FARhang Wireless

MCMC & MIMO:
Improving Wireless Capacity and Speed



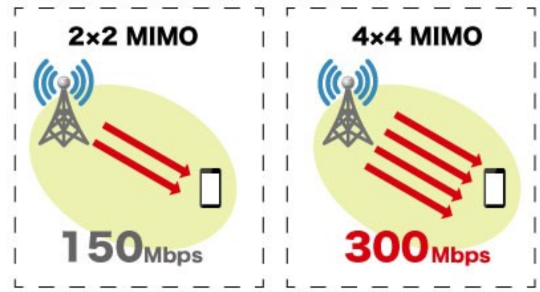
The goal of this whitepaper is to explain why MIMO is so important in the race to increase wireless capacity and the role that the MCMC detector will play in its success. This technology has dramatic implications for LTE cellular tower equipment, LTE small-cells, next generation LTE based broadband for communities without cabled internet, and WiFi.

Capacity's Curse

When speaking to home internet and cell phone consumers the same pain point is echoed again and again, they need more data! According to marketing material, WiFi routers can deliver gigabit speeds and LTE cell phones can supposedly provide 50 Mbps. This should be more than enough if an HD video stream consumes only 24 Mbps. So then why do families and college students have reliability problems with more than two people streaming video, and even smartphones have inconsistent web service when in the city with strong signal? The key is capacity, the number of people connected multiplied by the amount of data each person is consuming. At home, too many family members and neighbors all trying to watch their favorite shows at the same time, sharing a connection is an annoyance. For billion dollar cellular carriers, capacity limitations can have a huge affect on profitability and is why data plans are capped so aggressively. A necessary part of the solution is MIMO.

Magnificent MIMO and its Dark Secret

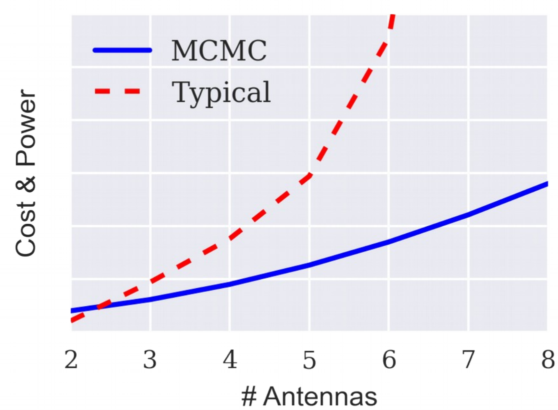
Even though the wireless industry has seemingly saturated the limited wireless capacity available, they are preparing for 1000x more data consumption in the next decade. This is an ambitious target and must be attacked with multiple new technologies, especially including MIMO. Using multiple in and out antennas (MIMO) can dramatically increase the capacity of each network by the number of antennas used, thus 3x3 MIMO (three antennas) increases the number of people that can use a home router or a tower by 3x which dramatically improves both customer satisfaction and provider profitability. In fact, 8x8 is included in the newest WiFi 802.11ac standard and a combination of 4x4 uplink and 8x8 downlink is included in the newest LTE cellular standard. It may be included in the standard but that doesn't mean it's actually used or works in practice.



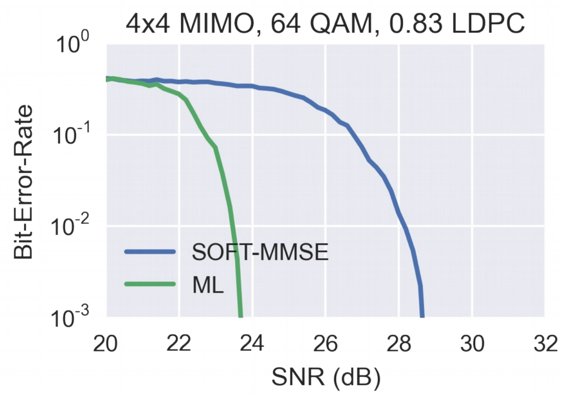
Progress to larger MIMO sizes with WiFi in computers has halted at 3x3 and LTE cellular is struggling at similar sizes. The reason is that at the receiver the signals are mixed together and require a tremendous amount of processing to pull them apart. Using typical methods, the amount of power and silicon needed increases exponentially as the number of antennas increases. Therefore a cost barrier exists which prevents the expansion to larger MIMO sizes. The key to breaking down this wall and to enable next generation performance, reliability, and profitability is to completely re-think how that processing is done.

