

## Anirudh Sivaraman

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**Research Interests**      Computer Networking  
High-Speed Programmable Routers

**Education**

- **Massachusetts Institute of Technology**  
Ph.D. in Computer Science (2012-2017)  
Advisors : Dr. Hari Balakrishnan and Dr. Mohammad Alizadeh
- **Massachusetts Institute of Technology**  
S.M. in Computer Science (2010-2012)  
Advisor : Dr. Li-Shiuan Peh
- **Indian Institute of Technology, Madras**  
B.Tech in Computer Science and Engineering (2006-2010)

**Awards**

- ACM SIGCOMM Best Paper Award, 2017
- The Internet Research Task Force's Applied Networking Research Prize, 2014
- Qualcomm Innovation Fellowship finalist, 2014
- Frederick C. Hennie III Teaching Award, 2012,  
given to 1-3 MIT EECS students annually

**Publications**

- **Peer-Reviewed Conference and Journal Papers**
  - **Language-Directed Hardware Design for Network Performance Monitoring**  
Srinivas Narayana, Anirudh Sivaraman, Vikram Nathan, Prateesh Goyal, Venkat Arun, Mohammad Alizadeh, Vimalkumar Jeyakumar, and Changhoon Kim  
ACM SIGCOMM 2017  
**Best Paper Award**
  - **dRMT: Disaggregated Programmable Switching**  
Sharad Chole, Andy Fingerhut, Sha Ma, Anirudh Sivaraman, Shay Vargaftik, Alon Berger, Gal Mendelson, Mohammad Alizadeh, Shang-Tse Chuang, Isaac Keslassy, Ariel Orda, and Tom Edsall  
ACM SIGCOMM 2017
  - **Encoding, Fast and Slow: Low-Latency Video Processing Using Thousands of Tiny Threads**  
Sadjad Fouladi, Riad S. Wahby, Brennan Shacklett, Karthikeyan Vasuki Balasubramaniam, William Zeng, Rahul Bhalerao, Anirudh Sivaraman, George Porter, and Keith Winstein  
USENIX NSDI 2017
  - **Programmable Packet Scheduling at Line Rate**  
Anirudh Sivaraman, Suvinay Subramanian, Mohammad Alizadeh, Sharad Chole, Shang-Tse Chuang, Anurag Agrawal, Hari Balakrishnan, Tom Edsall, Sachin Katti, and Nick McKeown  
ACM SIGCOMM 2016

- **Packet Transactions: High-Level Programming for Line-Rate Switches**  
Anirudh Sivaraman, Alvin Cheung, Mihai Budiu, Changhoon Kim, Mohammad Alizadeh, Hari Balakrishnan, George Varghese, Nick McKeown, and Steve Licking  
ACM SIGCOMM 2016
- **HULA: Scalable Load Balancing Using Programmable Data Planes**  
Naga Katta, Mukesh Hira, Changhoon Kim, Anirudh Sivaraman, and Jennifer Rexford  
ACM SOSR 2016
- **DC.p4: Programming the Forwarding Plane of a Data-Center Switch**  
Anirudh Sivaraman, Changhoon Kim, Ramkumar Krishnamoorthy, Advait Dixit, and Mihai Budiu  
ACM SOSR 2015
- **Mahimahi: Accurate Record-and-Replay for HTTP**  
Ravi Netravali, Anirudh Sivaraman, Somak Das, Ameesh Goyal, Keith Winstein, James Mickens, and Hari Balakrishnan  
USENIX ATC 2015
- **An Experimental Study of the Learnability of Congestion Control**  
Anirudh Sivaraman, Keith Winstein, Pratiksha Thaker, and Hari Balakrishnan  
ACM SIGCOMM 2014
- **Protocol Design Contests**  
Anirudh Sivaraman, Keith Winstein, Pauline Varley, João Batalha, Ameesh Goyal, Somak Das, Joshua Ma, and Hari Balakrishnan  
ACM SIGCOMM Computer Communication Review, July 2014
- **WiFi, LTE, or Both? Measuring Multi-Homed Wireless Internet Performance**  
Shuo Deng, Ravi Netravali, Anirudh Sivaraman, and Hari Balakrishnan  
ACM IMC 2014
- **Stochastic Forecasts Achieve High Throughput and Low Delay over Cellular Networks**  
Keith Winstein, Anirudh Sivaraman, and Hari Balakrishnan  
USENIX NSDI 2013
- **DIPLOMA: Consistent and Coherent Shared Memory over Mobile Phones**  
Jason Gao, Anirudh Sivaraman, Niket Agarwal, HaoQi Li, and Li-Shiuan Peh  
IEEE ICCD 2012
- **A Realistic Framework for Delay-Tolerant Network Routing in Open Terrains with Continuous Churn**  
Veeramani Mahendran, Sivaraman K. Anirudh, and C. Siva Ram Murthy  
ICDCN 2011
- **Efficient Segmentation Technique for Noisy Frontal View Iris Images Using Fourier Spectral Density**  
Niladri B. Puhan, N. Sudha, and Anirudh Sivaraman Kaushalram  
Springer Signal, Image and Video Processing Volume 5, Number 1, 105-119  
March 2011
- **Peer-Reviewed Workshop Papers**
  - **Hardware-Software Co-Design for Network Performance Measurement**  
Srinivas Narayana, Anirudh Sivaraman, Vikram Nathan, Mohammad Alizadeh, David Walker, Jennifer Rexford, Vimalkumar Jeyakumar, and Changhoon Kim  
ACM HotNets 2016

