# RAVI SUNDARAM

Northeastern University
College of Computer and Information Science
242 WVH, 360 Huntington Ave
Boston, MA 02115
Email: koods@ccs.neu.edu
http://www.ccs.neu.edu/groups/faculty/koods.html

## RESEARCH INTERESTS

To solve problems in the areas of *performance*, *security* and *ubiquity* in the context of the Internet, by designing new algorithms and implementing novel systems.

## EDUCATION

**Massachusetts Institute of Technology** **Cambridge, MA**
**Ph.D., Electrical Engineering and Computer Science** **August 1996**
Thesis: Interactive proof systems and approximation algorithms for optical networks
Advisor: Professor Michael Sipser, Department of Mathematics, MIT

**Massachusetts Institute of Technology** **Cambridge, MA**
**M.S., Electrical Engineering and Computer Science** **August 1993**
Thesis: Spanning trees short or small
Advisor: Professor Michael Sipser, Department of Mathematics, MIT

**Indian Institute of Technology** **Madras, India**
**B.Tech., Computer Science and Engineering** **July 1991**
President's Gold Medallist – top-graduating student across all majors at IIT Madras

## EXPERIENCE

**Northeastern University, College of Computer and Information Science** **Boston, MA**
**Associate Professor** **September 2003 – current**

- Confluent routing - research to determine the capacity of the Internet, involves the development of new routing algorithms that extend the celebrated work on flows by Ford-Fulkerson.
- Security of cyber infrastructure – research to determine the vulnerability of the Internet at the level of entire cities, involves developing and implementing algorithms for doing hop-limited probing of the Internet.
- Wireless networking – research to improve the capacity of wireless networks by scavenging energy from failed transmissions. Requires the development of a new foundational abstraction for wireless communication.

**Massachusetts Institute of Technology & Akamai Technologies, Inc** **Cambridge, MA**
**Research Scientist** **October 2002 – September 2003**

- Working on research problems in performance (measurement and improvement), algorithms for (ad-hoc and other communication) networks, and mobile and distributed systems.

**Akamai Technologies** **Cambridge, MA**
**Product Manager** **July 2001 – September 2002**

- Managed three product lines that collectively generated over $20 million annual revenue – Akamai Infrastructure Management and Analysis (user interface), Edgescape (IP intelligence) and Akamai Secure Content Delivery (SSL)
- Created multi-quarter roadmap for Engineering based on customer requirements and competitive demands and generated technical white papers and service descriptions for Sales
- Wrote grant proposals to defense agencies in the areas of security and cyber-surveillance

**Director of Engineering** **July 1999 – June 2001**

- Managed a group that grew from 5 to 35 – 23 developers and 12 scientists(PhD) over 2 years
- Led teams to deliver four new products from concept and design through to launch. As chief architect was responsible for all technical aspects of the products end-to-end – algorithmic foundations and system constraints to quality assurance and operationalization. Wrote code.
  - Mapper – Akamai's core and proprietary technology for directing browsers to the appropriate Akamai servers
  - FirstPoint – Global traffic management service in use by sites such as Yahoo!, Microsoft and Verizon; directs traffic to and load-balances between content providers' own web site mirrors
  - Edgescape – IP intelligence product in use by content providers such as Yahoo!, Microsoft and Nike; given an IP address returns a set of attributes ranging from geographic location to speed of connectivity, device type to number of users
  - Enhanced DNS – Secure and fault-tolerant DNS infrastructure product implementing BGP based anycast that is closely integrated with Akamai's content delivery service; used by sites such as Yahoo!, Victoria's Secret and BestBuy
- Built a reliable, scalable high-performance network for http, https and streaming media (all three formats – Windows Media, Real and Apple's QuickTime) content
- Played a key role in the build out of one of the larger distributed systems in the world – over 13,000 servers in 1500 networks in over 65 countries

**Research Scientist & Developer** **January 1999 – July 1999**

- Designed and implemented the proprietary algorithms for mapping – Akamai's core system
- Managed a team that grew to 5 – 3 developers and 2 scientists (PhD)

