

Sanjay Gopinatha Rao

June 2021

Education:

- B.Tech, Computer Science and Engineering, May 1997, Indian Institute of Technology, Madras
- M.S. in Computer Science, Dec 2000, Carnegie Mellon University
- Ph.D. in Computer Science, Dec 2004, Carnegie Mellon University

Professional Experience:

Aug 2020 – Present	Professor School of Electrical and Computer Engineering, Purdue University
Aug 2011 – July 2020	Associate Professor School of Electrical and Computer Engineering, Purdue University
Nov 2013 – Present	Courtesy Professor (since Aug 2020) & Associate Professor (Nov 2013-July 2020), Computer Science Department, Purdue University
Jan 2005 – July 2011	Assistant Professor, School of Electrical and Computer Engineering, Purdue University
Feb 2015-July 2015	Visiting Fellow, Department of Computer Science, Princeton University
June 2011 – July 2012	Visiting Research Scientist, Google
May 2006 - June 2006	Visiting Researcher, Network Management and Measurement Group, AT&T Research, Florham Park, New Jersey.
Nov 2004 - Dec 2004	Visiting Assistant Professor, School of Electrical and Computer Engineering, Purdue University
Aug 1997 - Oct 2004	Graduate Research Assistant, Carnegie Mellon University
May 1998 - Aug 1998	Research Intern IBM T.J. Watson Research Center, New York

Awards and Honors:

- NSF CAREER Award, 2010
- ACM SIGMETRICS Test of Time Award, 2011
This award recognizes an influential performance evaluation paper whose impact is felt 10-12 years after its initial publication. With Dr. Yang-hua Chu and Dr. Hui Zhang for the 2000 paper: "A Case for End System Multicast".
- Purdue University, Seed of Success Award, 2017 (Team Award)
This award was for being part of a team led by Prof. Karthik Ramani (Mechanical Engineering) and also consisting of Prof. Ananth V. Iyer (Krannert School of Management) that received the National Science Foundation grant, "PFI: BIC MAKERPAD: Making Everyone a Maker Through Intuitive Shape Modeling and 3-D Printing Service Platform".
- Recognized by the College of Engineering, Purdue University as an Outstanding Engineering Teacher for a teaching evaluation of higher than 4.7 for courses taught in Spring 2018, Spring 2019 and Spring 2020.

Ph.D Students Graduated:

1. Yu-Wei Sung (June 2010; now Software Engineering Manager, Network Platforms at Facebook), “An Abstraction-Driven Approach to Systematic Enterprise Network Design, Configuration and Validation.”
2. Ruben Torres (July 2011; now in Bay Area start-up; formerly at Narus/Symantec/Boeing), “Measurement-Driven Characterization of Emerging Trends in Internet Content Delivery.”
3. Xin Sun (July 2012; now Assistant Professor, Computer Science, Ball State University; formerly at Florida International University). “Towards Systematic Migration of Enterprise Networks.” (won a single PI NSF CRII (Research Initiation Initiative) Award for junior faculty, 2015)
4. Mohammad Hajjat (March 2014; now in Facebook; formerly at Microsoft (Azure Cloud Computing Team). “Architecting Delay Sensitive Applications for the Cloud.”
5. Shankaranarayanan Narayanan (July 2016; now at AT&T Research, Bedminister NJ) “A Holistic Approach to Lowering Latency in Geo-distributed Web Applications.”
6. Ashiwan Sivakumar (October 2017; now at AT&T Research, Bedminister, NJ, after completing post-doctoral fellowship in Carnegie Mellon University) “Scalable Redundant Proxy Execution for low-latency Web over Cellular Networks”
7. Yiyang Chang (June 2019; now at ByteDance; Bilsland Dissertation Fellowship 2018-19) “Ensuring Network Designs meet Performance Requirements under Failures”
8. Yun Seong Nam. (January 2020; now at Google) “Characterizing and Optimizing Internet Video Streaming”

Ph.D Students Currently Supervised:

9. Russ Shirey (expected graduation: Summer 2021; co-advised with Shreyas Sundaram)
10. Chuan Jiang (Prelims completed: Spring 2021; expected graduation Spring 2022; Gaw Dissertation Fellowship: Spring 2022)
11. Ehab Ghabashneh (since Summer 2018)
12. Zixuan Li (since Fall 2019)
13. Chandan Bothra (since Fall 2020)

Visiting Researchers Supervised

1. Alessandro Finamore (Visiting Ph.D student, Politecnico di Torino, Italy, Oct 2010 – May 2011)
2. Jose Luis Garcia-Dorado (Asst. Prof., Universidad Autónoma de Madrid ,Spain Feb 2013-July 2013)

Masters Thesis Students Graduated:

1. Yu-Wei Sung (April 2006; completed Ph.D under my supervision June 2010), “Enabling Contribution Awareness in an Overlay Broadcasting System.”
2. Ruben Torres (April 2006; completed Ph.D under my supervision July 2011), “Enabling Confidentiality of Data Delivery in an Overlay Broadcasting System.”
3. Mike Bishop (May 2006; now at Microsoft), “Considering Priority in Overlay Multicast Protocols under Heterogeneous Environments.”
4. Prashant Garimella (April 2008; now at Cisco), “Characterization and Visualization of VLANs in a Campus Network.”
5. Sunil Krothapalli (May 2009; now at Cisco) , “Design and Implementation of a toolkit for managing Virtual LANs in Campus Networks.”
6. Kripashankar Subramaniam (August 2009; now at Amazon), “Enhancing the performance of Distributed Hash Tables in the presence of Network Address Translators.”
7. Srivathsava Rangarajan (July 2014; now at Enova Financial LLC) “Paxos-based directory updates for geo-replicated cloud storage.”