- **Towards Programmable Packet Scheduling**  
Anirudh Sivaraman, Suvinay Subramanian, Anurag Agrawal, Sharad Chole, Shang-Tse Chuang, Tom Edsall, Mohammad Alizadeh, Sachin Katti, Nick McKeown, and Hari Balakrishnan  
ACM HotNets 2015
- **All Your Network Are Belong To Us: A Transport Framework for Mobile Network Selection**  
Shuo Deng, Anirudh Sivaraman, and Hari Balakrishnan  
ACM HotMobile 2014
- **No Silver Bullet: Extending SDN to the Data Plane**  
Anirudh Sivaraman, Keith Winstein, Suvinay Subramanian, and Hari Balakrishnan  
ACM HotNets 2013
- **Demonstrations**
  - **In-band Network Telemetry via Programmable Dataplanes**  
Changhoon Kim, Anirudh Sivaraman, Naga Katta, Antonin Bas, Advait Dixit, and Lawrence J Wobker  
ACM SIGCOMM 2015 Industrial Demo Session  
ACM SOSR 2015 Demo Session
  - **Mahimahi: A Lightweight Toolkit for Reproducible Web Measurement**  
Ravi Netravali, Anirudh Sivaraman, Keith Winstein, Somak Das, Ameesh Goyal, and Hari Balakrishnan  
ACM SIGCOMM 2014 demo session

## Research Summary

- High-Speed Programmable Routers
  - *dRMT*, a new hardware architecture for programmable routers that substantially improves hardware utilization relative to the standard pipeline-based architecture for programmable routers.  
Code: <http://www.github.com/anirudhsk/drmt>
  - *Domino*, a system to write router algorithms in a high-level imperative language and compile them to run on a programmable router at line rate. Domino’s programming model has been adopted by P4, an industry effort towards a unified language for network devices. Based on Domino, P4 now allows programmers to designate blocks of packet processing code that must execute atomically.  
Code: <http://web.mit.edu/domino>
  - *Push-In First-Out queues*, the first abstraction for *programmable scheduling*: flexibly deciding which packet is next transmitted from a router’s buffer.  
Code: <http://web.mit.edu/pifo>
  - *Performance Queries*, an abstraction to measure network performance (e.g., packet latencies, loss rates, and reordering rates) on a high-speed router.  
Code: <http://web.mit.edu/marple>
  - *DC.p4*, an empirical analysis of programming a datacenter router’s forwarding plane in P4.  
Code: <http://git.io/sosr15-p4>
  - *In-Band Network Telemetry*, a proposal to piggyback measurement information (queueing delays, queue sizes, etc.) on data packets, allowing end hosts to analyze such measurements.  
Code: <https://github.com/p4lang/p4factory/tree/master/apps/int>
  - *HULA*, a scalable and fault-tolerant load-balancing algorithm for datacenters that leverages emerging programmable switching chips.  
Code: <https://drive.google.com/open?id=0B0h6wPXnFG3RRHVZY245aGprUEk>

