

## EDUCATION

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- **Princeton University** Princeton, NJ  
*Ph.D. and M.A. in Computer Science* *Jan 2015 – Aug 2018 (expected)*
  - **Thesis:** Enabling Programmable Infrastructure for Multi-tenant Data Centers
  - **Advisors:** Nick Feamster and Jennifer Rexford (co-advisor)
- **National University of Sciences and Technology** Islamabad, PK  
*B.E. in Computer Engineering* *Sep 2004 – Sep 2008*
  - **Thesis:** Extraction and Evaluation of Cyber Social Structures
  - **Advisor:** Shoab A. Khan

## RESEARCH INTERESTS

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Domain-Specific Languages (DSLs) and Specialized Compilers, Software-Defined Networks (SDN), Programmable Data Planes, Wide-Area and Datacenter Networks.

## PROJECTS

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- **Network Services**
  - *Cloud, datacenter, and wide-area networks*
  - **Elmo:** A scalable source-routed multicast for cloud services. (*Maintainer*)
  - **SDX:** A software-defined internet exchange point. (*Contributor*)
  - **Kinetic:** Verifiable dynamic network control. (*Contributor*)
- **Data Plane Languages**
  - *Domain-specific languages (DSLs) and compilers*
  - **PISCES:** A programmable, protocol-independent software switch. (*Maintainer*)
  - **NetASM:** A network assembly language for programmable data planes. (*Maintainer*)
  - **P4:** A language for programming protocol-independent packet processors. (*Contributor*)
- **Virtual Switches**
  - *Network virtualization and overlay networking*
  - **Open vSwitch (OVS):** A production quality, multilayer open virtual switch. (*Contributor*)
- **Programmable Hardware**
  - *FPGAs*
  - **OSNT:** An open-source network tester. (*Maintainer*)
  - **NetFPGA:** A line-rate, flexible, and open platform for research, and classroom experimentation. (*Contributor*)

## PUBLICATIONS

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- **Conferences**
  - *Long papers, Refereed*
  - **Elmo: Source-Routed Multicast for Cloud Services.** Muhammad Shahbaz, Lalith Suresh, Nick Feamster, Jennifer Rexford, Ori Rottenstreich, and Mukesh Hira. *Under Submission*. (<http://elmo.cs.princeton.edu>)
  - **PISCES: A Programmable, Protocol-Independent Software Switch.** Muhammad Shahbaz, Sean Choi, Ben Pfaff, Changhoon Kim, Nick Feamster, Nick McKeown, and Jennifer Rexford. *ACM SIGCOMM, 2016*. (<http://pisc.es.cs.princeton.edu>)
  - **Kinetic: Verifiable Dynamic Network Control.** Hyojoon Kim, Joshua Reich, Arpit Gupta, Muhammad Shahbaz. *USENIX NSDI, 2015*. (<http://kinetic.noise.gatech.edu>)
  - **SDX: A Software Defined Internet Exchange.** Arpit Gupta, Laurent Vanbever, Muhammad Shahbaz, Sean Donovan, Brandon Schinkler, Nick Feamster, Jennifer Rexford, Scott Schenker, Russ Clark, and Ethan Katz-Bassett. *ACM SIGCOMM, 2014*. (<http://kinetic.noise.gatech.edu>)

## Workshops

### Short papers, Refereed

- **The Case for a Flexible Low-Level Backend for Software Data Planes.** Sean Choi, Xiang Long, Muhammad Shahbaz, Skip Booth, Andy Keep, John Marshall, and Changhoon Kim. *ACM APNet, 2017.*
- **The Case for an Intermediate Representation for Programmable Data Planes.** Muhammad Shahbaz and Nick Feamster. *ACM SOSR, 2015.* (<http://netasm.cs.princeton.edu>)
- **From 1G to 10G: Code Reuse in Action.** Gianni Antichi, Muhammad Shahbaz, Stefano Giordano, and Andrew Moore. *ACM HPPN, 2013.*
- **Addition of Virtual Interfaces in NetFlow Probe for the NetFPGA.** Muhammad Shahbaz, Zaheer Ahmed, Habibullah Jamal, Asrar Ashraf, Nadeem Yousaf, and Raania Naeem Khan. 1<sup>st</sup> *European NetFPGA Developers Workshop, 2010.*

## Journals

### Refereed

- **OSNT: Open-Source Network Tester.** Gianni Antichi\*, Muhammad Shahbaz\*, Yilong Geng\*, Noa Zilberman, Adam Covington, Marc Bruyere, Nick McKeown, Nick Feamster, Bob Felderman, Micahela Blott, Andrew W. Moore, and Philippe Owezarski. *IEEE Special Issue on Open Source for Networking: Tools and Applications, Sep 2014.* (\* These authors contributed equally to this work.)
- **Secure Cognitive Mobile Hotspot.** Zaheer Ahmed, Habibullah Jamal, Rizwana Mehboob, Shoab A. Khan, and Muhammad Shahbaz. *IEEE Transactions on Consumer Electronics, May 2010.*
- **Multigig Lossless Data Compression Device.** Rizwana Mehboob, Shoab A. Khan, Zaheer Ahmed, Habibullah Jamal, and Muhammad Shahbaz. *IEEE Transactions on Consumer Electronics, Aug 2010.*

