LTE VoIP Capacity with Soft Frequency Reuse

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Outline

- Motivation
- VoIP Scheduling
- Soft Frequency Reuse
- Scheduler Concept
- Scenario & Results
- Summary, Conclusion & Outlook
Motivation

- Long Term Evolution (LTE) has been standardized within 3GPP (3rd Generation Partnership Project)
- Efficient VoIP support is a fundamental requirement for LTE (no circuit switched domain)
- Potentially large number of VoIP users
- VoIP traffic QoS demands (delay <50 ms) must be met using packet switched scheduling
VoIP Scheduling

- Active (talking): Transmit Voice PDU (344 bit MAC PDU) every 0.02s
- Inactive (listening): Transmit Silence Insertion Descriptor (SID) PDU (144 bit MAC PDU) every 0.16s
- \( P(A) = P(I) = 0.5 \)
- Mean state sojourn time is 120s

- Deterministic IAT: \textbf{Persistent periodic resource allocation}
- Random state transmission: Changing number of active sources
VoIP Scheduling

- Semi-persistent scheduling:
  - Periodic resource assignment for voice PDUs
  - Dynamic scheduling of HARQ retransmissions and SID PDUs

→ Talk spurt multiplexing

1 TTI (1ms)

- Initial voice PDU transmission
- HARQ retransmission
- SID PDU transmission
Soft Frequency Reuse

- Fractional Frequency Reuse (FFR) method
- Increased power (e.g. x 3) on dedicated Resource Blocks (RBs) for cell edge users
- Default power on all RBs for cell center users
- VoIP: More RBs needed for VoIP-PDU ➔ closer to edge
Scheduler Concept

Candidate set $\mathbf{TB}_0 = \{\mathbf{TB}_1, \ldots, \mathbf{TB}_n\}$
**Scheduler Concept**

**Soft Frequency Reuse:**
- Limit search in time domain:
  - (no more than $d$ TTI between PDU arrival and scheduling)
- Allow increased power on 3 RBs
  - (different in each cell group)
- Those 3 RBs could all be occupied
- Then: try to use center cell RBs with default power
- If all center RBs occupied: use edge RBs
- Use TBs with shortest delay $d$
- Lowest RB index, shortest TB

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**LimitedRBSet**
- Boosted
  - **LimitedRBSet** $[1, 2, 3]$
  - **Boosted**
  - **NonEmpty Alternative**
  - **MinDelay**
  - **First**
  - **Shortest**

**NotBoosted**
- **LimitedRBSet** $[10...23]$
- **NonEmpty Alternative**
- **MinDelay**
- **First**
- **Shortest**

**TB$_{out}$**
- $|TB_{out}| = 1$
Scheduler Concept

Soft Frequency Reuse:
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$\text{TB}_{out}, |\text{TB}_{out}| = 1$
Scheduler Concept

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$\text{MinDelay}(d) \downarrow$
$\text{First} \downarrow$
$\text{Shortest} \downarrow$
$|TB_{out}| = 1$
### M.2135 IMT-Advanced Evaluation Urban Micro UPLINK

<table>
<thead>
<tr>
<th>Scenario &amp; Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cells</strong></td>
</tr>
<tr>
<td>21 (7 x 3 Sectors)</td>
</tr>
<tr>
<td><strong>ISD</strong></td>
</tr>
<tr>
<td>200 m</td>
</tr>
<tr>
<td><strong>TX Power [dBm]</strong></td>
</tr>
<tr>
<td>$\alpha \cdot \text{Pathloss} + P_0, \alpha = 0.8$ (WINNER+, 3GPP)</td>
</tr>
<tr>
<td><strong>Evaluated Call duration</strong></td>
</tr>
<tr>
<td>10 s (minimal difference to 20 s)</td>
</tr>
<tr>
<td><strong>Antenna configuration</strong></td>
</tr>
<tr>
<td>1x1 SISO</td>
</tr>
<tr>
<td><strong>Bandwidth, Ctrl. Channels</strong></td>
</tr>
<tr>
<td>5 MHz BW, 2 RBs Phy. Uplink Ctrl. Channel</td>
</tr>
<tr>
<td><strong>Small-scale fading</strong></td>
</tr>
<tr>
<td>disabled</td>
</tr>
<tr>
<td><strong>Time domain scheduling</strong></td>
</tr>
<tr>
<td>disabled (first results show reduced capacity)</td>
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</tbody>
</table>

A call is successful if packet loss is below 2%
A packet is dropped if delay exceeds 50 ms
System capacity is reached if more than 2% of calls are unsatisfied
Scenario & Results

Satisfied User Ratio

240 Calls

$P_0$
Scenario & Results

- Boosted
- Boosted SFR
- Not Boosted

Block Error Rate (1st TX)

Number of Calls

TUHH
Technische Universität Hamburg-Harburg

ComNets
Institute of Communication Networks
Scenario & Results

255 Calls

Satisfied User Ratio vs. Cell Edge Ratio
Summary
- A scheduler framework allowing Soft Frequency Reuse was developed
- VoIP capacity with SFR was evaluated

Conclusion
- SFR results in neglectable capacity gain
  - Due to channel estimation error?
  - SFR vs. reduced trunking gain?

Outlook
- Exploit further parameters (e.g. time domain)
- Multi-User MIMO
Thank you for your attention!

Questions?

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