Significant Publications and Impact:

- Please see: <https://engineering.purdue.edu/~sanjay/ResearchSummary/>

Refereed Journal Publications:

1. “Fast techniques for the optimal smoothing of stored video,” G.Sanjay and S.V.Raghavan, ACM/Springer Verlag Multimedia Systems Journal, Volume 7, May 1999, pgs 222-233.
2. “A Case For End System Multicast,” Y. Chu¹, S.G. Rao¹, S.Seshan and H. Zhang, IEEE Journal on Selected Areas in Communication (JSAC), Special Issue on Networking Support for Multicast, Vol. 20, No. 8, October 2002, pp. 1456-1471.
3. “Enabling Contribution Awareness in an Overlay Broadcasting System,” Y.W. Sung, M. Bishop, and S.G. Rao, IEEE Transactions on Multimedia Systems, Special Issue on Content Storage and Delivery in Peer-to-peer networks, Vol. 9, No. 8, December 2007, pp. 1605-1620.
4. “Enabling Confidentiality of Data Delivery in an Overlay Broadcasting System,” R. Torres, X. Sun, A. Walters, C. Nita-Rotaru and S. G. Rao, IEEE Journal on Selected Areas in Communication (JSAC), Special Issue on Advances in P2P Streaming, Vol. 25, No. 9, December 2007, pp. 1732-1743.
5. “Opportunities and Challenges of Peer-to-Peer Internet Video Broadcast,” J. Liu, S.G. Rao, B. Li, and H. Zhang, Proceedings of IEEE, Special Issue on Recent Advances in Distributed Multimedia Communications, *Invited Article*, Vol. 96, No. 1, January 2008, pp. 11-24.
6. “Configuration Management at a Massive Scale: System Design and Experience,” W. Enck, T. Moyer, P. McDaniel, S. Sen, S. Panagiotis, S. Spoerel, A. Greenberg, Y.Sung, S.G. Rao and W. Aiello, IEEE Journal on Selected Areas in Communication (JSAC), Special Issue on Network Infrastructure Configuration, Vol. 27, No. 3, April 2009, pp. 323-335.
7. “On the feasibility of exploiting P2P systems to launch DDoS attacks,” X. Sun, R. Torres and S.G.Rao, Springer Journal on Peer-to-Peer Networking and Applications, Special Issue on Dependable Peer-to-Peer Systems, Vol 3, No. 1, March 2010, pp 36-51.
8. “On-demand waypoints for live P2P video broadcasting,” A.Ganjam, S.G. Rao, K.Sripanidkulchai, J.Zhan and H. Zhang, Springer Journal on Peer-to-Peer Networking and Applications, Vol. 3, No. 4, December 2010, pp 277-293.
9. “Preventing DDoS Attacks on Internet Servers Exploiting P2P Systems,” X.Sun, R.Torres, and S.G. Rao, Elsevier Computer Networks Journal, Vol 54, Issue 15, October 2010, pp 2756-2774.
10. “Towards Systematic Design of Enterprise Networks,” Y. W.Sung, X. Sun, S.G.Rao, G.Xie and D. Maltz, IEEE/ACM Transactions on Networking, Vol 19, Issue 3 June 2011, pp 695-708 DOI: 10.1109/TNET.2010.2089640.
11. “A Design for Securing Data Delivery in Peer-to-Peer Streaming,” Jeff Seibert, Xin Sun, Cristina Nita-Rotaru, and Sanjay Rao. In the Elsevier Journal of Computer Networks, vol. 55, Issue 12, August 2011, pp 2730-2745.
12. “A Survey of Virtual LAN Usage in Campus Networks”, Minlan Yu, Xin Sun, Nick Feamster, Sanjay Rao and Jennifer Rexford. IEEE Communications Magazine, Network and Service Management Series, Vol. 49, Issue 7, pp 98-103, July 2011.
13. “The Internet-wide Impact of P2P Traffic Localization on ISP Profitability”, J. Seibert, R. Torres, M. Mellia, M. Munafo, C. Nita-Rotaru and S.G. Rao. IEEE/ACM Transactions on Networking, Vol. 20, Issue 6, 2012, pp 1910-1923
14. “Characterization of community based P2P systems and implications for traffic localization”, R. Torres, M Mellia, M. Munafo and S.G. Rao, Springer Journal on Peer-to-Peer Networking and Applications, Vol 6, Issue 2, 2013, pp 118-133
15. “Improving Performance of Interactive Cloud Application By Dynamic Request Splitting”, M.Hajjat, P.N. Shankaranarayanan, D. Maltz, S.G. Rao and K. Sripanidkulchai, IEEE Journal on Selected Areas

in Communication, Special Issue on Networking Challenges in Cloud Computing Systems and Applications, vol. 31, Issue 12, 2013, pp 2722-2737

16. "A flow measurement architecture to preserve application structure", M. Lee, M. Hajjat, R. Kompella and S.G.Rao, In the Elsevier Journal of Computer Networks, vol. 77, February 2015, pp 181-195
17. "Cost-aware multi data-center bulk transfer in the cloud from a customer-side Perspective", Jose Luis Garcia Dorado and S.G. Rao. IEEE Transactions on Cloud Computing, Accepted for publication, 2015. DOI: 10.1109/TCC.2015.2469666
18. "Alpaca: Compact Network Policies with Attribute-Encoded Addresses", Nanxi Kang, Ori Rottenstreich, Sanjay Rao and Jennifer Rexford. IEEE/ACM Transactions on Networking Vol. 25, Issue: 3, June 2017. DOI: 10.1109/TNET.2017.2657123
19. "Karma: Cost-effective Geo-replicated Cloud Storage with Dynamic Enforcement of Causal Consistency", Tariq Mahmood, Shankaranarayanan Narayanan, Sanjay Rao, T.N.Vijaykumar and Mithuna Thottethodi. IEEE Transactions on Cloud Computing, 2018 (Accepted March 2018).