**Redwood Risk Management, Inc** **Boston, MA**
**Software Developer** **November 1998 – December 1998**

- Implemented thread-based Java middleware for generating summary exposure reports

**Delta Global Trading L.P.** **Boston, MA**
**Bond Arbitrageur** **July 1996 – October 1998**

- Developed and traded a wide range of proprietary fixed income strategies – from cross currency volatility and futures squeezes to statistical "arbitrage" and EMU convergence

**Center for Nonlinear Sciences** **Los Alamos, NM**

**Finance Intern** **June 1995 – August 1995**

- Implemented HJM-based two-factor model for pricing interest-rate derivatives

**Bankers Trust, Inc** **New York, NY**
**Finance Intern** **June 1994 – August 1994**

- Developed automated system to estimate year-end turn effect from futures prices

## AWARDS AND HONORS

- Best Paper Award International Conference on Distributed Computing Systems, IEEE ICDCS (2006)
- Most Valued Employee award, Akamai Technologies, Inc, (2000)
- President's Gold Medal for 1st rank, IIT Madras (1991)
- 8th All-India in the highly competitive IIT Joint Entrance Exam (1987)
- 1st in the Indian National Mathematical Olympiad (1986)
- Top 20 all-India in the National Scholarship Examination in Physics (1986)

## TEACHING

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2011**
Course: Advanced Algorithms (CS7800)
Attendance: 7 MS and 12 PhD students

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2011**
Course: Discrete Structures (CS1800)
Attendance: 86 freshman students

**Northeastern University** **Boston, MA**
**Instructor** **Spring 2011**
Course: Logic and Computation(CS2800)
Attendance: 41 freshman students

**Northeastern University** **Boston, MA**
**Instructor** **Spring 2011**
Course: Network Security (CS4740/6740)
Attendance: 8 undergraduates and 44 MS students

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2010**
Course: Fundamentals of Networks (CS4700/5700)
Attendance: 5 undergraduates and 35 MS students

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2008**
Course: Wireless Networks (CSG250)
Attendance: 49 MS students

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2008**
Course: Undergraduate Algorithms (CSU690)
Attendance: 24 undergraduate seniors

**Northeastern University** **Boston, MA**
**Instructor** **Summer 2008**
Course: Network Security (CSG254)
Attendance: 12 undergraduate seniors and 30 MS and PhD students

**Northeastern University** **Boston, MA**
**Instructor** **Spring 2008**
Course: Network Algorithms (CSG359)
Attendance: 5 MS and 8 PhD students

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2007**
Course: Network Algorithms (CSG399)
Attendance: 4 MS and 8 PhD students

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2007**
Course: Network Security (CSG254/CSU645)
Attendance: 27 undergraduate seniors, 8 MS and 2 PhD students

**Northeastern University** **Boston, MA**
**Instructor** **Spring 2007**
Course: Network Security (CSU645)
Attendance: 29 undergraduate seniors
Materials: http://www.ccs.neu.edu/course/csu645

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2006**
Course: Fundamentals of Computer Networks (CSG150)
Attendance: 35 MS and 6 PhD students
Materials: http://www.ccs.neu.edu/course/csg150

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2005**
Course: Network Security (CSU645)
Attendance: 21 undergraduate seniors
Materials: http://www.ccs.neu.edu/course/csu645

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2005**
Course: Advanced Algorithms (CSG713)
Attendance: 10, graduate
Materials: http://www.ccs.neu.edu/course/csg713

**Northeastern University** **Boston, MA**
**Instructor** **Spring 2005**
Course: Network Security (CSU645)

Attendance: 20, undergraduate seniors
Materials: http://www.ccs.neu.edu/course/csu645

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2004**
Course: Fundamentals of Computer Networks (CSG150)
Attendance: 15 MS and 3 PhD students
Materials: http://www.ccs.neu.edu/course/csg150

**Northeastern University** **Boston, MA**
**Instructor** **Spring 2004**
Course: Computer and Network Security (CSU650)
Attendance: 17 undergraduate seniors
Materials: http://www.ccs.neu.edu/course/csu650

**Northeastern University** **Boston, MA**
**Instructor** **Fall 2003**
Course: Special Topics: Security (CSU650)
Attendance: 42 undergraduate seniors
Materials: http://www.ccs.neu.edu/course/csu650 Developed new undergraduate course.

