Xin Wang

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INTERESTS
- **A Researcher/Architect/Engineer position in wireless and/or wireline data networking fields:**
  - Applications, services, and protocols over Internet and wireless data networks
  - Integrated network infrastructure design and performance enhancement - *across various network layers, applications and heterogeneous networks*
  - Network and mobility management, QoS, signaling and control of telecommunications networks
  - Network performance and provisioning, traffic engineering, routing, scheduling, buffer management
  - Adaptive network services, adaptive multimedia applications, peer-to-peer networks

STRENGTHS
- ***Extensive R&D experience and in-depth knowledge of wired and wireless networking protocols and algorithms at various layers***
- ***Rigorous background in QoS, routing, congestion management, multimedia communications***
- ***Large-scale software engineering experience in C/ C++, Java, Network Simulator (NS) and Perl***

CURRENT STATUS: US permanent resident.

EDUCATION

2001	**PhD, Electrical Engineering**, **Columbia University** (**GPA 4.17/4.0**, **A = 4.0)**	New York, NY
	Thesis: *Scalable Network Architectures and Measurements for Multicast and Adaptive QoS*	
	Advisor: Henning Schulzrinne	
1993	**MS**, **Telecom. Eng**. **Beijing Univ. of Posts & Telecom (GPA 4.0/4.0**)	Beijing, China
	Thesis: *A Low-Bit Rate Video Phone System Design*	
1990	**BS**, **Telecom. Eng**. **Beijing Univ. of Posts & Telecom (GPA 4.0/4.0**)	Beijing, China

SKILLS
- **Network and protocols:**
  - *Wireless:* CDMA2000, UMTS, Wireless LAN (802.11) , Mobile IP
  - *Data Communications:* TCP, UDP, RTP, SIP, RTSP
  - *Traffic Engineering:* MPLS, VPN, Leaky Bucket, RED, CBQ, WFQ
  - *QoS:* RSVP, COPS, IntServ, DiffServ
  - *IP-based Routing:* RIP, OSPF, BGP, PIM, CBT, DVMRP, MOSPF, IGMP
  - *Misc:* ATM, VLAN, ARP, DNS, ICMP, SNMP, LDAP
- **Environments:** Solaris, FreeBSD, Linux, Windows 2000, Windows NT, X-WINDOWS, DOS
- **Programming Languages:** C, C++, Java, Perl, Tcl/Tk, HTML, WML, M68000 and TMS320 assembly.
- **Specialized Software Packages:** NS2, OPNET, Matlab, Mathematica, M2C Octtools

INDUSTRIAL EXPERIENCE
05/01- present *Member of Technical Staff*, **Bell Labs Research, Lucent Technologies**

01/02- Mobile Networking Research Department, Data Networking Research Center,   Holmdel, NJ
Wireless Access Internet Infrastructure Design
Research on enabling 3G Wireless Voice and Data on IP-based Radio Access Network (IP-RAN)
- Work on replacing traditional T1/ E1 dominated wireless backhaul with IP-based CDMA backhaul to reduce network operation cost, enhance scalability and reliability, and support data applications.
- Responsible for designing and developing resource management and QoS mechanisms over IP-RAN
- Designed two new admission control schemes to effectively control the backhaul load within the target level with little or no modifications at base stations, and only very simple implementation at Radio Network Controller (RNC). Both schemes add enhancements to CDMA call admission control so that both IP RAN and air interface resources are taken into consideration. The proposed schemes require no changes to protocol standards and no special service support from access network.

- Designed a set of schemes to efficiently manage the resources of air interface and backhaul network during handoff. The proposed schemes effectively handle the power allocation dynamics of on-going sessions due to the closed-loop/outer-loop power control, the changing traffic patterns, the diversified resource requirements and traffic loads of voice and data, users' mobility, as well as inaccuracy in handoff predictions. The schemes apply to both voice and high-speed circuit data that have different resource and QoS requirements and require soft handoffs.
- Designed two adaptive resource reservation schemes for IP backhaul, one in which resources are dynamically reserved, and another in which resources are statically provisioned. The proposed backhaul algorithms can be applied to various premium services in face of mobility, for example, mobile VPN support in access network.
- Implemented a customized air interface and IP-RAN simulator in Linux environment.

Overload Control in Packet Network

The purpose of this work is to design and evaluate a new active queue management (AQM) algorithm with performance comparable to existing ones, but is robust to various network conditions. Our designed algorithms are simulated and compared with other comparable schemes in the presence of TCP/UDP data traffic. Our proposed algorithm is shown to be robust with respect to changes in dynamic network parameters such as load and capacity.

