Massive Mimo

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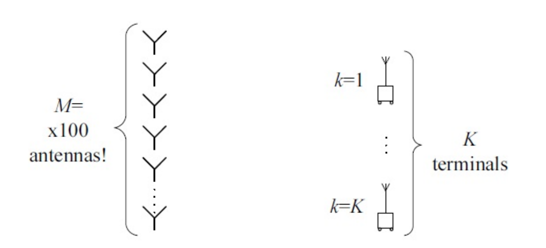
Introduction to Massive MIMO

Introduction to MIMO?

- MIMO stands for Multiple Input, Multiple Output
- Massive MIMO is a form of MU-MIMO systems where the number of BS antennas and the numbers of users are large. Massive MIMO is also known as very large MIMO or large scale antenna system abbreviated as (MU-MIMO).
- MU-MIMO is an emerging technology in wireless communications In this technology base station is equipped with a large number of antennas (say, tens to hundreds), and is serving several single-antenna users in the same time frequency resource

What is Massive MIMO?



- We think of very large (multiuser) MIMO as a system with $M >> K >> 1$
- coherent, but simple, processing We think of very large (multiuser) MIMO as a system with $M >> K >> 1$ which is
  Potential to improving rate, reliability dramatically
  Potential to scaling down TX power drastically

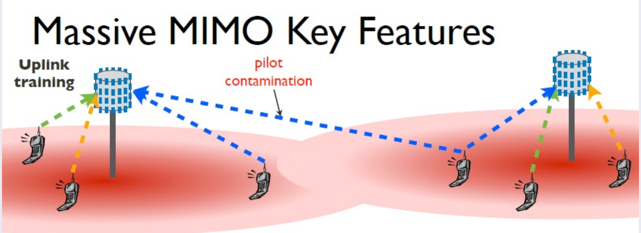
Introduction to Massive MIMO

What is Massive MIMO?

- So there are several possible operating points depending on
  number of antennas
  available TX power
  choice of receiver/precoder algorithm
  coherence time (dictates ultimately the number of users served)
- Designing a massive MIMO system requires four key attributes:
  1. Flexible Software Define Radio(SDRs) that can acquire and transmit RF signals
  2. Accurate time and frequency synchronization among the radio heads
  3. A high-throughput deterministic bus for moving and aggregating large amounts of data
  4. High-performance processing for Physical(PHY) and Media access control (MAC) execution to meet the real-time performance requirements

Introduction to Massive MIMO

How Does Massive MIMO Works?



- In Massive MIMO, TDD operation is preferable. During a coherence interval,
- There are three operations: channel estimation including
  1. uplink training and downlink training
  2. uplink data transmission
  3. downlink data transmission

How Does Massive MIMO Works?

1. Channel Estimation

- The BS needs CSI to detect the signals transmitted from the users in the uplink, and to precode the signals in the downlink. This CSI is obtained through the uplink training. Each user is assigned an orthogonal pilot sequence, and sends this pilot sequence to the BS. The BS knows the pilots sequences transmitted from all users, and then estimates the channels based the received pilot signals.
- Each user may need partial knowledge of CSI to coherently detect the signals transmitted from the BS. This information can be acquired through downlink training or some blind channel estimation algorithm. Since the BS uses linear precoding techniques to beamform the signals to the users, the user needs only the effective channel gain (which is a scalar constant) to detect its desired signals. Therefore, the BS can spend a short time to beamform pilots in the downlink for CSI acquisition at the users.

How Does Massive MIMO Works?

2. Uplink Data Transmission

- A part of the coherence interval is used for the uplink data transmission. In the uplink, all K users transmit their data to the BS in the same time-frequency resource. The BS then uses the channel estimates together with the linear combining techniques to detect signals transmitted from all users.

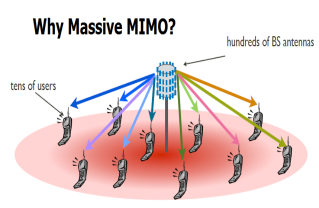
3. Downlink Data Transmission

- In the downlink, the BS transmits signals to all K users in the same time-frequency resource. More specifically, the BS uses its channel estimates in combination with the symbols intended for the K users to create M precoded signals which are then fed to M antennas.

Why Massive MIMO?

- The last ten years have seen a massive growth in the number of connected wireless devices. Billions of devices are connected and managed by wireless networks.
- At the same time, each device needs a high throughput to support applications such as voice, real-time video, movies, and games.
- Demands for wireless throughput and the number of wireless devices will always increase.
- In addition, there is a growing concern about energy consumption of wireless communication systems.
- Thus, future wireless systems have to satisfy three main requirements:
  i) having a high throughput
  ii) simultaneously serving many users
  iii) having less energy consumption.

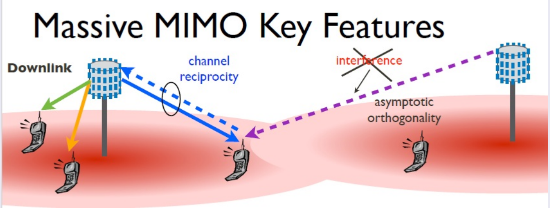
Why is Massive MIMO?



It has been shown both in theory and in real propagation environments that massive MIMO has very promising properties, including large gains in spectral efficiency and several orders of magnitude lower transmit power, as compared to conventional MIMO systems with a small number of antennas at the base station.

Advantage of Massive MIMO

Some Benefits of Massive MIMO?



- Benefits from many excess antennas
  1. Simplified multiuser processing
  2. Reduced transmit power
  3. Thermal noise and fast fading vanish
- Differences with MU MIMO in conventional cellular systems
  1. Time division duplexing used to enable channel estimation
  2. Pilot contamination limits performance

Advantage of Massive MIMO

Some Benefits of Massive MIMO?

- With massive antenna arrays at the BS, for most propagation environments, the channels become favorable, i.e., the channel vectors between the users and the BS are (nearly) pair-wisely orthogonal, and hence, linear processing is nearly optimal.
- A huge throughput and energy efficiency can be achieved due to the multiplexing gain and the array gain. In particular, with a simple power control scheme, Massive MIMO can offer uniformly good service for all users.

Limitation of Massive MIMO

What are the critical issues in Massive MIMO?

- Gains are not that big with not-so-many antennas
  1. Require many antennas to remove interference
  2. Need more coordination to remove effects of pilot contamination
- Massive MIMO seems to be more uplink driven
  1. Certain important roles are reserved between base stations and users
  2. A different layout of control and data channels may be required
- Practical effects are not well investigated
  1. Channel aging affects energy-focusing ability of narrow beams
  2. Spatial correlation reduces effective DoFs as increasing number of antennas
  3. Role of asynchronism in pilot contamination and resulting performance

Massive MIMO Conclusions

Conclusions

- **Observation**

  1. Pilot contamination is a big deal, but possibly overcome by coordination
  2. Performance is sensitive to channel aging effects
  3. Good performance can be achieved with distributed antennas
  4. Not clear how to pack so many microwave antennas on a base station
  5. Needs more extensive simulation study with realistic system parameters

- **Forecast**

  Massive MIMO will probably not be used in isolation Will be combined with distributed antennas or base station coordination Reduces the effects of pilot contamination Work with smaller numbers of antennas

The End