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# Rinku Shah

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## Research Interests

As a systems and network researcher, I build flexible, scalable, and fault-tolerant systems that solve real-world problems. My broad areas of interest include:

- Software-defined Networking (SDN)
- Dataplane programming
- Network Function Virtualization (NFV)

## Education

2013 – 2021 **Indian Institute of Technology Bombay**, *Ph.D., Computer Science & Engineering*, GPA – 9.08.

**Advisors:** Prof. Mythili Vutukuru and Prof. Purushottam Kulkarni

**Thesis title:** Hierarchical Control Plane Designs to Scale SDN Applications

**Thesis defence date:** February 8, 2021

2007 – 2010 **Ramrao Adik Institute of Technology**, *Masters, Computer Engineering*, Mumbai University, *Percentage – 75%*.

First Class with Distinction

1998 – 2002 **Shivajirao.S.Jondhale College of Engineering**, *Bachelors, Computer Engineering*, Mumbai University, *Percentage – 61%*.

First Class

1998 **Mithibai college**, *Higher Secondary Certificate (HSC)*, Maharashtra State Board, *Percentage – 80%*.

First Class with Distinction

1996 **St. Xavier's High School**, *Secondary School Certificate (SSC)*, Maharashtra State Board, *Percentage – 84%*.

First Class with Distinction

## Professional Experience

July 2021 onwards **IIT Delhi**, *Assistant Professor, Department of CSE*, Delhi, IN.

Nov 2020 – **IIT Bombay**, *Project Research Scientist (Huawei project)*, Mumbai, IN.

May 2021 **Principal Investigators:** Umesh Bellur, Purushottam Kulkarni

**Project Title:** High Performance Distributed Object Store

- Fall 2019 **VMware**, *Research Intern*, Pune, IN.  
**Mentors:** Sairam Veeraswamy, T. Shridhar, Raja Kommula, Rohan Gandhi, Abhijit Sharma  
**Project Title:** Capacity-aware Load Balancing for Network Functions
- 2010 – 2016 **Vidyalankar Institute of Technology**, *Assistant Professor*, Mumbai, IN.
- 2003 – 2010 **Vidyalankar Institute of Technology**, *Lecturer*, Mumbai, IN.
- Spring 2003 **St. Francis Institute of Technology**, *Lecturer*, Mumbai, IN.

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## Doctoral Thesis

- Title *Hierarchical Control Plane Designs to Scale SDN Applications*
- Advisors Prof. Mythili Vutukuru & Prof. Purushottam Kulkarni
- Description SDN controllers run as software programs over commodity servers; hence they are likely to become a bottleneck with high network control traffic. My dissertation research addresses the control plane scalability challenge in SDN applications. We develop scaling solutions that offload the subset of application computations and related global application state to local controllers (or switches), thereby improving the state-of-the-art in hierarchically scaled SDN controller design. My research comprises of two main threads.
- Cuttlefish SDN controller framework that helps SDN applications adaptively offload state and computation to local controllers (close to the user), based on whether the offload improves application performance or not, due to the amount of state synchronization cost.
  - TurboEPC framework offloads the state and computation to programmable switches in the data plane, close to the user. The hardware programmable switches have limited memory to store application state and application state is lost in case of switch failure. My dissertation provides scalability and fault tolerance solutions for complex real-world applications, such as the SDN-decomposed mobile packet core, offloaded to the switch, and demonstrate significant performance improvements.

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## Publications

Following are the publications accepted during my Ph.D. tenure at IIT Bombay. The complete list of publications is available at my [Google Scholar page](#)

### **Conferences (Full papers).**

- [1] [Rinku Shah](#), Vikas Kumar, Mythili Vutukuru, Purushottam Kulkarni. TurboEPC: Leveraging data plane programmability to accelerate the mobile packet core. In Proceedings of the ACM SIGCOMM Symposium on SDN Research (SOSR), 2020. **[Acceptance Rate: 16%]**
- [2] [Rinku Shah](#), Mythili Vutukuru, Purushottam Kulkarni. Cuttlefish: Hierarchical SDN Controllers with Adaptive Offload. In Proceedings of the IEEE 26th International Conference on Network Protocols (ICNP), 2018. **[Core Ranking: A] [Acceptance Rate: 18%]**