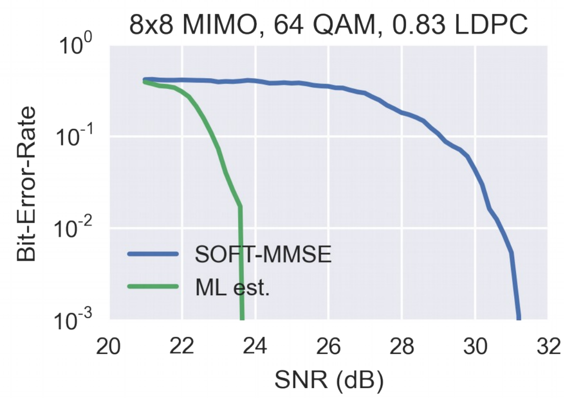
Mighty MCMC

Most of MIMO's cost increases incrementally as antennas are added, but one key portion of the processing done deep in the silicon chips becomes dramatically more difficult beyond 2-3 antennas, the detector. Its job is to take the information mixed together at the received antennas and separate them into intelligible, reliable data. Unfortunately, if the processing is done poorly, taking shortcuts to cut cost, the end product could actually perform worse with larger MIMO sizes.



The techniques used to separate the mixed signals can be broken into three general approaches. At one extreme MMSE based methods use simple math to find one possible way the signals are separated resulting in the cheapest, worst approach. At the other extreme maximum-likelihood (ML) literally tries every single possibility, which





can be in the billions of billions, making it good for comparison but otherwise an impossible theoretical curiosity. The difference between the MMSE and ML detectors can be seen in the plots showing 4x4 and 8x8 performance. Note that 6dB is equivalent to doubling the range, decreasing power requirements by 4x, or adding hundreds of paying subscribers!

Lastly, there are a number of approximate-ML approaches which identify a small subset of the billions of billions and then choose the best answer of the group. The difficulty is in finding as small a subset as possible, which reduces cost and power, while still containing the correct solution, which maximizes speed, capacity, and range.

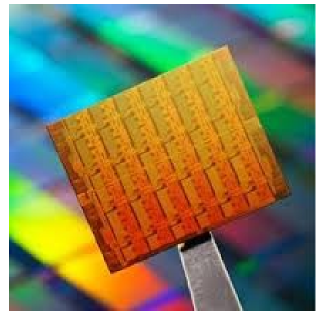
Industry's focus in the last decade has been on two major approximate-ML methods called sphere-decoding and k-best. They are what made 3x3 possible but are insufficient for larger sizes. Recent results show that a completely new approach based on a carefully controlled pseudo-random search outperforms all prior work by a large margin. This method called Markov Chain Monte Carlo (MCMC) can revolutionize MIMO by not only providing great 4x4 performance but by even making 8x8 and larger sizes easy, cheap, and reliable.

Application

The processing to separate MIMO spatial streams must be performed inside the main wireless chip because it is tightly integrated with other operations. Thus the best approach to getting the MCMC detector technology into the market is to provide it to existing wireless chip designers and manufacturers, enabling them to create amazing next generation products and capabilities. The timing is perfect with companies spending billions to acquire increasingly scarce frequency spectrum, the WiFi and LTE protocols recently expanding to 8x8 MIMO, and small-cells a near reality.

For the cellular phone market the MCMC detector will live in the tower infrastructure enabling a 4-8x increase in network capacity. This dramatic improvement will drive increased carrier profitability and improved customer satisfaction.

In communities with limited broadband internet options, wireless is an attractive option. It is simple, cheap, and fast to deploy to a wide number of customers without laying millions of dollars of cable or fiber. The difficulty is in overlapping enough users in the very limited frequencies to make it profitable and high-speed. By placing the MCMC detector in both the tower infrastructure and the customer premises equipment (CPE), unparalleled low cost and high performance is achievable.



With WiFi it can be placed in routers, security cameras, computers, laptops, and tablets. At the home this means happy families and college students streaming video reliability. At school it means auditoriums with trouble free connectivity. And simple, unfettered productivity at work, cáfes, coffee shops, and airports.

Status

Work towards MCMC detector commercialization is showing rapid progress. Using an 802.11ac WiFi framework, the technology has displayed unbeatable 4x4 and 8x8 performance at an affordable cost. The simulations have been verified with real world over-the-air transmissions using a 4x4 testbed. An 8x8 testbed is soon to be demonstrated. Silicon example designs are nearing completion, and work on an LTE framework is in development.

Summary

For consumers and carriers alike, there is a strong need for increased wireless network capacity. This pain is felt especially for LTE and WiFi users where MIMO can be a key solution. But current, industry standard MIMO detectors are limited to three spatial streams. By adopting the MCMC detector within their designs, chip makers can easily expand to 8x8 MIMO capabilities. Commercialization efforts are nearing completion of 4x4 and 8x8 for both WiFi and LTE.

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