**Massachusetts Institute of Technology** **Cambridge, MA**
**Instructor** **Spring 2002**
Course: Topics in Theoretical Computer Science – Internet Research Problems (18.996)
Attendance: 30 graduate and undergraduate
Materials: http://ocw.mit.edu/18/18.996/s02/index.html courtesy MIT's OpenCourseWare

**Akamai Technologies, Inc** **Cambridge, MA**
**Instructor** **Fall 2001**
Course: Internet Algorithms
Attendance: 10 – 20 Akamai employees, developers and scientists
Materials: hosted on Akamai-internal website, also webcast live using Akamai technologies

**Massachusetts Institute of Technology** **Cambridge, MA**
**Teaching Assistant** **1994, 1995**
Course: Mathematics for Computer Science (6.042)
Attendance: 90, undergraduate
Instructors: Professors Tom Leighton and Charles Leiserson
Materials: Developed content – lecture materials and problem sets – for brand new course

## STUDENTS

### PhD

1. Jiangzhuo Chen, "Confluent Flows," (co-advisor) graduated September 2005.
2. Xin Liu, "Cross-layer Design for Cooperative and Adversarial Wireless Networks," (thesis advisor) completed Fall 2007.
3. Fangfei Zhou "New Cloud Architectures for the Next Generation Internet" (thesis advisor) completed Spring 2012.

**Masters**

1. Daria Antonova, "Managing a Portfolio of Overlay Paths," graduated April 2005.
2. Gilberto Molina, "Prestar: A website for borrowing and lending," graduated April 2006.

**Bachelors**

1. Keith Bertolino, "Jamming Steganography using Steganography," graduated April 2008. See article in IEEE Spectrum.
2. David Baldwin, "On some matching problems," graduated August 2006.
3. Nathan Faber, "On Locating Parked Vehicles," April 2006. See article in Boston Globe on this work. Also, "MOVARTO: Server Migration across Networks using Route Triangulation and DNS," April 2007.

## FUNDING

1. $650,000 DARPA subcontract from BAE, joint with co-PIs Agnes Chan, Guevara Noubir and Rajmohan Rajraman, 2011-2013
2. $180,000 IARPA subcontract from Argon/Boeing, 2011-2012
3. $180,000 Northeastern-RBC grant, 2012 joint with co-PIs Jay Aslam and Nikos Passas.
4. $60,000 Microsoft grant, 2010-2011.
5. $100,000 SBIR subcontract from Mayflower, 2009-2010.
6. $200,000 NSF TF, joint with co-PI Rajmohan Rajaraman, 2006-2009.
7. $199,000 NSF MRI, joint with co-PIs Gene Cooperman, Javed Aslam, Jennifer Dy and David Kaeli, 2006-2008.
8. $15,000 Air Force subcontract through BBN, single PI, 2006.
9. $50,000 Microsoft grant,"Trustworthy Computing," joint with co-PI Guevara Noubir, 2006-2007.
10. $380,000 DARPA grant, "SPREAD," joint with co-PIs Agnes Chan, Guevara Noubir and Rajmohan Rajaraman, 2005-2007.
11. $114,000 DARPA grant "Internet Simulation," single PI, 2004-2006.
12. $25,000 Madhav Anand gift, "Summer Internship Program," single PI, 2005-2006.

## PUBLICATIONS AND PRESENTATIONS

### JOURNALS

1. "(Almost) Tight bounds and existence theorems for confluent flows," with J. Chen, R. Kleinberg, L. Lovasz, R. Rajaraman and A. Vetta. *Journal of the ACM*, 54(4), 2007.
2. "Meet and merge: Approximation algorithms for confluent flows," with J. Chen and R. Rajaraman. *Journal of Computer and System Sciences*, 72(3), pp. 468-489, 2006.
3. "Alternation in interaction," with M. Kiwi, C. Lund, A. Russell and D. Spielman. *Computational Complexity*, 9(3-4), pp. 202-246, 2000.
4. "Approximating Latin square extensions," with A. Russell and S. R. Kumar. *Algorithmica*, 24(2), pp. 128-138, 1999.
5. "Improving minimum cost spanning trees by upgrading nodes," with S. O. Krumke, M.V. Marathe, H. Noltemeier, R. Ravi, S.S. Ravi and H-C. Wirth. *Journal of Algorithms*, 33(1), pp. 92-111, 1999.