Refereed Conference Publications:

20. "A Case For End System Multicast," Y. Chu¹, S. G. Rao¹ and H. Zhang, Proceedings of ACM Sigmetrics Conference, Santa Clara , CA, June 2000, pp 1-12 (AR=17%, 28/165).
21. "Enabling Conferencing Applications on the Internet using an Overlay Multicast Architecture," Y. Chu¹, S.G.Rao¹, S. Seshan and H. Zhang, Proceedings of ACM SIGCOMM, San Diego, CA, August 2001 (AR=9%, 23/252).
22. "Measurement-Based Optimization Techniques for Bandwidth-Demanding Peer-to-Peer Systems," T. S. Eugene Ng, Y. Chu, S.G. Rao, K. Sripanidkulchai and Hui Zhang, Proceedings of IEEE Infocom Conference, San Francisco, CA, April 2003, pp. 2199-2209 (AR=21%, 224/1078).
23. "Early Deployment Experience with an Overlay Based Internet Broadcasting System," Y.Chu¹, A.Ganjam, T.S. Eugene Ng, S.G. Rao¹, K. Sripanidkulchai, J. Zhan and H. Zhang, Proceedings of the Usenix Technical Conference, Boston, MA, June 2004, pp 155-170 (AR=13%, 21/164).
24. "Considering Priority in Overlay Multicast Protocols under Heterogeneous Environments," M. Bishop, S.G. Rao, and K. Sripanidkulchai, Proceedings of IEEE Infocom, Barcelona, vol. 25, No. 1, April 2006 pp 653-665 (AR=18%, 252/1400).
25. "Enabling Contribution Awareness in an Overlay Broadcasting System," Y.W Sung, M. Bishop, and S.G. Rao, Proceedings of ACM SIGCOMM, Pisa, Volume 36, No. 4, September 2006, pp 411-422 (AR=11%, 37/340).
26. "Enabling Confidentiality of Data Delivery in an Overlay Broadcasting System," R. Torres, X. Sun, A. Walters, C. Nita-Rotaru and S.G. Rao, Proceedings of IEEE Infocom, Anchorage, vol 26, no. 1, May 2007, pp 607-615 (AR=18%, 252/1400).
27. "Configuration Management at a Massive Scale: System Design and Experience," W. Enck, P. McDaniel, S. Sen, A. Greenberg, S. Panagiotis, S. Spoerel, S.G. Rao and W. Aiello, Proceedings of the Usenix Technical Conference, June 2007, pp 73-86 (AR=23.53%, 24/102).
28. "Towards Systematic Design of Enterprise Networks," Y.W.Sung, S.G.Rao, G.Xie and D. Maltz, Proceedings of ACM CoNEXT, Madrid, Spain, December 2008 (AR= 17%,29/166)
29. "Extracting Network-wide Correlated Changes from Longitudinal Configuration Data," Y.W. Sung, S.G. Rao, S. Sen, and S. Leggett. Proceedings of Passive and Active Measurement Conference, Seoul, Korea, April 2009 (AR = 28.5%, 22/77).
30. "Inferring Undesirable Behavior from P2P Traffic Analysis," R. Torres, M. Hajjat, S.G. Rao, M. Mellia, and M. Munafa, Proceedings of ACM SIGMETRICS, Seattle, WA, June 2009 (AR=15%,27/180).

¹ Co-primary Authors. An alphabetic naming convention was used.

31. "Modeling and Understanding End-to-End Class of Service Policies in Operational Networks," Y.W. Sung, C. Lund, M. Lyn, S.G. Rao, S. Sen, Proceedings of ACM SIGCOMM, Barcelona, Spain, August 2009 (AR=10%,27/270).
32. "A Systematic Approach for Evolving VLAN Designs," X. Sun, Y.W. Sung, S. Krothapalli, and S.G.Rao, Proceedings of IEEE Infocom, San Diego CA, March 2010 (AR=17.52%, 276/1575).
33. "Towards Securing Data Delivery in Peer-to-Peer Streaming," J.Seibert, X. Sun, C. Nita-Rotaru and S.G. Rao, Proceedings of COMSNETS, Bangalore, India, January 2010 (invited paper).
34. "Cloudward Bound: Planning for Beneficial Migration of Enterprise Applications to the Cloud," M. Hajjat, X. Sun, Y.W.Sung, D. Maltz, S.G. Rao, K. Sripanidkulchai and M. Tawarmalani, Proceedings of ACM SIGCOMM, New Delhi, India, August 2010 (AR=12%,33/276).
35. "RelSamp: Preserving Application Structure in Sampled Flow Measurements," M. Lee, M. Hajjat, R. Kompella and S.G. Rao, Proceedings of IEEE Infocom, Shanghai, April 2011 (AR=15.96%, 291/1823)
36. "Dissecting video server selection strategies in the YouTube CDN," R. Torres, A. Finamore, J. Kim, M. Mellia, M. Munafo and S.G. Rao, Proceedings of IEEE ICDCS, Minneapolis, June 2011 (AR=15.45%, 87/563)
37. "YouTube Everywhere: Impact of Device and Infrastructure Synergies on User Experience," A. Finamore, M. Mellia, M. Munafo, R. Torres and S. G. Rao, Proceedings of Internet Measurement Conference, November 2011 (AR=19%, 42/220)
38. "Modeling Complexity of Enterprise Routing Design," X. Sun, S.G. Rao and G. G. Xie, ACM CoNEXT, December 2012 (AR= 17.5%, 31/177)
39. "Dealer: Application-aware Request Splitting for Interactive Cloud Applications", M. Hajjat, P.N. Shankaranarayanan, D. Maltz, S.G. Rao and K. Sripanidkulchai, ACM CoNEXT, December 2012 (AR = 17.5%, 31/177)
40. "Performance sensitive replication in geo-distributed cloud datastores", P.N. Shankaranarayanan, A. Sivakumar, S.G. Rao and M. Tawarmalani, IEEE/IFIP DSN, June 2014. Shankaranarayanan won the 3rd place in a poster/demo version at ACM Sigcomm 2013, which also served as an ACM Student Research Competition (AR = 30.9%, 56/181)
41. "PARCEL: Proxy Assisted browsing in Cellular networks for Energy and Latency Reduction", A. Sivakumar, P.N. Shankaranarayanan, V. Gopalakrishnan, S. Lee, S. G. Rao and S. Sen, ACM CoNext, Sydney, Australia, 2014 (AR = 19.8%, 37 /186).
42. "Application-specific configuration selection in the cloud: impact of provider policy and potential of systematic testing", M. Hajjat, R. Liu, Y. Chang, T.S.E. Ng, S.G. Rao, IEEE Infocom, Hong Kong, April 2015 (AR= 19.3%, 316/1640).
43. "Alpaca: Compact Network Policies with Attribute-Carrying Addresses", Nanxi Kang, Ori Rottenstreich, Sanjay Rao, and Jennifer Rexford, ACM CoNEXT 2015, December 2015 (AR=41/196 = 21%)
44. "Reducing latency through page-aware management of web objects by Content Delivery Networks", P.N. Shankaranarayanan, Yun Seong Nam, A. Sivakumar, B. Chandrasekaran, B. Maggs and S.G. Rao. ACM Sigmetrics, June 2016 (AR = 28/208 = 13.46%).
45. "Hydra: Leveraging Functional Slicing for Efficient Distributed SDN Controllers", IEEE COMSNETS, Yiyang Chang, Ashkan Rezaei, Balajee Vamanan, Jahangir Hasan, Sanjay Rao, and T.N. Vijaykumar, January 2017 (AR = 49/192 = 25.52%). The paper was one of ten selected papers invited to submit an extended version for a Special volume of Springer Lecture Notes in Computer Science (LNCS) series). It appeared as "Exploring Functional Slicing in the Design of Distributed SDN Controllers," vol. 10340, pp. 177–199, Communication Systems and Networks. COMSNETS 2017, Revised Selected Papers and Invited Papers. Lecture Notes in Computer Science (LNCS), Springer, 2017.
46. "Robust Validation of Network Designs under Uncertain Demands and Failures", Yiyang Chang, Sanjay G. Rao and Mohit Tawarmalani. Usenix NSDI, March 2017 (AR= 46/253 = 18.18%).
47. "NutShell: Scalable Whittled Proxy Execution for Low-Latency Web over Cellular Networks",

