

## Anirudh Sivaraman

Assistant Professor of Computer Science  
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### **Research Interests**

Computer Networks and Network Programmability

### **Education**

- **Massachusetts Institute of Technology**  
Ph.D. in Computer Science (2012–2017)  
Minor in Women’s and Gender Studies  
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)

### **Employment**

- **Assistant Professor of Computer Science, New York University**  
September 2017–now
- **Consultant, Clockwork**  
April 2019–now
- **Software Engineering Intern, Barefoot Networks**  
October 2014–October 2015
- **Hardware Engineering Intern, Google Platforms Networking Team**  
Summer 2014
- **Research Intern, Microsoft Research India**  
Summer 2009, 2010

### **Awards and Grants**

- Amazon Research Award, 2021
- NSF CNS Core: Small  
Autogenerating fast packet-processing code using program synthesis,  
Award Amount: \$500000, 2020–2023
- ACM SIGCOMM Doctoral Dissertation Award, 2017
- 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

**Professional Service**

- Program Committee Member, ACM SIGCOMM, 2023, 2020, 2019
- Program Committee Member, USENIX NSDI, 2024, 2020, 2019
- Program Committee Member, ACM HotNets, 2019
- Co-chair, P4 and Programmable Forwarding Summit 2020
- Panelist, The impact of P4 on SDN/NFV, 2020 IEEE NFV/SDN conference
- Panelist, P4 Developer Day Fall 2017
- NSF NeTS Review Panelist, 2021, 2022
- Co-organizer, SIGCOMM 2020 Tutorial on Networking for Financial Applications (NetFinance)
- Co-organizer, NSF Workshop on Programmable Networks, New York City, 2018
- Program Committee Member, ACM SOSR, 2018
- Program Committee Member, ACM SIGCOMM 2018 Afternoon Workshop on Self-Driving Networks, 2018

**Department Service**

- Organizer of the NYU Ph.D. visit weekend for new admits, 2018–now
- NYU Ph.D. admissions committee, 2017–2019
- NYU ad-hoc area committee for faculty hiring in systems and networking, 2021–2022

**Teaching Experience**

- **Instructor, NYU CS** **Spring 2018, 2019, 2020, 2021, 2022**  
CSCI-GA.2620-001: Networks and Mobile Systems
- **Instructor, NYU CS** **Fall 2017, 2018, 2020, 2021**  
CSCI-UA.0480-009: Computer Networks
- **Guest lectures on programmable routers, MIT EECS** **Spring, Fall 2016, Fall 2020**  
6.888 (Spring 2016): Advanced Topics in Networking  
6.829 (Fall 2016): Computer Networks
- **Teaching Assistant, MIT EECS** **Spring 2012**  
6.02: Digital Communication Systems
- **Graduate Instructor, MIT EECS** **January 2012**  
6.S092: Introduction to Software Engineering in Java

**Ph.D. students**

- Vig Sachidananda (co-advised with Balaji Prabhakar), graduated 2022
- Muhammad Haseeb, current
- Jessica Berg, current
- Xiangyu Gao (co-advised with Srinivas Narayana), current
- Fabian Ruffy, current
- Tao Wang (co-advised with Aurojit Panda), current
- Jinkun Geng (co-advised with Balaji Prabhakar and Mendel Rosenblum), current

