Cooperative Feeder Links for Relay Enhanced Networks

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Abstract
Heterogeneous networks are gaining more and more interest as one means to cope with the expected data rise in future mobile networks. The upgrade of cellular macro networks by placing relay nodes, as one option, has the benefit of avoiding any wired backhaul network, but has to be paid by lower performance compared to pico stations. In the ARTIST4G project we analyze options to get close to the performance of pico stations by using highly effective inband relaying. The goal is to maximize the performance of the donor eNB (DeNB) to RN links - i.e. of the feeder links - by a specifically adapted joint precoding coordinated multi-point (JP-CoMP) scheme to which we refer to as cooperative relaying (CoR). In this paper, the expected performance gains under ideal conditions will be assessed based on system level simulations and different measurements. A further focus is on the main enablers of any CoMP scheme, i.e. channel estimation and feedback techniques properly adapted taking the specific conditions of relay enhanced networks into account.

Index Terms—LTE-Advanced; cooperative relaying, Coordinated Multipoint transmission; interference mitigation; Clustering; CSI estimation;

I. INTRODUCTION
Relay stations or relay nodes (RN), as opposed to pico-stations, use part of the radio resources for their wireless backhaul links to connect to the so called donor enhanced nodeB (DeNB) according to 3GPP LTE. Besides the overhead, for relaying user data to the RNs over-the-air backhaul connections suffer from inter-link interference and have typically a much lower capacity when compared to a wired line. On the plus side, no wired infrastructure is required, enabling flexible, short-term, and cost efficient deployment. The efficiency of the feeder links determines the overall relaying performance. In case of significant higher throughput on the DeNB – RN relay feeder compared to the RN-UE links, the overall system performance would eventually approach that of pico stations, but without the need for costly infra-structure. In the EU founded project ARTIST4G [2] different levers for optimized system performance are considered for the achievement of the main project goals, i.e. a smoother user experience over the whole network area. Here, we investigate the combination of relaying and joint transmission – in 3GPP called joint precoding coordinated multipoint (JP-CoMP). Using this technique, we expect coverage as well as capacity gains at the same time. Therefore it is a strong candidate with respect to the ARTIST4G goals.

The cooperation might include DeNB – RN, RN – UE and DeNB – UE links or any combination of those. Several reasons motivated us to concentrate on cancellation of the inter DeNB – RN feeder link interference within one as well as between adjacent cells as being illustrated in Figure 1, in the following denoted as cooperative relaying (CoR).

Beside the importance of the feeder link for the overall relaying performance, CoR is expected to provide a greater flexibility in placing RNs because it turns otherwise signal-to-interference-and-noise ratio (SINR) limiting interferers into useful signals. Lampposts as often envisaged for RN sites – have quite a high non-line-of-sight (NLOS) probability, so directional antennas will be less effective as SINR boosters as they would be for LOS. In case there is LOS, the maximum rank of the channel matrix to the serving DeNB will be basically limited to two – the two polarizations – so that throughput gains by adding more Tx- and Rx-antennas for MIMO transmission will be limited as well. CoR leads to a rank enhancement [4], i.e. by serving the RNs from different sites, and therefore through typically uncorrelated radio channels, more data streams with higher modulation and coding schemes (MCS) can be spatially multiplexed, and accordingly higher throughput can be expected.

Figure 1: Cooperative Relaying on the DeNB –RN links
In work package 1 of ARTIST4G, a lot of effort was spend
on the maximization of SL JP CoMP gains for conventional macro cellular networks, and lately we achieved more than 100 to 200% gain in spectral efficiency for 4 x 2 MIMO systems with co-polarized eNB antennas under ideal conditions. As reference we used the 3GPP report of the second CoMP study item [5]. Some of the main concepts like user centric clustering based on partial CoMP in combination with cover shifts (or overlapping cooperation areas (CAs)) and the ‘Tortoise’ concept for interference floor shaping that make this success possible have been published in [6][7], and the overall concept will be presented in the final deliverable D1.4 [8] mid 2012.

The focus in D1.4 is on maximizing downlink (DL) JP CoMP gains for uniformly distributed UEs per cell. Here, for CoR we have a slightly different optimization problem, i.e. to maximize the throughput for fixed RNs located in a distance to the DeNBs of about e.g. two third of the cell range. Additionally these RNs have slightly different channel conditions than UEs at the same location due to the larger height of about 6m compared to about 1.6m. Nonetheless we will apply the well proven concepts to CoR in a similar manner.

