# Amogh Dhamdhere

College of Computing
Georgia Institute of Technology
266 Ferst Drive
Atlanta, GA 30332

Phone: +1 404 606 1019
Fax: +1 404 385 0332
amogh@cc.gatech.edu
www.cc.gatech.edu/~amogh

## Education

**Ph.D. in Computer Science** Fall 2002 – present
Georgia Institute of Technology, Atlanta, GA
Thesis: Provider and peer selection in the evolving Internet ecosystem
Minor: Network economics and stochastic optimization
Advisor: Dr. Constantine Dovrolis
GPA: 4.0

**Bachelor of Engineering (B.E.) in Computer Science** 1998-2002
Veermata Jijabai Technological Institute (V.J.T.I), Mumbai University, India

## Research Experience

**Summer Intern** Summer 2008
AT&T Labs-Research, Florham Park, NJ
Developed techniques for detecting routing events and quantifying their effects on data plane performance using passive flow-level measurements.

**Summer Intern** Summer, Fall 2006
Thomson Research, Paris, France
Developed techniques for troubleshooting unreachability failures between end systems in an internetwork environment.

**Graduate Research Assistant** Summer 2003 – present
College of Computing, Georgia Institute of Technology, Atlanta, GA
As a research assistant in the Networking group, I was involved in two main projects: 1) Understanding the evolution of the Internet ecosystem. 2) Buffer sizing for Internet routers.

## Teaching Experience

**Graduate Teaching Assistant** Fall 2002 - Spring 2003
College of Computing, Georgia Institute of Technology, Atlanta, GA
Courses: CS6250 (Graduate level Networking),
CS4260 (Undergraduate Telecommunications)

## Publications

1. Amogh Dhamdhere and Constantine Dovrolis, "An Agent-based Model for the Evolution of the Internet Ecosystem" *In the Proceedings of the First International Conference on COMmunication Systems and NETworkS (COMSNETS), Bangalore, India, Jan 2009 (Invited paper).*
2. Amogh Dhamdhere and Constantine Dovrolis, "Ten Years in the Evolution of the Internet Ecosystem", *In the Proceedings of the USENIX/ACM Internet Measurement Conference (IMC), Vouliagmeni, Greece, Oct 2008.*
3. Amogh Dhamdhere and Constantine Dovrolis, "Can ISPs be Profitable Without Violating Network Neutrality?", *In the Proceedings of ACM SIGCOMM Workshop on the Economics of Networks, Systems and Computation (Netecon), Aug 2008.*
4. Amogh Dhamdhere, Renata Teixeira, Constantine Dovrolis and Christophe Diot, "NetDiagnoser: Troubleshooting Network Unreachabilities using End to end Probes and Routing Data", *In the Proceedings of CoNEXT 2007, New York, Dec 2007.*
5. Amogh Dhamdhere and Constantine Dovrolis, "ISP and Egress Path Selection for Multihomed Networks", *In the Proceedings of IEEE Infocom, Barcelona, Spain, Apr 2006.*
6. Amogh Dhamdhere and Constantine Dovrolis, "Open Issues in Router Buffer Sizing", *in ACM Computer Communications Review (CCR), Jan 2006.*
7. Amogh Dhamdhere, Hao Jiang and Constantine Dovrolis, "Buffer Sizing for Congested Internet Links", *In the Proceedings of IEEE Infocom, Miami FL, Mar 2005.*
8. Muhammad Mukarram Bin Tariq, Amogh Dhamdhere, Constantine Dovrolis and Mostafa Ammar, *"*Poisson vs Periodic Path Probing (or Does PASTA Matter?)*", In the Proceedings of the ACM Internet Measurement Conference (IMC), New Orleans LA, Oct 2005.*
9. Pradnya Karbhari, Mostafa Ammar, Amogh Dhamdhere, Himanshu Raj, George Riley and Ellen Zegura, "Bootstrapping in Gnutella: A Measurement Study", *In the Proceedings of PAM 2004, published by Springer in the Lecture Notes in Computer Science (LNCS) series, Apr 2004.*

## Under Submission

10. Amogh Dhamdhere, Lee Breslau, Nick Duffield, Cheng Ee, Alexandre Gerber, Carsten Lund, Shubho Sen, "FlowRoute: Monitoring the Impact of Control-Plane Events Using Passive Flow-level Measurements".
11. Amogh Dhamdhere and Constantine Dovrolis, "A Model for Interdomain Network Formation, Economics and Routing".