- Master's students**
- Xiangyu Gao, CS Ph.D. program at NYU
  - Sai Anirudh Kondaveeti, software engineer at Microsoft
  - Thomas Mason, OccamSec LLC
  - Vikas Natesh, CS Ph.D. program at Harvard
  - Salil Kapur, software engineer at Apple
- Undergraduate students**
- Scott Chen, current
  - Doris Zhu, current
  - Yaojia Ju, software engineer at Microsoft
  - Khanh Nguyen, software engineer at Google
  - Nicholas Yang, software engineer at Rome Tools
  - Michael Wong, CS Ph.D. program at Princeton
  - Aatish Kishan Varma, software engineer at Amazon
  - Jiayang Wang, software engineer at Oracle and in the Stanford EE MS program
- Interns**
- Pravein Govindan Kannan, 2018, research scientist at IBM Research, India
- Publications**
- **Peer-Reviewed Conference and Journal Papers**
    - **Nezha: Deployable and High-Performance Consensus Using Synchronized Clocks**  
Jinkun Geng, Anirudh Sivaraman, Balaji Prabhakar, and Mendel Rosenblum  
VLDB 2023
    - **Revelio: ML-Generated Debugging Queries for Finding Root Causes in Distributed Systems**  
Pradeep Dogga, Karthik Narasimhan, Anirudh Sivaraman, Shiv Saini, George Varghese, and Ravi Netravali  
MLSys 2022
    - **Isolation mechanisms for high-speed packet-processing pipelines**  
Tao Wang, Xiangrui Yang, Gianni Antichi, Anirudh Sivaraman, and Aurojit Panda  
USENIX NSDI 2022
    - **NetVRM: Virtual Register Memory for Programmable Networks**  
Hang Zhu, Tao Wang, Yi Hong, Dan Ports, Anirudh Sivaraman, and Xin Jin  
USENIX NSDI 2022
    - **Synthesizing safe and efficient kernel extensions for packet processing**  
Qiongwen Xu, Michael D. Wong, Tanvi Wagle, Srinivas Narayana, and Anirudh Sivaraman  
ACM SIGCOMM 2021
    - **The Case for Model-Driven Interpretability of Delay-Based Congestion Control Protocols**  
Muhammad Khan, Yasir Zaki, Shiva Iyer, Talal Ahmad, Thomas Poetsch, Jay Chen, Anirudh Sivaraman, and Lakshmi Subramanian  
ACM SIGCOMM CCR, January 2021
    - **Breaking the Transience-Equilibrium Nexus: A New Approach to Data-center Packet Transport**  
Shiyu Liu, Ahmad Ghalayini, Mohammad Alizadeh, Balaji Prabhakar, Mendel Rosenblum, and Anirudh Sivaraman  
USENIX NSDI 2021

- **Testing Compilers for Programmable Switches Through Switch Hardware Simulation**  
Michael D. Wong, Aatish Varma, and Anirudh Sivaraman  
CoNEXT 2020 (short paper)
- **Gauntlet: Finding Bugs in Compilers for Programmable Packet Processing**  
Fabian Ruffy, Tao Wang, and Anirudh Sivaraman  
USENIX OSDI 2020
- **PANIC: A Programmable High-Performance NIC for Multi-tenant Networks**  
Jiaxin Lin, Kiran Patel, Brent Stephens, Anirudh Sivaraman, and Aditya Akella  
USENIX OSDI 2020
- **Switch Code Generation using Program Synthesis**  
Xiangyu Gao, Taegyun Kim, Michael Dean Wong, Divya Raghunathan, Aatish Kishan Varma, Pravein Govindan Kannan, Anirudh Sivaraman, Srinivas Narayana, and Aarti Gupta  
ACM SIGCOMM 2020
- **Programmable Calendar Queues for Packet Scheduling**  
Naveen Kr. Sharma, Chenxingyu Zhao, Ming Liu, Pravein Govindan Kannan, Changhoon Kim, Arvind Krishnamurthy, and Anirudh Sivaraman  
USENIX NSDI 2020
- **A System-Wide Debugging Assistant Powered by Natural Language Processing**  
Pradeep Dogga, Karthik Narasimhan, Anirudh Sivaraman, and Ravi Netravali  
ACM SOCC 2019
- **WatchTower: Fast, Secure Mobile Page Loads Using Remote Dependency Resolution**  
Ravi Netravali, Anirudh Sivaraman, James Mickens, and Hari Balakrishnan  
ACM MobiSys 2019
- **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 CCR, 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**
  - **Snicket: Query-Driven Distributed Tracing**  
Jessica Berg, Fabian Ruffy, Khanh Nguygen, Nicholas Yang, Taegyun Kim, Anirudh Sivaraman, Ravi Netravali, and Srinivas Narayana  
ACM HotNets 2021
  - **CloudEx: A Fair-Access Financial Exchange in the Cloud**  
Ahmad Ghalayini, Jinkun Geng, Vighnesh Sachidananda, Vinay Sriram, Yilong

