

Xin Wang

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Current Position Member of Technical Staff, Bell-Labs Research, Lucent Technologies

Holmdel, NJ

Research Interests

- Modeling and analysis of mobile, wireless, ad hoc and sensor networks
- Design of optimal network infrastructure across network layers, applications and heterogeneous networks
- Network and mobility management, QoS, signaling and control
- Overlay and peer-to-peer networks
- Adaptive network services, multimedia systems and protocols over wired and wireless networks
- Application and content service support over Internet and wireless data networks

Education

COLUMBIA UNIVERSITY

New York, NY

Ph.D. Electrical Engineering, GPA 4.17/4.0 (A = 4.0), May 2001

Advisor: Prof. Henning Schulzrinne, Department of Computer Science

Thesis: *Scalable Network Architectures and Measurements for Multicast and Adaptive QoS*

BEIJING UNIVERSITY OF POSTS AND TELECOMMUNICATIONS

Beijing, China

M.S. Wireless Communication Engineering, GPA 4.0/4.0, April 1993

Advisor: Prof. Jia-mou Zhang

Thesis: *Design of a Low-Bit Rate Video Phone System*

BEIJING UNIVERSITY OF POSTS AND TELECOMMUNICATIONS

Beijing, China

B.S. with highest distinction, Telecommunications Engineering, GPA 4.0/4.0, July 1990

Current Research

Mobile Networking Research Dept, Bell-Labs Research

My current work addresses the key challenges in migrating current CDMA radio access network (RAN) from point-to-point links to an IP-based RAN. The goal is to show that Radio Network Control (RNC) functionality can be implemented in a scalable manner and the IP network is able to support CDMA voice and data efficiently and effectively. Recently, I have developed a set of algorithms to effectively manage resources at both radio interface and wireless access network to guarantee the tight performance requirements of IP-RAN. I have also designed a predictive and adaptive algorithm to efficiently manage downlink voice and data during soft handoff.

Ph.D.

Advisor: Prof. Henning Schulzrinne

Dissertation

My thesis is concerned with scalable and efficient architectures for delivering multimedia applications over the Internet reliably and with high quality. My main contribution is the development of an integrated resource negotiation framework. The goal of this work is to promote more optimal network usage and pricing under a variety of network traffic, including multimedia applications, while assuring predictability of service. Particularly, the framework enables dynamic negotiation with short-term resource commitments by the network and users, accommodates service and rate adaptation by adaptive multimedia applications, and includes a pricing system based on QoS, and long-term and short-term demand. The thesis also has two smaller components: analysis and enhancement of the Lightweight Directory Access Protocol (LDAP) in a dynamic environment with frequent searches; and development of enhanced multicast routing to reliably transmit real-time multimedia and mission-critical financial data.

Background

US permanent resident

**Professional
Experience**

BELL LABS RESEARCH, LUCENT TECHNOLOGIES
Member of Technical Staff

Holmdel/Murray Hill, NJ
 May 2001- present

Mobile Networking Research Department, Data Networking Research Center

IP-based Radio Access Network (IP-RAN) Design

Conducted research to address the key challenges in migrating current CDMA radio access network (RAN) from point-to-point links to an IP-based RAN. Designed two novel admission control schemes to effectively control the load of both air interface and backhaul; the schemes require little or no modifications at base stations, and do not require changes to protocol standards or special support from access network. Designed a predictive and adaptive scheme to efficiently manage the resources during handoff. Designed two adaptive resource management schemes for IP backhaul network, one in which resources are dynamically reserved, and another in which resources are statically provisioned. Implemented a customized air interface and IP-RAN simulator in Linux.

Broadband Software Research Department, Network Systems Research Center

Lucent Gigabit Ethernet MPLS Switch (GEMS)

Technical consultant

Provided solutions for QoS support and MPLS control of GEMS, a family of 10 Gb/s Ethernet MPLS switches designed to deliver Ethernet and IP data services to small, medium and large enterprises and data centers. Designed a novel traffic engineering tool that could work with or as part of GEMS to allow service providers to efficiently provision and manage MPLS tunnels for the customers. Designed a Packet Tracking and Monitoring module (PTM) to perform real-time, in-network aggregation, association, and correlation of network traffic with the individual users. Provided advice on the development of flow management of GEMS.