## Technical Reports

12. Amogh Dhamdhere, Renata Teixeira, Constantine Dovrolis and Christophe Diot, "NetDiagnoser: Troubleshooting Network Unreachabilities using End-to-end Probes and Routing Data", Thomson Technical Report CR-PRL-2007-02-0002.

## Presentations and Talks

1. "An Agent-based Model for the Evolution of the Internet Ecosystem", *Invited talk, International Conference on COMmunication Systems and NETworkS (COMSNETS), Bangalore, India, Jan 2009.*
2. "Ten Years in the Evolution of the Internet Ecosystem", USENIX/*ACM Internet Measurement Conference (IMC), Vouliagmeni, Greece, October 2008.*
3. "Can ISPs be Profitable Without Violating Network Neutrality?", *ACM SIGCOMM Workshop on the Economics of Networks, Systems and Computation (Netecon), Seattle, WA, August 2008.*
4. "NetDiagnoser: Troubleshooting Network Unreachabilities using End to end Probes and Routing Data", *CoNEXT 2007, New York, December 2007*. Also presented at the *DIMACS/DyDAn Workshop on Internet Tomography, Rutgers University, May 2008.*
5. "ISP and Egress Path Selection for Multihomed Networks", *IEEE Infocom, Barcelona, Spain, April 2006.*
6. "Open Issues in Router Buffer Sizing", *Georgia Tech, Spring 2005.*
7. "Buffer Sizing for Congested Internet Links", *IEEE Infocom, Miami, FL, March 2005.*

## Summary of Research Contributions

**Internet evolution:**

The Internet at the interdomain level consists of thousands of autonomous networks, each of which changes its connectivity in a distributed manner to optimize a certain utility function. A challenging problem is to determine how the Internet as a whole evolves due to these distributed optimizations. In the first part of this work, we measure the evolution of the Internet ecosystem over the last decade. We classify Autonomous Systems (ASes) into different types based on their business function, and classify inter-AS links based on the semantics of the underlying business relationships. Our findings highlight some important trends in the evolution of the Internet over the last decade, and hint at what the Internet is heading towards, in terms of topological and economic organization.

Next, we propose a first-principles model for the interactions between ASes in the Internet ecosystem. Our model is based on the concept of *economic fitness of an AS* and incorporates the effects of topology, traffic flow and economics on the evolution of the Internet topology. Using this model, we examine the properties (topological, economic and performance-related) of the "equilibrium" that results when ASes use certain provider and peer

selection strategies. We study how the properties of this equilibrium depend on factors such as the nature of the interdomain traffic matrix (does it consist mostly of client-server or peer-to-peer traffic?), transit and peering cost structures, and customer behavior.

**Router buffer sizing:**

Packet buffers in router/switch interfaces constitute a central element of packet networks. The appropriate sizing of these buffers is an important and open research problem. In this work, we derive the minimum buffer requirement for a Drop-Tail link, given constraints on the minimum utilization, maximum loss rate, and maximum queuing delay, when it is feasible to achieve all three constraints. Our results are applicable when most of the traffic (80-90%) at the given link is generated by large TCP flows that are bottlenecked at that link. For heterogeneous flows, we show that the buffer requirement depends on the harmonic mean of their round-trip times, and on the degree of loss synchronization. To limit the maximum loss rate, the buffer should be proportional to the number of flows that are bottlenecked at that link, when that number exceeds certain threshold. We show that the buffer size for optimal application-level performance depends on the type of flows (short vs. long) and the flow arrival process (open-loop vs. closed-loop).

**Measurement based multihoming:**

Multihoming has been used by stub networks for several years as a form of redundancy, improving the availability of Internet access. A multihomed network has several ISP choices and the actual selection of ISPs can significantly affect cost, availability, and performance. In the first part of this work, we develop a methodology to select the best set of upstream ISPs, optimizing monetary cost and availability. Our results, based on measurements of actual Internet traffic and topology, show that the proposed algorithm selects the best possible set of ISPs in terms of resiliency to inter-AS link failures. In the second part of this work, we focus on the egress path selection problem. Specifically, we propose a stochastic search algorithm, based on simulated annealing, to allocate the network's egress traffic between upstream ISPs. The objectives are to minimize cost, also ensuring that the selected paths to the major destinations of egress traffic are congestion-free.