Geng, Balaji Prabhakar, Mendel Rosenblum, and Anirudh Sivaraman  
ACM HotOS 2021

- **Multitenancy for Fast and Programmable Networks in the Cloud**  
Tao Wang, Hang Zhu, Fabian Ruffy, Xin Jin, Anirudh Sivaraman, Dan Ports, and Aurojit Panda  
USENIX HotCloud 2020
- **Autogenerating Fast Packet-Processing Code Using Program Synthesis**  
Xiangyu Gao, Taegyun Kim, Aatish Kishan Varma, Anirudh Sivaraman, and Srinivas Narayana  
ACM HotNets 2019
- **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**
  - **Sluice: Network-Wide Data Plane Programming**  
Vikas Natesh, Pravein Govindan Kannan, Anirudh Sivaraman, and Ravi Netravali  
ACM SIGCOMM 2019 Demo Session
  - **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
- **Non-peer reviewed papers**
  - **Network Architecture in the Age of Programmability**  
Anirudh Sivaraman, Thomas Mason, Aurojit Panda, Ravi Netravali, and Sai Anirudh Kondaveeti  
ACM SIGCOMM CCR Editorial, January 2020
- **Programmable Networks**
  - *Nezha*, a consensus protocol based on a new deadline-ordered multicast network primitive.  
Code: <https://gitlab.com/steamgjk/nehav2>

Research  
Summary

- *NetVRM*, a system to virtualize memory on programmable switches
- *Menshen*, hardware primitives for enabling isolation between different modules on a packet-processing pipeline.  
Code: <https://isolation.quest/>
- *CloudEx*: a stock exchange in the cloud making use of time synchronized gateways.
- *K2*, an eBPF compiler based on superoptimization techniques.  
Code: <https://k2.cs.rutgers.edu/>
- *Snicket*, a distributed tracing system using WebAssembly extensions for programmable RPC processing. Code: [https://github.com/dyn-tracing/snicket\\_compiler](https://github.com/dyn-tracing/snicket_compiler)
- *On-Ramp*, a congestion-control underlay that improves the performance of any congestion-control algorithm in public cloud environments.
- *PANIC*, a new hardware architecture for multi-tenant programmable network interface cards.  
Code: [https://bitbucket.org/uw-madison-networking-research/panic\\_osdi20\\_artifact/src/master/](https://bitbucket.org/uw-madison-networking-research/panic_osdi20_artifact/src/master/)
- *Gauntlet*, tools to find bugs in packet-processing compilers.  
Code: <https://github.com/p4gauntlet>
- *Calendar queues*, an abstraction for high-speed programmable scheduling on multi-Tbit/s switches.
- *Chipmunk*, a code generator for packet-processing pipelines, which uses program synthesis to improve the quality of generated code.  
Code: <https://chipmunk-project.github.io/>
- *Sluice*, a network-wide programming model for programmable networks.  
Code: <https://github.com/sluice-project/sluice>
- *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 and hardware design 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*, 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
  - *Model-driven interpretability*, a technique for interpretable congestion control that proposes a unified Markov model representation for congestion-control algorithms.
  - *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/>
  - *WatchTower*, a system for accelerating Web page loads using cloud proxies while preserving user privacy.
- Machine Learning for Distributed Systems Debugging
  - *Revelio*, a debugging agent that uses ML techniques for analyzing user issue reports to provide debugging hints to developers.

## Invited Presentations

- Solver-Aided Compilers for Fast Packet Processing
  - Queen Mary University of London, Next-Generation Networking Seminar, Nov 2020
  - Microsoft Research, April 2021
  - Princeton Networking and Programming Languages Group, April 2021
  - University of Texas at Austin, Oct 2021
  - University of Washington at Seattle, Dec 2021
- Hardware and Software for Fast and Programmable Network Monitoring
  - ITX 2018 New York City, May 2018
  - Huawei Datacenter Networking Workshop, Madison, July 2018
  - Columbia University, October 2018
- Designing Fast and Programmable Routers
  - New York University, Electrical and Computer Engineering Seminar, September 2017
  - University of Washington at Seattle, Systems and Networks Seminar, February 2018
  - Arista Networks, June 2018
- 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
- 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

## References

- Prof. Hari Balakrishnan, MIT
- Prof. Mohammad Alizadeh, MIT
- Prof. Nick McKeown, Stanford
- Prof. Balaji Prabhakar, Stanford
- Prof. Arvind Krishnamurthy, UW
- Prof. Jennifer Rexford, Princeton
- Prof. Nate Foster, Cornell