GreenMO: Enabling Virtualized, Sustainable Massive MIMO with a Single RF Chain

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Increased carbon footprint of ICT over the years

Start of 2010s:
Limited penetration in upcoming markets

Start of 2020s:
Approaching ubiquitous deployments [1]

Telcos have about same carbon footprint as the “heavily scrutinized” aviation industry [2]

What is leading to such a high footprint? How do we support the growth of networks sustainably?
Importance of designing power-efficient base-stations in NextG

“With over 7 million BTS currently deployed around the world, base stations today consume more than 70% of the total energy used in mobile networks.” [3]

“With greater number of antennas, comes great power and thus great responsibility”

[3]: Sustainability and The Life of a Base-Station: Nokia
State of Today’s MIMO: MIMO growth possible while keeping power at bay?

- **SISO**
  - Using total NB spectrum with a single antenna to serve N Streams.

- **MIMO**
  - DBF (Massive MIMO Digital Beamformer): M >> N antennas to serve N Streams.

- **GreenMO concept**
  - Achieves best features of all worlds with its MIMO architecture.

- **Perceived Tradeoff**
  - Spectrum Efficiency vs. Energy Efficiency.

- **Massive MIMO Digital Beamformer (DBF)**
  - RF Chain #1, Bandwidth B, RF Chain #2, Bandwidth B, RF Chain #M, Bandwidth B.

- **Hybrid Beamforming (HBF)**
  - RF Chain #1, Bandwidth B, RF Chain #2, Bandwidth B, RF Chain #N, Bandwidth B.

- **M to N Analog Network**
  - RF Chain #M, Bandwidth B.

- **GreenMO**
  - RF Chain #1, Bandwidth NB.

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How does GreenMO enable spectrum & energy efficiency?

Target: Allow MIMO with single high bandwidth RF chain interfaced to many antennas

Within Radio Stackup, spreading in analog, de-spreading in digital domain allows MIMO with single RF Chain
How does GreenMO enable spectrum & energy efficiency?

Key Idea: Use High Intermediate BW to facilitate Massive MIMO with single RF chain

1. Ultra-low uW power Analog Network

2. Allows flexibility and user-proportionate digital interfacing

3. Enables low-complexity MIMO processing to reduce interference
GreenMO’s ultra-low power RF switch analog network for N streams

1. RF switches with analog spreading codes: <1 dB insertion loss, ~100 uW power draw

2. Supply same spreading codes across multiple antennas to gain diversity

3. 1/N duty cycle codes enable creating N different phase codes (1 per stream)

GreenMO configures the M antenna array into N sub-arrays, in form of N different spreaded bandwidth signals
Getting back to B bandwidth: Creation of virtual RF chains to sub-arrays

1. 1/N duty cycle codes sampled at NB creates orthogonalized time-samples

2. Digital de-spreader splices through to downsample ↓N + create N “virtual RF chains”

GreenMO flexibly changes number of (virtual) RF chains by controlling the sampling rate + switching duty cycle
Easy-to compute MIMO Processing atop virtual RF chains

1. A N*N equivalent channel gets created on N virtual chains

2. Antenna Selection leads to diagonal heavy channel matrices

3. Leads to interference cancellation with simple matrix inversion

GreenMO’s spreading de-spreading combined with efficient MIMO processing gets back the per-user streams
Implementing and testing GreenMO on a PCB prototype
Putting it all together: Actual trace captured using the hardware
Baseline comparisons vs DBF, HBF, SISO with GreenMO for 2-4 users, 8 antennas

GreenMO meets both SE of mMIMO and EE of FDMA
Larger scale simulations: Comparisons with 5G TX/RX MIMO via 8 100 MHz streams

GreenMO can increase EE of Massive MIMO base-station by 1.8 times while meeting similar SE performance.
Extreme MIMO Next G: Can we scale even higher? 100 streams, 100 MHz each?

“Power Consumption of RF chains should be linear with sampling frequency”

GreenMO introduces optimization of physical/virtual RF chains as we build next generation Massive MIMO
Thank you, open for questions and discussions!

More about GreenMO, Artefacts

Next big step with GreenMO: building a university wide testbed!

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