6. "Improving spanning trees by upgrading nodes," with S. O. Krumke, H. Noltemeier, H-C. Wirth, M.V. Marathe, R. Ravi and S.S. Ravi. *Theoretical Computer Science*, 221(1-2), pp. 139-155, 1999.
7. "A note on the asymptotics and computational complexity of graph distinguishability," with A. Russell. *Electronic Journal of Combinatorics*, 5(1), R23, 1998 (http://www.combinatorics.org/Volume_5/v5i1toc.html).
8. "Symmetric alternation captures BPP," with A. Russell. *Computational Complexity*, 7(2), pp. 152-162, 1998.
9. "Bicriteria network design problems," with M.V. Marathe, R. Ravi, S.S. Ravi, D. Rosenkrantz and H. Hunt. *Journal of Algorithms*, 28(1), pp. 142-171, 1998.
10. "A note on embedding complete graphs into hypercubes," with M. Klugerman and A. Russell. *Discrete Mathematics*, 186, pp. 1-3, 1998.
11. "A note on optical routing," with R. Panigrahy, A. Russell and S. R, Kumar. *Information Processing Letters*, 62, pp. 295-300, 1997.
12. "Service-constrained network design problems," with M. V. Marathe and R. Ravi. *Nordic Journal of Computing*, 3(4), pp. 367-387, 1996.
13. "Spanning trees short or small," with R. Ravi, M.V. Marathe, D. Rosenkrantz and S.S. Ravi. *SIAM Journal of Discrete Mathematics*, 9(2), pp. 178-200, 1996.
14. "The relationship between probabilistically checkable debate systems, IP and PSPACE," with A. Russell. *Information Processing Letters*, 53(2), pp. 61-68, 1995.
15. "Treewidth of circular-arc graphs," with K.S. Singh and C.P. Rangan. *SIAM Journal of Discrete Mathematics*, 7(4), pp. 647-655, 1994.
16. "Efficient parallel shuffle recognition," with M. Nivat, C.P. Rangan and A. Saoudi. *Parallel Processing Letters*, 4(4), pp. 455-463, 1994.
17. "Optimal path cover problem on block graphs and bipartite permutation graphs," with R. Srikant, K.S. Singh and C.P. Rangan. *Theoretical Computer Science*, 115(2), pp. 351-357, 1993.

**CONFERENCES**

1. ``Optimization of Directional Antenna Network Topology in Airborne Networks," with Gregory Hadynski, Seoungbum Lee, Gowri Rajappan, Xiaofei Wang and Fangfei Zhou. MILCOM 2010.
2. ``Policy-Agile Encrypted Networks Via Secure Function Computation," with Rajesh Krishnan. MILCOM 2010.
3. ``HARD-DNS: Highly-Available Redundantly-Distributed DNS," with Carlos Gutierrez, Rajesh Krishnan and Fangfei Zhou. MILCOM 2010.
4. "Existence theorems and approximation algorithms for generalized network games," with V. Anil Kumar, R. Rajaraman and Z. Sun. To appear in Proceedings of IEEE ICDCS, 2010
5. "Algorithms for constrained bulk-transfer of delay-tolerant data," with P. Chhabra, V. Erramilli, N. Laoutaris and P. Rodriguez. To appear in Proceedings of IEEE ICC, 2010.
6. "Reducibility among fractional stability problems," with S. Kintali, L. Poplawski, R. Rajaraman and S. Teng. Proceedings of ACM FOCS, pp. 283-292, 2009.
7. "Delay tolerant bulk data transfers on the Internet," with N. Laoutaris, G. Smaragdakis and P. Rodriguez. Proceedings of ACM SIGMETRICS, pp. 229-238, 2009.
8. "Preprocessing DNS log data for effective data mining," with M. Snyder and M. Thakur. Proceedings of ICC, pp. 1-5, 2009.

