Cornell-Princeton Network Programming Initiative

http://network-programming.org

The development of high-level programming languages in the early decades of computing was a major achievement that provided a key catalyst for the explosion of rich applications we are seeing today. High-level languages offer numerous advantages over machine code: intuitive programming abstractions, powerful reasoning techniques, portability across platforms, and even opportunities for optimization. There is widespread agreement that the benefits of high-level languages outweigh the modest costs they impose, and few programs today are written in machine code.

In networking, however, the situation is completely different. Network devices are expected to implement a wide variety of complex services—e.g., computing routes, balancing load, analyzing traffic, caching content, enforcing security, etc.—but these services must be expressed using the low-level languages supported by routers, switches, and middleboxes. Doing this correctly is a major challenge for programmers and operators, as can be seen from the large number of costly service disruptions in the news headlines. Even small mistakes, such as installing the wrong access control list on a device, can have a big impact, leading to problems such as outages, performance degradations, and security vulnerabilities.

We created the Cornell-Princeton Network Programming Initiative to support research on languages, algorithms, and tools for network programming, and to facilitate closer interactions with partners in industry and government. Our goal is to initiate a transformation from low-level to high-level languages in networking similar to the one that occurred in the rest of computing many years ago.

Scope. This effort will require a multi-year effort involving a collaborative team doing work in areas such as networking, systems, programming languages, formal verification, and algorithms. Our team has collaborated successfully in the past and is well-known for many early results in software-defined networking. Following is a list of areas we believe are ripe for further innovation and are “in scope” for the center:

- *Programming Languages:* design of high-level languages for specifying network behavior and compilers that generate efficient low-level code for network devices (e.g., Frenetic, Pyretic, FatTire, Merlin, NetKAT);
- *Verification Tools:* tools for checking control plane and data plane properties automatically (e.g., NetKAT, Kinetic, etc.);
- *Data Plane Architectures:* hardware and software platforms for supporting network programming (e.g., OpenFlow, P4, NetFPGA, PISCES);
- *Controllers:* architectures that support distribution, fault tolerance, and software upgrades (e.g., Frenetic, Ravana, Morpheus);

- *Consistency Models:* dynamic programming models that provide strong consistency properties (e.g., Consistent Updates, Update Synthesis, SNAP, Stateful NetKAT);
- *Interoperability and Deployment:* techniques for implementing network programs using traditional routing protocols on conventional devices (e.g., Fibbing, Propane);
- *Novel Applications:* network programs that solve practical problems related to traffic engineering, measurement, time synchronization, distributed consensus, etc. (e.g., HALO, DTP, Felix, NetPaxos);
- *Security:* techniques for automatically enforcing security properties such as access control policies and traffic isolation between tenants (e.g., NetKAT, Splendid Isolation).

Our goal in creating this center is to build on and significantly extend these initial efforts, while working with our partners to help transition our existing research prototypes into practice.

Personnel. Nate Foster (Cornell: networking and programming languages) and Jennifer Rexford (Princeton: networking and systems) will serve as co-directors and will coordinate efforts at their respective institutions. Other faculty members will include Rachit Agarwal (Cornell: networking and systems), Nick Feamster (Princeton: networking and systems); Aarti Gupta (Princeton: formal verification), Bobby Kleinberg (Cornell: algorithms); Dexter Kozen (Cornell: programming languages), Sharad Malik (Princeton: formal verification), Kevin Tang (Cornell: networking and control), David Shmoys (Cornell: algorithms and optimization), Robbert Van Renesse (Cornell: networking and distributed systems), David Walker (Princeton: networking and programming languages), and Hakim Weatherspoon (Cornell: networking and systems). We expect that several dozen researchers, postdocs, and graduate students will also participate in the initiative.

Activities. To facilitate close interactions with partners in industry and government, we will organize an annual retreat that will highlight recent research successes and identify key directions for the upcoming year. We will also organize workshops on specific technical topics as the need arises. We will broadcast a monthly “Hangouts on Air” with presentations on recent research results and discussions of compelling use cases. Finally, we will publish a blog on our website.

Affiliates. We have a formal industrial affiliates program with a modest membership fee to help fund our activities. The primary benefits of affiliate membership include invitations to workshops and other events; an annual report with summaries of research highlights; early access to research papers; and increased opportunities for collaboration with faculty, postdocs, and students. Affiliates are also invited to send visiting scholars to Cornell and Princeton, subject to an additional fee to cover the associated costs.