- Ashwan Sivakumar, Chuan Jiang, Yun Seong Nam, P.N. Shankaranarayanan, V. Gopalakrishnan, Sanjay G Rao, S. Sen, Mithuna Thottethodi and T.N. Vijaykumar. ACM Mobicom, 2017 (AR = $35/186 = 18.81\%$).
48. "Oboe: Auto-tuning video ABR algorithms to network conditions", Zahaib Akhtar, Yun Seong Nam, Ramesh Govindan, Sanjay Rao, Jessica Chen, Ethan Katz-Bassett, Bruno Ribeiro, Jibin Zhan and Hui Zhang. ACM Sigcomm, May 2018 (AR = $40/222 = 18.01\%$).
 49. "Understanding Video Management Planes", Zahaib Akhtar, Yun Seong Nam, Jessica Chen, Ramesh Govindan, Ethan Katz-Bassett, Sanjay Rao, Jibin Zhan, Hui Zhang, Proceedings of the ACM Internet Measurement Conference, October 2018 (AR = $43/174 = 24.71\%$).
 50. "Lancet: Better network resilience by designing for pruned failure sets", Yiyang Chang, Chuan Jiang, Ashish Chandra, Sanjay Rao and Mohit Tawarmalani, Proceedings of ACM Sigmetrics, June 2020 (AR = $55/279 = 19.7\%$).
 51. "Exploring the interplay between CDN caching and video streaming performance", Ehab Ghabashneh and Sanjay Rao, Proceedings of IEEE Infocom, July 2020 (AR = $268/1354 = 19.8\%$).
 52. "PCF: Provably Resilient Flexible Routing", Chuan Jiang, Sanjay G. Rao and Mohit Tawarmalani, Proceedings of ACM Sigcomm, August 2020 (AR = $53/250 = 21.2\%$).
 53. "Optimizing Quality of Experience for Long-Range UAS Video Streaming", Russell Shirey, Sanjay Rao, and Shreyas Sundaram, In IEEE/ACM 29th International Symposium on Quality of Service (IWQoS), June 2021 (AR = $64/256 = 25\%$).
 54. "Hey, Lumi! Using Natural Language for Intent-Based Network Management", Arthur S. Jacobs, Ricardo Pfitscher, Rafael Ribeiro, Ronaldo Alves Ferreira, Lisandro Granville, Walter Willinger and Sanjay Rao, In Usenix Annual Technical Conference, July 2021 (AR= $64/341 = 18.8\%$)

Refereed Workshop and Mini Conference Publications:

55. "MERCURY: A Scalable Publish-Subscribe System for Internet Games," A.R. Bharambe, S. G. Rao and S. Seshan, First International Workshop on Network and System Support for Games, Braunschweig, Germany, April 2002 (AR=60%, 12/20).
56. "The Impact of Heterogeneous Bandwidth Constraints on DHT-Based Multicast Protocols," A.R. Bharambe, S.G. Rao, V. Padmanabhan, S. Seshan and H. Zhang, Fourth International Workshop on Peer-to-Peer Systems (IPTPS), Ithaca, NY, February 2005, (AR=20%, 24/123).
57. "Characterizing VLAN usage in an Operational Network," P. Garimella, Y.W. Sung, N. Zhang and S.G. Rao, ACM SIGCOMM workshop on Internet Network Management (INM'07), Kyoto, Japan, August 2007, Short Paper,(AR=27%, 15/55).
58. "DDoS Attacks by Subverting Membership Management in P2P Systems," X. Sun, R. Torres, and S.G. Rao, Third Workshop on Secure Network Protocols (NPsec), Beijing, October 2007 (held in conjunction with IEEE ICNP) (AR = 44%, 8/18).
59. "A Toolkit for Automating and Visualizing VLAN Configuration," S.Krothapalli, X. Sun Y.W.Sung, Suan-Aik Yeo and S.G. Rao , Workshop on Assurable and Usable Security Configuration(SafeConfig), October 2009 (Co-located with ACM CCS) (AR= 44%, 11/25).
60. "A Cost-Benefit Framework for Judicious Enterprise Network Redesign," X.Sun and S.G. Rao, Proceedings of IEEE Infocom Mini-Conference, Shanghai, April 2011 (AR=23.42%, 427/1823)
61. "A Software Toolkit for Visualizing Enterprise Routing Design," X. Sun, J. Wei, S.G. Rao and G.G. Xie, 4th Symposium on Configuration Analytics and Automation, October 2012 (AR=24.12%, 7/29)
62. "Cloud is not a silver bullet: A Case Study of Cloud-based Mobile Browsing", A. Sivakumar, V. Gopalakrishnan, S. Lee, S.G. Rao, S. Sen and O. Spatscheck, ACM HotMobile, February 2014 (AR=30.5%, 22/72).
63. "VIDalizer: An Energy Efficient Video Streamer", A. Raha, S. Mitra, V. Raghunathan, and S.G. Rao, IEEE Wireless Communications and Networking Conference, Services, Applications, and Business Track, March 2015 (AR = 45%, 385/855).