05/01- 12/01 Network Software Research Department, Network System Research Center   Murray Hill, NJ

Lucent Gigabit Ethernet MPLS Switch (GEMS)

Provided solutions for QoS support in, and MPLS control of GEMS

GEMS is a family of 10 G Ethernet MPLS Switches designed to deliver Ethernet and IP data services to small, medium and large enterprises and data centers, and provide high-capacity Ethernet aggregation for large xSP and enterprise data centers. GEM Switches will be deployed in conjunction with optical transport (DWDM, SONET/SDH) and IP services products (Core & Edge Routers, IP service switches, VoIP gateways) to enable service providers to deliver IP and Ethernet services at a lower cost-per-port/cost-per-bit than traditional T1, T3, and Frame Relay services that rely on TDM for sub-wavelength grooming, multiplexing and switching of traffic. My contributions were:

- Designed a traffic engineering tool that could work with or as part of GEMS to find a Label Switching Path (LSP) that provides the networks with resource efficiency, quality of service support, and transmission reliability. The design includes the construction of traffic engineering database, route computation, signaling, restoration of an LSP and network stability. Both on-line and off-line routing schemes were designed.
- 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. The PTM module captures usage data at the level of individual users and service classes, and records detailed user and service performance metrics that can be used for resource provisioning, service monitoring, and flexible network billing.
- Consulted on the development of flow management of GEMS. Flow management in GEMS entails creation, deletion, and configuration of traffic flows. It bridges the system control functions with the system forwarding functions, and decides on the allocation of system resources and service quality of users.

Lucent Imminent Content Switch (ICS)

Team lead, led the architectural design of QoS subsystem and Packet Tracking and Monitoring (PTM) subsystem

The imminent Content Switch (iCS) is 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:

- Evolved and reviewed product requirements
- Designed a complete infrastructure to support QoS for value-added services from Layer 2-7. The design takes into account the features and limitations of the chip set, the high-speed nature and resource constraints of ICS. This work accounted for TOS/COS, queue management, scheduling, traffic classification/conditioning, CBR/VBR/VLAN priority, resource provisioning, admission control, and interactions with OAM&P.
- Designed a Packet Tracking and Monitoring subsystem to support high-speed data tracking, statistics monitoring for service verification, detailed data records for flexible data and content billing.

6/99-8/99   *Summer Intern***, Bell Lab, Lucent Technologies**   Holmdel, NJ

ARM: Aggregation and Refinement based Monitoring (*Developed simulation model in NS2)*

ARM is an algorithm to enable a service provider to efficiently detect violations of end-to-end service level agreement (SLA) and isolate trouble links and nodes. I participated in the design of the algorithms and implemented histogram-based dynamic QoS data aggregation/refinement mechanisms at each network node, and central reasoning engine at network management system (NMS). I also studied the performance of the proposed algorithms.

5/98-8/98   *Summer Intern*, **IBM T.J. Watson Research Center**,   Hawthorne, NY
        Measurement and Analysis of LDAP Performance (described under PhD Research)

9/97-11/97   *Consultant*, Applied Research, **Telcordia Technologies (previous Bellcore)**,   Redbank, NJ
        Designed a **Call Admission Control (CAC) scheme** to improve the performance of the Fujitsu ATM switch.

7/96 -9/96   *Summer Intern*, **GTE Laboratories**,   Waltham, MA
        An Intelligent, Distributed Multimedia Service Location and Setup System
        In collaboration with Telcordia Technologies, implemented in Java, over IP and ATM
        Participated in the design of a multimedia system that software package was installed automatically and executed remotely to enable information searching over a large, heterogeneous network. Implemented the information distribution and searching functions.