By itself, CoMP is a complicated technique, but there are important simplifications for relay enhanced network feeder links compared to moving UEs such as: fixed and known RN locations in combination with their greater height reducing the time variance – or equivalently increasing the correlation time $t_{corr}$ - of the radio channels. This gives room for some optimizations with respect to the main challenges of JP CoMP, i.e. accurate channel estimation and excessive feedback overhead for channel state information (CSI) for many channel components (CC). This is highly desirable as the above mentioned CoMP gains were reported under ideal conditions and will require excellent channel knowledge.

By literature search and own measurements we tried and try to find out the typical behavior of feeder links and how one can exploit this knowledge for obtaining very good CSI accuracy in combination with low feedback overhead. For fixed – compared to a mobile – complex channel components $h(t)$, a much higher K-factor of the Ricean fading defined as $K=|V|^2/\sigma^2$ can be expected [16]. Thereby $h(t)=V+v(t)$ is splitted into the fixed part $V$ and the time varying one $v(t)$. An obvious idea is to exploit the larger correlation time $t_{corr}$ by increasing the time interval between the transmissions of so called CSI reference signals (CSI RS), being used for channel estimation. Due to the lower rate of CSI RSs more - and also more orthogonal - resources can be used per channel estimation instant allowing for improved estimation accuracy.

Despite the larger correlation time, small scale channel fluctuations are a challenge. One goal is to identify deterministic channel variations causing these fluctuations like for example mechanical swings of the RNs and to find efficient feedback schemes.

There are some further benefits of CoR. A limited number of fixed RNs allows for fixed clustering and partly predefined scheduling, which might mainly vary for different load conditions and, thus, allows doing offline optimizations. RNs have a power supply and more processing capabilities than UEs usable for advanced algorithms. The DeNB to RN links are easier to standardize as it does not violate UE backwards compatibility.

Chapter II introduces the basic CoR setup, Chapter III analyzes expected performance of CoR based on SL simulation and measurement evaluations, Chapter IV provides the current status regarding channel estimation, while chapter V concludes the paper.

II. COOPERATIVE RELAYING SETUP

Figure 2 illustrates an exemplary single CA consisting of three sites with three sectors each and two antenna elements (AE) per sector, i.e. there are overall nine cells. Without going into detail of clustering and interference floor shaping, we apply the partial CoMP, cover shift (CS) and Tortoise concepts (see [6][7]). Forming comparably large CAs of nine cells is already the first step to noticeable CoMP gains as it drives up the probability that a RN has a reasonable number of strongest cells within this CA.

Partial CoMP means that the RNs will report only a limited set of strongest channel components (CC) above a certain threshold (TH) from the overall nine cells to limit channel estimation and feedback overhead. The unreported CCs will generate intra CA interference, which can be kept small for a proper chosen TH.

Cover shifts (CS) of CAs are organized differently in different orthogonal resources like frequency bands and/or time slots. As we assume 3GPP LTE [9] as our baseline system, this means different physical resource blocks (PRB) and/or subframes (SF): Differently organized means that the cooperation is implemented for a different set of three direct neighbor sites. This allows scheduling RNs into their best fitting CS $CS_o - o=1...6$ - including the highest number of strongest CCs for this RN. In Figure 2 red RNs are served in the center of the red CA, and blue RNs will be served in the center of other CSs, indicated by the dotted circles. Overall six CSs are sufficient to serve all RNs CA centric, at least as long as the strongest cells are not spread over more than nine adjacent cells. Otherwise many RNs would have their strongest interferers from different adjacent CAs, leading to strong inter CA interference and accordingly low CoMP gains for these UEs or here RNs.

The tortoise concept has the goal to generate a tortoise like shape for the signal power of a CA with a strong power at the
CA center and a fast decline outside the CA. As a result the served RNs will experience a very good coverage and, at the same time, inter CA interference is minimized. By beam individual antenna tilting and Tx power allocation – i.e. inbound beams directing to the CA center with low tilt and high Tx power and outbound beams vice versa - we achieved a very good decoupling of CAs and, thus, a very low interference floor. Only few far off interferers that occur due to wave guiding effects need special attention. This is a great step ahead as we can concentrate in the following on a single CA.

