Reverse Link Performance of Relay-based Cellular Systems in Manhattan-like Scenario

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Reverse Link Performance of Relay-based Cellular Systems in Manhattan-like Scenario

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Outline

• Relay Deployment Scenario

• Simulation Models

• Simulation Results

• Summary
Relay Deployment Scenario

- Consider an existing cellular network with well-planned coverage
  - Fixed Relay Stations (FRS) are deployed within the coverage of each cell
    - FRSs are deployed for throughput enhancement
  - The same deployment scenario as C80216mmr-05_041

multi-cell environment

FRSs provide full coverage within each cell
Relay Deployment Scenario

- Interfering cells can be separated by increasing frequency reuse factor \((K)\)
  - However, it takes \(K\) times radio bandwidth throughout the system.
Relay Deployment Scenario

Without relaying:
- Non-Line-Of-Sight (NLOS) transmission in general
- Longer distance from MS to BS
- Higher transmit power for MS

With relaying:
- Line-Of-Sight (LOS) transmission in general
- Shorter distance from MS to FRS
- Lower transmit power for MS
• Relay Deployment Scenario

• Simulation Models

• Simulation Results

• Summary
Simulation Models

- **Mobile Station (MS)**
  - Max. transmit power (0.5 Watts) for 1km cell radius
  - **Power control** for reverse link transmission
    - **Adaptive resource allocation (ARA)** is an alternative option
  - If FUSC permutation is applied for each sector, MS and FRS in different sector can reuse the same sub-channel.
    - Additional intra-cell interference will be raised

- **Fixed Relay Station (FRS)**
  - 14 FRSs are deployed to provide full coverage within the cell
    - 4 directional antennas for each main street direction
    - 1 stand alone directional antenna is steering toward the BS’s direction
    - **Power control** for the reverse link transmission from FRS to BS
  - **Time domain relaying** within the same radio bandwidth
Simulation Models

- Propagation models are the same as C80216mmr-05_041

\[
\text{Pathloss}(dE) = 38.4 + 35 \log_{10}(d) + 20 \log_{10}(\frac{f_c}{5})
\]

\[
\sigma = 8 \text{dB}
\]

\[
\text{Pathloss}(dE) = 36.5 + 23.5 \log_{10}(d) + 20 \log_{10}(\frac{f_c}{2.5})
\]

\[
\sigma = 3.4 \text{dB}
\]

\[
\begin{align*}
\text{Pathloss}(dE) &= \begin{cases} 
41 + 22.7 \log_{10}(d) + 20 \log_{10}(f_c/5) & \text{if LOS} \\
0.096d_1 + 65 + 20 \log_{10}(f_c/5) + (28 - 0.024d_1) \log_{10}(d_2) & \text{if NLOS}
\end{cases} \\
\sigma(dE) &= \begin{cases} 
2.3 & \text{if LOS} \\
3.1 & \text{if NLOS}
\end{cases} \\
P_{\text{LOS}}(d) &= \begin{cases} 
1 & \text{if } d \leq 15 \text{m} \\
1 - \left(1 - (1.56 - 0.48 \log_{10}(d))^3\right)^{3.1} & \text{if } d > 15 \text{m}
\end{cases}
\end{align*}
\]
Simulation Models

• Reference System: IEEE 802.16e OFDMA mode
  – Radio bandwidth for each cell: 6MHz
  – Total number of sub-carriers: 2048
  – Carrier frequency: 3.5GHz
  – Number of sub-channels in each sector: 96(FUSC), 32(PUSC)
  – Number of sub-carriers within each sub-channel: 18
  – Number of sectors: 3
  – Max. transmit power of each MS: 0.5W
  – Max. transmit power of each FRS: 5W
  – Antenna height of BS: Above rooftop (35m)
  – Antenna height of FRS: Above / below rooftop (to BS / MS)
  – MS speed: 30km/hr
  – Probability of changing direction at intersection: 50%
  – MS arrival: Poisson process
  – Handoff type: Hard handoff
• Relay Deployment Scenario

• Simulation Models

• Simulation Results

• Summary
Simulation Results

- CDF (Cumulative Distribution Function) of MS transmit power
  - ARA: Adaptive Resource Allocation
  - PUSC permutation
Simulation Results

- System capacity (Mbps/cell)

![Bar chart showing system capacity for different relay conditions and frequency reuse factors](chart.png)
Simulation Results

- System capacity (Mbps/cell)
## Simulation Results

<table>
<thead>
<tr>
<th>K=1</th>
<th>MS Transmit Power</th>
<th>Cell Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reference case</strong> (+0%)</td>
<td><strong>Reference case</strong> (+0%)</td>
<td></td>
</tr>
<tr>
<td>No Relay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay, PUSC</td>
<td>-7.21dB</td>
<td>-44.53%</td>
</tr>
<tr>
<td>Relay, PUSC + adaptive resource allocation</td>
<td>-0.20dB</td>
<td>+40.95%</td>
</tr>
<tr>
<td>Relay, FUSC</td>
<td>-4.30dB</td>
<td>-35.44%</td>
</tr>
<tr>
<td>Relay, FUSC+ adaptive resource allocation</td>
<td>+1.19dB</td>
<td>+41.66%</td>
</tr>
</tbody>
</table>
## Simulation Results

<table>
<thead>
<tr>
<th>K=3</th>
<th>MS Transmit Power</th>
<th>Cell Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Relay</td>
<td>-1.59dB</td>
<td>+5.97%</td>
</tr>
<tr>
<td>Relay, PUSC</td>
<td>-11.05dB</td>
<td>-40.99%</td>
</tr>
<tr>
<td>Relay, PUSC + adaptive resource allocation</td>
<td>-2.46dB</td>
<td>+69.29%</td>
</tr>
<tr>
<td>Relay, FUSC</td>
<td>-6.69dB</td>
<td>-7.67%</td>
</tr>
<tr>
<td>Relay, FUSC+ adaptive resource allocation</td>
<td>+0.90dB</td>
<td>+129.96%</td>
</tr>
</tbody>
</table>
## Simulation Results

<table>
<thead>
<tr>
<th>K=7</th>
<th>MS Transmit Power</th>
<th>Cell Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Relay</td>
<td>-1.60dB</td>
<td>+13.01%</td>
</tr>
<tr>
<td>Relay, PUSC</td>
<td>-12.65dB</td>
<td>-40.35%</td>
</tr>
<tr>
<td>Relay, PUSC + adaptive resource allocation</td>
<td>-4.67dB</td>
<td>+75.08%</td>
</tr>
<tr>
<td>Relay, FUSC</td>
<td>-9.80dB</td>
<td>-2.68%</td>
</tr>
<tr>
<td>Relay, FUSC+ adaptive resource allocation</td>
<td>-0.29dB</td>
<td>+152.31%</td>
</tr>
</tbody>
</table>
• Relay Deployment Scenario

• Simulation Models

• Simulation Results

• Summary
Summary

- Relaying provides significant reverse link performances improvement:
  - saving MS transmit power
    - Shorter distance between MS and FRS
    - Higher probability to have LOS transmission condition
      → Propagation loss reduction
  - increasing system capacity
    - Transform the conserved MS transmit power into cell throughput improvement through adaptive resource allocation
    - Overall cell throughput is outperformed to the case without relaying
- Adaptive resource allocation/scheduling mechanism is an important function for relay-based systems
  - System capacity can be improved by relaying through this function
  - Relay station should have necessary features to make this achievable