ACADEMIC EXPERIENCE

9/96-5/01 *Research Assistant*, **Internet** Real-time Transport Laboratory, **Columbia University**   New York, NY
        An Integrated Resource Negotiation, Pricing, and QoS Framework for Adaptive Multimedia Applications:
        Sponsored by Hughes Network Systems, Ericsson, and NSF
        My thesis work spans different aspects of service negotiation and resource allocation in the Internet. The central objective is to improve network availability and QoS for the user, and enable the network to price and allocate resources efficiently and equitably. We have been able to demonstrate greatly improved network performance under various stressed conditions. The proposed protocols and algorithms allow the network providers to enable various value-added services and improve the network revenue. The work has the following components:

- **RNAP: A Resource Negotiation and Pricing Protocol for the Internet**
  With implementation in C/Java on Solaris and FreeBSD platforms
  Designed RNAP protocol that enables the user and the network (or two network domains) to dynamically negotiate network services, and enables end-to-end price formulation in the Internet. RNAP can be applied to both a hop-by-hop distributed architecture and a centralized architecture with global control. RNAP can be implemented as an independent protocol or as an extension of RSVP to communicate QoS specifications, user traffic profiles, updated network statistics, and pricing and charging information for premium services. RNAP was implemented over FreeBSD, with admission control, traffic scheduling, buffer management and congestion control. Aggregation of RNAP messages is through a proposed sink-tree based mechanism.

- **RSVP Extension for RNAP**
  Implementation in C
  Embedded RNAP protocol in ISI rsvpd-v4 to support dynamic resource negotiation and communicate network statistics and price. Resource reservation was performed using Class-Based Queueing (CBQ), as part of the ALTQ package. A Local Resource Negotiator LRN was implemented as part of the Local Policy Decision Point (LPDP) proposed in COPS.

- **Resource Adaptation in QoS-enhanced Network**
  Simulation over NS2 using C++ and Tcl
  Designed optimal resource allocation and adaptation algorithms. Compared performance of networks with dynamic service- and rate-adaptive users and networks with non-adaptive users. Studied effect of traffic bursts, network overloads, load balancing between classes, admission control, user demand elasticity, and control parameters. Framework was on top of DiffServ network, with Weighted Fair Queuing (WFQ) for scheduling, tail dropping for Expedited Forwarding (EF), extended RIO for Assured Forwarding (AF), Random Early Drop (RED) for best effort traffic. COPS protocol was implemented to allow a central control entity to collect network statistics.

- **Smart Multimedia Terminal**
  Implemented in C++, Tcl, and Java
  Enabled multimedia applications to gain optimal perceptual value based on network conditions and user profile. A Host Resource Negotiator (HRN) negotiates services with network on behalf of a multimedia system. HRN optimally distributes network-allocated resources among applications in a multimedia system and controls Mbone tools VIC (Video Conferencing Tool) and RAT (Robust Audio Tool) through a Message Bus to adapt sending rates based on allocated resources.

- **Adaptive Wireless Terminal**
  Implemented in WML, WML Script over Nokia WAP toolkit 2.0
  Prototyped various service plans for wireless users to study tradeoffs between blocking rate, QoS, and budget.

- **Congestion Sensitive Pricing Models in the Internet**
  Simulation over NS2 using C++ and Tcl
  Designed a pricing infrastructure in a differentiated service environment based on level of service, long-term user demand, resource availability, and short-term congestion. Proposed and compared two congestion-pricing algorithms, based on tatonnement (in which the price is updated iteratively until the aggregate user demand meets bandwidth supply), and bandwidth auction. Both mechanisms were shown to achieve much higher network availability, revenue, and perceived user-benefit than a fixed pricing policy. The proposed *M*-bid auction model resolves previously un-addressed practical issues.

Measurement and Analysis of LDAP Performance
Joint work with IBM T. J. Watson Research Center, implemented in C and Perl
Developed a benchmark tool to study LDAP performance for the first time 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, 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 the server performance.

Multicast and Network Reliability
Supported by Reuters, implemented in C over OPNET
Enhanced multicast framework to reliably transmit mission-critical real-time data. Implemented the IP multicast test-bed, including IGMP, PIM-DM and PIM-SM on top of unicast routing OSPF. Measured the fault recovery time and associated protocol control overheads, and tested the influence of important protocol parameters. Investigated fail-over of router, link, LAN, WAN, and the interaction of OSPF, PIM, and IGMP to recover a multicast channel. Experiments were also done over Cisco routers.

9/94-6/96   *Research Assistant*, **Northeastern University, ECE**,   Boston, MA
- Designed a group-based packet scheduling algorithm. Scheduling deadlines were defined for blocks of data instead of each packet to reduce scheduling overhead and improve utilization (supported by DARPA).
- Developed an MPEG source model for ATM protocol design; Investigated packet video over ATM network.