64. “Measuring and characterizing the performance of interactive multi-tier cloud applications”, Mohammad Hajjat, Shankaranarayanan P N, Ashiwan Sivakumar, Sanjay Rao, IEEE LANMAN Workshop, 2015 (*invited paper*).
65. “Composing middlebox and traffic engineering policies in SDNs”, Yiyang Chang, Gustavo Petri, Sanjay Rao and Tiark Rompf IEEE Infocom Workshop on Software-Driven Flexible and Agile Networking, 2017 (AR=10/20 =50%).
66. “Accord: Automated Change Coordination across Independently Administered Cloud Services”, Tariq Mahmood, Bharath Balasubramaniam, Mithuna Thottethodi, Sanjay Rao and Kaustubh Joshi. IEEE Cloud Workshop: Cloud Management and Operations.
67. “Learning network design objectives using a program synthesis approach”, Yanjun Wang, Chuan Jiang, Xiaokang Qiu and Sanjay Rao. ACM Workshop on Hot Topics in Networking, November 2019 (AR=20/98=20.4%).
68. “Measuring fixed wing UAS networks at long range”, Russell Shirey, Sanjay Rao and Shreyas Sundaram. 6th ACM Mobisys Workshop on Micro Aerial Vehicle Networks, Systems, and Applications (DroNet@Mobisys), June 2020 (AR = 6/13 = 46%).
69. “Pitfalls of data-driven networking: A case study of latent causal confounders in video streaming”, P.C. Sruthi, Sanjay Rao and Bruno Ribeiro. ACM Sigcomm Workshop on Network meets AI, August 2020 (AR = 9/19 = 47%).

Patents Awarded:

1. “Methods and apparatus to model end-to-end class of service policies in networks”, S. Sen, C. Lund, S.G. Rao and Y.W. Sung. US Patent 8775352B2, 7/8/2014
2. “Scalable whittled proxy execution for low-latency web over cellular networks”, V. Gopalakrishnan, S. Sen, P. N. Shankaranarayanan, A. Sivakumar, S.G Rao, M. Thottethodi, and T. Vijaykumar, US10846356B2, 11/24/2020.

Grants:

1. \$85,000, Sole PI, “Network Management,” AT&T Research (unrestricted gift), July 2006
2. \$10,000, Sole PI, “Network Management Curriculum Development,” Cisco (unrestricted gift), December 2006.
3. \$416,000, PI, NSF Cybertrust, “Towards Trustworthy Peer-to-Peer Systems,” 2007-2010 (with Co-PI Cristina Nita-Rotaru, Purdue University. My portion is \$229,540, which includes a \$6000 REU supplement received in addition to the main grant.
4. \$287,000, PI (Purdue), NSF NETS, “Collaborative Research: NBD: An Abstraction Driven Approach to Characterizing and Designing Networks with Analyzable Properties,” 2007-2010. (with PI Geoff Xie, Naval Post-Graduate School. The following served as senior personnel: Albert Greenberg and David Maltz, Microsoft Research; Jennifer Rexford, Princeton; Shubho Sen, AT&T Research. Total Grant is \$562,000. Purdue University’s share and my portion is \$287,000, which includes a \$12,000 REU supplement in addition to the main grant). \$80,572, Sole PI, “Monitoring Peer-to-Peer Systems for Anomalous Traffic,” Cisco, July 2007.
5. \$100,000, PI, “Classification of Distributed Hash Table methods, and their suitability to various application domains,” Cisco, November 2007. (with Co-PI Charlie Hu, Purdue University. My portion is \$50,000).
6. \$480,000, Sole PI, NSF CAREER, “Towards Automated and Assurable Enterprise Network Migration”, 2010-2015. Includes a \$80,000 supplement awarded as part of the “Computing in the Cloud” program which provides access to Microsoft Azure.
7. \$116,006, Sole PI, NSF, “EAGER: Enabling research on migrating enterprises to the cloud using GENI”, 2010-2012

