Recent advances in non-coherent massive MIMO

Ana García Armada
Communications Research Group (GCOM)
Universidad Carlos III de Madrid, Spain

Global Information Infrastructure and Networking Symposium (GIIS 2018)
October 23-25, Thessaloniki, Greece
New requirements call for new technologies

Non coherent processing may be a good solution if combined with massive MIMO
Non coherent communications – why now?

• In non-coherent (NC) communications, there is no channel estimation, even at the receiver
• Traditionally not used: 3 dB loss with respect to coherent
• When we consider the needs of channel state information (CSI) obtaining and sharing, this loss may become negligible
  – Channel estimation is wasteful in some circumstances (channels with low coherence time, low SNR)
  – CSI estimation and sharing is very complex in massive MIMO (TDD required, pilot contamination, insufficient pilots for high time variability)
• NC massive MIMO: the perfect match!
  – NC may solve some of these problems for massive MIMO
  – The “magic” of massive MIMO (self interference cancellation) may improve NC performance
Massive MIMO

• Benefits of increasing (a lot) the number of antennas
  – Improve data rates and reliability (multiplexing and diversity gains)
  – Decrease required transmit power
  – Very simple precoders/decoders

• Most usual configuration is MU-MISO(MIMO)

\[ R \text{ antennas at BS, } R \gg K \]
\[ K \text{ single antenna users, } K \ll R \]
Non-coherent massive MIMO

• ASK (amplitude shift keying) energy-detection schemes
  – They achieve rates which are not different from coherent schemes in a scaling law sense
  – Too many antennas are required for reasonable performance with actual constellation designs

• Differential PSK schemes
  – Single user with improved performance (wrt req. number of antennas)
  – Multi-user through constellation design

Multi-user uplink with M-DPSK

- Data symbol sequences M-PSK
- Tx signal comes from differentially encoding the data symbols: D-MPSK

The phase difference of two consecutive symbols received at each antenna is non-coherently detected and they are all added to give the decision variable $z[n]$. 

$$z[n] = \frac{1}{R} \sum_{i=1}^{R} y_i[n-1] * y_i[n]$$
Multiple users

• Can we obtain the users information from this decision variable?

• We define the joint symbol as a (weighted) combination of the original users constellations

• The massive number of antennas will help us get rid of the channel effects and interference
Joint constellation

User 1:

User 2:

Not a good choice .. Cannot decode unambiguously all points of individual users

User 1:

User 2:

16 distinct points
Good choice!

Design A
Another feasible joint constellation

User 1:

User 2:

16 distinct points
Good distance between them
Good choice!

(Design B)
Equal error protection constellation

User 1:

User 2:

16 distinct points
Same performance for both users
Good choice!

(EEP)
Getting rid of the interference

\[ \text{SINR} = \frac{E\{|\xi|^2\}}{I} = \frac{R \sum_{j=1}^{K} \beta_j^2}{\left(\sum_{j=1}^{K} \beta_j\right)^2 + 2\sigma^2 \sum_{j=1}^{K} \beta_j + \sigma^4} \]

Energy efficiency scaling with \( R \), same as with perfect CSI
Two users and low SNR (0 dB)

Higher order constellations

\[ P_e \] vs SINR dB for different constellations:
- DQPSK
- DBPSK
- 8-DPSK

(Design B)
Multiplexing more users in the constellation (SNR=0 dB)

Design B

$P_e$ vs $R$ for different numbers of users (UB, LB)
Reducing the number of antennas with channel coding

RSC rate $\frac{1}{2}$, SNR=0dB
### Number of antennas vs coding rate

<table>
<thead>
<tr>
<th>Coding rate</th>
<th>Outer RSC</th>
<th>Required number of antennas $R$ for each SNR: users 1,2 EEP</th>
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<tbody>
<tr>
<td></td>
<td>1/10</td>
<td>0 dB</td>
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<td>3/20</td>
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<td></td>
<td>9/10</td>
<td>0 dB</td>
</tr>
</tbody>
</table>

What about channel variability?

• For $BW/f_D > 10$ the performance is the same as with constant channel. That is, for any realistic channel we can envisage.

• Examples
  
  – $f_c=2.6$ GHz, $BW=20$ MHz and a mobile velocity of 120 km/h, we have $BW/f_D = 70,000$
  
  – $f_c=2.6$ GHz, $BW=20$ MHz and a mobile velocity of 500 km/h, we have $BW/f_D = 16,600$
  
  – $f_c=60$ GHz, $BW=100$ MHz and a mobile velocity of 120 km/h, we have $BW/f_D = 15,000$

This is all very nice, but the channel is not always Rayleigh ...

• When the fading is Rice (LOS component) there are new interference terms that do not go away with increasing number of antennas.
So we need to re-design the constellations

- Avoid symmetries
Improved decoding process that considers this new interference

- Rice and Rayleigh are the same for very low SNR and Rice is better for moderate-high SNR.
And the channel is for sure not always frequency-flat ...

Combined with OFDM, differential modulation across frequency or time

It is time for non coherent massive MIMO!

• DMPSK for massive MIMO does not need CSI
• Coding reduces the number of antennas to feasible values
• New constellations and detection process needed when the channel is Rice
• Not far from coherent systems when CSI is noisy and pilot overhead is taken into account
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Ana García Armada
agarcia@tsc.uc3m.es

ACK: joint work with Victor Monzon Baeza, Kun Chen Hu, Wenbo Zhang, Mohammed El-Hajjar, and Lajos Hanzo