![Figure 2: CA in CSx with three sites serving the red RNs in tortoise center. Blue RNs are served in different CSs](image)

![Figure 3: schematic of a single CA and single CS of 9 cells](image)

III. EVALUATION OF EXPECTED COR PERFORMANCE

To get a high level estimate of the expectable CoR feeder link performance, we combined and adapted the results of different system level (SL) simulations and combined them with results of different measurement campaigns. This approach is necessary to validate SL results with real measurements and to tackle CoR specific issues like height dependent channel conditions or inter antenna correlations. Figure 4 sketches a further height related issue, i.e. potential differences in how vertical antenna tilting affects the Rx power. The tortoise based interference floor shaping relies on the cell individual vertical tilting, and it is therefore important to verify the concept also for typical RN positions. According measurements have been started and will be evaluated soon.

Generally we assume a simultaneous and synchronized transmission on the feeder links so that only DeNB – RN links are active at a certain time instant. The macro as well as RN UEs will be served on different orthogonal resources. This is a certain restriction, but leads to a robust system concept and provides the intended predictable interference conditions. Anyway for the hopefully extremely efficient feeder links potential further gains will be marginal.

For the first SL simulations we used a hexagonal grid with 19 sites or 57 cells. The main simulation parameters can be found in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of eNBs</td>
<td>57</td>
</tr>
<tr>
<td>Number of Cellsites</td>
<td>19</td>
</tr>
<tr>
<td># of cells per CA</td>
<td>9</td>
</tr>
<tr>
<td>Cells per Cellsite</td>
<td>3</td>
</tr>
<tr>
<td>Sector width</td>
<td>120 deg</td>
</tr>
<tr>
<td>Height of RNs</td>
<td>1.6m</td>
</tr>
<tr>
<td>Number of Subcarriers</td>
<td>32</td>
</tr>
<tr>
<td>Bandwidth per sub carrier</td>
<td>180 kHz</td>
</tr>
<tr>
<td>TxAEs, RxAEs</td>
<td>1</td>
</tr>
<tr>
<td>Algorithm for JP</td>
<td>ZF</td>
</tr>
<tr>
<td>Channelmodel</td>
<td>SCME</td>
</tr>
<tr>
<td>InterCellSiteDistance</td>
<td>500m</td>
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<tr>
<td>Antenna Tilting</td>
<td>12 deg</td>
</tr>
<tr>
<td>Penetration Loss</td>
<td>No</td>
</tr>
<tr>
<td>CSI</td>
<td>Ideal</td>
</tr>
</tbody>
</table>

Table 1: System level simulation parameters
In Figure 5 the signal to interference and noise ratio (SINR) for the cooperative transmission to the RNs has been simulated for the above mentioned simulation parameters with the RN distance from cell center as a parameter. As can be expected RNs near to the cell center have generally a higher performance compared to cell edge RNs, but interestingly and despite the cooperative transmission all RNs have a similar outage probability defined as the 5 percentile RNs. This is due to the strong NLOS probability for the assumed SCMe channel model.

Typical RN distances will be in the range of 2/3rd of the cell radius. A simple SINR to data rate mapping based on the CDF for 150-250m leads to a large throughput variation of 3-20bit/s/Hz for the assumption of 4 antenna elements per relay node and donor base station (see illustration in Figure 1). This is a very rough estimation and depends on achievable after CoMP SINR and the channel rank. The large value of about 20bit/s, while promising, assumes a real rank 4 CoMP scenario. In addition the strong variation of the feeder link performance is unsatisfying and invoked therefore more advanced investigations.

As basis we took multi-site measurements done for the validation of the tortoise concept on the CoMP testbed from TU Dresden [10] with the layout according to Figure 7. It comprises seven sites of which the three red sites form a tortoise cooperation area. This means that the out bound beams use 15° and the inbound beams 7° downtilt and the Tx power of outbound beams is reduced by 6dB.

Note, similar like for the SL simulations above the measurement height had been 1.6m as usual for UEs. Some height specific measurements have already been done and more are planned in the future. In special cases like a nearby garage of about 2.5m height a dramatic increase in Rx power of at least some of the CCs has been observed. From the shadowed location at 1.6m to the almost LOS conditions at 6m looking over the roof of the garage there was a PL variation of more than 10dB. Typically for scenarios as illustrated in Figure 4 few dB stronger CCs of e.g. 1 to maybe 3-5 dB can be expected.

1300 measurements have been recorded along the dotted lines covering the whole testbed area and have been used in [10] for validation of the tortoise like shape of the Rx signal power. Here we reused the measurements to place artificially 6 RNs at 6 suitable locations similar to Figure 2 into the central cooperation area in distances close to 2/3rd of the cell radii.

