Ultra Massive MIMO

Vision and different embodiments

Emil Björnson

Visiting professor, KTH Royal Institute of Technology, Sweden
Associate professor, Linköping University, Sweden
Massive MIMO versus Ultra Massive MIMO

5G in 3.5 GHz band
64 antenna-integrated radios
1 m x 0.5 m

Ultra Massive MIMO
Even more antennas
Electrically large

Massive MIMO array
Many antennas
Electrically small

Beamforming gain
Spatial multiplexing gain
Ways to Increase the Capacity Towards 1 Terabit/s

- Capacity of a communication system:

\[
\text{Multiplexed layers} \cdot \text{Bandwidth} \cdot \log_2 \left( 1 + \frac{\text{Signal power} \cdot \text{Beamforming gain} \cdot \text{Pathloss}}{N_0 \cdot \text{Bandwidth}} \right)
\]

- Three ways to increase it:

  - **Multiplexed more layers**
    - To one or multiple users

  - **Use more bandwidth**
    - Must be associated with higher power or beamforming gain

  - **Reduce range**
    - Improve pathloss
Scoring the Terabit/s Goal in Different Bands

**Low bands**
- Multiplex 10000 signals per site
- Good channel coherence

**High bands**
- Multiplex fewer signals
- Use more bandwidth

50 MHz bandwidth, 3 GHz band

1 GHz bandwidth, 60 GHz band

---

Fundamental Limit: Spatial Degrees-of-Freedom

Definition:
Number of layers $\eta$ that can spatially multiplexed, while controlling the interference

- Determines how many signals an array can separate
  - Like sampling of a band-limited signal, but we have a space-limited signal

Planar array (length $L$, height $H$):

$$\eta \approx \frac{\pi}{\lambda^2} LH$$

Ultra Massive MIMO

$$L = 10 \text{ m}, \ H = 30 \text{ m}$$

$$\eta \approx \frac{\pi}{\lambda^2} LH \approx 100000$$

We are very far from the limits!
The richness of the channels is key
Three Potential Embodiments of 6G MIMO Technology

1) Cell-free Massive MIMO

2) Intelligent reflecting surface

3) Ultra Massive MIMO
Holographic Radio: A New Paradigm in Array Design

Arrays with ultra many elements
Radio units at the same order as desired spatial degree-of-freedom

Why “holographic”?
Phase-shift pattern is the hologram
Record it from uplink pilots

What about Orbital Angular Momentum (OAM)?
Generate wavefronts that spin in different ways
Special case of MIMO: No extra degrees-of-freedom
FOR MORE INFORMATION

Listen to my podcast:

Check out my YouTube channel:

Blog: https://ma-mimo.ellintech.se