8. \$50,000, Sole PI, “Abstracting and simplifying routing designs of operational enterprise networks”, Cisco, 2011-2012
9. \$400,000 PI (Purdue), NSF, “CSR: Medium: Collaborative Research: Architecting Performance Sensitive Applications for the Cloud”, 2012-2016. (Collaborative with PI Eugene Ng, Rice University, Co-PI Mohit Tawarmalani, Purdue, and Senior Personnel Dave Maltz, Microsoft Research and Kunwadee Sripanidkulchai NECTEC, Thailand. Total Grant is \$800,000. Purdue University’s share is \$400,000 and my portion is about \$338K).
10. \$46,500, Sole PI, Google Research Award, “Self configuring data stores for geo-replicated cloud Storage”, 2013-14. Includes a 2500\$ supplement for travel to Google Research at I/O.
11. \$45,000, Sole PI, NetApp Faculty Fellowship, “Workload-aware data placement for multi-cloud architectures”, 2013-14
12. \$25,000, Sole PI, AT&T Research Award, “Proxy assisted browsing in cellular networks for latency reduction”, 2015-16
13. \$47,500, Sole PI, Google Research Award, “QoSTuner: Auto-tuning QoS policies in SDNs”, 2015-16
14. \$20,000, Co-PI, AT&T Research Award, “ConFed: Coordination under federation”, 2016-17 (with Co-PI Mithuna Thottethodi. My portion is \$10K. The award was used to support Tariq Mahmood, a Ph.D student of Mithuna who performed the research for the project).
15. \$1,000,000, Co-PI, NSF, “PFI:BIC MAKERPAD: Making everyone a maker through intuitive Shape-Modeling and Personalized Fabrication”, 2016-19 (with PI Karthik Ramani, School of Mechanical Engineering and Co-PI Anant Iyer, Krannert). My portion is about \$97K.
16. \$500,000, Co-PI, NSF, “CSR: Small: SmartEdge for Low Latency and Consistent Mobile Web Applications”, 2016-20 (with PI Mithuna Thottethodi and Co-PI T.N. Vijaykumar. My portion is \$215,179).
17. \$30,000, PI, Facebook Faculty Research Award (for project in collaboration with Prof. Mohit Tawarmalani, Krannert School of Management)
18. \$300,000, Sole PI. NSF, “ICE-T:RC: Optimizing Internet video through support from the network edge”, 2018-21 (with Senior Personnel Marco Mellia, Politecnico di Torino, Italy, who is an unfunded collaborator).
19. \$742,001. Co-PI, NSF, “FMitF: Transplanting Syntax-Guided Synthesis to Computer Networks”, 2018-22 (with PI Xiaokang Qiu; My portion is \$381,283).
20. \$99,531. Sole PI. Cisco, “Comparing and selecting adaptive bit rate algorithms for video streaming in mobile environments”.
21. \$500,000, PI. NSF, “NeTS:Small: Ensuring network designs meet service-level objectives using an optimization-theoretic approach”, 2018-21 (with Co-PI Mohit Tawarmalani, Krannert. My portion is 299K).
22. \$600,000, PI. NSF, “CNS Core: Medium: Collaborative Research: Delivering next generation multi-perspective video at Internet scale”, 2020-23 (with Co-PI Alex Quinn. My portion is about half). Collaborative with USC (PI Ramesh Govindan and Co-PI Antonio Ortego). USC also budgeted 600K, and Purdue is the lead.
23. \$108,070. Sole PI. Cisco, “Optimizing Internet video as a value-added mobile edge service”, 2020-21

External Presentations, and Invited Talks:

This excludes talks given at conferences and workshops, and talks given prior to being a faculty at Purdue.

1. “Data-driven optimization of Internet Video Delivery”, Purdue ECE faculty seminar, June 2020.
2. Invited faculty participant in Facebook Systems & Network Faculty Summit, Virtual Event, August 2020

3. "Meeting stringent Internet performance requirements in the face of uncertainty", University of California, Berkeley, May 2019
4. "Ensuring network designs meet Service Level Objectives", Facebook, August 2018
5. "Scalable redundant execution at the edge for low-latency Web over cellular networks", Invited talk at Microsoft Research in the context of the workshop "At the bleeding edge of Intelligent Edges", Microsoft Research, Redmond, WA, July 2018
6. "Creating a low-latency mobile Web", Computer Science Department, Purdue University, November 2017
7. Invited faculty participant in Facebook Systems & Network Faculty Summit, Dallas, October 2017
8. "Validation of quantifiable network properties under uncertainty", Department of Computer Science, University of Southern California, May 2017
9. "Validation of quantifiable network properties under uncertainty", Department of Computer Science and Engineering, University of Washington, Seattle, May 2017
10. "Robust validation of network designs under uncertain demands and failures", Google, February 2017
11. "Robust guarantees for networks with flexible routing", Princeton University, June 2016
12. "Robust network design with flexible routing", NSF Algorithms in the Field (AiTF) Workshop on Algorithms for Software-Defined Networking, DIMACS Center, Rutgers University, May 2016
13. "Performance sensitive replication in geo-distributed cloud datastores", Huawei workshop on Networking and Big Data, Princeton NJ, December 2015
14. Invited faculty participant related to Network Verification at Microsoft Faculty Summit, Seattle, WA, July 2015 (no talk given)
15. Invited faculty participant to "Research Lab at Google I/O", San Francisco, CA, June 2014 (no talk given)
16. "Architecting Latency Sensitive Applications for the Cloud", Computer Science Department, Purdue University, October 2013
17. "Cloud Computing: Opportunities and Challenges", Indian Institute of Technology, Chennai, India, August 2013
18. "Architecting Latency Sensitive Applications for the Cloud", Twitter, San Francisco, California, July 2013
19. "Architecting Latency Sensitive Applications for the Cloud", Facebook, Menlo Park, California, July 2013
20. "Architecting Latency Sensitive Applications for the Cloud", Net App, Santa Clara, California, July 2013
21. "Architecting Latency Sensitive Applications for the Cloud", VMWare, Palo Alto, California, July 2013
22. "Modeling the Complexity of Enterprise Routing Design", IRTF Network Complexity Research Group, IETF, Atlanta, November 2012 (joint presentation with Xin Sun)
23. "Migrating Enterprises to the Cloud", Google, Bangalore, India, June 2011.
24. "Towards Systematic Management of Enterprise Networks," Cisco, San Jose, California, July 2010.
25. "Towards Systematic Management of Enterprise Networks," Google, Mountain View, California, July 2010.
26. "Towards Systematic Management of Enterprise Networks," IBM T.J. Watson Research Center, June 2010.
27. Invited Participant, GENI Experimenter Workshop, Princeton University, June 2010
28. "Towards Systematic Management of Enterprise Networks," University of California, Berkeley, April 2010.
29. "Towards Systematic Design and Configuration of Enterprise Networks," University of Massachusetts, Amherst, April 2010.
30. "Towards Systematic Management of Enterprise Networks," University of California, San Diego, March 2010.