We made a fine tuning of the best RN locations similar as being applied in 3GPP for conventional RN solutions, but taking into account the CoMP specific conditions. Conventionally the best location is where there is one strong CC and low to very low interferers from other cells. For CoMP strong CCs of cells forming the CA are increasing the performance and are especially for RNs very helpful in rising the overall channel rank. Therefore in Figure 8 the relative position ‘75’ for the exemplary RN measurement position ‘1030’ is beneficial over position ‘50’. ‘75’ has about 5 strong CCs compared to ‘50’ with only a single one; restricting the possible number of data streams to 1 or maybe 2 (e.g. in case of 2 polarizations).

These measurements alone are not sufficient for an accurate performance evaluation as there have been only 2 cross polarized antennas per cell. For serving e.g. 4 data streams per RN, as assumed for the SL simulations above, one would need at least 4*6=24 Tx antennas. Polarization diversity tends to fade away in NLOS scenarios [11] so the effective number of antennas – or better the usable spatial degree of freedom (SDF) – of the testbed is less than 2*9=18 for a single CA. In addition CoMP systems should be using some degree of diversity for limiting the power normalization loss (PNL) β of the precoder W.

\[
\beta_k = \sum_{m} w_{mk}^2 ; \quad (1)
\]

With \(w_{mk} \in \mathbb{C}^{1x1}\) being the precoding elements over all Tx antennas \(M = N_{Tx} \cdot N_{cell}\) for RN RNk with \(k \in \{1...K\}\). \(N_{Tx}\) is the number of antenna elements per cell and \(N_{cell}\) the number of cells forming the CA. Additionally for single sector antennas, it is not possible to generate any wideband beam forming, which is important for the interference floor shaping.

A useful overall system setup requires therefore 4 to maybe even 8 Tx antennas per cell or sector and similarly 4, 6 or even 8 Rx–antennas per RN. Otherwise the number of data streams determining the peak data rate for the RNs will be limited to e.g. 1 or 2 streams already from the system setup.

For that reason the estimated wideband pathloss values \(\alpha_{km} = \frac{1}{N_{SC}} \sum_{N_{SC}} |h_{km}(j_{SC})|^2\); of the pathloss matrix \(A \in \mathbb{R}_{KxM}\) - reflecting the pathloss of all CCs \(h_{km}\) between all eNBs m to all RNs k of the CA - have been combined with further 8x8 MIMO measurements from Arlington Height [12]. These have been conducted for a single 3 sector site and 8 \(\lambda/2\) spaced Tx antennas per sector. The UEs were equipped with 8 \(\lambda/2\) spaced Rx antennas as well. In Figure 6 a wideband
beamformer for a four \( \lambda \)-spaced antennas allocated as a uniform linear array (ULA) has been swept over 360° by according unitary precoding weights. The result at the UE side is measured for one of the 8 antennas. It is good to see that the beamforming gain can be observed for the whole frequency range of 1200 subcarriers (SC) equal to a bandwidth of 20 MHz. But, despite the usage of 4 antennas with \( \lambda \)-spacing - the beamwidth is still in the range of about 100 degree leading to a strong correlation between 4 WB beams transmitted from one sector of 120 degree. This correlation between the Tx- and Rx-antennas is expected due to the close collocation of the antenna elements. To have a realistic analysis of the correlation effects we constructed an artificial combined channel matrix from both measurements:

\[
H_{CA}^{comb} = (A \ast \Psi) \otimes B ;
\]

(2)

\( A \) delivers the values of all cells of the CA to all six RN positions. As the cells can be assumed to be uncorrelated, we multiply \( A \) with a unitary phase matrix \( \Psi \in \mathbb{C}^{8x8} \) where each element \( \psi_{ij} \) has a random phase value between 0 and 2 \( \pi \). By forming the Kronecker product with a measured 8x8 MIMO matrix \( B \in \mathbb{C}^{8x8} \) taken from a certain UE position in Arlington Height we get realistic correlation conditions in the artificially constructed channel matrix \( H_{CA}^{comb} \in \mathbb{C}^{8x8} \). Note, to be even more realistic we used for each RN a different matrix \( B \) taken from a different UE position.

