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Mitigation of Intercell Interference without Base Station Cooperation

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***Abstract*—We consider the downlink of a cellular system based on the spatial channel model of the 3GPP MIMO urban macro cell with multiple antenna base stations and single antenna mobile devices. We analyze the impact of path-loss and intercell interference and classify mobile devices according to their location in a cell. We discuss non-cooperative approaches for maximizing the network sum-rate and propose an algorithm that combines altruistic avoidance of intercell interference and egoistic sum-rate maximization. The sum-rate reached with this algorithm is still limited by intercell interference but outperforms existing non-cooperative methods without introducing a large overhead.**

I. Introduction

Intercell interference (ICI) is the strongest effect limiting the performance of today's cellular networks. It can be overcome by letting *base stations* (BS) cooperate. But, this cooperation introduces a large overhead, which minders the gains of cooperation. To have a fair comparison between different levels of cooperation, the performance of non-cooperative methods has to be sized. In this contribution, the cooperation is restricted to synchronized scheduling, a predefined *mobile device* (MD) selection, and the knowledge of channel state information. No communication is allowed between the BSs.

A major problem of the ICI is, that it changes due to scheduling and beamforming decisions. Even, if all BSs optimize their scheduling and beamforming at the same time, the measured ICI is outdated, as soon as the optimization is applied. This ICI blindness degrades the possible data rates vastly. We show in Section II-B, how interference awareness can be achieved.

Algorithms for cellular systems need to be designed for the specific channel model. Algorithms, which work very well for independent and identically-distributed channels, can completely fail for channels, which are strongly influenced by path-loss. Therefore, we take a close look at the chosen channel model in Section III and analyze the influence of path-loss and ICI on different MD classes according to their location in the cell.

In Section IV, we derive a non-cooperative sum-rate maximization, and discuss different approaches to optimize it. Non-cooperative algorithms are usually limited by ICI and need to incorporate ICI mitigation to achieve higher data rates. A new algorithm, which finds a tradeoff between the avoidance of some of the worst interference contributions and the maximization of the sum-rate of the local cell is presented in Section V. Simulation results with the newly proposed algorithm can be found in Section VII.

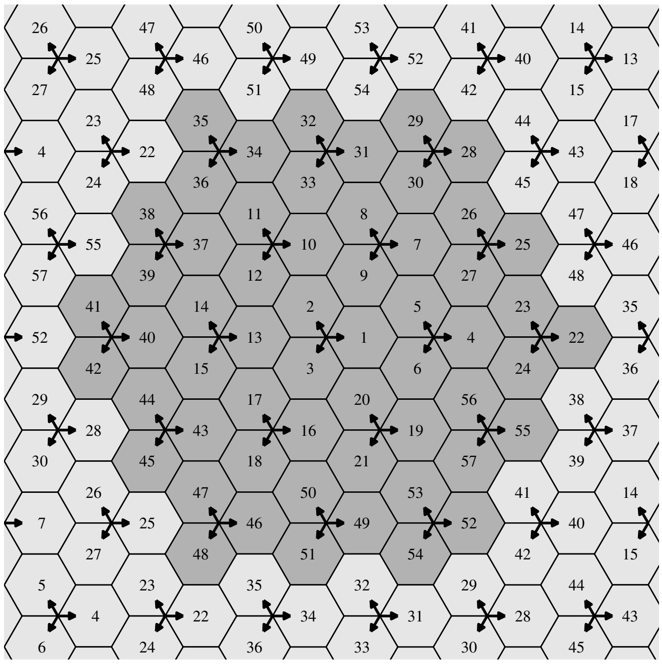

Fig. 1. Cellular Cluster with Wrap-a-Round

II. System Model

A cellular system with 19 sites, which employ three faced sectorization, is considered. Therefore, the system consists of 57 BSs. Each BS serves the MDs of the hexagonal shaped cell it covers. An MD in the set $\mathcal{K}$ of all MDs is specified by the tuple $(b, k) \in \mathcal{K}$, where $b \in \mathcal{B}$ identifies the BS in the set $\mathcal{B}$ of all BSs and $k \in \mathcal{K}_b$ the MD in the set $\mathcal{K}_b$ of all MDs in the cell of BS b.

In order to treat all cells equally, the wrap-around method is used. The 57 BSs are copied, including their beamforming, and placed six times around the central cluster. Each MD only sees the 57 BSs, which are closest by Euclidean distance. The cellular layout can be seen in Figure 1. The central cluster is inked slightly darker than the wrap-a-round clusters. The placement and orientation of the BSs is indicated by small arrows.