- Congestion Control
  - *Sprout*, a congestion-control protocol designed for high throughput and low latency over highly variable cellular networks.  
Code: <http://alfalfa.mit.edu>
  - *Learnability of congestion control*, an empirical study of the difficulty of learning congestion-control protocols given an imperfect model of the network.  
Code: <https://github.com/pratiksha/learnability-reproduce>
  - *Protocol-Design Contests*, a classroom contest to design good congestion-control protocols.  
Code: <http://web.mit.edu/anirudh/www/contest.html>
- Application Aware Networking
  - Measuring application and transport layer performance of multi-homed mobile hosts connected simultaneously to WiFi and LTE.  
Data: <http://web.mit.edu/cell-vs-wifi/>
  - *Mahimahi*, tools to record HTTP resources during a page load and replay the page load under emulated network conditions.  
Code: <http://mahimahi.mit.edu>
  - *ExCamera*, a system for low-latency video encoding that parallelizes video encoding across thousands of threads running on AWS Lambda.  
Code: <http://ex.camera/nsdi17/>

## Industry Experience

- **Software Engineering Intern, Barefoot Networks**  
**October 2014-October 2015**
  - Worked on several research problems related to the design and implementation of programmable routers: Domino, Push-In First-Out Queues, In-Band Network Telemetry, and DC.p4.
  - Contributed to the evolution of the P4 programming language.
  - Implemented a simulator to validate some hardware designs within a switching chip.
- **Hardware Engineering Intern, Google Platforms Networking Team**  
**Summer 2014**  
Worked on applying ideas from computer-generated congestion control to design a datacenter congestion-control algorithm.
- **Research Intern, Microsoft Research India**  
**Summer 2009, 2010**  
Worked on non-invasive monitoring of building-wide energy consumption using sensors such as thermometers (for HVAC energy consumption) and CPU performance counters (for desktop energy consumption).

## Invited Presentations

- Making the Fastest Routers Programmable
  - University of Southern California, February 2017
  - University of Illinois at Urbana-Champaign, February 2017
  - New York University, March 2017
  - Cornell University, March 2017
  - University of Wisconsin at Madison, March 2017
  - Microsoft Research, Redmond, March 2017,  
<https://www.youtube.com/watch?v=4PAA6dSdguQ>

- University of Texas at Austin, March 2017,  
<https://video.cs.utexas.edu/node/213>
- Programming Line-Rate Routers
  - Google Tech Talk, October 2016,  
[https://www.youtube.com/watch?v=df2\\_72wjEdw](https://www.youtube.com/watch?v=df2_72wjEdw)
  - Stanford Platforms Lab Seminar, October 2016
  - VMWare Research, October 2016
  - Microsoft Research India, June 2016
  - IIT Bombay, June 2016
  - Cornell University, May 2016
  - Columbia University, March 2016
  - Nokia Bell Labs, March 2016
- Abstractions for Programming the Data Plane at Line Rate, Princeton University, December 2015
- Packet Transactions: A Model for Data-Plane Algorithms at Hardware Speed, 2nd P4 Workshop, November 2015
- Towards Programmable Packet Scheduling, New England Networking and Systems Day, October 2015
- An Experimental Study of the Learnability of Congestion Control
  - Stanford NetSeminar, December 2014,  
<https://www.youtube.com/watch?v=NdRhLmqSr9s>
  - MIT Signals, Information, and Algorithms Laboratory, September 2014
  - Google Platforms Networking Team, August 2014
- CoRA: Towards Programmable Data Planes For High-Speed Networking, Qualcomm Innovation Fellowship Finalists Presentation, March 2014
- Sprout : Stochastic Forecasts Achieve High Throughput and Low Delay over Cellular Networks, IIT Madras, August 2013

**Teaching  
Experience**

- **Graduate Instructor, MIT EECS** **January 2012**  
6.S092: Introduction to Software Engineering in Java
- **Teaching Assistant, MIT EECS** **Spring 2012**  
6.02: Digital Communication Systems  
Overall rating: 6.4 on 7.0
- **Guest lectures on programmable routers** **Spring, Fall 2016**  
6.888 (Spring 2016): Advanced Topics in Networking  
6.829 (Fall 2016): Computer Networks