Taking \( H_{CA}^{comb} \), one can analyze different scenarios with 4 to 8 Tx- and Rx-antennas and use a common CA wide zero forcing (ZF) precoder for joint transmission of as much data streams as possible:

\[
W = \text{pinv}\left(H_{CA}^{comb}\right) ; \quad y = H_{CA}^{comb} W + N + IF_{\text{floor}}
\]

(3)

\( y \in \mathbb{C}^{8x1} \), is the Rx signal stacked with all the data streams to all RNs, \( N \) is the additional white Gaussian noise of the RN receivers and \( IF_{\text{floor}} \) is the residual inter CA interference. \( \Gamma \in \mathbb{R}^{N_{DS} x 1} \) contains the achievable SINRs \( \gamma_i \) of the data streams 1 to \( N_{DS} \):

\[
R = H_{CA}^{comb} W ; \quad I = N + IF_{\text{floor}} ; \quad \Gamma = (\gamma_1, \ldots, \gamma_i \ldots, \gamma_{N_{DS}})^T ; \quad \gamma_i = \frac{[R(i)]^2}{I(i)}
\]

(4)

The noise \( N \) is assumed to be negligible in this interference limited scenario, which is also confirmed by a closer look to the measurement results in the Dresden testbed. Not available yet is a good estimate of the inter CA interference floor \( IF_{\text{floor}} \) as despite the implementation of 7 sites or 21 cells there are still too few cells for a realistic interference floor. Therefore we reused our SL simulation results from [7] and generated a linear approximation of the simulated SINR CDF going from 12 to 36dB. In each simulation and for each RN a random value is chosen from this IF floor distribution. Simulations are repeated till a statistical meaningful SINR could be found.

By using an appropriate SINR to data rate mapping table constructed similarly as in [13], one can estimate the achievable data rate per data stream and calculate the overall sum as well mean data rate per RN.

As already mentioned above, the CCs from one cell to one RN are correlated. For that reason the PNL \( \beta \) will get very large for large number of data streams. As the UE precoding weights per UE will have to be normalized by \( \beta \) there is a trade-off between more data streams and the effective SINR per data stream. In Figure 9 the PNL has been calculated for different number of streams, and we see that for 18 simultaneously served streams per CA the PNL is getting reasonably small. Note, in this case we switched off the streams generating the highest PNL, i.e. this can be seen as a first scheduling decision.

We verified the result for the achievable data rate DR per RN and found an optimum for 18 streams. The achieved mean DR per RN was thereby about 14 bits/s/Hz verifying our first guess according to Figure 1.

This is only a first relative simple analysis of the potential performance still ignoring some of the relevant effects of a typical CoR scenario like the already above mentioned RN height.

**Potential Optimizations**

One can think of a number of potential optimizations which have not been evaluated yet. Most of these optimizations benefit from the static allocation of RNs allowing for an offline in depth search for the overall optimum, which is than just slowly adapted to small channel fluctuations.

Of great help can be for example the adaptation of the RN Rx-beamformer or Rx filter \( F_k \). Similarly as explained in [14] a common optimization of all Rx beamformers \( F_k, k=1...K \) to the overall channel matrix \( H_{CA}^{comb} \) can help to increase the overall channel rank. Similar performance as for NL precoding techniques was reported in [14]. The Rx beamformers might further include some form of interference rejection combing (IRC) for cancellation or suppression of some far off interferers esteeming from other CAs.

A frequency dependent scheduler might further exploit the channel diversity.

For the fixed setup of RNs a fine tuning of the vertical antenna tilting plus power allocation might help to maximize the decoupling between adjacent CAs. This might even include some adaptation to different load conditions.
More challenging might be a further selection of the best RN positions taking not only a single RN into account – as we did above - , but tries to optimize the relative positions of the RNs so that the overall performance is maximized. This might include again the RN height as well.

Beside the SINR the rank of the composite CoMP channels is another important parameter not easily to derive from current channel models. For different sites a relatively low correlation of radio channels can be expected [15], but typical values at the height of RNs and for the envisaged CoR scenario are not available.

A better understanding of all these effects is expected after the evaluation of the measurement results.

As mentioned above, the channel estimation for CoR provides several opportunities for optimization due to the fixed allocation of RNs. To get a first feeling for the expected channel stability over longer time periods, and accordingly a rough estimation of the required overhead for CSI reporting even in case of large CAs and high number of data streams per RN, some first single link channel measurements have been conducted with the NSN LTE Advanced demonstrator. The measurements have been performed for a 2x2 MIMO link from the DeNB site on the Munich campus of NSN and on a height of the receiver antenna of 2.1 m. This is above the height of moving persons and for that reason the channel transfer functions (CTF) varies for a fixed location very slowly and marginally.

