Kausik Subramanian

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My research interests lie in the application of formal reasoning and programming languages techniques for verification and synthesis of networks. In recent times, networks have become increasingly complex and difficult to reason about and manage. My vision envisages developing techniques for verifiying and correctly programming networks based on intent, where operators should specify what the network should do, instead of how these intents are met.

Education

- **University of Wisconsin-Madison**
  M.S Computer Science, CGPA: 3.839/4.00 — *Fall 2015–Fall 2017*
  PhD Computer Science, Advisors: Aditya Akella and Loris D'Antoni — *Fall 2017–Present*

- **Indian Institute of Technology, Bombay**
  BTech. Computer Science and Engineering — Fall 2011-Spring 2015
  Advisors: Purushottam Kulkarni and Umesh Bellur

Publications

- **Synthesis of Fault-Tolerant Distributed Router Configurations**
  Kausik Subramanian, Loris D'Antoni and Aditya Akella
  ACM International Conference on Measurement and Modeling of Computer Systems (SIGMETRICS), Irvine, California, USA, 2018
- **Genesis: Synthesizing Forwarding Tables in Multi-tenant Networks**
  Kausik Subramanian, Loris D'Antoni and Aditya Akella
  44th ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages (POPL), Paris, France, 2017, (23% acceptance rate)

Experience

- **Barefoot Networks, Santa Clara** — *Summer 2017*
  Research Intern, Advanced Applications — Mentors: JK Lee, Robert Soule and Changhoon Kim
  - Implemented various static analysis techniques for optimizing P4 programs in the Barefoot Tofino backend compiler pertaining to table dependencies and metadata usage based on P4 developers' programming styles. Made several bug fixes to the open-source P4 compiler (https://github.com/p4lang/p4c).

- **Samsung Electronics, Suwon, South Korea** — *Summer 2014*
  Research Intern, Software R&D Center — Mentors: Jeongshik In and Jaehoon Ko
  - Proposed four Optimizations for Hadoop's Distributed File System. Analysed and modified the source code of HDFS to find the performance bottlenecks and add features.

- **Fraunhofer ITWM, Kaiserslautern, Germany** — *Summer 2013*
  Research Intern — Mentor: Mirko Rahn
  - Implemented the Chord distributed hash table protocol using Fraunhofer's communication middleware GPI, which provides synchronous and asynchronous communication methods

Research Projects

- **Genesis: Forwarding Table Synthesis for Multi-tenant Networks**
  Research Assistant, UW-Madison — Fall 2015 - Summer 2016

Developed Genesis, a network management system with support for end-to-end policies like reachability, middlebox traversals, isolation, traffic engineering and network resource management. Genesis synthesizes switch forwarding tables using fast off-the-shelf SMT and MaxSMT solvers, thus offering generality and extensibility. To speed up synthesis, Genesis incorporates domain-specific search strategies which leverage the structure of datacenter topologies and policy interactions. Genesis supports network repair which minimizes the overhead of rule updates in the event of network failures, and synthesis of policy-compliant resilient data-planes by transforming input policies with isolation policies, which can be used to synthesize edge-disjoint paths between endpoints.

- **Synthesis of Fault-Tolerant Distributed Router Configurations**
  Research Assistant, UW-Madison Summer 2016 - Fall 2017

  Operators of modern networks require support for diverse and complex end-to-end policies, such as, middlebox traversals, isolation, and traffic engineering. While Software-defined Networking (SDN) provides centralized custom routing functionality in networks to realize these policies, many networks still deploy "traditional" control planes running distributed routing protocols like OSPF and BGP because these protocols are scalable and robust to failures. However, realization of policies by distributed control plane configurations is manual and error-prone. We show that synthesizing policy-compliant highly-resilient control planes is a challenging problem and propose, Zeppelin, a tool for automatically generating policy-compliant control planes that also behave well under small network failures. Zeppelin differs from existing approaches in that it uses policy-compliant paths to guide the synthesis process instead of directly generating policy-compliant configurations. We show that Zeppelin can synthesize highly resilient and policy-compliant configurations for real topologies with up to 80 routers.

- **P4 Compiler Optimizations**
  Research Intern, Barefoot Networks Summer 2017

  P4 is an emerging language for expressing how packets are processed by the data plane of a programmable forwarding element such as hardware switches. One of the foremost challenges to compiling P4 programs to the switch is resource fitting, i.e., the P4 program must be able to execute using the switch's fixed resources (otherwise the compiler returns error). Thus, it is important to optimize P4 programs to aid fitting. I worked on prototyping different P4 program optimizations for Barefoot's P4 compiler for Tofino switches. First, I analysed real-world P4 programs for inefficiencies of programming in P4 which can be automatically optimized by the compiler (akin to gcc optimizations). I identified various candidates for optimizations pertaining to table dependencies (which decide the placement of tables on the switch) and metadata usage (which are mapped to limited number of physical containers) and implemented static control- and data-flow analyses to optimize P4 programs.