9. "Jamming steganography using steganography," with K. Bertolino. Proceedings of IEEE International Conference on Technologies for Homeland Security, 2008.
10. "Bounded budget connection (BBC) games or how to make friends and influence people on a budget," with N. Laoutaris, L. Poplawski, R. Rajaraman and S. Teng. Proceedings of ACM PODC, pp. 165-174, 2008.
11. "A Game-Theoretic Framework for Bandwidth Attacks and Statistical Defenses," with M. Snyder and M. Thakur. To appear in Proceedings of IEEE LCN (Local Computer Networks) Conference, 2007.
12. "SPREAD: Foiling Jammers using Multi-layer Agility," with X. Liu, G. Noubir and S. Tan. IEEE INFOCOM Minisymposium, 2007.
13. "MOVARTO: Server Migration across Networks using Route Triangulation and DNS," with N. Faber. VMWorld, San Francisco, 2007.
14. "On completing Latin Squares," with I. Hajirasouliha, H. Jowhari and Ravi Kumar. Proceedings of STACS, LNCS 4393, pp. 524-535, 2007.
15. "Scaling laws for the Internet over Urban Regions," with V. S. Anil Kumar, M. V. Marathe, M. Thakur and S. Thulasidasan, CAIDA's ISMA WIT, (Short Paper) 2006.
16. "Group-independent Spanning Tree for Data Aggregation in Dense Sensor Networks," with L. Jia, G. Noubir and R. Rajaraman. Proceedings of IEEE DCOSS, LNCS 4026, pp. 282-304, 2006.
17. "Steganographic Communication in Ordered Channels," with Ch. Ravi Chandra, A. Kumarasubramaniam, R. Manokaran, G. Noubir and C. Pandu Rangan. Proceedings of Information Hiding IH 2006.
18. "The Confluent Capacity of the Internet: Congestion vs. Dilation," with J. Chen, M. V. Marathe and R. Rajaraman. Proceedings of IEEE ICDCS 2006. (Best Paper Award)
19. "Towards a Topology Generator Modeling AS Relationships," with X. Dimitropoulos, G. Riley and D. Krioukov. Proceedings of IEEE ICNP (Short Paper) 2005.
20. "Unweaving a web of documents," with R. Guha, Ravi Kumar and D. Sivakumar. Proceedings of KDD, pp. 574-579, (Short Paper) 2005.
21. "Expressiveness and complexity of crosscut languages," with K. Lieberherr and J. Palm. Proceedings of FOAL 2005.
22. "Universal approximations for TSP, Steiner tree and set cover," with L. Jia, G. Lin, G. Noubir and R. Rajaraman. Proceedings of STOC, pp. 386-395, 2005.
23. "Minimum energy accumulative routing in wireless networks," with J. Chen, L. Jia, X. Liu and G. Noubir . Proceedings of INFOCOM, vol. 3, pp. 1875-1886, 2005.
24. "A methodology for estimating inter-domain web traffic demand," with A. Feldmann, O. Maennel, N. Kammenhuber, B. Maggs and R. de Prisco. Proceedings of *Internet Measurement Conference (IMC)*, pp. 322-335, 2004.
25. "Managing a portfolio of overlay paths," with D. Antonova, A. Krishnamurthy and Z. Ma. Proceedings of *Networking and Operating Systems Support for Digital Audio and Video* (*NOSSDAV)*, pp. 30-35, 2004.
26. "Batching Schnorr identification scheme with applications to privacy-preserving authorization and low-bandwidth communication devices," with R. Gennaro, D. Leigh and W. Yerazunis. Proceedings of *AsiaCrypt*, LNCS 3329, pp. 276-292, 2004.
27. "(Almost) Tight bounds and existence theorems for confluent flows," with J. Chen, R. Kleinberg, L. Lovasz, R. Rajaraman and A. Vetta. Proceedings of *Symposium on Theory of Computing (STOC)*, pp. 529-538, 2004.
28. "Meet and merge: approximation algorithms for confluent flows," with J. Chen and R. Rajaraman. *Symposium on Theory of Computing (STOC)*, pp. 373-382, 2003.

