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Rinku Shah

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Research Interests

As a systems and network researcher, I build flexible, scalable, secure, and fault-tolerant systems that solve real-world problems. My broad areas of interest include:
- Software-defined Networking (SDN)
- Programmable data planes

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 − 60%*.
First Class

Professional Experience

July 2021 – present **IIIT Delhi**, *Assistant Professor, Department of CSE*, Delhi, IN.

Nov 2020 – May 2021 **IIT Bombay**, *Project Research Scientist (Huawei project)*, Mumbai, IN.
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.

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.

Publications

Following is the recent publication list. The complete list of publications is available at my Google Scholar page

Conferences (Full papers).

[1] Abhik Bose, Shailendra Keshav Kirtikar, Shivaji Chirumamilla, <u>Rinku Shah</u>, Mythili Vutukuru. AccelUPF: Accelerating the 5G user plane using programmable hardware. In Proceedings of the ACM SIGCOMM Symposium on SDN Research (SOSR), 2022 — 13 pages

[2] <u>Rinku Shah</u>, 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. — 12 pages

[3] <u>Rinku Shah</u>, Mythili Vutukuru, Purushottam Kulkarni. Cuttlefish: Hierarchical SDN Controllers with Adaptive Offload. In Proceedings of the IEEE 26th International Conference on Network Protocols (ICNP), 2018. — 11 pages **[Core Ranking: A] [Acceptance Rate: 18%]**

Workshops & Short Papers.

[1] Harish S A, K Shiv Kumar, Anibrata Majee, Amogh Bedarakota, Praveen Tammana, Pravein Kannan, <u>Rinku Shah</u>. In-Network Probabilistic Monitoring Primitives under the Influence of Adversarial Network Inputs. In Proceedings of the ACM Asia-Pacific Workshop on Networking (APNet), 2023.

[2] Lasani Hussain, Mayank Rawat, Neeraj Kumar Yadav, Sumit Darak, Praveen Tammana, <u>Rinku Shah</u>. Microservice-based in-network security framework for FPGA NICs. In Proceedings of the IEEE/ACM CCGRIDW 2023.

[3] Shaguftha Kottur, Krishna Kadiyala, Praveen Tammana, <u>Rinku Shah</u>. Implementing ChaCha Based Crypto Primitives on Programmable SmartNICs. In Proceedings of the ACM SIG-COMM Workshop on FFSPIN, 2022. — 6 pages

[4] S. VenkataKeerthy, Yashas Andaluri, Sayan Dey, <u>Rinku Shah</u>, Praveen Tammana, and Ramakrishna Upadrasta.Packet Processing Algorithm Identification using Program Embeddings. In Proceedings of the ACM 5th Asia-Pacific Workshop on Networking (APNet), 2022. — 6 pages

[5] Abhik Bose, Diptyaroop Maji, Prateek Agarwal, Nilesh Unhale, <u>Rinku Shah</u>, Mythili Vutukuru. Leveraging Programmable Dataplanes for a High Performance 5G User Plane Function. In Proceedings of the ACM 5th Asia-Pacific Workshop on Networking (APNet), 2021 .— 6 pages

[6] <u>Rinku Shah</u>, 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. — 6 pages **[Core Ranking: A]**

[7] <u>Rinku Shah</u>, 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 — 6 pages.

[8] Rohit Gupta, <u>Rinku Shah</u>, and Apurva Mhetre. In-memory, high speed stream processing. In Proceedings of the 8th ACM International Conference on Distributed Event-Based Systems (DEBS), 2014. — 4 pages **[Qualis Ranking: A2]**

Research Grants

2023 <u>Cybersecurity and Cybersecurity for Cyber-Physical Systems Innovation Hub (C3iHub)</u>

Project title: Programmable cryptosystem for 5G telecommunication networks
Grant support (PI): Rs. 32 lakhs

2023 <u>Cybersecurity and Cybersecurity for Cyber-Physical Systems Innovation Hub (C3iHub)</u>

Project title: Siegebreaker II: End-to-middle Covert Internet Communication Using Programmable Network Hardware
Grant support (as Co-PI): Rs. 28 lakhs

2022 <u>NIDHI PRAYAS Program (Cohort 3)</u>

Project title: FastCrypt — a smart security hardware for data centers
Grant support (PI): Rs. 7 lakhs

Professional Activities

<u>Conference Session Chair</u>

2023 COMSNETS 2023

<u>Conference Area Chair</u>

2023 ACM India ARCS (Academic Research and Careers for Students)

<u>Member of Technical Program Committee</u>

2022 ACM SIGMETRICS PerfNA Workshop

2022 ACM SIGCOMM Symposium on SDN Research (SOSR)

<u>Shadow Program Committee member</u>

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

<u>Conference Reviewer</u>

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

2017	The Eighth ACM SIGOPS Asia-Pacific Workshop on Systems (APSys)
2014	The 8th ACM International Conference on Distributed Event-Based Systems (DEBS)

Presentations

Building programmable networks
Invited talk at ACM SIGMETRICS PerfNA 2022.

P4 Language and Programable Data Planes
Tutorial conducted at COMSNETS 2022.

Leveraging Programmable Networks to Accelerate Networked Systems
University: IIT Hyderabad (January 2021), IIIT 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: Vidyalankar 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)

Current students

Neeraj Kumar Yadav, Ph.D.

Siddharth Nayak, MTech thesis.

Shaguftha Kottur, MTech thesis.

Lasani Hussain, MTech thesis.

Sidharth Jha, BTech RA

Mayank Rawat, BTech RA

Shivansh Mittal, coadvised with Dr. Sujay Deb, BTech thesis.

Mohammed Kaif, coadvised with Dr. Sujay Deb, BTech thesis.

Yashasvi Chaurasia, coadvised with Dr. Sumit Darak, BTech thesis.

Ritika Nagar, coadvised with Dr. Sumit Darak, BTech thesis.

Samarth Saxena, coadvised with Dr. Sambuddho, BTech thesis.

Rohan Hiranandani, coadvised with Dr. Sambuddho, BTech thesis.

Vishrut Arora, coadvised with Dr. Arani, BTech thesis.

Teaching

Assistant Professor

2021 – present Courses taught at IIIT Delhi
- Computer Networks (CSE 232)
- Programmable Networking (CSE 567)

Teaching Assistant

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

Assistant Professor

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)
- Compiler Construction (PG)

Spring 2003 Course taught at St. Francis Institute of Technology, Mumbai University
- Computer Communication & Networks (UG)

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	<u>Carbon copy</u> 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	<u>pcube</u> 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	<u>Cuttlefish</u> 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.

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.

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

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

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