## Technical Reports

### Non-refereed

- **Per-Flow Quality of Service for Broadband Access Networks.** M. Said Seddiki, Muhammad Shahbaz, Sean Donovan, Sarthak Grover, Miseon Park, Nick Feamster, and Ye-Qiong Song. *Georgia Institute of Technology, Sep 2015.*

## Books and Book Chapters

- **Digital Design of Signal Processing Systems: A Practical Approach.** Editing, synthesis and simulation of Verilog codes. *John Wiley & Sons, 2007.*

## PROFESSIONAL AND RESEARCH EXPERIENCE

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### Princeton University

Princeton, NJ

#### Assistant in Research

Feb 2015 – Present

- **NetASM:** Technical lead on the design and development of a network assembly language for programmable data planes.
- **Other projects:** Elmo, PISCES, SDX, Kinetic, and OSNT, in collaboration with VMware, Barefoot Networks, and Stanford University (see below).

### VMware

Palo Alto, CA

#### Data Plane xCloud Intern

Jun – Sep 2017

- **Elmo:** Technical lead on the design and development of a source-routed multicast for cloud services, scaling to millions of multicast groups.

### VMware

Palo Alto, CA

#### Software Engineering Intern

Jun 2016 – Jan 2017

- **Open vSwitch (OVS):** Worked with the OVS team on adding support for a domain-specific language (DSL), called P4, to Open vSwitch. Responsible for implementing the P4 frontend for OVS.

### Barefoot Networks

Palo Alto, CA

#### Software Engineering Intern

May – Sep 2015

- **PISCES:** Technical lead on the design and development of a high-performance programmable protocol-independent software switch which is customizable via a high-level DSL (*i.e.*, P4).
- **P4 Specification (version 14):** Introduced new annotations to the language for efficient compilation to software-switch targets.

- **P4-to-eBPF:** Worked with the compiler team on adding a P4 frontend to eBPF. Responsible for understanding and implementing the match-action tables and checksums using the new eBPF helper functions, introduced in Linux Kernel v4.2.

- **Stanford University**

Stanford, CA

*Visiting Scholar*

*Jun – Aug 2013*

- **OSNT:** Collaborated with a team from Stanford and Cambridge university, Google, and Xilinx on designing and developing an open-source network tester for academia and research community. Responsible for implementing the traffic generator part of the network tester.

- **Georgia Institute of Technology**

Atlanta, GA

*Research Assistant*

*Jan 2013 – Jan 2015*

- **SDX:** Participated in the design and development of a software-defined internet exchange to enable novel applications at the exchange points (like application-specific peering and inbound traffic engineering). Responsible for the design of the new software-defined route server using ExaBGP and Pyretic controller.
- **Kinetic:** Participated in the design and development of a dynamic network control system and the accompanied DSL. Responsible for implementing the event-notification drivers using sFlow-RT.

- **University of Cambridge, Computer Laboratory**

Cambridge, UK

*Research Assistant*

*Aug 2011 – Oct 2012*

- **NetFPGA-10G:** Collaborated with a team at Cambridge and Stanford university, and Xilinx on launching a new hardware platform for research and classroom experimentation. Acted as a developer lead on the project. Responsible for leading the weekly group meetings, and implementation and maintenance of the RTL codebase.

- **Xilinx, Research Laboratory**

Dublin, IE

*Research Assistant*

*Oct 2011*

- **NetFPGA-10G:** Technical lead on the design and development of the reference Flash controller IP.

- **Center for Advanced Research in Engineering (CARE)**

Islamabad, PK

*Senior Design Engineer*

*April 2008 – July 2011*

- **NGN-VOIP Monitoring:** Worked on a national-scale VoIP monitoring solution to prevent rapid proliferation of Internet and VoIP-based communication. Served as a technical lead on the design and implementation of the FPGA-based hardware accelerator – and the accompanied device driver for Windows – for pre-filtering network traffic at various ISPs, around the country, before forwarding it to a central collector located inside the country's capital. (The project won the best in Security Applications award at APICTA, Malaysia, 2010.)

## TEACHING EXPERIENCE

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- **Princeton University**

Princeton, NJ

*Assistant in Instruction*

*Feb – May 2015*

- **Computer Networks (COS 461):** Responsible for teaching weekly precepts, and grading assignments and exams.

- **Udacity – Georgia Tech's Online Master Program**

Atlanta, GA

*Teaching Assistant*

*May – Aug 2014*

- **Computer Networks:** Responsible for managing the discussions on Piazza, and grading assignments and exams. Also, helped create programming assignments for the course.

- **Georgia Institute of Technology**

Atlanta, GA

*Teaching Assistant*

*Jan – May 2014*

- **Advanced Computer Networks (CS 6250):** Responsible for grading assignments and exams.

