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Interference mitigation using antenna selection for the heterogeneous networks

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ABSTRACT

A rapid increase in the wireless internet-based applications led to an enormous increase in wireless data rates. Intensification of future wireless networks faces a great challenge to meet such growing demand for payload data. A suggested solution that can be used to resolve this issue is to overlay small cell networks with macro cell networks to provide higher network capacity and better coverage. Small cell networks experience large interference from macro cell base stations (BSs) making data rates received by the small cell users not reliably. In this paper, an antenna selection scheme based on small cell user's (SCU) channel gain is proposed. Whereas, the two tiers use the same network bandwidth resources; the macro BS selects a subset of antennas which has a minimum interfering effect to the SCU based on a pilot sent from SCU to macro cell. The proposed selection scheme has been compared with convex optimization antenna selection scheme. Simulation results show that the SCU data rates are significantly improved using proposed scheme. Execution time required for antenna selection is reduced significantly using the proposed scheme.

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1. INTRODUCTION

The extent of wireless voice services and data communications has grown at an exponential pace for many decades. To keep up with such exponential traffic growth rate and simultaneously provide ubiquitous connectivity, industrial and academic researchers need to turn every stone to design new revolutionary wireless networks technologies [1, 2]. It is commonly acknowledged that higher data demand for wireless cellular networks can only be satisfied by significant networks densification. Two main method currently considered to meet these requirements are: massive MIMO [3, 4] and small-cell networks [5]. Massive MIMO is the first method, where large-scale antenna arrays are deployed at the standing macro BSs [6]. It is a promising solution to handle several magnitudes more wireless data traffic than today's technologies by focusing emitted energy on the intended users, subsequently, energy efficiency dramatically increase [7]. Transmission in massive MIMO significantly depends on time-division duplex (TDD) technique, where channel estimation mainly affects the exploitation of channel reciprocity using TDD. A great benefit gained using TDD is that the channel estimation depends on the number of users and not on the number of BS antennas which makes estimates more feasible [8].

The second method is to deploy an additional layer of small-cell access points (SCs) into the network to off-load traffic from macro BSs. SCs are a powerful solution to introduce services to uncovered areas especially cell edges and indoor areas, therefore, network capacity is improved significantly [9, 10]. That most data traffic is localized and requested by users with low-mobility, hence small cells can meet this requirement. Channel propagation losses are decreased because of the small distance between SCs and its users, additionally, low transmission power is used, and the total energy efficiency is improved [11]. However, macro cells ensure area coverage and support high mobility terminals. This arises at the price of having a highly heterogeneous network topology where it is difficult to control and manage inter-user interference. Small cell BSs usually have an output power less than 0.1 Watt, and they allow a small number (typically less than 10) of simultaneous calls and data sessions at any time [5]. The high density of deployment means that the small cell spectrum is re-used over and over again, far more than the re-use in macro networks (with its comparatively macro cells) can achieve. Trying to reach the same levels of re-use with macro cellular technology would be prohibitively expensive in equipment and site acquisition budgets. By using small cells, frequency re-use, spectrum efficiency and therefore the aggregate capacity of the network can be greatly increased with a small cost compared to macro cellular cost. Small cells typically experience fierce cross-interference from macro cells [12], this interference is destroying the communication between small cells and SCUs. Antenna selection techniques can decrease the cross-interference between massive macro cells and small cells.

The antennas in large arrays do not contribute equally in the process of transmission and reception, and therefore some antennas can be excluded from process of transmission, and this is called antenna selection techniques. The number of radio frequency chains are reduced using antennas selection while the system performance is preserved at a certain required level, therefore, transmit and receive antenna selection attracted great attention from researchers [13]. Conventional MIMO with small-scale antennas had many selection algorithms. Antennas selection based on error-rate criteria with specific selection algorithms for existed receivers is studied in [14, 15]. Non-orthogonal multiple access is merged with the choice of transmitting antennas in [16], where the authors suggested moderate complexity and low-cost technology, and they demonstrated that diversity gain increases using the merge. Greedy schemes in [17, 18], convex optimization schemes in [19] and dominant-submatrix scheme in [20] search on the capacity selection criteria. In recent years, some of these selection algorithms have also been studied and extended for the massive MIMO systems, such as the work in [21, 22]. The Exhaustive search, the optimum antenna selection method widely investigated in the conventional small-scale MIMO systems, becomes infeasible for the massive MIMO system due to the large number of BS antennas. An optimal antenna selection algorithm faster than the exhaustive search is thus necessary for the massive MIMO antenna selection systems [23].

In this paper, an interference mitigation scheme using antenna selection based on SCU's channel gain is proposed, the massive MIMO BS selects a subset group of antennas based on channel statistics of the SCU to be used in the transmission to reduce the cross-interference power between macro cell and the SCU. The rest of paper is introduced as in section 2, we described the system model and the related assumptions used to form the problem formulation. The proposed interference mitigation scheme using antenna selection based on the SCU channel gain is introduced in section 3. The data rate equations and the network parameters used in calculation is presented in section 4. Section 5 and 6 are the results discussion and conclusion respectively.

