Increasing Transmit Diversity at the Cell Border with Smart Antennas

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Motivation

- Future communications systems should have frequency reuse of one
  - high spectral efficiency
  - large performance degradation at the cell border

- Mobile terminal at the cell border can be broadcasted by two base stations
  ➔ Can we increase the transmit diversity and decrease the inter-cellular interference?
Outline

- OFDMA Downlink System
- Transmit Diversity Techniques
  - Delay Diversity (DD)
  - Cyclic Delay Diversity (CDD)
- Cellular Cyclic Delay Diversity (C-CDD)
- Simulation Results
- Conclusions
OFDMA Downlink System

**Transmitter**

- Source
  - User 1
  - User $K_u$
- COD
- $\pi$
- MOD
- MUX
- $\pi$
- OFDM $+ T_G$

**Receiver**

- Sink
- DECOD
- $\pi^{-1}$
- DEMOD
- DEMUX
- $\pi^{-1}$
- -T$_G$
- IOFDM

Multipath Channel
Delay Diversity (DD)

- Idea: Increase number of propagation paths
- Delay of TX-signal in time domain

Advantage: very low complexity, no additional complexity at mobile

Drawback: additional delay
Channel Transfer Function $|H(f,t)|^2$

Delay spread: $\Delta \tau \approx 0.750 \mu s$

Delay-Diversity, $\Delta \tau \approx 1.850 \mu s$

Symbol Duration $T_U = 224 \mu s$, Carrier Spacing $\Delta f_C = 4.464 \text{ kHz}$, $f_D = 10 \text{ Hz}$
From Delay Diversity to Cyclic Delay Diversity (CDD)

\( s_0(k) \)

\[ Cyclic \ Prefix \quad OFDM \ Symbol \]

Time Window for OFDM Demodulation

\[ \tau_{\text{max}} \]

\( s_1(k) \)

\[ Cyclic \ Prefix \quad OFDM \ Symbol \]

\[ -N_g \quad 0 \quad \delta_1 \quad \delta_{\text{cyc}} \]

CDD

\[ Cyclic \ Prefix \quad OFDM \ Symbol \]

Time Window for OFDM Demodulation

ISI influence of multipath channel
Cyclic Delay Diversity (CDD)

- Cyclic delay of OFDM-symbols in time domain

Advantage: ⬆ no additional inter-symbol interference
            ⬆ no additional complexity at mobile

Drawback: ⬇ higher complexity compared to DD
Cellular Cyclic Delay Diversity (C-CDD)
Cellular Cyclic Delay Diversity (C-CDD)

- Network has to distribute the same signal to both base stations
- Available sub-carriers are needed
- No additional complexity at the mobile terminal
- Possibility of exploiting the unused ‘interfering’ sub-carriers
- Reduction of inter-cellular interference
- Inherent delay diversity
Simulation Results
## System Parameters & Channel Model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier frequency</td>
<td>5 GHz</td>
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<tr>
<td>Bandwidth</td>
<td>100 MHz</td>
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<tr>
<td>FFT length</td>
<td>2048</td>
</tr>
<tr>
<td>OFDM symbols / Frame</td>
<td>16</td>
</tr>
<tr>
<td>Modulation</td>
<td>4-QAM or 16-QAM</td>
</tr>
<tr>
<td>Coding</td>
<td>Conv. Code, R=1/2</td>
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<tr>
<td>Cyclic delay</td>
<td>30 samples</td>
</tr>
<tr>
<td>Velocities</td>
<td>0 mph or 100 mph</td>
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<tr>
<td>Channel model</td>
<td>IEEE 802.11n C</td>
</tr>
<tr>
<td>Taps</td>
<td>14</td>
</tr>
</tbody>
</table>
Impact on Error Performance

- Robustness to high velocities
- Best performance with C-CDD at the cell border
- Performance gain and decreased interference with halved TX power
Impact on Throughput

High throughput gains with C-CDD technique

Reliable throughput throughout the cell for 4-QAM
Conclusions

- Introduction of new cellular transmit diversity technique for the severe cell border area:
  Cellular Cyclic Delay Diversity (C-CDD)

- C-CDD offers:
  - Increased transmit diversity at the cell border
  - No additional complexity for the mobile terminal
  - Robustness to different velocities
  - Reliable throughputs all-over the cell edge
  - Reliable handoff procedures