Handover parameter optimization in LTE self-organizing networks

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Introduction

- **Problem**
  - Handover parameter optimisation is done manually
    - high OPEX
    - long optimisation intervals based on error reports
  - Non-optimal handover performance
    - handover failures
    - ping-pong handovers
    - call dropping

- **Handover parameter optimisation objective**
  - automate the optimisation
  - adapt the handover parameters on a short-term scale
  - optimise the handover performance

- **Approach**
  - analyse the system behaviour
  - develop handover optimisation algorithm
Input data
- Realistic SOCRATES scenario
  - 1.5 km * 1.5 km area
  - Up to 78 cells
- Microscopic traffic simulator
  - Mobile users (cars) with different speed (up to 50 km/h)
  - Ray-Tracer
    - Pathloss information to best 30 cells
  - User position updates every 100 ms

Update RSRP/SINR
- 3dB shadow fading map

Handover procedure / algorithm
Control parameters
  - Hysteresis
  - Time-to-Trigger

Assessment metrics
  - Handover failure ratio
    \[ HPI_{HOF} = \frac{N_{HO\_fail}}{N_{HO\_fail} + N_{HO\_succ}} \]
  - Ping-Pong handover ratio
    \[ HPI_{HPP} = \frac{N_{HO\_pp}}{N_{HO\_pp} + N_{HO\_npp} + N_{HO\_fail}} \]
  - Call dropping ratio
    \[ HPI_{DC} = \frac{N_{HO\_dropped}}{N_{HO\_accepted}} \]
Simulation metrics

- **System metrics**

  - **RSRP** (Reference Signal Received Power)
  
  - cell transmit power $P_c$
  
  - pathloss $L_{ue}$ to the UE
  
  - shadow fading $L_{fad}$ with a standard deviation of 3dB

  $\text{RSRP}_{c,ue} = P_c - L_{ue} + L_{fad}$

- **SINR** (Signal to Interference Noise Ratio)

  - interfering cells $N$

  $\text{SINR}_{c,ue} = \text{RSRP}_{c,ue} - 10 \cdot \log_{10} \left( \sum_{n=1}^{N} \frac{\text{RSRP}_{n,ue}}{10} \right)$
Initial performance studies

- **Objective**
  - Analyse the system behaviour and sensitivity
  - Find handover algorithm approach

- **Simulation assumptions**
  - All resources are used in all cells (maximum interference)

- **Simulation approach**
  - Perform system simulations for all hysteresis and time-to-trigger value combination (handover operating point)

<table>
<thead>
<tr>
<th>Simulation parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation time</td>
<td>200 [s]</td>
</tr>
<tr>
<td>Simulation step time</td>
<td>0.01 [s]</td>
</tr>
<tr>
<td>Simulation area (mobile users)</td>
<td>1.5 km * 1.5 km</td>
</tr>
<tr>
<td>Number of users</td>
<td>30</td>
</tr>
<tr>
<td>eNodeB transmit power</td>
<td>46 [dBm]</td>
</tr>
<tr>
<td>Number of considered cells in the scenario</td>
<td>76</td>
</tr>
<tr>
<td>Measured cells (N)</td>
<td>21</td>
</tr>
<tr>
<td>Considered interfering cells for SINR calculations</td>
<td>20</td>
</tr>
<tr>
<td>Critical ping-pong handover time (T_crit)</td>
<td>5 [s]</td>
</tr>
<tr>
<td>Handover execution time</td>
<td>0.25 [s]</td>
</tr>
<tr>
<td>SINR averaging window</td>
<td>0.1 [s]</td>
</tr>
<tr>
<td>Min. SINR threshold</td>
<td>- 6.5 [dB]</td>
</tr>
</tbody>
</table>
Call dropping behaviour

Dipl.-Ing. Thomas Jansen, TU Braunschweig, Institut für Nachrichtentechnik

3D plot showing the relationship between call drops, time-to-trigger, and hysteresis dB.
Handover performance weighting function

- $\mathbf{HP} = w_1 \mathbf{HPI}_{\text{HOF}} + w_2 \mathbf{HPI}_{\text{HPP}} + w_3 \mathbf{HPI}_{\text{DC}}$

- $w_x$ is the weight of the individual HPI
- $\mathbf{HPI}_{\text{HOF}}$ is the handover failure performance indicator
- $\mathbf{HPI}_{\text{HPP}}$ is the ping-pong handover performance indicator
- $\mathbf{HPI}_{\text{DC}}$ is the dropped calls performance indicator

