**Stochastic Congestion Control Protocols for High End-to-End Throughput in Next Generation Cellular Networks**

Faculty: Prof. Subramanian, Prof. Panwar, Prof. Jay Chen (NYU Abu Dhabi)

Potential Students: One potential student I would like to support in this grant is Renfei Zou who is an MS student in my Networks and Mobile Systems class and stood out as among the top students in the class. Renfei may be a potential candidate for PhD in the future and I have recruited him as an RA this summer.

This work aims to improve upon the Sprout work by Keith Winstein who got an offer from Stanford and Princeton for the Sprout work. This proposal builds upon current joint work of Prof. Jay Chen and Prof. Subramanian and the work is led by Yasir Zaki, a postdoc of Jay Chen. Yasir does not require support.

Affiliate Sponsors whom it could interest: Any sponsor who cares about end-to-end performance on cellular networks. Potentially AT&T, Cisco, NSN, Huawei, Qualcomm, Ericsson, L3.

Overview Research Statement: Cellular network channels are highly variable and users often experience high fluctuations in their radio link rates over short time scales due to scarce radio resources. This makes the underlying channel relatively hard to predict. Legacy congestion control protocols, such as TCP and its variants, are known to not perform well over cellular networks due to high capacity variability, self-inflicted packet delays, stochastic packet losses that are not linked to congestion, and large bandwidth-delay products. The congestion problem is bound to potentially get significantly worse in next-generation mmWave networks where the underlying channel capacity may vary highly over very short time scales. None of the existing congestion control protocols can operate in such highly variable network conditions and either sacrifice end-to-end throughput or experience high end-to-end delay variability due to the use of large buffers at base stations. In this proposal, we aim to explore the design of new stochastic exploration based congestion control protocols for highly variable cellular channels.

Research Thrusts and Improvements to NYU WIRELESS: Our goal is to design new stochastic exploration based congestion control protocols for highly variable cellular channels that can significantly improve over prior art. Sprout is a recent well-received congestion control proposal by Winstein et al. that aims to partially address this problem, based on stochastic modeling of the cellular channel model, with the objective of maximizing throughput while significantly reducing self-inflicted queuing delays. Based on preliminary channel measurements of two commercial 3G and LTE cellular networks we have observed that some of Sprout’s assumptions fail in the face of competing traffic especially when operating under high contention. We also observe that the bursts experienced by end-to-end flows are of highly variable sizes and simple channel predictors fail in predicting the cellular channel. In addition, mobility has a significant impact on performance. The key idea we aim to explore is to design congestion control protocols that constantly remain in a stochastic exploration mode for highly variable channel conditions. In this vein, as an initial prototype, we have designed Verus, which represents one version of such a stochastic exploration based congestion control protocol. Unlike conventional congestion control protocols, Verus does not preset a fixed sending window (or rate) but stochastic chooses an operational window that varies every epoch based on using cues from delay variations and packet losses. Verus leverages the basic window-based framework of the TCP protocol including slow start and loss-based window decrement, but replaces the additive increase step with a combination of stochastic increment and decrement steps. The stochastic steps can be viewed as an adaptive congestion avoidance measure in Verus to quickly react to rapidly changing channel conditions using delay variations over small windows as an important hint for measuring the impact of window growth on self-inflicted queuing delays. Our early results are very encouraging. Based on real world evaluation in 3G and LTE networks, we show that especially under mobility and contention Verus outperforms Sprout in terms of throughput (1.2-5.9x) while only incurring a small buffering delay penalty ranging from (0-50 ms). Verus offers similar throughput as TCP Cubic without incurring a heavy delay penalty; Verus reduces the end-to-end delay experienced by Cubic by a factor 2-5. While these represent some early results, much more work needs to be done to characterize different cellular network channel variations and experiment with stochastic congestion control mechanisms under highly variable conditions. In addition, we aim to extend this design to 5G cellular networks that operate in mmWave environments. Specifically, we would like to utilize the channel measurements in NYU WIRELESS to experiment with these congestion control protocols in mmWave channel environments.

Need for Additional Funding: We seek funding to support 1 student (MS or PhD) who can help lead this project effort. One potential candidate is Renfei Zou who is currently funded as a summer RA from Prof. Subramanian’s Google Faculty Award. We currently have one postdoctoral researcher at NYU Abu Dhabi funded by Prof. Jay Chen who is leading this project effort and will continue to be involved.

Justification for the project: Congestion control is one of the fundamental problems in networks and in the contexts of next generation cellular networks with mmWaves where the underlying channel will be highly variable and potentially hard to predict. NYU WIRELESS should also potentially consider focusing on higher layers of the networking stack and we believe focusing on the congestion control problem for mmWave channels will be a hot topic of research once commodity mmWave devices become available.