- **Coursera**

*Teaching Assistant*

*May – Aug 2013*

- **Software Defined Networks (SDN):** Offered the first online course on SDN with my advisor, Prof. Feamster. More than five thousands students enrolled in the course. Responsible for managing discussions on Piazza and keeping the students engaged. Also, created all the programming assignments offered during the course.

- **NetFPGA**

*Instructor*

- **Summer Camp:** Instructor for the hands-on workshop at Stanford University (Week-long, Aug 2013).

- **Tutorial:** Instructor for the hands-on workshop at ACM SIGMETRICS (Day-long, Jun 2012).

## • Xilinx EDA

*Instructor*

- **Tutorial:** Instructor for the hands-on workshop at NUST (Day-long, Oct 2010).

## STUDENT MENTORING

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- **Sean Choi:** Graduate student at Stanford University, 2015 – 2016.
- **Kamran Ali Akhtar:** Graduate student at National University of Sciences and Technology (NUST), 2014.

## TALKS

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### • PISCES: A Programmable, Protocol-Independent Software Switch

- *Barefoot Networks, P4 Developer Day, and OVSCon.* Nov 2016.
- *VMware and Microsoft Research (Redmond).* Jul 2016.
- *P4 Workshop.* May 2016.
- *AT&T Research Academic Summit.* Mar 2016.
- *OVSCon.* Nov 2015.

### • NetASM: A Network Assembly Language

- *ONF Workday Event: PIF Session.* Sep 2015.
- *ACM SOSR.* Jun 2015.

### • SDX: A Software-Defined Internet Exchange

- *Internet2 Global Summit.* Apr 2014.
- *US Ignite ONF Join Workshop.* Oct 2013.
- *Open Networking Laboratory.* Aug 2013.

### • From 1G to 10G: Code Reuse in Action

- *ACM HPPN.* Jun 2014.

## PANELIST

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### • Juniper Software Defined Networking Event

Atlanta, GA

*Georgia Institute of Technology*

*Sep 24, 2013*

## PROFESSIONAL SERVICES

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### • IEEE/ACM Transactions on Networking (ToN)

*Reviewer, 2015 and 2017*

## PROFESSIONAL MEMBERSHIPS

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### • Association for Computing Machinery (ACM)

*Student Member*

*2013 – Present*

### • USENIX Association

*Student Member*

*2013 – Present*

## GRADUATE COURSES

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- **Princeton University:** Fundamentals of Machine Learning, and Reading and Writing about the Scientific Literature.
- **Georgia Institute of Technology:** Computer Networks; High-Performance Computer Architecture; Introduction to Graduate Studies; Software Defined Networking; Design and Analysis of Network/Router Algorithms and Hardware; Computability, Algorithms, and Complexity; Software Analysis and Testing.

## PROGRAMMING SKILLS

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- **Languages** – Python, C and C++, P4 (proficient); C#, Java, Haskell, Verilog, VHDL, and Matlab (prior experience)
- **Technologies** – **Virtualization:** Open vSwitch, Docker, Kubernetes, Proxmox VE, Linux Virtual Server (LVS); **Key-Value Store:** Memcached, etcd; **Messaging:** RabbitMQ, ZeroMQ; **DevOps:** Ansible, Fabric; **Cloud:** AWS, GCE; **SDN:** OpenFlow; **Hardware:** NetFPGA-1G and 10G; **Network Testing:** MoonGen, iperf, httpperf; **Route Server:** Quagga, ExaBGP; **Monitoring:** sFlow; **Kernel Bypass:** Intel DPDK.

## RECOGNITION AND HONORS

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- **Nominated to attend Google Networking Research Summit.** Sunnyvale, CA, Feb 2017.
- **Second place in ONUG SDN Hackathon** for demonstrating excellence in the area of code development for open programmable networks, New York, NY, 2014.
- **Graduate Teaching Assistant Award** for outstanding work on the Coursera SDN MOOC, Georgia Tech, 2014.
- **NSF Travel Award** for US Ignite ONF Joint Workshop, Juniper Networks, Sunnyvale, CA, 2013.
- **Internet2 Innovative Applications Award** for the applications of Software Defined Networking (SDN) in Internet Exchange Points (IXPs), 2013.
- **Google Travel Grant** for Open Networking Summit (ONS), San Jose, CA, 2013.
- **Star Laureate Award** in recognition of credentials par excellence on Pakistan level, South Asia Publications, 2008.
- **Excellence Award** and honorable mention in the Galaxies of Who's Who in Pakistan, South Asia Publications, 2007.
- **Gold Medal** for the best final year project at National University of Sciences and Technology (NUST), Islamabad, PK, 2008.
- **Silver Medal** in the field of Intermediate Computer Sciences (ICS) in Federal Board of Intermediate and Secondary Education (FBISE), Islamabad, PK, 2004.

## REFERENCES

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- **Dr. Jennifer Rexford**
  - *Professor and Chair, Department of Computer Science, Princeton University*
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- **Dr. Nick McKeown**
  - *Professor, Department of Computer Science, Stanford University*
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