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scenario	urban macro-cell
inter site distance	500m
center frequency	2GHz
bandwidth	9.7656kHz
carriers	1
antenna configuration	$N_b \times 1$ MISO
sectors	$19 \cdot 3 = 57$
users per sector	$\|\mathcal{K}_b\|$
user speed	30km/h
min distance to site	25m
height site	25m
height user	1.5m
average building height	20m
street width	20m
antenna spacing	0.5λ

TABLE I
SIMULATION PARAMETERS

A. Channel Model

The spatial channel model of the 3GPP MIMO urban macro cell with a distance of 500m between the two closest sites is utilized [1]. The applied parameters for the simulations can be seen in Table I. In this work, we do not optimize over different frequency subbands and, therefore, simulate with only one subcarrier at a bandwidth of 9.7656kHz.

In this paper, BS b has N_b antennas and every MD has one antenna. The vectors $\boldsymbol{h}_{\hat{b},b,k} \in \mathbb{C}^{N_{\hat{b}}}$ contain the channel coefficients between the antennas of BS $\hat{b}$ and MD (b,k). With $(\bullet)^{\mathrm{T}}$ for the transposition and dirty paper coding, the achievable, normalized rates of MD (b,k) can be expressed as

$$r_{b,k} = \log_2\left(1 + \frac{|\boldsymbol{h}_{b,b,k}^{\mathrm{T}}\boldsymbol{p}_{b,k}|^2}{\theta_{b,k}^2 + \sum_{\hat{k}<k}|\boldsymbol{h}_{b,b,k}^{\mathrm{T}}\boldsymbol{p}_{b,\hat{k}}|^2}\right), \quad (1)$$

where

$$\theta_{b,k}^2 = \sigma_{b,k}^2 + \sum_{\hat{b}\in\mathcal{B}\setminus b}\sum_{\hat{k}\in\mathcal{K}_{\hat{b}}}|\boldsymbol{h}_{\hat{b},b,k}^{\mathrm{T}}\boldsymbol{p}_{\hat{b},\hat{k}}|^2 \quad (2)$$

is the power of the received *intercell interference plus noise* (IIPN), $\sigma_{b,k}^2$ is the power of the noise, and $\boldsymbol{p}_{b,k} \in \mathbb{C}^{N_b}$ is the beamforming vector for MD (b,k). $\sum_{\hat{k}<k}|\boldsymbol{h}_{b,b,k}^{\mathrm{T}}\boldsymbol{p}_{b,\hat{k}}|^2$ is the power of the intracell interference if dirty paper coding is applied. Furthermore, a transmit power constraint $\sum_{k\in\mathcal{K}_b}\|\boldsymbol{p}_{b,k}\|_2^2 \le P_b$ is imposed for every BS.

B. Channel Measurements and Interference Awareness

The channel measurements are divided in two steps. In the first step, all BSs send orthogonal pilots in such a way, that each MD $(b,k) \in \mathcal{K}$ can measure all channel vectors $\boldsymbol{h}_{\hat{b},b,k}$ from all BSs $\hat{b} \in \mathcal{B}$. Therefore, each MD knows the power of its IIPN $(\theta_{b,k}^{\mathrm{1st}})^2$, if all BSs send with scaled identity transmit covariance matrices, respectively, e. g., $\sum_{\hat{k}\in\mathcal{K}_{\hat{b}}}(\boldsymbol{p}_{\hat{b},\hat{k}}^{\mathrm{1st}})^*(\boldsymbol{p}_{\hat{b},\hat{k}}^{\mathrm{1st}})^{\mathrm{T}} = \frac{P_{\hat{b}}}{N_{\hat{b}}}\mathbf{I}$, $\forall\hat{b} \in \mathcal{B}$, where $(\bullet)^*$ denotes the complex conjugate. Then, each MD feeds the channel $\boldsymbol{h}_{b,b,k}$ from the associated BS b and the power of its IIPN $(\theta_{b,k}^{\mathrm{1st}})^2$ back to the associated BS b. The BSs calculate their beamforming $\boldsymbol{p}_{b,k}^{\mathrm{2nd}}$ and assume achievable rates $r_{b,k}^{\mathrm{1st}}$ for the MDs depending on the assumed IIPN powers $(\theta_{b,k}^{\mathrm{1st}})^2$, which are outdated the moment the beamforming $\boldsymbol{p}_{b,k}^{\mathrm{2nd}}$ is applied.

In the second step, again, all BSs send orthogonal pilots, but, with the calculated beamforming vectors $\boldsymbol{p}_{b,k}^{\mathrm{2nd}}$. The number of pilot symbols can be considerably lower compared to the first phase, because the MDs have to estimate only a scalar instead of a vector. Now, the MDs can measure the updated IIPN power $(\theta_{b,k}^{\mathrm{2nd}})^2$. This value is then fed back to the associated BS. Also, the associated feedback resources for the second step are less than for the forst step. After this, the BSs do not alter their beamforming anymore, but, with the 2nd pilot they can serve the MDs with ICI-aware rates $r_{b,k}^{\mathrm{2nd}}$.

