RESEARCH STATEMENT

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My research has mainly been in two areas of distributed MIMO and millimeter wave communication. A brief summary of each is given below.

DMIMO techniques enable the cooperation of many independent nodes to communicate a common message to one or more distant receivers. One special case is distributed transmit beamforming where transmitters coordinate their signals to form a virtual array toward a receiver. Achieving the tight synchronization required for realizing distributed beamforming has been the subject of my research.

Frequency synchronization:

The distributed nature dictates that each node utilizes its own local oscillator which operates with an independent frequency offset and drift from nominal. To lock these oscillators together with minimal overhead, short bursts of carrier broadcast from a reference node are used for synchronization. Since one-shot frequency estimation is not possible from these short bursts, we devise an approach for accurately detecting frequency offset from phase measurements by "unwrapping" the phase from one measurement to the next. We utilize a Rao-Blackwellized particle filter with dithered measurement times to achieve this and demonstrate the efficiency of the proposed method in detecting frequency offset and tracking drift as well as fast adaptation to synchronization loss[1].

Phase synchronization:

To provide the phase synchronization required for distributed beamforming, aggregate feedback techniques such as the one-bit-feedback algorithm iteratively move toward synchronization by introducing small random variations in phase offsets and deciding to keep or discard the variation based on feedback from the receiver. This scheme can be extended to a wideband setting using OFDM with slightly increased feedback overhead[2]. We found, however, that the one-bit-feedback algorithm is highly susceptible to noise and cannot scale well with noisy measurements[3]. We therefore proposed an aggregate feedback scheme based on batch transmissions of quasi-orthogonal sequences that provides the same robust performance of one-bit-feedback while maintaining scalable performance in noise[4].

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[1] Rasekh, M. E., Madhow, U., & Mudumbai, R. (2014, November). Frequency tracking with intermittent wrapped phase measurement using the Rao-Blackwellized particle filter. In Signals, Systems and Computers, 2014 48th Asilomar Conference on (pp. 247-251). IEEE.

[2] Gencel, M. F., Rasekh, M. E., & Madhow, U. (2015, June). Scaling wideband distributed transmit beamforming via aggregate feedback. In Communications (ICC), 2015 IEEE International Conference on (pp. 2356-2362). IEEE.

[3] Gencel, M. F., Rasekh, M. E., & Madhow, U. (2015, June). Distributed transmit beamforming with one bit feedback revisited: How noise limits scaling. In Information Theory (ISIT), 2015 IEEE International Symposium on (pp. 2041-2045). IEEE.

[4] Gencel, M. F., Rasekh, M. E., & Madhow, U. (2015, November). Noise-resilient scaling for wideband distributed beamforming. In Signals, Systems and Computers, 2015 49th Asilomar Conference on (pp. 276-280). IEEE.

In the area of **millimeter wave communication**, the focus of my research has been on technologies that enable next generation mobile networking through realization of high-throughput urban picocells.

Compressive user tracking:

Utilization of wideband directional mmwave links for base station-to-mobile communication has the potential to increase the data rate delivered to users by orders of magnitude through vigorous spatial reuse, yet the task of maintaining beam alignment toward mobile users is challenging as array sizes grow. To this end, my collaborators and I worked to develop noncoherent compressive tracking techniques that perform fast user tracking with minimal overhead on the simplified front-ends of commodity hardware[5]. The efficiency of the proposed methods was demonstrated on a 60 GHz antenna array testbed provided by the facebook Terragraph team.

Millimeter wave mesh backhaul:

Another important challenge in the realization of urban picocells is providing backhaul for the high density of base stations that cell shrinking entails. Wireless backhaul solutions provide a cost-effective and robust alternative to wired backhaul, which motivates the implementation of a multi-hop mesh network of high-rate directional mmwave links for routing cell data to and from gateways. Resource allocation in such a network must be carried out to obtain optimal backhaul throughput in the face of interference. Our work, in collaboration with Prof. Guo at Northwestern University, addresses this problem by proposing a joint routing and scheduling algorithm for the mmwave mesh network that maximizes throughput given the interference behavior of the network[6].

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[5] Rasekh, M. E., Marzi, Z., Zhu, Y., Madhow, U., & Zheng, H. (2017, February). Noncoherent mmWave path tracking. In Proceedings of the 18th International Workshop on Mobile Computing Systems and Applications (pp. 13-18). ACM

[6] Rasekh, M. E., Guo, D., & Madhow, U. (2015, September). Interference-aware routing and spectrum allocation for millimeter wave backhaul in urban picocells. In Communication, Control, and Computing (Allerton), 2015 53rd Annual Allerton Conference on (pp. 1-7). IEEE.