Project Summary

The design and analysis of network algorithmics solutions is a rich area of research that has led to numerous successful deployments in commercial Internet routers and network monitoring appliances. In general, network operators would like to have solutions that are robust under a wide variety of, *often unforeseen*, operating conditions. However, the performance of a network appliance or the accuracy of an estimation method is often dependent on workload uncertainties that are beyond the control of the operator. Unfortunately, applicable mathematics for the rigorous analysis of worst-case stochastic behaviors of network algorithmics solutions under arbitrary workloads is largely lacking.

Intellectual Merit: In this project, we propose to investigate the fundamental science behind the analysis of worst-case stochastic behaviors in network algorithmics problems. Understanding how a solution would behave in the worst-case, not just in the typical case, is important for two reasons. First, with suitable mathematics to characterize worst-case workloads, we can design solutions that will work well under any conditions, including those in which an adversary is trying to break the system, or under unexpected changes in the usage pattern. Second, more often than not, we have found surprisingly in our past efforts that delivering solutions that can guarantee high performance under worst-case conditions cost only slightly more than designs that don't, but coming up with such solutions hinges on our ability to understand the characteristics of the worst-case scenarios so that we can design around them.

In particular, we seek to sustain our highly successful collaborative efforts on a rich family of worst-case large deviation problems that naturally arise in network algorithmics. Worst-case large deviation theory is concerned with the probability that the sum of some parameterized random variables will exceed a given threshold under all parameter settings, which may correspond to various operating conditions or workloads. Although establishing such probability tail bounds is often straightforward through Chernoff bounding techniques for a specific parameter setting (i.e., a specific operating condition or a specific type of workloads), establishing the worst-case bounds for all parameter settings proves to be very difficult.

Over the past few years, we have identified and solved several worst-case large deviation problems in our quest for robust network algorithmics solutions, and have developed some mathematical and system design methodologies for attacking such problems. In this effort, we have also discovered many open problems that we are going to tackle in this project. The intellectual merit of this project stems from our proposed unified conceptualization of mathematical techniques and design principles that will enable future network algorithmics solutions to be robust under worst-case settings. We expect powerful new methodologies based on the combination of convex and stochastic ordering, Schur-convexity, and large deviation theory to emerge from our research that will find new applications to a broad range of networking problems.

Broader Impact: This project will engage both graduate and undergraduate students through integrated classroom curriculum and research training that span multiple disciplines, from fundamental mathematics, algorithm design, to hardware implementation. The results will be broadly disseminated through publications, invited talks, tutorials, and open-sourcing of software developed for this project in accordance with the policies of each institution. The PIs will work closely with leading networking and systems solution providers to facilitate the transfer of technology from the research environment to actual commercial deployments. Further, both PIs are committed to outreach efforts at our corresponding campuses to broaden the participation of under-represented groups in research and higher education, e.g., via the McNair Program for low-income first-generation college students from under-represented groups at UCSD.

Keywords: worst-case large deviation; network algorithmics; mathematical foundation of network science; performance evaluation; convex and stochastic ordering theory.