III. SYSTEM MODEL EVALUATION

Although, fading and shadowing according to line-of-sight conditions are important factors of the 3GPP MIMO model, the path-loss has a very strong influence. It depends on the distance between the BS and the MD and the *line-of-sight* (LOS) condition. An MD is very likely to have a LOS connection if it is close to the BS and very unlikely if it is far away [1]. Neglecting this would result in higher ICI for each MD in average and especially in the vicinity of the BSs. An MD has always the same LOS condition to all BSs of the same site.

In this Section, the cellular system is discussed, where each BS has only one directional antenna, $N_b = 1\ \forall b$, and serves only one MD, $\mathcal{K}_b = \{(b,1)\}\ \forall b$, with all its transmit power. Therefore, there is no intracell interference. The transmit power is set to $P_b = 10\text{W}$ for all BSs and the variance of the thermal noise is $\sigma_{b,1}^2 = 8.3\cdot 10^{-14}\text{W}$ at every MD. In Figure 2 the average normalized rate $\bar{r} = \mathrm{E}[r_{1,1}]$ in *bits per channel usage* (bpcu) is plotted over the distance between an MD and its BS in the boresight direction of the BS for cell $b = 1$. $\bar{r}$ drops from ca. 7.4bpcu at 25m, which is the minimum distance for the path-loss model, to ca. 1.4bpcu at 310m. At farther locations a connection to a neighboring BS would give a higher rate in average.

Except for points very close to the BS and very far away from the BS, $\bar{r}$, which employs *frequency reuse one* (FR1) and uses the complete bandwidth, outperforms the average rate with *frequency reuse three* (FR3) [2]. For the average rate of FR3, $\bar{r}^{\mathrm{FR3}} = \frac{1}{3}\mathrm{E}[r_{1,1}|_{\theta_{1,1}^2=(\theta_{1,1}^{\mathrm{FR3}})^2}]$, on the one hand, only every third BS produces ICI, the IIPN $(\theta_{1,1}^{\mathrm{FR3}})^2$ is modified accordingly. On the other hand, only a third of the frequency band can be used by every BS. This suggests, that FR3 is not a good choice for the given system model with interference awareness. Even for fractional frequency reuse [3], which assigns different frequency bands to different user classes in the cell, the results indicate little room for improvement.

By setting the ICI to zero, $\bar{r}^{\mathrm{noici}} = \mathrm{E}[r_{1,1}|_{\theta_{1,1}^2=\sigma_{1,1}^2}]$ in Figure 2 shows the exponential attenuation by the path-loss. Setting the norm of the information channel to one, $\bar{r}^{\mathrm{ici}} = \mathrm{E}[r_{1,1}|_{|\boldsymbol{h}_{1,1,1}^{\mathrm{T}}\boldsymbol{p}_{1,1}|^2=P_b}]$, reveals the influence of the ICI on the average rate. The ICI has the worst influence very close to the BS, due to the BSs at the same site with the same path-loss. The ICI lessens rapidly, remains almost constant over

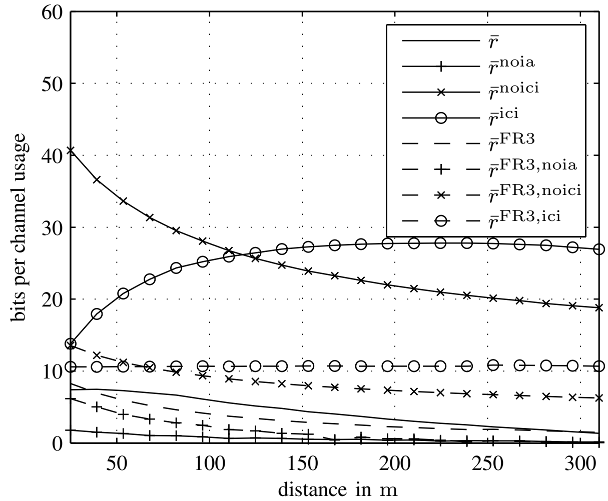

Fig. 2. Normalized Average Cell Sum-Rate over Distance between BS and MD for $N_b = 1$ and 1 MD per Cell