**Route monitoring using passive data plane measurements:**

Understanding the behavior of an intradomain routing protocol in a large network is a challenging problem. Mechanisms that monitor the control plane (such as OSPFmon, the system for monitoring OSPF networks), rely on control plane messages to infer changes. Control plane information alone, however, cannot be used to infer when routers actually converged to a new routing state after a link or router failure. Further, observing control plane events does not allow an operator to assess the impact of a routing change in terms of the amounts of traffic that shifted, or the network-wide effects of that change. In this work, we develop techniques to detect routing changes using passive flow-level measurements from the data plane. We use these techniques to analyze the effect

of routing changes on the data plane, focusing on the convergence time of routers and the network-wide traffic shifts due to OSPF events.

**Network troubleshooting:**
The distributed nature of the Internet makes it difficult for a single service provider to troubleshoot the disruptions experienced by its customers. We develop NetDiagnoser, a troubleshooting algorithm to identify the location of failures in an internetwork environment. NetDiagnoser is designed to work in an internetwork environment, in the presence of multiple link failures, logical failures (for instance, misconfigurations of route export filters), and incomplete topology inference. NetDiagnoser takes advantage of rerouted paths, routing messages collected at one provider's network and Looking Glass servers. Our results show that NetDiagnoser can successfully identify a small set of links, which almost always includes the actually failed/misconfigured links.

## Other Projects

- "Poisson vs. Periodic Path Probing" with Dr. Constantine Dovrolis and Mukarram Bin Tariq, College of Computing, Georgia Tech, Spring 2005.
- "CoopGame: A Co-operative Architecture for Large Scale Multiplayer Games", course project for CS7270, College of Computing, Georgia Tech, Spring 2005.
- "Determining the Characteristics of the Gnutella Network" with Dr. Ellen Zegura, College of Computing, Georgia Tech, Fall 2002.
- "End to End Link Capacity Measurement using Pathrate" with Dr. Constantine Dovrolis, College of Computing, Georgia Tech, Fall 2002.
- "Object Location Schemes in Peer to Peer Networks" with Dr. Mostafa Ammar, College of Computing, Georgia Tech, Fall 2002.
- "Simulation Study of Routing Protocols for Mobile Ad Hoc Networks", summer project at the K.R. School of Information Technology, Indian Institute of Technology (IIT) Bombay, Summer 2001.

## Professional Service

- **Journal activities**: Reviewer for Elsevier Computer Networks Journal 2006 and 2008, ACM Computer Communications Review 2008.
- **Conference activities**: Reviewer for ACM SIGCOMM 2004, IEEE INFOCOM 2004, 2005, 2007, IWQoS 2003 and 2004, ACM Netgames 2004, IEEE ICC 2004, IEEE Globecomm 2007, PAM 2007.

## Technical Expertise

- **Programming languages:** C, C++, Java, Perl, Tcl, Python.
- **Tools used:** ns-2 network simulator, Pathload, Pathrate, MATLAB, RouteViews, PlanetLab, C-BGP routing simulator, Netflow tools.
- **Operating Systems:** Windows, Linux, Solaris.

## References


Prof. Constantine Dovrolis
Associate Professor
College of Computing, Georgia Tech
Atlanta, GA 30332
+1 404-385-4205
dovrolis@cc.gatech.edu

Prof. Mostafa Ammar
Regents' Professor
College of Computing, Georgia Tech
Atlanta, GA 30332
+1 404-894-3292
ammar@cc.gatech.edu

Dr. Nick Duffield
Distinguished Member of Technical Staff
AT&T Labs Research
Florham Park, NJ 07932
+1-973-360-8726
duffield@research.att.com

Dr. Subhabrata Sen
Principal Member of Technical Staff
AT&T Labs Research
Florham Park, NJ 07932
+1 973-360-5827
sen@research.att.com

Dr. Christophe Diot
Director
Thomson Paris Research Lab
46 Quai A. Le Gallo
92648 Boulogne Cedex France
christophe.diot@thomson.net