Lucent Imminent Content Switch (ICS)

Technical Lead and Principal Investigator

Led the architectural design of QoS subsystem and Packet Tracking and Monitoring subsystem for ICS, a next-generation intelligent application platform built for distributing and delivering content to a variety of users. ICS moves beyond existing web switching and content delivery products. It provides a Layer 2-7 framework for building key content delivery services. My contributions were: 1) Enabled services and data distribution through overlay network; 2) Designed a complete infrastructure to support transmission quality for value-added services from Layer 2-7 and overlay network; 3) Designed a Packet Tracking and Monitoring subsystem to support high-speed data tracking, monitoring of statistics for service verification, and detailed record-keeping and aggregation for flexible data and content billing.

BELL LABS RESEARCH, LUCENT TECHNOLOGIES

Holmdel, NJ

Summer Intern,

Summer, 1999

Participated in the design of an Aggregation and Refinement based Monitoring (ARM) algorithm to enable a service provider to efficiently detect violations of end-to-end Service Level Agreement (SLA) and isolate trouble links and nodes. Implemented histogram-based dynamic QoS data aggregation/refinement mechanisms at each network node, and central reasoning engine at Network Management System (NMS). Studied the performance and simulated the proposed algorithms using NS2.

IBM T.J. WATSON RESEARCH CENTER

Hawthorne, NY

Summer Intern,

Summer, 1998

Measurement and Analysis of LDAP Performance (described under PhD Research)

APPLIED RESEARCH, TELCORDIA TECHNOLOGIES

Redbank, NJ

Summer Intern

Summer, 1997

Designed a call admission control algorithm to improve the performance of Fujitsu ATM switch.

GTE LABORATORIES

Waltham, MA

Summer Intern

Summer, 1996

Participated in DARPA funded project for design of service location and information dissemination schemes for distributed multimedia in a battlefield environment. Enabled automatic software distribution and remote execution. Designed information searching mechanisms over heterogeneous networks.

**Academic
Experience**

COLUMBIA UNIVERSITY

New York, NY

Research Assistant, Internet Real-time Transport (IRT) Laboratory, Department of Computer Science.

Sept 1996 - May 2001

My Ph.D. thesis work consists of the following three parts:

1. Integrated Resource Negotiation, Pricing, and QoS for Adaptive Multimedia Applications*Sponsored by Hughes Network Systems, Ericsson, and NSF*

Conducted research on supporting real-time multimedia applications over wired and wireless network. Developed an efficient network service model that bridges QoS assurance and differentiation in the network with rate adaptation by adaptive users. Proposed a network architecture that integrates resource reservation, negotiation, pricing and adaptation in a flexible and scalable way. Designed optimal resource allocation and adaptation algorithms for multimedia systems over QoS-enhanced network. Designed a novel pricing mechanism in a differentiated service environment based on level of service, long-term user demand, resource availability, and short-term congestion. Initialized a Resource Negotiation and Pricing (RNAP) protocol that enables the user and the network (or two network domains) to dynamically negotiate network services, and end-to-end price formulation in the Internet. Extended RSVP to support dynamic resource negotiation and communicate network statistics and price. Implemented the framework, verified the proposed algorithms and protocols through extensive simulation and test-bed experiments.

2. Measurement and Analysis of LDAP Performance*Joint work with IBM T. J. Watson Research Center, implemented in C and Perl*

Developed the first benchmark tool and initialized the effort to study LDAP performance in a dynamic environment with frequent searches. Investigated the potential of LDAP as network policy database and Internet telephony address server. Expanded the Webstone benchmark tool to support directory benchmarking, with the schema proposed for Service Level Specification (SLS). Used Berkeley DB 2.4.14 as backend and OpenLDAP 1.2 as front-end. Studied the overall system latency and throughput under a variety of access patterns. Investigated factors in determining scalability. Proposed different mechanisms to improve server performance.

3. Multicast and Network Reliability*Sponsored by Reuters, implemented in C over OPNET*

Investigated the end-to-end performance upon fault recovery over a complete multicast routing architecture consisting of IGMP for multicast group membership management in a LAN, OSPF for unicast routing, and PIM sparse-mode and dense-mode for multicast routing. Enhanced multicast framework to reliably transmit mission-critical real-time data; Studied the fault recovery time and associated protocol control overheads, and the effect of parameters and interactions of different protocols; Investigated fail-over of router, link, LAN, WAN, and the interaction of OSPF, PIM, and IGMP to recover a multicast channel; Verified the results through experiments over Cisco routers.