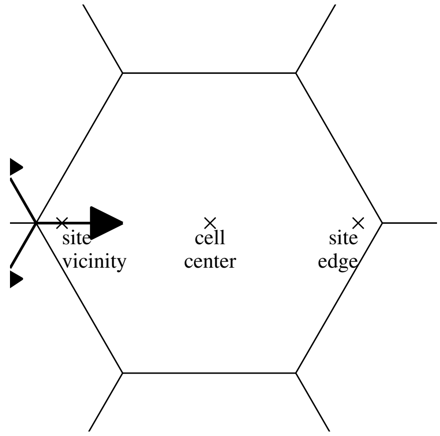

Fig. 3. Mobile Device Classes

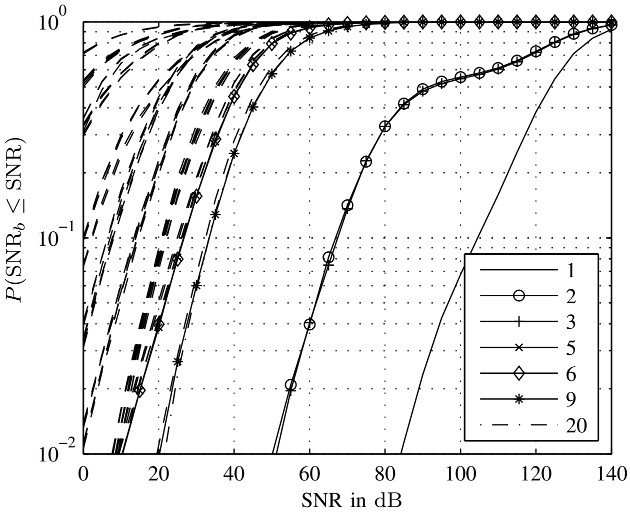

Fig. 4. CDF of SNRs from all BSs to an MD in the Site Vicinity for $N_b = 1$ and 1 MD per Cell

a large range in the center of the cell, and increases only slightly at the cell edge. With FR3, the average rate without ICI, $\bar{r}^{\mathrm{FR3,noici}} = \frac{1}{3}\,\mathrm{E}[r_{1,1}|_{\theta^2_{1,1}=\sigma^2_{1,1}}]$, is only a third compared to FR1. But, the average influence of the ICI is much smaller and remains almost constant over the complete range, which can be seen by $\bar{r}^{\mathrm{FR3,ici}} = \mathrm{E}[r_{1,1}|_{|\boldsymbol{h}^{\mathrm{T}}_{1,1,1}\boldsymbol{p}_{1,1}|^2=P_1,\theta^2_{1,1}=(\theta^{\mathrm{FR3}}_{1,1})^2}]$.

$\bar{r}^{\mathrm{noia}}$ and $\bar{r}^{\mathrm{FR3,noia}}$ in Figure 2 represent the gambling algorithm from [4], which is ICI blind, for FR1 and FR3, respectively. This displays the gain of interference awareness.

A. Mobile Device Classes

The MDs can be divided into different classed according to their location in the cell, see Figure 3. Close to the BS, in the site vicinity, the MDs experience strong ICI in average, do not suffer from path-loss, and the average normalized rate is the best compared to other locations in the cell. In the cell center the ICI is at a minimum and the influence of path-loss becomes stronger. Far away from the BS, at the site edge, the ICI increases, the path-loss has the strongest influence, and the average normalized rate is the worst.

To identify the worst interferers, the *cumulative distribution function* (CDF) of the *signal to noise ratio* (SNR), $\mathrm{SNR}_b = 10\log_{10}(\frac{P_b \boldsymbol{h}^{\mathrm{T}}_{b,1,1}\boldsymbol{h}^{*}_{b,1,1}}{\sigma^2_{b,1}})\mathrm{dB}$, for the channels from all BSs to an MD in each class on the boresight of the BS is plotted. Unconventionally, the interfering links are expressed with a SNR as well as the information links. The numbering of the BSs is consistent with Figure 1. Figure 4 shows the CDFs of an MD at a distance of $25\mathrm{m}$, in the site vicinity. The SNR of the regarded BS is very strong and has a large gap to the SNRs of the two strongest interferers, which are the BSs of the same site. The gap to the rest of the SNRs, which actually indicates a signal to interference ratio, is very large. The average rate of this MD class can be improved significantly by eliminating the ICI from the BSs of the same site. An MD at $167.5\mathrm{m}$, in the cell center, has the CDFs in Figure 5. The SNR of the regarded cell is still very strong and has a large gap to the SNRs of the interferes. There is no single strongest interferer. Finally, the CDFs in Figure 6 are of an MD at $310\mathrm{m}$, the site edge. The SNR of the regarded cell is as strong as the SNRs of the two strongest interferers, which are the directly neighboring BSs in the boresight direction. To get a similar gap to the SNRs of the interferers as in the cell center, at least the interference from the four closest BSs has to be suppressed. The identity of the strongest interferer depends on the location on the edge.

The simulations display, that suppressing the ICI from the BSs at the same site has a strong influence on the system performance. This can be achieved with FR3. But, shared transmit processing of the three collocated BSs stands as a more promising candidate, challenging the design of the antenna arrangements.

