Performance Evaluation & SON Aspects of Vertical Sectorisation in a Realistic LTE Network Environment

IWSON 2014 - Barcelona
26 August 2014

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Outline

- Introduction
- Vertical Sectorisation
- Modelling & Simulation Scenarios
- Numerical Results & Analysis
- SON Function Analytical Model
- SON Function Calibration
- Conclusions & Further Steps
Introduction

- Motivation
  - Increasing traffic demand in mobile networks
  - New systems & features for higher network capacity & improved performance

Active Antenna Systems (AAS)
- Improved network performance
- Reduced costs
- Long-term sustainability

Vertical Sectorisation (VS)
- Increased network capacity
- Improved UE performance

Self-Organizing Networks (SON)
- Intelligent networks
- Multi-layer & multi-RAT functionality
- High degree of flexibility
- High degree of adaptability
  - Spatial traffic variations
  - Temporal traffic variations

How to combine VS with SON to maximize gains and optimize performance?
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Vertical Sectorisation

- VS is performed by splitting the antenna beam serving one cell, into two beams with different electrical tilts – $\theta_e$ (split in the vertical plane)

- The mechanical tilt of the antenna remains the same

- The former cell is split into two new cells / sectors serving different areas

- The two sectors have their own physical cell IDs

- Full reuse of the available spectral resources

- Sharing of the total transmit power available for the cell ($P_{\text{total}} = P_{\text{inner}} + P_{\text{outer}}$)
Vertical Sectorisation

- **Pros**
  - Spatial reuse of resources
  - Reduced inter-cell interference (reduced Tx power)
  - Focused beam on high traffic demand area (increased SINR)

- **Cons**
  - Reduced Tx power per sector
  - Increased inter-cell interference (additional cell)
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Modelling & Simulation Scenarios

- Realistic LTE network (Hannover, Germany)
- Advanced AAS model based on Kathrein 3GPP contributions
- Realistic in/outdoor ray tracing propagation model (including 3D building data)
- Realistic traffic intensity maps

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area size</td>
<td>5x7 km² (3x5 km²)</td>
</tr>
<tr>
<td>Nº sites / cells</td>
<td>63 (36) / 84 (51)</td>
</tr>
<tr>
<td>Frequency band</td>
<td>1800 MHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>20 MHz</td>
</tr>
<tr>
<td>Cell max Tx power</td>
<td>40 W (46 dBm)</td>
</tr>
<tr>
<td>Antenna gain</td>
<td>18 dBi</td>
</tr>
<tr>
<td>Antenna mech. tilt</td>
<td>4°</td>
</tr>
<tr>
<td>Session file size</td>
<td>16 Mb</td>
</tr>
<tr>
<td>Scheduling</td>
<td>Fair sharing</td>
</tr>
<tr>
<td>Link adaptation</td>
<td>Modified Shannon curve</td>
</tr>
</tbody>
</table>
Highly loaded scenario (Average cell load 42% - centre of Hannover 60% - 85%)

Simulation of multiple scenarios for different VS parameters values

Electrical tilts are on top of $4^\circ$ mechanical tilt

$\theta^e_{\text{outer}}$ was kept at $0^\circ$ to maintain the coverage level

<table>
<thead>
<tr>
<th>Inner Sector</th>
<th>Outer Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical downtilt</td>
<td>$\theta^e_{\text{inner}} \in {6^\circ, 8^\circ, 10^\circ}$</td>
</tr>
<tr>
<td>Power split</td>
<td>$P_{\text{inner}} \in {0.2, 0.5, 0.8} \times P_{\text{total}}$</td>
</tr>
</tbody>
</table>

$P_{\text{outer}} = P_{\text{total}} - P_{\text{inner}}$

VS status
- VS always ON
- VS always OFF
- VS controlled by SON function

VS level
- Entire network
- Single cell

KPIs
- Average & 10$^{th}$ user throughput
- Coverage ratio
- Resource utilization
- Nº users served per cell
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Numerical Results & Analysis

- Network-wide VS
  - For a highly loaded scenario VS is always beneficial for the network
  - Almost all of the cells present gains in performance
  - Average gains of up to 33% for average user throughput and 95% for 10th percentile
  - Best performance for tilts $\theta$ 8-0 and power split depends on KPI
    - P50-50 for average user throughput
    - P20-80 for 10th percentile user throughput

- Power split matching to traffic distribution is very important

- Where does the gain come from? Resource re-use? Change in interference?
Numerical Results & Analysis

- **Single cell VS**
  - When matching of power split is close to traffic distribution, the performance of the VS cell improves
  - Neighbouring cells performance always improves due to decreased inter-cell interference (highly dependent of $P_{outer}$)
  - Majority of users are served by the outer sector (larger footprint)
  - Different power splits have great effect on sector resource utilization

- **Need for a SON function**
  - Activation / de-activation of VS
  - Selection of appropriate cells for VS
  - Optimization of VS parameters
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SON Function Analytical Model

- Design of a VS controller for VS activation / de-activation on a per cell basis
  - Decision based on load estimation of inner & outer sectors
  - Goal: Maximize Mean User Throughput (MUT) within the cell

- Two decision boundaries
  - Activate when VS is OFF (based on estimated load)
  - De-activate when VS is ON (based on actual loads)

- Assumptions
  - Tri-sector site surrounded by six interfering eNBs
  - Worst case scenario = full interference from all eNBs

- Maximize MUT
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SON Function Calibration

- SON model adjustment using the realistic LTE system level simulator
  - Variable loading
  - Evaluate MUT in cases of VS ON & VS OFF
  - Find decision boundaries (logistic regression fitting) by choosing action for maximum MUT
SON Function Calibration

- Performance of VS SON depends on multiple factors
  - Decision timing interval / macroscopic vs microscopic application
  - Cell characteristics
  - Load & traffic distribution
  - Inter-cell interference
  - Tilt & power settings

Average User Throughput

Average User Throughput

Throughput (kbps)

Cell ID
Cell 52
Cell 62

Load
L 0.001
L 0.002
L 0.004
L 0.007

Average User Throughput

Scenario

Throughput (kbps)

Scenario

VS OFF
VS ON
SON VS

VS OFF
VS ON
SON VS

VS OFF
VS ON
SON VS

VS OFF
VS ON
SON VS

VS SON - Per call
VS SON - 1 sec
VS SON - 10 sec

Throughput (kbps)

Throughput (kbps)
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Conclusions & Further Steps

- VS can offer significant gains which depend on
  - Cell load & traffic distribution
  - Interference conditions
  - VS parameters settings

- Need for a smart (de)activation rule & parameter optimization

- SON controller can offer improved performance of VS on a per cell basis

- SON controller performance is sensitive to multiple factors

- Next steps
  - Assess VS performance with respect to the cell’s vertical angular spread
  - Inner & outer sector load estimation optimization
  - VS decision timing optimization
  - VS parameters optimization (tilt & power)
Thank you

Questions ?