NORTHEASTERN UNIVERSITY,

Boston, MA

Research Assistant, Electrical and Computer Engineering Department

1994 - 1996

Designed a novel group-based packet scheduling algorithm to reduce scheduling overhead and improve utilization for multimedia applications (funded by DARPA). Developed an MPEG traffic model. Investigated the performance of packet video over ATM network.

BEIJING UNIVERSITY OF POSTS AND TELECOMMUNICATIONS

Beijing, China

Research Assistant, Wireless Communication Research Center,

1990 - 1993

Design of A Low Bit Rate Video Phone System*The 8th Five-Year National Scientific and Technological Projects of China, using TMS320C25 DSP chip*

Designed and prototyped a fully functional 64Kb/s Motion Videophone Decoder hardware/software system based on H.261 recommendation, including network interfaces. Solved problems resulting from rapid updating in HDTV and videophone. Designed a medium-rate vector speech quantizer and performed vector code book training.

Selected Publications**Journal/Book Publications**

1. S. Kasera, R. Ramjee, S. Thuel, X. Wang, "Congestion Control Policies for IP-based CDMA Radio Access Network," submitted to *IEEE Transactions on Mobile Computing*.
2. X. Wang, H. Schulzrinne, "An Integrated Resource Negotiation, Pricing, and QoS Adaptation Framework for Multimedia Applications," *IEEE Journal on Selected Areas in Communications (IEEE JSAC)*, vol. 18, issue 12, Dec 2000. Special Issue on Internet QoS (Acceptance ratio 14%).
3. X. Wang, H. Schulzrinne, "Comparison of Adaptive Internet Multimedia Applications," *IEICE Transactions on Communications*, Vol. E82-B, No. 6, pp. 806--818, June 1999.
4. X. Wang, I. Stavrakakis, "Study of Scheduling for Group-based Quality of Service Delivery," *Third Volume on Performance Modeling and Evaluation of ATM Networks*, D. Kouvatsos, Chapman & Hall, Chap. 5, 1997.

Conference Publications

5. S. Kasera, R. Ramjee, S. Thuel, X. Wang, "Congestion Control Policies for IP-based CDMA Radio Access Network," to appear in *Proceedings of IEEE INFOCOM'2003*, San Francisco, March 2003.
6. X. Wang, H. Schulzrinne, "Pricing Network Resources for Adaptive Applications in a Differentiated Services Network," in *Proceeding of IEEE INFOCOM'2001*, Anchorage, Alaska, April 2001.
7. X. Wang, H. Schulzrinne, D. Kandlur, D. Verma, "Measurement and Analysis of LDAP Performance," *ACM International Conference on Measurement and Modeling of Computer Systems (ACM SIGMETRICS'2000)*, Santa Clara, California, June 2000 (Acceptance rate 17%).
8. X. Wang, H. Schulzrinne, C. Yu, P. Stirpe, W. Wu, "IP Multicast Fault Recovery in PIM over OSPF," in *8th IEEE International Conference on Network Protocols (IEEE ICNP'2000)*, Osaka, Japan, November 2000. Also appears at *ACM SIGMETRICS'2000* as short paper.
9. M. Chan, Y. J. Lin, X. Wang, "On Reducing QoS Data Exchange in Monitoring Flows with Service Level Agreements," in *8th IEEE International Conference on Network Protocols (IEEE ICNP'2000)*, Osaka, Japan, November 2000.
10. X. Wang, H. Schulzrinne, "Performance Study of Congestion Price based Adaptive Service," in *Proc. International Workshop on Network and Operating System Support for Digital Audio and Video (NOSSDAV'2000)*, Chapel Hill, North Carolina, June 2000.
11. X. Wang, H. Schulzrinne, "Adaptive Reservation: A New Framework for Multimedia Adaptation," *IEEE International Conference on Multimedia and Expo. (ICME'2000)*, New York, July 2000.
12. X. Wang, H. Schulzrinne, "RNAP: A Resource Negotiation and Pricing Protocol," In *Proc. International Workshop On Network and Operating System Support for Digital Audio and Video (NOSSDAV'99)*, New Jersey, June 1999.
13. X. Wang, I. Stavrakakis, "An Efficient VBR Traffic Scheduling Policy using Dynamic Bandwidth Allocation," *4th IFIP Workshop on Performance Modeling and Evaluation of ATM Networks*, July 8-10, 1996, W. Yorkshire, U.K.
14. X. Wang, J. Zhang, W. Zhu, "64 Kb/s Motion Videophone Hardware System Design," *The 6th National conference on Speech and Image Communications*, Beijing, China, 1993.
15. X. Wang, J. Li, W. Zhu, J. Zhang, "Using TMS 320C25 to Realize 64Kb/s Motion Videophone Decoder," *The 6th National United Conference on Multimedia Communications*, Beijing, China, 1993.
16. X. Wang, L. Zhang, "A High-Quality Medium-Rate Speech Vector Quantizer," *Journal of Beijing University of Posts & Telecommunications*, Vol. 15, No 1, 1992.