In contrast to the average of the normalized rate, the CDF of it can be seen in Figure 7. The figure contains CDFs for three different locations on the boresight direction of the BS with FR3 and FR1. Site vicinity is at $25\mathrm{m}$, cell center is at $167.5\mathrm{m}$

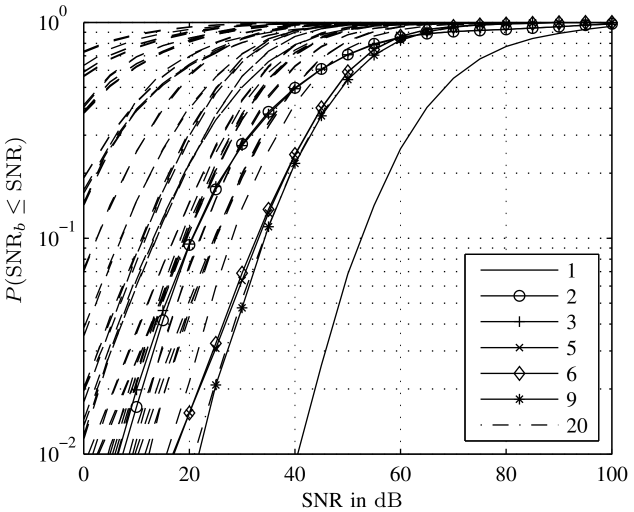

Fig. 5. CDF of SNRs from all BSs to an MD in the Cell Center for $N_b = 1$ and 1 MD per Cell

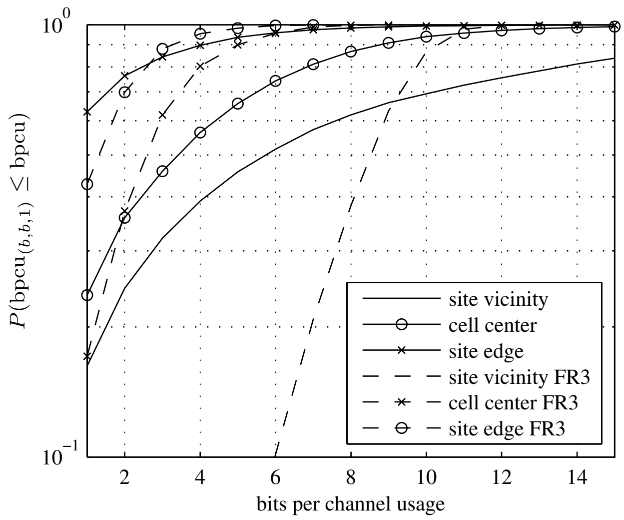

Fig. 7. CDF of Normalized Rate for $N_b = 1$ and 1 MD per Cell

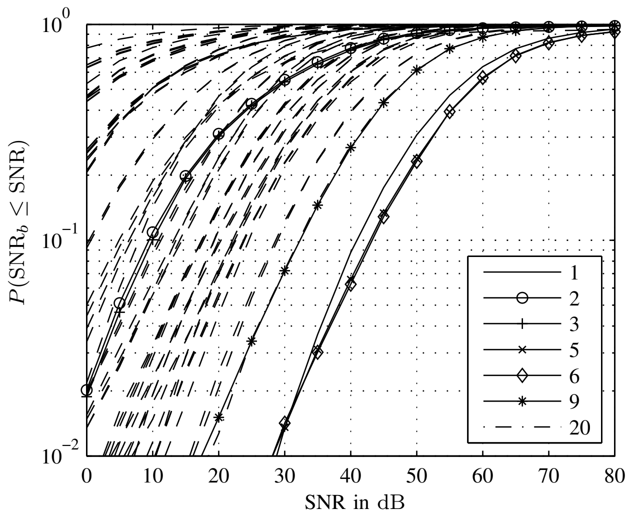

Fig. 6. CDF of SNRs from all BSs to an MD at the Site Edge for $N_b = 1$ and 1 MD per Cell

and site edge is at $310\mathrm{m}$. The CDFs with FR3 are much steeper than with FR1, telling that the possible normalized rates vary less. With the same probability, the normalized rate with FR1 can be found between $2\mathrm{bpcu}$ and $15\mathrm{bpcu}$ and with FR3 between $7\mathrm{bpcu}$ and $10\mathrm{bpcu}$ at the site vicinity. Therefore, systems with FR3 are more robust than with FR1.

IV. Non-Cooperative Sum-Rate Maximization

In contrast to the network sum-rate maximization

$$\left\{\boldsymbol{p}^{\mathrm{net}}_{b,k} | \forall (b,k) \in \mathcal{K}\right\} = \underset{\{\boldsymbol{p}_{b,k} | \forall (b,k) \in \mathcal{K}\}}{\operatorname{argmax}} \sum_{b \in \mathcal{B}} \sum_{k \in \mathcal{K}_b} r_{b,k}$$
$$\text{s.t.} \quad \sum_{k \in \mathcal{K}_b} \|\boldsymbol{p}_{b,k}\|_2^2 \leq P_b \;\; \forall b, \tag{3}$$

where all beamforming vectors $\boldsymbol{p}^{\mathrm{net}}_{b,k}$ $\forall (b,k) \in \mathcal{K}$ for the second transmit phase are optimized jointly, only the beamforming vectors $\boldsymbol{p}^{\mathrm{nc}}_{b,k}$ $\forall (b,k) \in \mathcal{K}_b$ belonging to one BS, are optimized jointly in the non-cooperative sum-rate maximization and the other beamforming vectors are kept fixed for the independent optimizations for each BS. With the rates $r^{\mathrm{nc},b}_{\hat{b},k} = r_{\hat{b},k}|_{\boldsymbol{p}_{\tilde{b},\tilde{k}} = \boldsymbol{p}^{\mathrm{1st}}_{\tilde{b},\tilde{k}} \; \forall (\tilde{b},\tilde{k}) \in \mathcal{K} \setminus \mathcal{K}_b} \;\; \forall (\hat{b},k) \in \mathcal{K}$, the non-cooperative optimization