### **Workshops & Short Papers.**

- [1] Abhik Bose, Diptyaroop Maji, Prateek Agarwal, Nilesh Unhale, [Rinku Shah](#), Mythili Vutukuru. Leveraging Programmable Dataplanes for a High Performance 5G User Plane Function. In Proceedings of the ACM 5<sup>th</sup> Asia-Pacific Workshop on Networking (APNet), 2021. **[Acceptance Rate: 45%]**

- [2] [Rinku Shah](#), Aniket Shirke, Akash Trehan, Mythili Vutukuru, Purushottam Kulkarni. pcube: Primitives for network data plane programming. In Proceedings of the IEEE 26th International Conference on Network Protocols (ICNP), 2018. **[Core Ranking: A]**
- [3] [Rinku Shah](#), Mythili Vutukuru, Purushottam Kulkarni. Devolve-Redeem: Hierarchical SDN Controllers with Adaptive Offloading. In Proceedings of the ACM First Asia-Pacific Workshop on Networking (APNet), 2017. **[Acceptance Rate: 35%]**
- [4] Rohit Gupta, [Rinku Shah](#), and Apurva Mhetre. In-memory, high speed stream processing. In Proceedings of the 8th ACM International Conference on Distributed Event-Based Systems (DEBS), 2014. **[Qualis Ranking: A2]**

## Teaching

### Teaching Assistant

Spring 2018 Operating Systems (CS347/CS333), IIT Bombay

### Course Faculty

2003 – 2016 Courses taught at Vidyalankar Institute of Technology, Mumbai University

- Computer Networks (UG)
- Mobile Computing (UG)
- Operating Systems (UG)
- System Programming (UG)
- System Security (UG)
- Convergence of Network Technologies & Communication (UG)
- Programming Mobile & Remote Computers (UG)
- Next Generation Networks (PG)
- Compiler Construction (PG)

Spring 2003 Course taught at St. Francis Institute of Technology, Mumbai University

- Computer Communication & Networks (UG)

## Mentoring

Fall 2019 Abhik Bose, IIT Bombay, Ph.D.

2018 – 2019 Kanak Agarwal, IIT Bombay, B.Tech

2018 – 2019 Arijit Pramanik, IIT Bombay, B.Tech

Fall 2018 Vishal Rawat, IIT Bombay, M.Tech

Fall 2018 Maharishi Bhargava, IIT Bombay, M.Tech

Spring 2018 Aniket Shirke, IIT Bombay, B.Tech

Spring 2018 Akash Trehan, IIT Bombay, B.Tech

2016 – 2017 Sanjana Vohra, IIT Bombay, M.Tech

2011 – 2016 Vidyalankar Institute of Technology, Supervised 7 (seven) PG student dissertations

2003 – 2016 Vidyalankar Institute of Technology, Supervised 28 (twenty-eight) UG student projects

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## Open Source Projects

- 2020 SDN controller designs  
This project implements multiple SDN controller scalability designs, viz., Centralized, Horizontal scaling, Hierarchical scaling with computation offload to local controllers, and Hierarchical scaling with computation offload to programmable hardware, with the goal to compare them. The 4G LTE-EPC application is implemented as the common application for each design, and the limitations and benefits are evaluated empirically.
- 2019 – 2020 TurboEPC  
This project implements the offload of the subset of 4G LTE-EPC computations that depend on some global state to programmable hardware. This project designs and implements mechanisms for scalability and failure handling.
- 2019 Carbon copy  
Recent advancements of programmable dataplanes have caught the attention of the research community to offload application computations with high network activity to the dataplane. This project intends to reduce the P4 programmer's effort by providing abstractions for replicating offloaded application state that resides on switches, and application agnostic fail-over handling. We have implemented three state replication designs, and compared them with the traditional SDN based state replication design. The choice of the design depends on the application behavior and requirement.
- 2018 pcube  
This project implements the preprocessor framework to simplify the development of P4 applications. We provide primitives to write loops, conditional statements, boolean expressions, and state synchronization mechanisms between P4 switches. This project helps in reducing the P4 programmer's effort.
- 2016 – 2018 Cuttlefish  
Researchers have proposed various designs for scaling SDN controllers. Each design has its benefits and limitations. This project implements the framework that adaptively switches between the centralized and hierarchical SDN controller designs, based on the incoming traffic-mix. The application programmer writes the application using Cuttlefish APIs, therefore the adaptation process is agnostic to the programmer.

