Scalable Synchronization for Distributed MIMO

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Problem

Wireless spectrum is a limited resource, and we’re running out of available spectrum right as wireless data usage is poised to explode. Further complicating matters, adding more basestations to serve this additional traffic increases interference, thereby making spectrum sharing more difficult.

Solution

By coordinating separate transmitters to act as a single, multiple antenna transmitter we can eliminate interference. Through a common processor with channel state information, beamforming vectors can be calculated (e.g., Zero-Forcing Beamforming) such that all transmitted signal power is useful and none is wasted on interference.

Intuition

Southeast Asian Fireflies are known to blink simultaneously, even in large groups where an individual cannot see all the others. We wish to emulate this Emergent Behavior through a class of algorithms known as Consensus. Our nodes exploit only local information yet come to a globally agreed upon solution.

Challenge

Three parameters require synchronization:
- Carrier clock
- Sampling clock
- Timing (transmission start)

Under OFDM, these impairments exhibit as rotations of the baseband symbols dependent upon the time and frequency indices. From the figure at right, the combined effect of these impairments should be less than 2 degrees.

Results

Using well-designed timing and frequency estimators is key to the consensus algorithm. We see from the normalized mean-squared error that above a certain threshold, the frequency estimator approaches the Cramer-Rao Bound.

This Figure illustrates the simulated topology. Circle markers are APs, spaced at regular intervals, while + markers are clients, distributed randomly throughout the field.

This Figure shows the progression of the consensus algorithm. None of the nodes know the frequency to which they are converging, but the final frequency is irrelevant. The key result is that the nodes come within less than 10 Hz of one another, well within the imposed constraint.