$$\left\{\boldsymbol{p}^{\mathrm{nc}}_{b,k} | \forall k \in \mathcal{K}_b\right\} = \underset{\{\boldsymbol{p}_{b,k} | \forall k \in \mathcal{K}_b\}}{\operatorname{argmax}} \sum_{k \in \mathcal{K}_b} r^{\mathrm{nc},b}_{b,k} + \sum_{\hat{b} \in \mathcal{B} \setminus b} \sum_{k \in \mathcal{K}_{\hat{b}}} r^{\mathrm{nc},b}_{\hat{b},k}$$
$$\text{s.t.} \quad \sum_{k} \|\boldsymbol{p}_{b,k}\|_2^2 \leq P_b \tag{4}$$

can be expressed, where the left summation in the maximization is the sum-rate of the regarded cell. Handled independently, this part of the maximization is optimized with the water-filling solution presented in [5]. The right summation is the sum of the rates of all other MDs, for which the regarded BS b only produces interference and should be shut down to optimize this part of the maximization.

Approaches for optimizing this non-convex problem without communication between the BSs are the egoistic maximization, which drops the term containing the produced interference [4], and to employ frequency reuse additionally to limit the produced ICI by assigning different frequency bands to neighboring BSs, while the usable bandwidth is reduced [2]. Recent work has been done on fractional frequency reuse, which assigns different frequency bands to different MD classes within a cell.

V. Proposed Partly Altruistic Algorithm

For our proposed algorithm, each BS additionally needs to know the channels to the MDs, which are mostly affected by the ICI it generates. Therefore, the single antenna MDs transmit this information back in the first measurement phase, which can be received by all BSs, and especially by those which cause strong ICI for them.

Then, each BS selects the MD, which is mostly affected by their interference

$$\left\{(b^{\mathrm{al}},k^{\mathrm{al}})\right\} = \underset{\left\{(\hat{b},k)\in\mathcal{K}\setminus\mathcal{K}_b\right\}}{\mathrm{argmax}} \; r^{\mathrm{al},b}_{\hat{b},k} - r^{\mathrm{1st}}_{\hat{b},k}, \quad (5)$$

where $r^{\mathrm{al},b}_{\hat{b},k}$ is the rate of MD $(\hat{b},k)$ when BS b is shut down. Now, this BS is forced to transmit in the nullspace $\mathrm{Null}(\boldsymbol{h}^{\mathrm{T}}_{b,b^{\mathrm{al}},k^{\mathrm{al}}}) = \boldsymbol{V}_{b,b^{\mathrm{al}},k^{\mathrm{al}}} \in \mathbb{C}^{N_b\times N_b-1}$ of the channel to this MD using the beamforming vector $\boldsymbol{p}^{\mathrm{al}}_{b,k} = \boldsymbol{V}_{b,b^{\mathrm{al}},k^{\mathrm{al}}}\boldsymbol{u}_{b,k}$, where $\boldsymbol{u}_{b,k} \in \mathbb{C}^{N_b-1}$ can still be optimized. Plugging this in (5) and omitting the term containing the produced interference, this results in the optimization

$$\left\{\boldsymbol{u}^{\mathrm{al}}_{b,k}|\forall k\in\mathcal{K}_b\right\} = \underset{\left\{\boldsymbol{u}_{b,k}|\forall k\in\mathcal{K}_b\right\}}{\mathrm{argmax}} \sum_{k\in\mathcal{K}_b} r^{\mathrm{nc},b}_{b,k}, \quad \mathrm{s.\,t.} \; \sum_{k} \|\boldsymbol{u}_{b,k}\|_2^2 \leq P_b, \quad (6)$$

which can be solved by [5].

The method in [6], [7] can be used to limit the generated ICI for MDs to a certain level with very high complexity. This would have the advantage of waisting less resources for mitigating ICI. But, this poses the problem of the selection of the MDs, which will benefit from ICI mitigation. In addition, the level of ICI mitigation must be chosen for each MD. Both problems are most likely to need high complexity to be solved or need a similar heuristic approach as discussed in this paper. Compared to [7], we consider a more realistic simulation setting based on the 3GPP MIMO model.

VI. Overhead

The discussed overhead concerns the channel measurements. Each BS sends foreknown orthogonal pilots for all of its antennas, which allows each MD to measure all channel vectors. Therefore, each MD knows its information channel and all interference channels and can compute its IIPN. If these pilots are not allowed to be reused withing the 57 BSs, the measurements need at least $T = \sum_b N_b$ time slots in each frequency subband. With FR3 only a third of the time slots is required in each frequency subband. If the number of time slots, the channels can be assumed to remain constant, is not much larger than T, it is likely, that frequency reuse larger than one has to be employed. The second pilot phase for ICI awareness increases the piloting overhead.