Other Projects

- **Predictive Queue Management in SDNs:** *Advanced Networks Course Project @ UW-Madison*

  We provide latency guarantees to latency-sensitive flows in a software-defined datacenter setting by building predictive models of switch queue buildups using OpenFlow's support for querying switches for flow statistics to predict flow characteristics. With a predictive model in place, we develop a greedy earliest-deadline-first scheduling algorithm for finding new paths for flows to prevent queue buildups affecting mice flows.

- **POXVine: Multi-Tenant Virtual Network Emulator:** *BTech. Thesis Project @ IIT Bombay*

  Designed and built a multi-tenant virtual network emulation application POXVine using the POX controller which controls a network emulated over Mininet. POXVine emulates multiple virtual networks over an emulated physical network in Mininet. The virtual-to-physical mapping tries to minimize the number of physical switches which contain rules to the virtual topology. The POX controller adds routing rules such that the virtual network abstraction is preserved, on the physical topology, packets traverse the virtual network entities in the order of the virtual network topology.
  Github repository: https://github.com/sskausik08/poxvine

- **Hadoop Optimizations:** *Internship @ Samsung Software R&D Center, South Korea*

Proposed four Optimizations for Hadoop's Distributed File System. Analysed and modified the source code of HDFS to find the performance bottlenecks and add features: (1) Replicator: Independent module to find frequently accessed files in a cluster and increase its replication factor. (2) Disk Access Optimization: Analysed the bottleneck in read operations at a datanode and implemented a memory-buffered read to reduce disk seeks. Achieved a 6 percent improvement for a single datanode benchmark. (3) Balanced Block Placement Policy: Modified Hadoop's default block placement policy to create a balanced cluster by accounting memory usage of nodes and racks while choosing a node to place a replica. (4) Block-level Caching and Pre-fetching: Extended HDFS's file-level caching mechanism to a finer block-level caching and performed pre-fetching of blocks in a read operation. Achieved 6% improvement in a 4-node cluster.

Talks and Posters

- Genesis: Synthesizing Forwarding Tables in Multi-tenant Networks
  Talk at POPL'17, Paris, France
  Talk at VMWare Research Group, August 2017
- Synthesizing Data and Control Planes for Multi-tenant Networks
  Poster at Google Networking Research Summit 2017

Academic Honors

- Awarded the UW-Madison CS Summer Research Assistantship, 2016 (awarded to 6 people).
- Awarded Grant to attend POPL and PLMW 2017, held in Paris, France.
- Awarded Student Travel Grant to SIGCOMM'16, held in Florianopolis, Brazil.
- Secured All India Rank 87 in IIT-JEE 2011 out of 485,000 students.
- Secured All India Rank 3 in 10^{th} CBSE Board Examination, 2009. Was invited by the PM's Office to witness the Republic Day Parade from the Prime Minister Box in New Delhi in 2010.

Technical and Personal skills

- Proficient in Python, Z3, Gurobi, LaTeX, P4
- Familiar with Android, C++, Java, Hadoop, POX

Courses

- *Networks/Systems*: Advanced Networking, Big Data Systems
- *Programming Languages*: Program Verification and Synthesis, Theory of Programming Languages, Advanced Compilation
- *Pedagogy*: Teaching in the College Classroom, Effective Teaching in Internationally Diverse College Classroom
- *Miscellaneous*: Topics in Databases, Advanced Algorithms, Computational Complexity Theory

Positions of Responsibility

- Mentor, Institute Student Mentorship Programme 2014-15
  Mentoring a group of 12 freshmen and easing their transition to the academic and social aspects of institute life. Also serving as a Department Academic Mentor to 12 sophomores, guiding them about CS academic aspects.
- Internship Coordinator, Placement Cell 2013-14
  Involved in the communication and scheduling of various companies as well as universities and assisting them in the process of recruiting of students for internships. Awarded Certificate of Appreciation by Dean, Academic Affairs for exemplary work during the tenure.

Teaching

- Teaching Assistant, Computer Networks (CS640)
  University of Wisconsin-Madison — Fall 2015
  Prof. Paul Barford
- Teaching Assistant, Compilers Lab (CS306)
  Indian Institute of Technology, Bombay — Spring 2015
  Prof. Amitabha Sanyal

References

- Available on request