9/90-4/93   *Research Assistant,* **Beijing Univ. of Posts & Telecom**.,   Beijing, China
Low Bit Video Phone Design and Development
The 8th Five-Year National Scientific and Technological Key Projects of China, using TMS320 C25 DSP chip
- Designed and prototyped a fully functional 64Kb/s motion videophone decoder hardware/software system based on H.261 recommendation and its network interfaces.
- Solved problems resulting from rapid updating in HDTV and videophone.
- Designed a medium rate vector speech quantizer.

PROFESSIONAL ACTIVIES
- Supervised M.S. Projects of seven graduate students at Columbia University
- Refereed articles for IEEE INFOCOM, ACM SIGCOMM, ICC, Global Internet, Packet Video, IEEE Communication Magazine, IEEE JSAC, Journal for Communications and Networks (JCN), ACM Multimedia, IEEE Transactions on Multimedia, IEEE Transactions on Mobile Computing (TMC), etc.

REFERENCES

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SELECTED PUBLICATIONS

1. S. Kasera, R. Ramjee, S. Thuel, X. Wang, "Congestion Control Policies for IP-based CDMA Radio Access Network", to appear in *Proceeding of INFOCOM'2003,* San Francisco, Mar. 2003,
2. X. Wang, R. Ramjee, "A Predictive and Adaptive Resource Management Scheme for CDMA Downlink Data and Voice," to be submitted.
3. G. Gopalakrishnan, S. Kasear, C. Loader, X. Wang "Robust Router Overload Control Using Acceptance and Departure Rate Measures", under submission.
4. 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).*
5. X. Wang, H. Schulzrinne, "Pricing Network Resources for Adaptive Applications in a Differentiated Services Network," In *Proceeding of INFOCOM'2001*, Anchorage, Alaska, Apr. 2001.
6. X. Wang, H. Schulzrinne, C. Yu, P. Stirpe, W. Wu, "IP Multicast Fault Recovery in PIM over OSPF," In *8th International Conference on Network Protocols (ICNP'00)*, Osaka, Japan, Nov. 2000. Also appears at *ACM SIGMETRICS'2000* as short paper.
7. M. Chan, Y. J.Lin, X. Wang, "On Reducing QoS Data Exchange in Monitoring Flows with Service Level Agreements," In *8th International Conference on Network Protocols (ICNP'00)*, Osaka, Japan, Nov. 2000.
8. X. Wang, H. Schulzrinne, "An Integrated Resource Negotiation, Pricing, and QoS Adaptation Framework for Multimedia Applications," *IEEE Journal on Selected Areas in Communications (JSAC)*, vol. 18, 2000. Special Issue on Internet QoS.
9. 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'00)*, Chapel Hill, North Carolina, Jun. 2000.
10. X. Wang, H. Schulzrinne, "Adaptive Reservation: A New Framework for Multimedia Adaptation," *IEEE International Conference on Multimedia and Expo. (ICME'2000)*, New York, Jul. 2000.
11. X. Wang, H. Schulzrinne, D. Kandlur, D. Verma, "Measurement and Analysis of LDAP Performance," *International Conference on Measurement and Modeling of Computer Systems (ACM SIGMETRICS'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, Jun. 1999.
13. X. Wang, H. Schulzrinne, "Comparison of Adaptive Internet Multimedia Applications," Invited paper, *IEICE Transactions on Communications*, Vol. E82-B, No. 6, pp. 806--818, June 1999.
14. 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, Champman & Hall, Chap. 5, 1997.
15. 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.
16. 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.
17. 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.
18. X. Wang, L. Zhang, "A High-Quality Medium-Rate Speech Vector Quantizer," *Journal of Beijing University of Posts & Telecommunications*, Vol. 15, No 1, 1992.

INVITED TALKS

1. 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
2. X. Wang, H. Schulzrinne, "Resource Negotiation and Pricing Protocol," *Internet2 Network Research Workshop*, Chicago, June 2000.
3. X. Wang, H. Schulzrinne, "An Integrated Resource Negotiation, Pricing, and Quality of Service Framework for Adaptive Multimedia Applications," Sun Microsystems, San Jose, California, Aug. 2000.
4. X. Wang, H. Schulzrinne, "Measurement and Analysis of LDAP Performance," Sun Microsystems, San Jose, California, Aug. 2000.

HONORS

Full research fellowship of Columbia University

First class scholarship every year for top 2% students in Beijing University of Posts and Telecommunications (BUPT).

Exemption of master entrance exam of BUPT for top 2% student

Ranked 1st out of 800,000 in National College Entrance Exam of Chengdu City, Sichuan Province, China