The proposed algorithm requires additional channel state information at the BSs. To fulfill the premise of non-cooperative BSs, MDs might have to communicate with other BSs than the one they are assigned to. For an egoistic maximization, a BS needs to know the channels to and the IIPN at the MDs it serves. Therefore, each MD transmits this information in the uplink, which can be received by every BS with a good enough channel. For the new algorithm, a BS additionally has to know the assumed rate of, the channels to, and the interference at the MDs it produces significant interference for. As the channel from the interfering BS is strong in the downlink, it is likely that the channel in the uplink is good enough for the interfering BS to receive all this information from the MD. Assuming, that an MD has only one significant interferer, this doubles the signaling overhead in the uplink, but introduces no additional overhead in the downlink. If multiple pilots are required to improve the channel state information measurements, the overhead of the new algorithm increases faster.

VII. Numerical Results

The following results are obtained with Monte Carlo simulations and the parameters, which can be found in Table I. The normalized average cell sum-rate is plotted over the ratio of transmit power to noise power for different MD and antenna constellations. Every BS has the same transmit power $P_b = P$ and the noise at every receive antenna has the same power $\sigma^2_{(b,k)} = \sigma^2$. The newly proposed partly altruistic algorithm is labled as altruism combined with a number l reflecting the degrees of freedom, which are used for interference cancellation. A BS suppresses the interference for the l MDs, which would be affected by the generated interference most. The egoistic dirty paper coding algorithm, which does not cancel any interference, is labled as egoism and FR3, when it is combined with frequency reuse three. The so called stabilization algorithm serves in each resource block with a fixed transmit covariance matrix only the one MD, which has the best channel.

In Figure 8 this can be seen for 4 transmit antennas and 4 MDs per cell. With medium to high power, the newly proposed algorithm with $l = 1$ clearly beats all other methods under this figure of merit. Figure 9 shows the same for a system with more antennas than MDs, $N_b = 8$ and $|\mathcal{K}_b| = 2$. Under these circumstances, the newly proposed algorithm with $l = 2$ performs a little bit better than with $l = 1$ and the other algorithms. A scenario with more MDs than antennas can be seen in Figure 10, $N_b = 2$ and $|\mathcal{K}_b| = 8$. Here, the altruistic algorithm is only as good as the egoistic algorithm. FR3 performs in all this scenarios worse than egoism with FR1.

Figure 11 is generated with site edge MDs only. MDs, which have at least a distance of $260\mathrm{m}$ to the BS. Again, the altruistic algorithm with $l = 1$ performs best, but FR3 exceeds the results of egoism with FR1. For site vicinity MDs, MDs with a distance to the BS between $25\mathrm{m}$ and $75\mathrm{m}$, FR3 performs much better than egoism with FR1 in the high power domain, as can be seen in Figure 12. But, the altruistic algorithms tops all other algorithms again.

VIII. Conclusion

We showed, how ICI awareness can be achieved by increasing the overhead for piloting. We analyzed the 3GPP MIMO model, classified users according to their location in a cell, and showed that MDs close to the BS are exposed to the strongest interference if FR1 is utilized. Algorithms with FR1 will always profit from mitigating this interference. Possibly even more than from mitigating the ICI at the site edge. FR3 performed poorly for the interference aware system when signaling overhead is neglected. But, we found

