and streaming applications by a factor of 2.8 and 4.4 respectively. Our results show that significant benefits can be obtained by exploiting the diversity in coverage offered by many cellular operators, different technology networks (e.g. GPRS, CDMA), and diverse wireless channels.

Flow Aggregation for Enhanced TCP over Wide-area Wireless

Rajiv Chakravorty, Sachin Katti, Jon Crowcroft and Ian Pratt
IEEE INFOCOM 2003 (Also appeared in IEEE J-SAC)

Throughout the world, GSM cellular mobile networks are being upgraded to support the "always-on" General Packet Radio Service (GPRS). Despite the apparent availability of levels of bandwidth not dissimilar to that provided by conventional fixed-wire telephone modems, the user experience using GPRS is currently considerably worse.

In this paper we examine the performance of TCP and HTTP over GPRS, and show how certain network characteristics interact badly with TCP to yield problems such as: link under-utilization for short-lived flows, excess queueing for long-lived flows, ACK compression, poor loss recovery, and gross unfairness between competing flows.

We present the design and implementation of a transparent TCP proxy that mitigates many of these problems without requiring any changes to the TCP implementations in either mobile or fixed-wire end systems. The proxy transparently splits TCP connections into two halves, the wired and wireless sides. Connections destined for the same mobile host are treated as an aggregate due to their statistical dependence. We demonstrate packet scheduling and flow control algorithms that use information shared between the connections to maximise performance of the wireless link while inter-working with unmodified TCP peers. We also demonstrate how fairness between flows and response to loss is improved, and that queueing and hence network latency is reduced. We conclude that installing such a proxy into GPRS network would be of significant benefit to users.

GPRSWeb: Optimizing the Web for GPRS Links

Rajiv Chakravorty, Andrew Clark and Ian Pratt
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The General Packet Radio Service (GPRS) is being deployed by GSM network operators worldwide, and promises to offer users "always-on" data access at bandwidths comparable to that of conventional fixed-line telephone modems. Unfortunately, many users have found the reality to be rather different, experiencing very disappointing performance when, for example, browsing the web over GPRS.

In this paper we investigate what causes the HTTP protocol and its underlying transport TCP to underperform in a GPRS environment. We examine why certain GPRS network characteristics interact badly with TCP to yield problems such as: link under-utilization for short-lived flows, excess queueing for long-lived flows, ACK compression, poor loss recovery, and gross unfairness between competing flows. We also show that many web browsers tend to be overly aggressive, and by opening too many simultaneous TCP connections can aggravate matters.

We present the design and implementation of GPRSWeb – a mobile HTTP proxy system that mitigates many of the performance problems with a simple software update to a GPRS mobile device. The update is a 'client proxy' that sits in the mobile device, and communicates with a 'server proxy' located at the other end of the GPRS link close to the wired-wireless border. The dual proxy architecture collectively implements a number of key enhancements – an aggressive caching scheme that employs content-based hash keying to improve hit rates for dynamic content, a preemptive push of web page support resources to mobile clients, resource adaptation to suit client capabilities, delta encoded data transfers, DNS lookup migration, and a UDP-based reliable transport protocol that is specifically optimized for use over GPRS. We show that these enhancements result in significant improvement in overall WWW performance over GPRS.

Performance Issues with Vertical Handovers: Experiences from GPRS and WLAN Integration

Rajiv Chakravorty, Pablo Vidales, Kavitha Subramanian, Ian Pratt and Jon Crowcroft
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Interworking heterogeneous wireless access technologies is an important step towards building the next generation, all-IP wireless access infrastructure. In this paper, we present an experimental study of inter-network mobility between GPRS Cellular and 802.11b-based WLAN hot-spots, and analyse its impact on active transport TCP flows. Our experiments were conducted over a loosely-coupled, Mobile IPv6-based, GPRS-WLAN experimental testbed. Detailed analysis from packet traces of inter-network (vertical) handovers reveals a number of performance bottlenecks. In particular, the disparity in the round trip time and bandwidth offered by GPRS and WLAN networks, and presence of deep buffers in GPRS, can aggravate performance during vertical handovers. This paper, therefore, summerizes practical experiences and challenges of providing ***transparent mobility*** in heterogeneous environments.

Based on our observations, we propose a number of network-layer handover optimisation techniques, e.g. Fast Router Advertisements (RA), RA Caching, Binding Update (BU) simulcasting and layer-3 based soft handovers that improve performance during vertical handovers. The paper concludes with our experiences of migrating TCP connections, thereby also improving application e.g. ftp, web performance in this environment.

A Dynamic SLA-based QoS Control for UMTS

Rajiv Chakravorty, Maurizio D'Areinzo, Ian Pratt and Jon Crowcroft
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With the evolution of QoS-capable 3G wireless networks, the wireless community has been increasingly looking for a framework that can provide effective network-independent end-to-end QoS control. In this article we first construct such a framework and then describe how dynamic SLA-based QoS control can be used to achieve end-to-end QoS in a wired and wireless (UMTS) environment. The proposed framework, which is an extension to the IST CADENUS project, offers effective wired-wireless QoS translation, efficient QoS control and management, and dynamic SLA policy-based QoS provisioning.

Performance Issues with General Packet Radio Service

Rajiv Chakravorty and Ian Pratt
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The General Packet Radio Service (GPRS) is being deployed by GSM network operators worldwide, and promises to provide users with "always-on" data access at bandwidths comparable to that of conventional fixed-wire telephone modems. However, many users have found the reality to be rather different, experiencing very disappointing performance when, for example, browsing the web over GPRS.

In this paper, we examine the causes, and show how unfortunate interactions between the GPRS link characteristics and TCP/IP protocols lead to poor performance. A performance characterisation of the GPRS link-layer is presented, determined through extensive measurements taken over production networks. We present measurements of packet loss rates, bandwidth availability, link stability, and round-trip time.

The effect these characteristics have on TCP behaviour are examined, demonstrating how they can result in poor link utilization, excessive packet queueing, and slow recovery from packet losses. Further, we show that the HTTP protocol can compound these issues, leading to dire WWW performance. We go on to show how the use of a transparent proxy interposed near the wired-wireless border can be used to alleviate many of these performance issues without requiring changes to either client or server end systems.