29. "Improving spanning trees by upgrading nodes," with S.O. Krumke, M.V. Marathe, H. Noltemeier, R. Ravi, S.S. Ravi and H-C. Wirth. *International Colloquium on Automata, Languages and Programming (ICALP)*, LNCS 1256, pp. 281-291, 1997.
30. "Faster algorithms for optical switch configurations," with A. Russell and S.R. Kumar. *IEEE International Conference on Communications (ICC)*, pp. 1320-1324, 1997.
31. "Approximating Latin square extensions," with A. Russell and S. R. Kumar. *International Conference on Computation and Combinatorics (COCOON)*, LNCS 1090, pp. 280-289, 1996.
32. "Service-constrained network design problems," with M.V. Marathe and R. Ravi. *Scandinavian Workshop on Algorithm Theory (SWAT)*, LNCS 1097, pp. 28-40, 1996.
33. "Bicriteria network design problems," with M.V. Marathe, R. Ravi, S.S. Ravi, D. Rosenkrantz, and H. Hunt. *International Colloquium on Automata, Languages and Programming (ICALP)*, LNCS 944, pp. 487-498, 1995.
34. "Symmetric alternation captures BPP," with A. Russell. *Workshop on Interactive Proof Systems*, Weizmann Institute, Israel, 1995.
35. "Alternation in interaction," with M. Kiwi, C. Lund, A. Russell and D. Spielman. *IEEE Conference on Structure in Complexity Theory*, pp. 294-303, 1994.
36. "Spanning trees short or small," with R. Ravi, M.V. Marathe, D. Rosenkrantz and S.S. Ravi. *ACM-SIAM Symposium on Discrete Algorithms (SODA)*, pp. 546-555, 1994.
37. "Efficient parallel shuffle recognition," with M. Nivat, C.P. Rangan, G.D.S. Ramkumar and A. Saoudi. *International Parallel Processing Symposium (IPPS)*, pp. 112-115, 1992.
38. "Treewidth of circular-arc graphs," with K.S. Singh and C.P. Rangan. *Workshop on Algorithms and Data Structures (WADS)*, LNCS 519, p. 41, 1991.

**BOOK CHAPTERS**

1. "Improved results on service-constrained network design problems," with M.V. Marathe and R. Ravi. *Network Design: Connectivity and Facilities Location*, P.M. Pardalos and D.Z. Du, editors, DIMACS Series, Vol. 40, AMS, pp. 269-276, 1998.

**PATENTS**

1. "Low bandwidth zero knowledge authentication protocol and device," with W. Yerazunis. Patent #: 7,245,718. Granted July 17, 2007.
2. "Methods and systems for network attack detection and prevention through redirection," with W. Milliken. Filed June 2003.
3. "Method and system for providing on-demand content delivery for an origin server," with H. Rahul. Patent #: 7,136,922. Granted November 14, 2006. Continuation patent #: 7,376,736. Granted May 20, 2008.
4. "Method and system for protecting websites from public Internet threats," with M. Afergan, A. Ellis and H. Rahul. Patent #: 7,260,639. Granted August 21, 2007.
5. "Global load balancing across mirrored data centers," with F. T. Leighton, D. Lewin, R. Dhanidina, R. Kleinberg, M. Levine, B. Maggs, H. Rahul, S. Thirumalai, J. Parikh and Y. Yerushalmi. Patent #: 7,111,061. Granted Sep 19, 2006.