31. "Towards Systematic Design and Configuration of Enterprise Networks," Stanford University, February 2010.
32. "Towards Systematic Design and Configuration of Enterprise Networks," Columbia University February 2010.
33. "Towards Systematic Design and Configuration of Enterprise Networks," University of Michigan, Ann Arbor, December 2009.
34. "Towards Systematic Design and Configuration of Enterprise Networks," Rice University, December 2009.
35. "Towards Systematic Design of Enterprise Networks," Invited talk at the DIMACS Workshop on Designing Networks for Manageability, Rutgers University, November 2009.
36. "Towards Systematic Design of Enterprise Networks," Invited talk at the NSF Workshop on Assurable and Usable Security Configuration, Washington D.C., August 2008.
37. "Peer-to-Peer Streaming: Opportunities and Challenges," Department of Computer Science, University of Illinois, Urbana-Champaign, April 2008.
38. "Peer-to-Peer Streaming: Opportunities and Challenges," Cisco Systems, June 2007.
39. "An Overview of Research at the Internet Systems Laboratory," Microsoft Research, Bangalore, India, July 2007.
40. "Peer-to-Peer Streaming: Opportunities and Challenges," Lucent Bell Laboratories, Bangalore, July 2007.
41. "Automated Configuration Generation via Abstraction," Invited talk at the LISA Configuration Workshop, Washington D.C., December 2006.

Synergistic Activities:

1. **End System Multicast:** Played a leadership role in the End System Multicast project. The project pioneered live streaming using peer-to-peer systems, which became a mainstream research area, and attracted significant industry interest. Received the ACM SIGMETRICS Test of Time Award in 2011 for this work. The award recognizes an influential performance evaluation paper whose impact is still felt 10-12 years after its initial publication. The paper originally published in ACM Sigmetrics 2000 and its associated journal version have together received over 3600 citations on Google Scholar.
2. **Release of Datasets:**
 - a. The (anonymized) configurations of switches and routers of the Purdue University network has been made publically available to academic researchers at <https://engineering.purdue.edu/~isl/network-config/>. This is one of the first and few publically available sources of network configuration data, and has already been requested by over fifty research groups within and outside the United States, and is being used for research related to Software Defined Networking and Network verification.
 - b. Bandwidth traces of real-world Internet video sessions to enable research in Internet video streaming have been released to the community along with the Oboe paper (Sigcomm 2018) at: <https://github.com/USC-NSL/Oboe>. The paper has already seen 122 Google Scholar citations since publication.
3. **Industry Outreach:** Has extensively participated in industry outreach, and technology transfer activities. Some notable successes include:
 - a. The work on Presto for configuration management (JSAC09) has led to a system deployed in production within AT&T. The work on verification of quality of service configuration policies (Sigcomm09) has led to a joint patent awarded in 2014.
 - b. Spent a year at Google (2011-12) on leave as Visiting Researcher working on Google App Engine, one of the premier cloud computing platforms.

- c. The work on reducing mobile web front-end latencies (HotMobile14, Conext14, Mobicom17) was done in collaboration with AT&T (a joint patent has been awarded). The project on tackling whole page experience in edge caching was done in collaboration with Akamai, a prominent Content Delivery Network (Sigmetrics 2016), and was of direct interest to CDN operators.
 - d. The work on CDN Edge Caching and Internet video streaming performance was featured in an internal Cisco [blog https://blogs.cisco.com/sp/cdn-caching-and-video-streaming-performance](https://blogs.cisco.com/sp/cdn-caching-and-video-streaming-performance)
 - e. The joint work on cloud configuration selection (Infocom 2015) done in collaboration with Rice University influenced a continuous price-performance benchmarking approach of the cloud by Burstorm Inc. a cloud technology platform company. The report may be accessed here: <https://www.burstorm.com/price-performance-benchmark/1st-Continuous-Cloud-Price-Performance-Benchmarking.pdf>
 - f. Has extensively given talks in the industry to disseminate research findings including IBM, Cisco, Google, VMWare, NetApp, Facebook and Twitter. Has been invited to faculty summits hosted by Microsoft, Facebook and Google.
- 4. Adoption of curriculum material:** Has developed a security course, whose laboratory projects were adopted in the 4th Edition of the book “Cryptography and Network Security” authored by William Stallings.

Professional Service:

- Associate Editor, IEEE/ACM Transactions on Networking (2017-2021)
- Organizing Committees of Conferences and Workshops:
 - Area Technical Program Chair, IEEE Infocom (2017, 2018)
 - Technical Program Co-Chair, Internet Management Workshop/Workshop on Research in Enterprise Networks (co-located with the Usenix NSDI conference), April 2010.
 - Publicity Chair, ACM CoNext, 2013
 - Student Travel Grant Chair, ACM CoNext, 2008.
- Proposal Review Panel:
 - NSF, 2020
 - NSF, 2020
 - NSF, 2019
 - NSF, 2018
 - NSF, 2018
 - Reviewer, Swiss National Science Foundation (2017)
 - NSF, 2014
 - NSF, 2013
 - DOE, 2013
 - NSF, 2009.
- Technical Program Committee member for the following conferences and workshops:
 - ACM SIGMETRICS 2021
 - ACM Symposium on Cloud Computing (SoCC) 2021
 - ACM Multimedia Systems 2021
 - ACM CoNext 2021, 2013, 2009, 2008
 - ACM SIGCOMM 2020, 2008; Poster Committee: 2019, 2018, 2013, 2010, 2007

