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Research Interests:

Internet Technologies, Protocols, Architecture and Applications; Group Communication in wide-area networks; Overlay and peer-to-peer networks; Self-Managing Systems

Education:

Ph.D. in Computer Science, Carnegie Mellon University, August 2004 (expected)
Thesis Title: The Case for End System Multicast
Research Advisor: Prof. Hui Zhang

M.S. in Computer Science, Carnegie Mellon University, December 2000

Bachelor of Technology, Computer Science and Engineering, Indian Institute of Technology (IIT), Madras, India, May 1997

Publications:

- *"A Case For End System Multicast"*, Yang-hua Chu, Sanjay G. Rao, Srinivasan Seshan and Hui Zhang, *IEEE Journal on Selected Areas in Communication (JSAC), Special Issue on Networking Support for Multicast, Vol. 20, No. 8, October 2002.*

- *"Enabling Conferencing Applications on the Internet using an Overlay Multicast Architecture"*, Yang-hua Chu, Sanjay G. Rao, Srinivasan Seshan and Hui Zhang, *Proceedings of ACM Sigcomm, San Diego, CA, August 2001.*

- *"A Case For End System Multicast"*, Yang-hua Chu, Sanjay G. Rao and Hui Zhang, *Proceedings of ACM Sigmetrics, Santa Clara, CA, June 2000.*

- "Early Deployment Experience with an Overlay Based Internet Broadcasting System", Yang-hua Chu, Aditya Ganjam, T.S. Eugene Ng, Sanjay Rao, Kay Sripanidkulchai, Jibin Zhan and Hui Zhang, *Technical Report CMU-CS-03-214,December 2003. Revised version to appear in the Usenix Technical Conference, June 2004.* Selected as 1 of the top 4 posters at the Poster Session of the *Symposium on Operating Systems Principles* held in conjunction with the ACM Student Research Competition.

- *"The Effect of Heterogeneous Bandwidth Constraints on Protocols for Overlay Multicast" (Currently submitted for publication)*

- *"Measurement-Based Optimization Techniques for Bandwidth-Demanding Peer-to-Peer Systems"*, T. S. Eugene Ng, Yang-hua Chu, Sanjay G. Rao, Kunwadee Sripanidkulchai and Hui Zhang, *Proceedings of IEEE Infocom, San Francisco, CA, April 2003.*

- *"Fast techniques for the optimal smoothing of stored video"*, Sanjay G. Rao and S.V.Raghavan, *ACM/Springer Verlag Multimedia Systems Journal, Volume 7, May 1999, pgs 222-233.*

- *"MERCURY: A Scalable Publish-Subscribe System for Internet Games"*, Ashwin Bharambe, Sanjay Rao and Srinivasan Seshan, *First International Workshop on Network and System Support for Games , Braunschweig, Germany, April 2002*

Research Experience:

- **8/97 - present: Graduate Research Assistant, Carnegie Mellon University**

I initiated the End System Multicast project at Carnegie Mellon along with my colleague Yang-hua Chu, and have played a leadership role since its inception. We were one of the earliest groups to argue for migrating multicast related functionality from routers to end systems and we demonstrated that the performance penalties of doing so were small compared to the benefits. Overlay Multicast has subsequently evolved into a research area of its own right. The key challenge with End System Multicast that my thesis addresses is the design of protocols that construct efficient overlay networks among participating end systems in dynamic and heterogeneous Internet environments, in a self-organizing and self-improving fashion. I was responsible for the design and implementation of Narada, perhaps the first published self-organizing overlay protocol. While Narada was targeted at multi-source conferencing applications, I also designed and implemented a protocol for single-source, larger-scale broadcasting applications, and led efforts to build tools to analyze the performance of the protocol. This protocol is the key component of a fully operational broadcasting system that my colleagues and I have built as part of the ESM project. The system has been used to successfully broadcast several lectures and conferences including Sigcomm 2002, Sigcomm 2003, SOSP 2003, and has been used by over 3000 users in home, academic and commercial environments, spread over four continents. It is the only non-commercial deployment of self-organizing overlay multicast prototypes among live users to my knowledge. My extensive experience designing self-organizing protocols and experimenting with them in real Internet conditions, is leading me to formulate important principles fundamental to the design of such protocols

- **5/98-8/98 : Summer Intern, IBM T.J. Watson Research Center, New York.**

I conducted a trace-based study to evaluate the benefits of multi-layer cache hierarchies, This work was done with Erich Nahum and Srinivasan Seshan.

- **9/96 -5/97: Bachelor's Thesis, Indian Institute of Technology, Madras**

I designed algorithms and techniques that enabled fast computation of work-ahead scheduling algorithms in an online fashion. Such algorithms are used in scenarios where a server transmitting stored compressed video to a client utilizes client buffer space to reduce the rate variability of the transmitted stream. My work led to a publication in the ACM/Springer Verlag Multimedia Systems journal.

- **5/96-8/96: Summer Intern, Theoretical Computer Science Group, Tata Institute of Fundamental Research, Bombay, India.**

I was selected for the Visiting Student Research Program in 1996. I studied multiprocessor scheduling algorithms, under the supervision of Prof.R.K.Shyamsundar and Dr. Jaikumar Radhakrishnan.

- **5/95-8/95: Summer Intern, DON Laboratory, Indian Institute of Technology (Madras).**

I participated in the design of the Acacia Nova Switch and the Excellent XLS family of Ethernet Switches, an effort led by Prof. Timothy Gonsalves. I performed a comparison study of various hash functions for their suitability, and designed and implemented an ARP/RARP server.

Teaching Experience:

- **8/99-12/99: Teaching Assistant, Carnegie Mellon University**
Sophomore course, "Introduction to Computer Systems", taught by Prof. Randy Bryant and Dave O' Halloran.
My responsibilities included teaching weekly recitations as well as preparing course projects and examinations. I designed and managed a course project where students had to implement chat clients as an introduction to socket programming.

- **8/00-12/00: Teaching Assistant, Carnegie Mellon University**
Upper level undergraduate course, "Databases", taught by Prof. Christos Faloutsos
My responsibilities included designing and grading course projects and homework problems.

- **April 2003: Guest lecture** on Multicast in the undergraduate networking class.

Mentoring Experience:

I have interacted and worked closely with several undergraduate and Masters students as part of the End System Multicast Project. In particular, I have played a key role in mentoring and supervising the following Master's theses:

- *"A Monitoring Tool for Self-Organizing Overlay Networks"*, TungFai Chan and Annie Cheng, Master of Science in Information Networking, December 2000
- *"Design and Experience with NATs and Firewalls in End System Multicast"*, Aditya Ganjam, 5th Year Masters Program, Carnegie Mellon, May 2003

Software:

- **End System Multicast toolkit,** that enables Internet users to conduct their own live Internet broadcasts free of cost. The system is available in Linux, Windows and MAC and has seen signficant operational use. (http://esm.cs.cmu.edu/)

Professional Service:

Referee for several conferences and journals including ACM SIGCOMM, IEEE INFOCOM, ACM/IEEE Transactions on Networking, RTSS, IPTPS, HotNets and ACM Multimedia

Academic Achievements and Honors:

- Semi-finalist in the ACM Student Research Competition conducted by the Symposium on Operating System Principles (SOSP) 2003.
- National Talent Search Scholarship winner (India), 1991-97.
- Selected to attend the Republic Day Parade from the Prime Minister's box for being among the top 0.1% of students who took the All India Senior School Certificate Examination, 1993

References:

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