6. "Method for predicting file download time from mirrored data centers in a global computer network," with F. T. Leighton, A. Soviani, M. Levine, A. Parker, S. Hanono-Wachman and A. Berger. Patent #: 7,096,263. Granted Aug 22, 2006.
7. "Method for generating a network map," with F. T. Leighton, M. Levine and A. Soviani. Patent #: 7,251,688. Granted July 31, 2007.
8. "Optimal route selection in a content delivery network," with C. Bornstein, T. Canfield, G. Miller and S. Rao. Patent #: 7,274,658. Granted Sep 25, 2007.
9. "Method and system for providing content providers with information about how their users access the Internet." Filed August 18, 2000.
10. "Network performance monitoring in a content delivery service." Filed July 20, 2000.
11. "System and Method for Virtual Server Migration across Networks using DNS and Route Triangulation," with N. Faber. Application #: 12/180,813. Filed July 28, 2008.
12. "Jamming Steganography using Steganography," with K. Bertolino. Provisional: INV-0949, filed May 5, 2009.
13. "Offering Incentives in a Flat Rate Charging System," with P. Chhabra, N. Laoutaris and P. Rodriguez. Application #: 12/832,417. Filed June 8, 2010.

2 more patent applications currently in the process of being drafted and filed.

**INVITED TALKS**

1. "Search-based complexity classes," Boston University, Boston, MA, April 2010.
2. "Stealing Cycles in the Clouds," Microsoft Research, Redmond, WA, April 2010.
3. "Game theory and the Internet," Telefonica R&D, Barcelona, Spain, March 2008.
4. "Confluent Capacity of the Internet, University of Massachusetts Boston, Boston, MA, April 2007.
5. "Net and the City," Virginia Tech, Blacksburg, VA, January 2006.
6. "Net and the City," opening speaker in Dan Rosenkrantz Festschrift, SUNY Albany, New York, USA, May 2005.
7. "CDNs – Principles and Practice," University of Glasgow, Glasgow, Scotland, March 2005.
8. "Net and the City," NU Innovation Series, Northeastern University, Boston, MA, February 2005.
9. "Algorithms for CDNs and Sensor Networks," HP, Palo Alto, USA, November 2004.
10. "Algorithms for CDNs and Sensor Networks," BBN, Cambridge, Massachusetts, USA, October 2004.
11. "Confluent flows," CSAIL MIT, Cambridge, Massachusetts, USA, May 2004.
12. "FirstPoint – Location-aware mapping," Microsoft Research Redmond, Washington, USA, March 2004.
13. "Content delivery," RPI Troy, New York, USA, November 2003.
14. "The mapping problem," SUNY Albany, New York, USA, November 2003.
15. "Some problems of content delivery," IBM Hawthorne, New York, USA, April 2003.
16. "Content Delivery Networks – Practice and Theory," Center for Discrete Mathematics and Theoretical Computer Science (DIMACS), Rutgers, New Jersey, USA, March 2001.
17. "Statistical models in finance," Los Alamos National Laboratory, New Mexico, USA, September 1997.
18. "Approximating Latin square extensions," Hong Kong University, Hong Kong, May 1996.

19. "Approximation algorithms for optical networks," Bellcore, New Jersey, US, April 1996.
20. "Alternation in Interaction," Centrum Wiskoonde Informatik, Amsterdam, Netherlands, June 1994.
21. "Alternation in Interaction," Universite Paris-Sud, Paris, France, May 1994.
22. "Spanning trees short or small," SUNY Albany, New York, USA, October 1993.

## SERVICE

- College Committees – served on MS (1 time), PhD (1 time), and Colloquium (2 times) Committees.
- University Committee – serving member on Patents Committee.
- Conference Program Committees – served on the following international conference committees – WCAN'05, AdHoc Now'06, ACNS'06, WCAN'06, NCA'06, WCAN'07, NCA'07, HiPC'07, SODA'08, INFOCOM'08, INFOCOM'09, COMSNETS'09, ICC'10.
- Distinguished Lecture Series – initiated and manages the series, invited speakers, printed posters, set up website and managed logistics.
- IIT – obtained funding from Northeastern alumnus to support summer interns from IIT with goal of attracting them to Northeastern for graduate studies.
- PhD Recruiting – worked with Agnes Chan to print and distribute posters to NITs and set up website to attract students from top Indian universities.
- Placement – placed many PhD, MS and undergraduate students in coops, summer internships and full-time jobs.