Scalable SCMA

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New Technologies for Future Releases

SoftAI: Programmable Air-Interface
- Adaptive numerology
- Adaptive transmission duration
- Adaptive multiple access scheme
- Adaptive HARQ
From Orthogonal Multiple Access to Non-orthogonal Multiple Access

Dual-layer non-orthogonality for SoftAI

- **Inter-subband non-orthogonality:**
  - Subband based numerology optimization enabled by spectrum localized waveform from filtering/windowing
- **Intra-subband non-orthogonality**
  - Non-orthogonal multiple access
Multiple Access Scheme Evolution

Power domain and spatial domain separation can be further exploited.
## NoMA Application Scenarios

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Motivations</th>
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<tbody>
<tr>
<td>eMBB</td>
<td>• Enhance spectrum efficiency  &lt;br&gt; • Improve edge UE experience  &lt;br&gt; • Enable seamless mobility  &lt;br&gt; • Support more UEs</td>
</tr>
<tr>
<td>mMTC</td>
<td>• Support massive connectivity  &lt;br&gt; • Reduce signaling overhead  &lt;br&gt; • Reduce UE energy consumption</td>
</tr>
<tr>
<td>URLLC</td>
<td>• Reduce latency  &lt;br&gt; • Improve reliability</td>
</tr>
</tbody>
</table>
Non-orthogonal Multiple Access for UE Experience Enhancement

Multi-TRP Cooperation for guaranteed data rate everywhere

Transparent TRP HO for seamless mobility
Non-orthogonal Multiple Access for Latency/Signaling Overhead/Energy Consumption Reduction

Grant-free for sporadic small packet transmission
- Low latency
- Low signaling overhead
- Low energy consumption
- However potential UE collision

Grant-free for sporadic small packet transmission
- More delay and overhead for grant based TDD transmission

Non-orthogonal Multiple Access
- Robust to UE collision
- Better SE
Grant-free for Different UE States

- **Active-State**
- **Echo State (Inactive-State)**
- **Idle-State**

<table>
<thead>
<tr>
<th>UE State</th>
<th>mMBB</th>
<th>URLLC</th>
<th>mMTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Echo</td>
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<td>Idle</td>
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</tbody>
</table>

- NR Cell

- eMBB
- mMTC
- URLLC
Non-orthogonal Multiple Access for Hyper Connectivity

- Superposed transmission to support more concurrent users
  - Enhanced connectivity
- Synchronous transmission is maintained within UE group without TA.
  - Close proximity based local time synchronization
- Asynchronous transmission is allowed between UE groups.
  - Time synchronization is not required between different groups.
  - Sub-band filter is applied to eliminate inter-group interference
Non-orthogonal Multiple Access Construction

- Non-orthogonal multiple access has been studied in Rel-14 NR study item phase.
- All proposed non-orthogonal MA schemes follow the following basic representation

- Non-orthogonal multiple access components:
  - Symbol level operation:
    - Without spreading or with spreading (linear or non-linear)
  - Resource mapping
    - Sparse or on-sparse
Non-orthogonal Multiple Access
- Symbol Level Operation

- Without spreading
  - Power domain superposition
  - Rely on advanced Rx to separate users

- With spreading
  - Additional code domain separation
  - Better inter-user interference suppression

- Linear spreading
  - Symbol level repetition
  - Spreading code optimization to allow more UE collision

- Non-linear spreading
  - Symbol level non-repetitive spreading
  - Additional code gain/diversity gain
Resource Mapping: Partial Collision With Sparse Spreading

Sparse RE mapping:
- Partial collision reduces inter-UE collision
- Partial collision reduces multi-user detection complexity
SCMA (Sparse Coded Multiple Access)
NoMA with Sparse Non-linear Spreading

Example 1: SCMA 4-point codebook

Example 2: SCMA 8-point codebook

Non-zero component-1
Non-zero component-2
Scalable SCMA

SCMA codebook Adaptation to meet different system requirements
Flexible SCMA codebook Design for Different Application Scenarios

For coverage enhancement
- Long codeword
- Non-sparse RE mapping

For connectivity enhancement
- Short codeword
- Sparse RE mapping

For PAPR reduction
- Short codeword
- Only one RE is active at each time
Benefits of Non-linear Spreading

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission mode</td>
<td>UL</td>
</tr>
<tr>
<td>Antenna configuration</td>
<td>1x2 uncorrelated</td>
</tr>
<tr>
<td>Channel model</td>
<td>TDLC-1000</td>
</tr>
<tr>
<td>Channel estimation</td>
<td>perfect</td>
</tr>
<tr>
<td>Resource allocation</td>
<td>12 RBs for NoMA, 1RB for OFDMA</td>
</tr>
</tbody>
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<table>
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<tr>
<th>Scheme</th>
<th>Receiver</th>
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<tbody>
<tr>
<td>OFDMA</td>
<td>MMSE &amp; Turbo-ML</td>
</tr>
<tr>
<td>MC-CDMA (linear non-sparse spreading)</td>
<td>MMSE-SIC</td>
</tr>
<tr>
<td>LDS (linear sparse spreading)</td>
<td>Turbo-MPA</td>
</tr>
<tr>
<td>SCMA (non-linear sparse spreading)</td>
<td>Turbo-MPA</td>
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</tbody>
</table>
Conclusions

- Non-orthogonal multiple access can be applied to enhance the performance of different applications:
  - eMBB
  - mMTC
  - URLL

- Scalable SCMA can be configured to meet different requirements of different services.
Thank you

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