- ACM/IEEE Symposium on Edge Computing, 2020, 2019, 2018
 - IEEE INFOCOM: 2019, 2018, 2017, 2016, 2015, 2014, 2013, 2012, 2011, 2010, 2009, 2008; Distinguished Member in 2015.
 - Usenix NSDI, 2014
 - ACM Multimedia, 2014, 2013, 2011
 - IEEE ICDCS, 2013, 2012, 2006
 - IEEE ICNP, 2012
 - NOSSDAV 2012, 2011, 2010, 2009
 - Usenix Hot Topics in Internet, Cloud and Enterprise Management, 2012 (in conjunction with Usenix NSDI)
 - Usenix HotCloud, 2011
 - IEEE Hot Topics in Multimedia Delivery, 2011
 - IFIP Networking 2010.
 - ACM Workshop on Assurable and Usable Security Configuration (in conjunction with ACM CCS), 2010, 2009
 - IEEE Workshop on Grid and P2P Systems and Applications, 2009.
 - IEEE NPSec, 2008 and 2007 (in conjunction with IEEE ICNP).
 - Internet Management Workshop, 2008 (in conjunction with IEEE ICNP) and 2007 (in conjunction with ACM Sigcomm)
 - IEEE Workshop on Automated Network Management, 2008 (in conjunction with IEEE Infocom).
 - IEEE IWQoS, 2007.
 - IEEE Workshop on P2P Multicasting, 2007.
 - International Workshop on Multimedia Systems and Networking, 2006.
 - IEEE ICCCN, 2006.
- Has served on (or is serving on) the Ph.D/Masters Thesis Committees of 53 students (49 at Purdue, and 4 students outside Purdue as an external Ph.D Committee member).
 - Referee for several journals and conferences including ACM Computer Communication Review; IEEE/ACM Transactions on Networking. ACM Transactions on Computer Systems; IEEE Transactions on Multimedia; IEEE Transactions on Parallel and Distributed Systems; IEEE Networks; IEEE Journal on Selected Areas in Communication; Elsevier Computer Networks Journal; ACM Multimedia; RTSS; IPTPS; HotNets.

Departmental Service:

- Graduate Admissions Committee (2017-21, 2005-11)
- ECE Faculty Search Committee (2019-20)
- Served as ECE faculty host, for Dr. Robert Kahn (co-inventor of TCP/IP), Purdue Engineering Distinguished Lecture Series, 2018. Collaborated with Professor Saurabh Bagchi to craft the theme of the panel, and served as a panelist.
- Curriculum Committee (2013 – 2016)
- Lectures in ECE 694 on “How To PhD” (Sp16), “How to write papers” (Sp13, Fa13, Sp14, Fa15, Sp16)
- New graduate student orientation: Presented Computer Engineering course overview, Fall16
- Talk in Academic and Professional Development of Purdue Graduate Student Government (APD-PGSG) on “How To Ph.D”, Spring 2016
- Admissions Committee, CERIAS Interdisciplinary Graduate Program In Information Security (INSC), Spring 2016

- ECE Faculty Search Committee (Spring 2014)
- Qualifying Examination Committee (2007-09)

Teaching:

New courses created at Purdue ECE:

1. Created *ECE 495F, "Introduction to Computer Security,"* Spring 2005, a new course on computer security targeted at undergraduate students (primarily seniors). The course is now offered as ECE 404.
2. Created *ECE 50863, "Computer Network Systems,"* Spring 2009-11,13-14,16-19, an introductory graduate course on computer networking emphasizing a systems and experimental approach.
3. Created *ECE 695B, "Advanced Computer Networks,"* Spring 2006,2008, an advanced graduate computer networking course later redesigned as a 500 level course.
4. Created *ECE 695U, "Principles of Network Management Systems,"* Spring 2006,2007. A graduate course co-created and co-taught with Prof. Doug Comer in 2006. Sanjay significantly revamped the course and taught it again in 2007 supported by a curriculum development grant from Cisco.

Courses taught at Purdue ECE

1. *Introduction to Computer Networks Fall 2005-10, Fall 2012-20.* This is an introductory course in computer networking for undergraduate students (juniors and seniors). Sanjay significantly revamped the course to bring in a stronger systems focus, and place a greater emphasis on programming projects.
2. *Computer Network Systems (ECE 50863 and ECE 595):* Spring 2009-11, 2013-14, 2016-20
3. *Advanced Computer Networks (ECE 695B),* Spring 2006, Spring 2008
4. *Principles of Network Management Systems (ECE 695U),* Spring 2006, Spring 2007
5. *Introduction to Computer Security (ECE 495F)* Spring 2005
6. *EPICS, Fall 2014,* Co-Advised the Greater Lafayette Area Special Services Team with Dr. Carla Zoltowski. The team helps improve the life of special needs children by implementing a variety of assistive computer engineering technology, with a special emphasis on mobile applications.

Undergraduates Supervised on Research Projects:

I have supervised students on independent study projects, and as part of the Summer Undergraduate Research Fellowships (SURF) program at Purdue University including:

1. Nathan Cohen (Purdue University, CS). Supervised as part of CS 490 and ECE 496, Spring and Fall 2020
2. Harsh Agawal (IIT, Hyderabad) Supervised as part of the PURE program, 2018
3. Touheed Anwar Atif (IIT, Hyderabad) Supervised as part of the PURE program, 2016. Touheed joined the Ph.D program in the University of Michigan (ECE)
4. Akash Kumar (2015-16)
5. Zaiwei Zhang (2014-15). Zaiwei joined the Ph.D program at University of Texas, Austin (ECE) in Fall 2015
6. Zisheng Liao (2014 Summer and Fall). Zisheng received Ph.D offers from Purdue, Princeton and UIUC. He chose to go to industry and later joined an online Masters program at UIUC.

7. Jiawei Wang (2013 Summer, Computer Science). Jiawei joined University of Pennsylvania, Computer Graphics and Game Technology Masters Program, Fall 2014
8. Jinliang Wei (2011). Co-author of paper that appeared in SafeConfig 2011. Jinliang joined the Ph.D program at the School of Computer Science, Carnegie Mellon
9. Suan-Aik Yeo (2009). One of 2 students nominated by Purdue ECE for the Undergraduate CRA award in 2009. Received first place in the 2010 Purdue Undergraduate Research Poster Symposium in the category "Best Abstract Award - Mathematics and Computational Science."
10. Kee Shen Quah (2010): Joined Graduate program at the University of Michigan, 2011.
11. Samuel Oshin (2011)
12. Brian Crone (2011)
13. Andrew Huff (2011)
14. Upsham Dawra (2010)
15. Keywhan Chung (2009)
16. Ankit Kuwadekar (2008, Computer Science)
17. Amey Rane (2008).