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## Presentations

### Leveraging Programmable Networks to Accelerate Networked Systems

University: IIT Hyderabad (January 2021), IIT Delhi (December 2020), BITS Pilani (Goa) (July 2020)

### TurboEPC: Leveraging data plane programmability to accelerate the mobile packet core

Conference: ACM SIGCOMM SOSR (March 2020)

Video link: <https://www.youtube.com/watch?v=CbgPYwK4nDs&t=219s>

### Capacity-aware Load Balancing for Network Functions

Industry: VMware Intern Expo (December 2019), VMware RADIO (November 2019)

### Leveraging Network Programmability to Accelerate SDN Applications

Sprint Thesis Talk & Poster Presentation: RISC 2019, IIT Bombay

### Cuttlefish: Hierarchical SDN Controllers with Adaptive Offload

Conference: IEEE ICNP (September 2018)

### Devolve-Redeem: Hierarchical SDN Controllers with Adaptive Offloading

Conference: ACM SIGCOMM APNet (August 2017)

### Adaptive Vertical Distributed SDN Controller

Sprint Thesis Talk: RISC 2017, IIT Bombay

#### Software-defined Networking Basics

Guest Lecture: Vidyalkar Institute of Technology, Mumbai (October 2016)

Topics: Evolution of traditional networks, SDN basics, Openflow basics, NFV basics

#### Mobile and Wireless Networks

Guest Lecture: M.H.Saboo Siddik College of Engineering, Mumbai (September 2014)

Topics: 4G mobile architecture, Mobile IP, and Mobile Number Portability

In-memory, high speed stream processing

Conference: ACM DEBS—Grand Challenge Poster Presentation (May 2014)

Simultaneous Multiple Link/Node Failure Handling for Different Service-Paths in MPLS Networks

Conference: ICAC3 (January 2011)

## Workshop Presentations

The New Generation 4G and 5G Innovations, Research, Scope and Limitations

Short-Term Training Program (2 days): K. J. Somaiya College of Engineering, Mumbai (November 2014)

Topics: ns2 simulation for wired and wireless networks

Linux Network Programming

Short-Term Training Program (1 day): Thadomal Shahani College of Engineering, Mumbai (December 2014)

Title: Shell script & Socket Programming

Topics: Shell scripts—bash, awk & sed, gnuplot, socket programming

Open Source Scripting Tools

CESA Student Workshop (10 days): Vidyalkar Institute of Technology, Mumbai (December 2013)

Topics: Bash, Gnuplot, Latex, ns2, GNS3

Moving towards open source

Short-Term Training Program (1 day): Vidyalkar Institute of Technology, Mumbai (July 2012)

Topics: Bash, Python, Gnuplot, Latex

## Professional Activities

Shadow Program Committee member

2020 The ACM SIGOPS European Conference on Computer Systems(EuroSys)

Student Organizing Committee Member

2017 The Eighth ACM SIGOPS Asia-Pacific Workshop on Systems (APSys)

Conference Reviewer

2015 The IEEE International Conference on Advances in Computing, Communications and Informatics (ICACCI)

Conference Sub-Reviewer

2014 The 11th Annual IEEE India Conference (INDICON)

Student Organizing Committee Member

2014 The 8th ACM International Conference on Distributed Event-Based Systems (DEBS)

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## Research Experience

Fall 2019 **VMware**, *Research Intern*.

**Mentors:** Sairam Veeraswamy, T. Shridhar, Raja Kommula, Rohan Gandhi, Abhijit Sharma

**Title:** Capacity-aware Load Balancing for Network Functions

Traditional load balancers for network functions (NFs) split the input load equally amongst the NF replicas, assuming that all the replicas provide equal performance. The assumption is not true in virtualized environments since multiple VMs share the same host resources which results in non-deterministic performance degradation due to the noisy neighbor problem. Following are our contributions:

- We model the capacity-aware load balancing problem as a congestion control problem. We increase or decrease the load at the NF replica based on feedback signals like latency or packet drop.
- We have designed the proposed model and implemented a C-based simulator to analyze the accuracy and performance.

Spring 2019 **IIT Bombay**, *Mentor, R&D project*.

