System-Level Simulation for Non-Orthogonal Multiple Access: A Platform Built atop the Vienna LTE-A Downlink System-Level Simulator

Introduction
Non-orthogonal multiple access (NOMA) has recently received a lot of attention as a promising technique for the next-generation (5G) communication system. Different from orthogonal multiple access (OMA) used by the current LTE-A system, NOMA allows a resource block (RB) to be shared by multiple users when their signals are multiplexed in the power domain at the transmitter side and separated at the receiver side. To fully utilize its advantage, an effective NOMA scheduler for pairing users in available RBs is needed. As part of our research endeavors on advanced resource allocation techniques for 5G NOMA, we design and implement an efficient scheduler based on the Vienna LTE-A downlink system-level simulator for supporting multiuser superposition transmission (MUST). The proposed scheduler takes into consideration not only user pairing and power allocation, but also modulation and coding scheme (MCS) selection such that the chosen MCS settings result in acceptable block error rate (BLER) while achieving proportional fairness among users.

Central to the proposed scheduler is the link-to-system mapping method involving an MCS table at the eNodeB and a $\beta$ table at the user equipment (UE). While the MCS table records the set of feasible MCS settings and power split factors for any user pair with given channel qualities such that the eNodeB can have a more accurate estimation of user performance before scheduling, the $\beta$ table captures the practical performance of MUST receivers such as symbol-level interference cancellation (SLIC) for a more accurate system-level simulation with low complexity. The following highlights the design of the link-to-system mapping method for the proposed NOMA scheduler.

Construction of the MCS Table
Designed for use by the scheduler, the MCS table is built offline by recording the power split factors and MCS settings that can be used by any user pair of given channel qualities to satisfy the BLER constraint. Given the SNRs (or CQIs) of two candidate users (near and far users), link-level simulation is performed for different preset power split factors ($\mu_N, \mu_F$) and MCS settings (MCS$N$, MCS$F$) to obtain achievable throughputs ($r_N$, $r_F$) and BLERs (BLER$N$, BLER$F$). The set of (MCS$N$, MCS$F$, $r_N$, $r_F$, $\mu_N$, $\mu_F$) is recorded in the MCS table if both BLER$N$ and BLER$F$ satisfy the predefined BLER threshold.

![Two-user MCS table for symbol-level NOMA](Fig.1: Throughput map of the MCS table)
Fig. 1 shows a throughput map obtained from the MCS table when the MCS setting resulting in the highest throughput sum for each pair is chosen for plotting.

**Construction of the β Table**

We implement symbol-level interference cancellation (SLIC) in the Vienna LTE-A link-level simulator for the near user to cancel the interference from the far user. To model the practical performance of SLIC in the system-level simulator, a β table for link-to-system mapping is constructed. The key idea of the mapping method is to estimate the mutual information per bit (MIB) of the SLIC receiver. The MIB on each time-frequency resource element (RE) is estimated with the calibration factor β as a weighting of the bit-interleaved coded modulation (BICM) capacity (BICMc), given as follows:

\[ \text{MIB}_{\text{SLIC}} = \beta \times \text{BICM}_c \]

The calibration factor β with \(0 < \beta < 1\) is found by solving the optimization problem:

\[ \beta = \arg \min_{\beta \in \mathbb{R}} \max_{i \leq N} \left| \log g(f^{-1}(\beta \times \text{BICM}_c)) - \log \text{BLER}(i) \right|, \]

where the BLER of the near user is obtained by running link-level simulation using the SLIC receiver. Function \(f(\cdot)\) maps an SNR value to received bit mutual information rate (RBIR), and function \(g(\cdot)\) maps an SNR value to BLER, both in the AWGN channel. While BICMc is obtained given SNR, modulation order (MOD) of both near and far users and \(\mu_r\), the β value is obtained given MCSN, MODF, \(\mu_r\). After MIB is calculated from β and BICMc, we convert it to the practical SINR for calculating the final throughput as Fig. 2 shows.

**Evaluation Results**

We evaluate the performance of the proposed NOMA wideband scheduler in a scenario with a hexagonal grid of 19 sites with 3 cells per site. The macroscopic path loss model follows the TS 36.942, while shadow fading is generated as a log-normal-distributed 2D-space-correlated map. The simulation result in Table 1 shows that our proposed NOMA wideband scheduler can achieve gain up to 44% compared to OMA. It is especially noted that, this performance gain is twice better than the result in 3GPP TS 36.859 V1.0.

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Average UE throughput (Mbps)</th>
<th>Edge UE throughput (Mbps)</th>
<th>Average UE throughput gain (%)</th>
<th>Edge UE throughput gain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMA</td>
<td>1.47</td>
<td>0.44</td>
<td>19.73</td>
<td>111.36</td>
</tr>
<tr>
<td>Docomo (ideal receiver)</td>
<td>1.76</td>
<td>0.93</td>
<td>19.73</td>
<td>111.36</td>
</tr>
<tr>
<td>Docomo (ML-receiver)</td>
<td>1.73</td>
<td>0.79</td>
<td>17.69</td>
<td>79.55</td>
</tr>
<tr>
<td>MCS-based (ML-receiver)</td>
<td>2.2</td>
<td>0.77</td>
<td>49.66</td>
<td>75</td>
</tr>
<tr>
<td>MCS-based (SLIC-receiver)</td>
<td>2.12</td>
<td>0.64</td>
<td>44.22</td>
<td>45.45</td>
</tr>
</tbody>
</table>

For better understanding the performance gain, the left figure in Fig. 3 shows that the proposed scheduler obtains the highest throughput for wideband SINR falling in between [5, 20] dB compared to Docomo’s method for NOMA and conventional PF scheduling for OMA. For SINR > 20 dB, the
throughput drops to lower values. It is because the near user (with very high SINR) does not need to select the highest modulation order and coding rate; instead it selects an appropriate setting such that the best total throughput for both near and far users can be achieved. The argument is supported by observing the right figure in Fig. 3 when we see that the spectral efficiency obtained from the proposed method increases steadily when the UE wideband SINR increases. In contrast, the Docomo’s method has lower spectral efficiency for SINR>12dB.

![Fig. 3: UE wideband SINR-to-throughput (left) and SINR-to-spectral-efficiency (right) mapping](image)

**Reference**


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