RESOURCE ALLOCATION TECHNIQUES FOR SPECTRALLY EFFICIENT MASSIVE ACCESS

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Mobile traffic => 10x increase in 5 years
Spectral resources scarce
New techniques required to accommodate

Promising Approach: Non-Orthogonal Multiple Access
Several variants
- Power-domain NOMA
- Sparse code multiple access (SCMA)
- Layer division multiplexing (LDM)
**PD-NOMA**
- Serve multiple users non-orthogonally on the same frequency resource
- Different power values to users multiplexed on the same frequency band

**Definitions**
- $x_{k,s}$: signal relative to user $k$ on subband $s$
- $P_{k,s} = \mathbb{E}[|x_{k,s}|^2]$: power allocated to user $k$ on subband $s$

**Downlink**
- Successive interference cancellation (SIC) performed at the receiver side
- SIC performed in the increasing order of channel gains
- Achieved rates:
  
  \[
  R_{k_1,s} = B_c \log_2 \left( 1 + \frac{P_{k_1,s} h^2_{k_1,s}}{N_0 B_c} \right) \]
  
  \[
  R_{k_2,s} = B_c \log_2 \left( 1 + \frac{P_{k_2,s} h^2_{k_2,s}}{P_{k_1,s} h^2_{k_1,s} + N_0 B_c} \right)
  \]

**Uplink**
- SIC detection at the level of the BS performed in the decreasing order of channel gains
- Achieved rates:
  
  \[
  R_{k_1,s} = B_c \log_2 \left( 1 + \frac{P_{k_1,s} h^2_{k_1,s}}{P_{k_2,s} h^2_{k_2,s} + N_0 B_c} \right)
  \]
  
  \[
  R_{k_2,s} = B_c \log_2 \left( 1 + \frac{P_{k_2,s} h^2_{k_2,s}}{N_0 B_c} \right)
  \]
4 PhD theses, 1 postdoc and 3 Master theses

Distribution of subband power budget between NOMA users

Distribution of total power budget between subbands

User allocation on subbands

User pairing on the same subband

Colour = user allocation
Amplitude = power allocation
4 PhD theses, 1 postdoc and 3 Master theses
RESOURCE ALLOCATION FOR NOMA SYSTEMS

Contributions

**Allocation metrics**
- Weighted proportional fairness
- Flexible throughput vs fairness maximization metric
- Fairness maximization metric
- Waterfilling-based power allocation (MaxH-min D)
- Analysis of NOMA rate vs channel gain of paired users

**Interference management**
- Mutual Successive Interference Cancellation (SIC)
- Mutual SIC for efficient Coordinated Multi-Point (CoMP) systems
- Drone placement strategies for complete interference cancellation in two-cell NOMA CoMP Systems

**Deployment scenarios / Services**
- Cognitive radio scenario with target user rates
- Support of broadcast services using NOMA with minimum impact on broadband
- Distributed Antenna Systems (DAS) with and without individual antenna-based power constraints
- Mixed traffic types using NOMA and DAS
HOLISTIC SOLUTION FOR SPECTRALLY EFFICIENT MASSIVE ACCESS

Network architecture:

- Distributed Antenna Systems (DAS)
  => short links, improve diversity, allocation
- Device to Device (D2D)
  => offload infrastructure, interference
- Coordinated Multipoint (CoMP)
  => reduce interference, allocation
- Unmanned Arial Vehicles (UAV)
  => coverage extension, positioning, allocation
- Non-Orthogonal Multiple Access techniques (NOMA)
  => spectral efficiency, interference, allocation

Support of massive access ...with shared and limited resources
System Model
- Downlink system
- $R$ RRHs, $S$ subbands
- System bandwidth $B$
- Maximum of 2 multiplexed users per subcarrier
- $K$ users per cell with rate requirements $R_{k,\text{req}}$
- With(out) individually power constrained antennas

Study Items: joint user-antenna-subcarrier selection and power allocation

Solution: Method to mitigate interference at both NOMA users: mutual SIC
POWER MINIMIZATION IN DAS WITH NOMA
Centralized Antenna System (CAS) vs Distributed Antenna System (DAS)

Parameters

- Number of antennas $R$: 4
- Number of subbands $S$: 64
- Number of users in the cell: 15
- Required rates per user: 7 Mbps to 13 Mbps
- Cell Radius $R_c$: 500 m
- Overall Transmission Bandwidth: 10 MHz
- Distance Dependent Path Loss: $128.1 + 37.6 \log_{10}(d)$ (dB), $d$ in Km
- Lognormal shadowing variance: 8 dB
- Receiver Noise Density: $4.10^{-18}$ mW/Hz

Power as a function of the required rates

- OMA-CAS
- NOMA-CAS
- OMA-DAS
- SRRH
- SRRH-LPO
- SRRH-OPA

Graphs showing the power as a function of the required rates for different antenna systems:

CAS

DAS

$\div 10$

POWER MINIMIZATION IN DAS WITH NOMA
Proposed interference management results

Power as a function of the required rates

Without interference management

With proposed interference management

SIC receiver complexity mitigated thanks to hybrid OMA NOMA system

Subcarrier Statistics

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<th>RA technique</th>
<th>Sub</th>
<th>MutSIC</th>
<th>SingSIC</th>
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\[\div 10\]
- Enable cell coordination for improving cell-edge performance without restricting network resources
- CSI and data exchange: Dynamic Point Selection (DPS), Joint Transmission (JT)
- Extension of proposed interference management technique => complete interference cancellation

No interference on E3

No interference on F3

Coherent signal reception at E1 and F1
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- Non-Orthogonal Multiple Access techniques NOMA
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Support of massive access
...with shared and limited resources

Intelligence
⇒
Self-organizing capabilities
⇒
Higher resilience to overload and failure