**Advisors:** Prof. Mythili Vutukuru, Prof. Purushottam Kulkarni

**R&D team:** Kanak Agarwal, Arijit Pramanik

**Title:** Abstractions for dataplane state replication and fault tolerance in SDN networks

This project intends to reduce the P4 programmer's effort by providing abstractions for replicating offloaded application state that resides on switches, and application agnostic fail-over handling.

- We have implemented three state replication designs, and compared them with the traditional SDN controller state replication design.
- We observed that the choice of the replication design depends on the application requirements and input traffic behavior.

Fall 2018 **IIT Bombay**, *Mentor, R&D project*.

**Advisor:** Prof. Mythili Vutukuru

**R&D team:** Maharishi Bhargava, Vishal Rawat, Kanak Agarwal, Arijit Pramanik

The focus of this project was to setup the testbed and analyze the performance of various dataplane backends.

- Following dataplane backends were setup and their performance was evaluated: OVS, VPP, P4 bmv2 switch, eBPF, XDP, and Netronome smartNIC.
- The knobs varied by the experiments include input traffic distribution, switch table size, table match method (exact/lpm).
- The performance metrics like throughput, latency and cache miss rate were evaluated.

Spring 2018 **IIT Bombay**, *Team member, R&D project*.

**Advisors:** Prof. Mythili Vutukuru, Prof. Purushottam Kulkarni

**Other team members:** Aniket Shirke, Akash Trehan

**Title:** pcube: Primitives for network data plane programming

We have developed macro language support for the P4 language that reduces the dataplane (P4) programmer's effort.

- We have implemented primitives for switch state synchronization for the application running at the switches. The programmer could use our primitives, and our system generates the P4 code depending on the current network topology.
- Our example dataplane applications such as a distributed load balancer, show that our system reduces the programming effort (in term of lines of code) significantly.

Fall 2013 **DEBS Grand Challenge 2014: Smart homes**, *Team member*.

**Other team members:** Rohit Gupta & Apurva Mhetre

**Title:** In-memory, high speed stream processing

The focus of the project is to timely predict the expected load for smart grids, given the power usage from large number of houses.

- Challenges addressed- (1) Malformed data set (2) Simultaneous processing for thousands of plugs, within deadline (3) Median computation on dynamic data-set with millions of records within milliseconds.
- Designed and implemented two median computation techniques with computation complexity of  $O(1)$ . We used techniques like reuse of in-memory data, and prediction of next data block for prefetching, to improve data access performance.

2008 – 2010 **Ramrao Adik Institute of Technology**, *Masters thesis*.

**Advisor:** Prof. Madhumita Chatterjee

**Title:** Multiple link(/node) failure handling in MPLS networks.

My masters thesis identified the challenge of failure identification with MPLS fast reroute technique. We designed and implemented the system that identifies simultaneous link/node failures on different service paths in MPLS networks at real-time, and quickly assigns new paths. We used ns2 simulation tool to implement and compare our proposed method with the existing LDP (Link Discovery Protocol) re-route method.

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## Achievements

- 2014 Accepted solution at the Distributed Event-Based Systems(DEBS) Grand Challenge Competition (Pre-finalist)
- 2013 Received Scholarship for the Ph.D. programme under QIP (Indian Institute of Technology Bombay)
- 2011 Department Topper: Masters programme, RAIT college
- 2003 Cisco Certified Network Associate (CCNA)  
Marks: 975/1000, Valid upto 2006

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## Skills

### Languages

C, C++, Java, Shell scripts, Python, P4 (dataplane programming language)

### Technologies

ONOS SDN controller, Floodlight SDN controller, Openflow, LXC containers, eBPF, XDP, DPDK

### Tools

Netronome NFP SDK for programming smartNICs, ns2, GNS3, gnuplot, wireshark, tcpdump, iperf, Latex, moongen high-speed load generator

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## References

- (1) **Prof. Mythili Vutukuru, IIT Bombay.**  
Ph.D. Thesis Advisor  
**Contact:** mythili@cse.iitb.ac.in
- (2) **Prof. Purushottam Kulkarni, IIT Bombay.**  
Ph.D. Thesis Co-advisor  
**Contact:** puru@cse.iitb.ac.in

- (3) **Prof. Umesh Bellur, IIT Bombay.**  
Ph.D. Research Progress Committee Member & IITB–Huawei research project's PI  
**Contact:** umesh@cse.iitb.ac.in