<table>
<thead>
<tr>
<th>Weighting parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w_1$</td>
<td>1.0</td>
</tr>
<tr>
<td>$w_2$</td>
<td>0.5</td>
</tr>
<tr>
<td>$w_3$</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Handover performance

Handover Performance (weights = [1 0.5 2])

Time-to-Trigger [s]

Normalised sum of weighted HO failure rate, ping-pong HO rate and call dropping rate

Hysteresis [dB]
<table>
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<tr>
<td>Simulation step time</td>
<td>0.01 [s]</td>
</tr>
<tr>
<td>Simulation area (mobile users)</td>
<td>1.5 km * 1.5 km</td>
</tr>
<tr>
<td>Number of users</td>
<td>50</td>
</tr>
<tr>
<td>eNodeB transmit power</td>
<td>46 [dBm]</td>
</tr>
<tr>
<td>Operating points (Hysteresis, Time-to-Trigger)</td>
<td>(4, 0.48), (6, 0.32), (8, 0.1), (9, 0.08) in [dB, s]</td>
</tr>
<tr>
<td>Number of considered cells in the scenario</td>
<td>78</td>
</tr>
<tr>
<td>Measured cells (N)</td>
<td>21</td>
</tr>
<tr>
<td>Considered interfering cells for SINR calculations</td>
<td>20</td>
</tr>
<tr>
<td>Handover performance averaging window</td>
<td>60 [s]</td>
</tr>
<tr>
<td>Critical ping-pong handover time (T_crit)</td>
<td>5 [s]</td>
</tr>
<tr>
<td>Handover execution time</td>
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<td>- 6.5 [dB]</td>
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</tbody>
</table>
Performance of the non-optimised network

Handover Performance for the operating point (4, 0.48)

- Handover failure
- Ping-Pong handover
- Call dropping

Ratio [%]

Time [s]
Comparison of the network performance for four different operating points

- (4 dB Hys, 0.48 s TTT)
- (6 dB Hys, 0.32 s TTT)
- (8 dB Hys, 0.1 s TTT)
- (9 dB Hys, 0.08 s TTT)
Handover optimisation SON algorithm

Optimisation criteria for HPIs

<table>
<thead>
<tr>
<th>Handover Performance Indicator</th>
<th>Hysteresis</th>
<th>Time-to-Trigger</th>
<th>Optimisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handover failure ratio</td>
<td>&lt; 5 dB</td>
<td>↑ TTT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 dB – 7 dB</td>
<td>↑ TTT &amp; ↑ HYS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 7 dB</td>
<td>↑ HYS</td>
<td></td>
</tr>
<tr>
<td>Ping-Pong handover ratio</td>
<td>&lt; 2.5 dB</td>
<td>↑ TTT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.5 dB – 5.5 dB</td>
<td>↑ TTT &amp; ↑ HYS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 5.5 dB</td>
<td>↑ HYS</td>
<td></td>
</tr>
<tr>
<td>Call dropping ratio</td>
<td>&gt; 6 dB</td>
<td>↓ TTT &amp; ↓ HYS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;= 6 dB</td>
<td>↓ TTT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 7.5 dB</td>
<td>↓ TTT &amp; ↓ HYS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.5 dB – 6.5 dB</td>
<td>&lt;= 0.6 s</td>
<td>↑ HYS</td>
</tr>
<tr>
<td></td>
<td>&lt; 3.5 dB</td>
<td>&lt;= 0.6 s</td>
<td>↑ TTT &amp; ↑ HYS</td>
</tr>
</tbody>
</table>

- Optimisation actions are added up
- Hys and TTT are only changed by one step at a time
- The new operating point has to belong to the set of “meaningful operating points”
Handover optimisation simulation results

Handover performance for the operating point (6, 0.32)

- Handover failure
- Ping-Pong handover
- Call dropping

Time [s]

Ratio [%]
Handover optimisation simulation results

Handover performance (Optimisation)

- Handover failure
- Ping-Pong handover
- Call dropping

Time [s]
Ratio [%]
The system behaviour for different handover operating points has been analysed.

- Handover performance can be optimised using the proposed algorithm.
- Handover operating points are chosen for every cell individually.
- The overall network performance is increased and the handover failure ratio and ping-pong ratio drop to zero in the shown case.

Next steps:
- Run the algorithm in other scenario (done)
  - Problem: Fixed ratio of target thresholds between the HPIs
- Enhance the handover optimisation algorithm (ongoing)
- Introduce different user types (pedestrians, indoor, etc) (ongoing)
Thank you very much for your attention