Paper Under Submission

17. X. Wang, R. Ramjee, "A Predictive and Adaptive Resource Management Scheme for CDMA Downlink Data and Voice," to be submitted.
18. G. Gopalakrishnan, S. Kasera, C. Loader, X. Wang, "Robust Router Overload Control Using Acceptance and Departure Rate Measures," under submission.
19. X. Wang, H. Schulzrinne, "Auction or Tatonnement - Finding Congestion Prices for Adaptive Applications," submitted to *International Conference on Measurement and Modeling of Computer Systems (ACM SIGMETRICS'2003)*.

Workshop Publications and Presentations

20. X. Wang, H. Schulzrinne, "Resource Negotiation and Pricing in Diffserv for Adaptive Multimedia Applications," *First NY Metro Area Networking Workshop*, IBM T. J Watson Research Center, Hawthorne, New York, Mar 2001
21. X. Wang, H. Schulzrinne, "RNAP: A Framework for Congestion-Based Pricing and Charging for Adaptive Multimedia Applications," *First International Workshop Quality of future Internet Services (QofIS'2000)*, Berlin, Germany, Sep. 2000
22. X. Wang, H. Schulzrinne, "Resource Negotiation and Pricing Protocol," *Internet2 Network Research Workshop*, Chicago, June 2000.

Invited Talks

1. X. Wang, H. Schulzrinne, "An Integrated Resource Negotiation, Pricing, and Quality of Service Framework for Adaptive Multimedia Applications," Sun Microsystems, San Jose, CA., Aug. 2000.
2. X. Wang, H. Schulzrinne, "Measurement and Analysis of LDAP Performance," Sun Microsystems, San Jose, CA, Aug. 2000.
3. X. Wang, H. Schulzrinne, "Resource Negotiation, Pricing, and Quality of Service for Adaptive Multimedia Applications," Sprint Advanced Technology Labs, Burlingame, California, Feb. 2001
4. X. Wang, H. Schulzrinne, "Integrated Resource Negotiation, Pricing, and Quality of Service for Adaptive Multimedia Applications," PacketVideo, Rochelle Park, New Jersey, Mar. 2001

Teaching Experience

- **Student project supervisor**, Department of Computer Science, Columbia University, 1999 to 2001. Supervised seven graduate and undergraduate student projects. Three students worked on implementing a multicast test-bed, four students worked on prototyping the RNAP system. Most of the students worked on the project for two consecutive semesters for credits towards their degrees.
- **Lecturer**, Department of Telecommunications Engineering, Beijing University of Posts & Telecommunications (BUPT), 1991 to 1993. Taught undergraduate courses data structures and computer networks .

Professional Activities

- Referee for IEEE Transactions on Wireless Communications, IEEE Transactions on Mobile Computing (TMC), IEEE Journal on Selected Areas in Communications (JSAC), IEEE Transactions on Multimedia, Journal for Communications and Networks (JCN), IEEE Communication Magazine, IEEE INFOCOM, ACM Multimedia, ACM SIGCOMM, ICC, Global Internet, and Packet Video.
- Member of IEEE (Communications Society and Computer Society).
- Member of "Women in Bell Labs" at Bell Labs Research, Lucent Technologies, 2001-present

Honors

- Research Fellowship, Columbia University, 1996 to 2001.
- Distinguished Lecturer, Department of Telecommunications Engineering, BUPT, 1993.
- Graduated ranking first in class of 1990, exemption of Entrance Exam for Graduate School, BUPT.
- First class scholarship for academic excellence (top 1%) in BUPT, 1986 to 1990.
- Ranked first (of 800,000 applicants) in National College Entrance Exam, Chengdu, Sichuan, 1986.

References

Prof. Henning Schulzrinne (PhD thesis advisor)
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