At least this can be concluded from the results in Figure 10 where the CTF has been measured at one position two times with a time delay of about 40 minutes in between. Despite this long time duration the CTFs differ by only few dB. Figure 11 contains the short term variations of the amplitude of the CTF for a single location and over a time of about 100ms. Again only small variations are visible and these might be partly attributed to measurement errors.

From the literature, it is also known that for example leaves and wind affects the channel conditions [16]. The reported K-factors for winter and summer are accordingly quite different.
The challenge of these type of fluctuations is that they are similar to noise and therefore unpredictable. Fortunately, these fluctuations are relatively slow with respect to the LTE subframe duration of 1ms or frame duration of 10ms.

In contrast for moving UEs one has to expect that the CTF has completely changed within 10 to 20 ms, even in case of low mobility. Accordingly for LTE Release 8 the overhead for common reference signals (CRS) is in case of 4 Tx antennas already about 14%. Relying on this long term channel stability should allow for much lower overhead with even higher CSI accuracy for CoR.

Currently we are working on further measurements analyzing some specific effects like the decoupling of nearby moving persons or cars in case of increasing RN height. For a typical UE at 1.6m nearby moving persons are a serious challenge as they easily might block or change important multipath components. This we could verify in an indoor measurement, where the channel is getting increasingly unpredictable and chaotic with increasing number of moving persons. For a RN in 6m height we expect - and hope to verify soon – that nearby persons affect only lower order multi path components.

Another interesting effect is the behavior of a RN placed e.g. at a traffic light. In case of strong wind large swings of the traffic light can be observed at least in the range of several cm. For a carrier frequency of e.g. f_c=2.6 GHz with a wavelength \( \lambda \) of about \( \lambda = 12 \text{cm} \) this is already a significant portion of the wavelength. In our measurement we tracked the CTF over 50 cm with a step width of 1cm and observed as expected significant channel variations over a distance of 1 to few cm.

Due to mechanical reasons the amplitude of the swinging will be defined by the strength of the wind, while the swing frequency is defined by the eigenmode of the traffic light. It can be estimated to be in the range of few to maybe 10Hz. That means we have about 100ms for one full swing. Assuming an amplitude of 5cm one can further estimate that the location might change by 1cm within about 5-10ms. So we experience a strong channel variation within 5-10ms violating our assumption of a fixed RN position with accordingly rising overhead for CSI estimation and reporting. This motivated us to search for an improved estimation and reporting scheme, exploiting that RNs will more or less have to move on a predefined trajectory. As a result the CTF will vary in a periodic and therefore predictable manner providing room for novel reporting schemes with lower overhead. For example it should be possible to map a location \( s(t) \) to a CTF \( \text{CTF}(t) \) and report only \( s(t) \), while \( \text{CTF}(t) \) will be reported only semi statically every second or even more seldom. For a harmonic swing \( s(t) \) can even be estimated by the eNBs with quite good accuracy needing only seldom updates of the true location.

Figure 10: measured CSI of OFDM reference signals over 30MHz bandwidth at 2.6GHz RF at time t=0 and 40min.

Figure 11: channel transfer function amplitude variation in [dB] over a bandwidth of 30MHz for a time duration of about 100ms

We hope to verify our overall CSI estimation and reporting concepts on the TUD testbed in Dresden in the near future, for example by adding artificial mechanical swings to the testbed. Based on the gathered measurements we will offline calculate the achievable performance in combination with a hopefully very low reporting effort.

V. CONCLUSION

Cooperation on the RN feeder links is a promising approach as it addresses the main shortcoming of relays compared to pico stations. First SL simulations for an 8x4 MIMO system based on the partial CoMP concept in combination with interference floor shaping promise very high throughput rates of about 14 bit/s/Hz on the feeder links. For the analysis large scale field trial measurements have been combined with an outdoor multi antenna measurement and available system level simulations to tackle the most relevant effects in the CoR scenario.

The RN positions have been preselected with the goal to maximize their channel rank, but otherwise a number of further optimizations like common Rx-beamformer selection or multi RN frequency scheduling gains have been identified, but could not be evaluated yet. This gives hope to a further boost in system performance.
RNs have specific conditions like high and fixed placement over ground at e.g. 6m – the typical height of lamp posts. Therefore organization of CoMP becomes much simpler compared to CoMP for moving UEs, but it raises also a number of open issues like realistic channel conditions for the envisaged scenarios, which we have started to analyze by specific measurements.

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