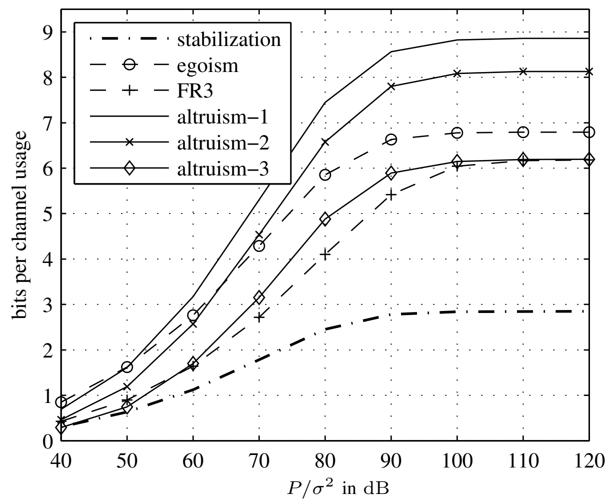

Fig. 8. Normalized Average Cell Sum-Rate for $N_b = 4$ and 4 MDs per Cell

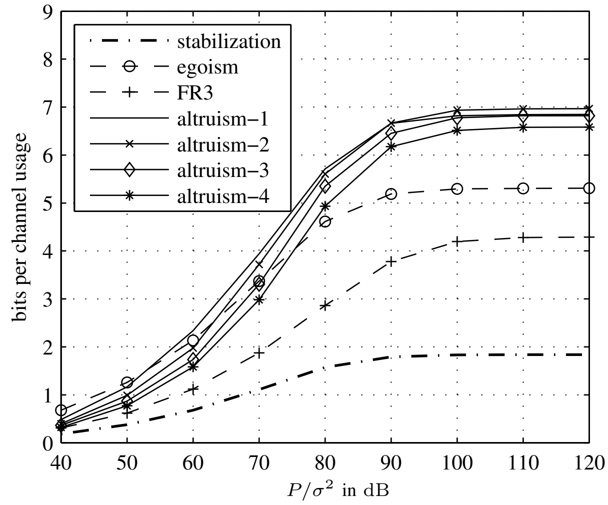

Fig. 9. Normalized Average Cell Sum-Rate for $N_b = 8$ and 2 MDs per Cell

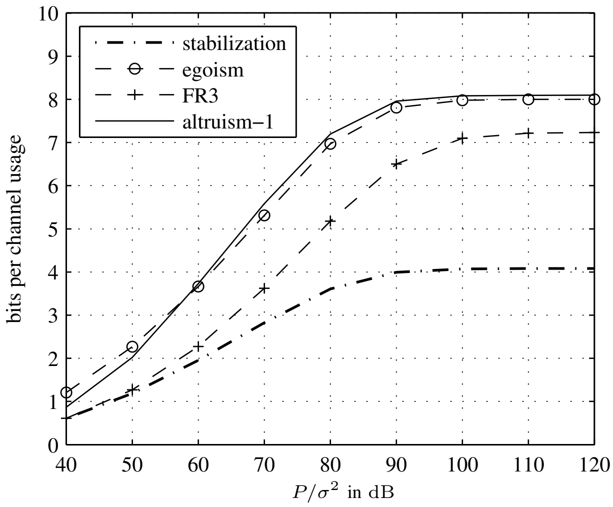

Fig. 10. Normalized Average Cell Sum-Rate for $N_b = 2$ and 8 MDs per Cell

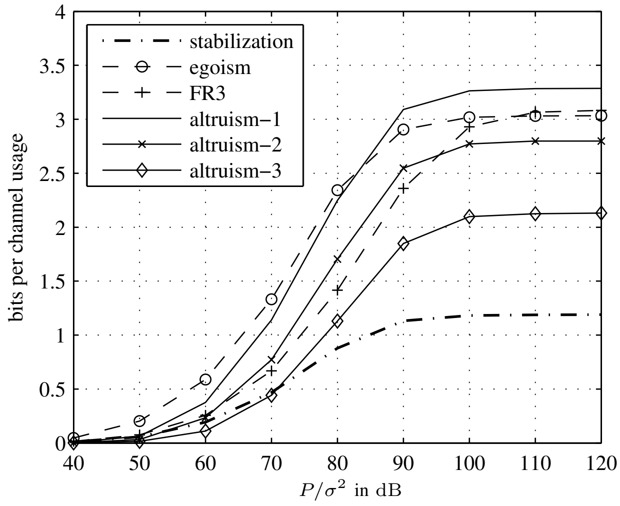

Fig. 11. Normalized Average Cell Sum-Rate for $N_b = 4$ and 4 MDs per Cell at the Site Edge

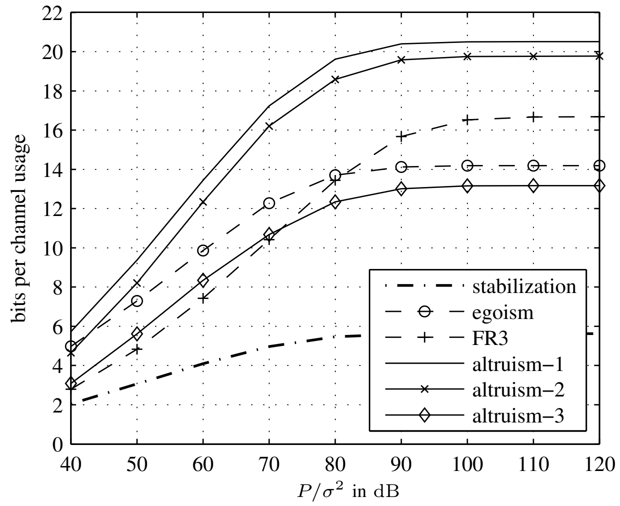

Fig. 12. Normalized Average Cell Sum-Rate for $N_b = 4$ and 4 MDs per Cell at the Site Vicinity

that FR3 improves the robustness of the system and lowers the overhead. Therefore, it might be well suited for fast fading environments. We derived a non-cooperative sum-rate maximization and discussed approaches for its optimization. A new algorithm based on transmitting in the null space of the most affected MDs by the generated ICI is presented and it was shown, that this approach outperforms all existing non-cooperative methods under the selected sum-rate criterion.

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