2. THE PROPSED ANTENNA SELECTION SCHEME

Let us consider a heterogeneous network consisting of $\mathcal{L}$ cells, each with a massive macro BS divided into Z sectors employs M transmit antennas to serve its K associated single-antenna macro cell users (MCUs) for each sector. Number of small cells $\mathcal{S}$ with a single antenna is distributed uniformly over the sectors. Each small cell serves one SCU with one antenna as shown in Figure 1.

Perfectly synchronized transmissions across the heterogeneous network had been assumed. The available bandwidth W with universal frequency reuse is shared between cells. All uplinks and downlinks are assumed to take place over flat fading channels. Each user whether SCU or MCU transmits a pilot sequence to macro cell, number of users assumed to be limited in one cell where small cell BS essential job is to offload the macro cell. The pilot sequence of a user in a cell may contaminate with other user's pilot vector of another cell or user from adjacent sector whereas the number of pilots is limited due to limited channel coherence time, so pilot vectors may be reused in adjacent sectors and cells. Suppose SCU k in cell j sends a pilot sequence to the macro cell, so the received pilot vector at macro cell antennas $M \times 1$ from all users in cell j

$$\boldsymbol{y_p} = \sqrt{p_k}\, \boldsymbol{h}_k\, \boldsymbol{x_k} + \sum_{\substack{i=1 \\ i\neq k}}^{K} \sqrt{p_i}\, \boldsymbol{h}_i\, \boldsymbol{x_i} + \sum_{\substack{l=1 \\ l\neq j}}^{\mathcal{L}} \sum_{i=1}^{K} \sqrt{p_{li}}\, \boldsymbol{h}_{li}\, \boldsymbol{x}_{li} + \boldsymbol{N} \tag{1}$$

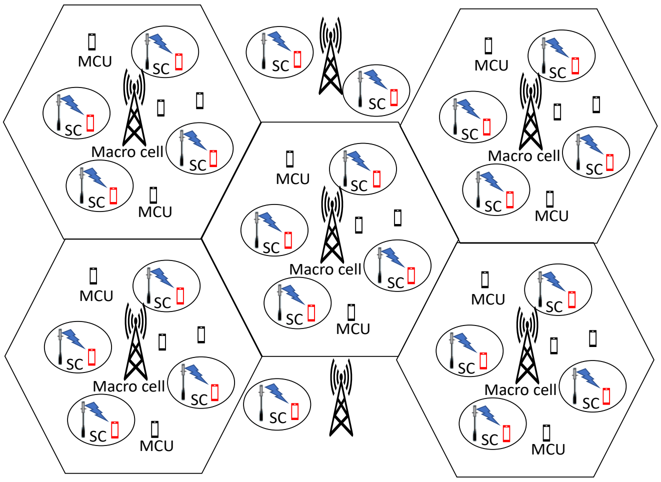


Figure 1. Heterogeneous network

where p_k is received power from user k, $\boldsymbol{h}_k \in \mathbb{C}^{M\times 1}$ is SCU channel vector to macro BS, p_i is the received power from the i^{th} user in cell j, $\boldsymbol{h}_i \in \mathbb{C}^{M\times 1}$ is the channel vector between the macro cell antennas and the i^{th} user in cell j. p_{li} is users' uplink power from adjacent cells which using same pilot sequence, $\boldsymbol{h}_{li} \in \mathbb{C}^{M\times 1}$ is the channel vector between adjacent cell users and macro BS j. $\boldsymbol{N} \in \mathbb{C}^{M\times 1}$ is white Gaussian noise with variance $\sigma^2 I_M$. and $\boldsymbol{x_k}$ *and* $\boldsymbol{x}_i \in \mathbb{C}^{M\times 1}$ are the orthogonal pilot vectors contains the SCU pilot and the MCUs pilots. K stands for all users in that sector even SCUs or MCUs. The first term refers to desired pilot signal while second and third term refer to intra-cell pilot interference and inter-cell pilot interference respectively.

Let that BS j wants to estimate the channel $\boldsymbol{h}_k$ of the SCU k. The BS can then multiply $\boldsymbol{y}_p$ with the pilot sequence $\boldsymbol{x}_k^H$ of this UE, leading to the processed received pilot signal $\hat{\boldsymbol{y}}_{\boldsymbol{p}}$:

$$\hat{y}_p = y_p \, x_k^H \tag{2}$$

$$\hat{y}_p = \sqrt{p_k}\, h_k\, x_k\, x_k^H + \sum_{\substack{i=1 \\ i\neq k}}^{K} \sqrt{p_i}\, h_i\, x_i\, x_k^H + \sum_{\substack{l=1 \\ l\neq j}}^{\mathcal{L}} \sum_{i=1}^{K} \sqrt{p_{li}}\; h_{li}\; x_{li}\; x_k^H + N\, x_k^H \tag{3}$$

The second and third terms in eqn. (3) refer to interference pilots from other users in adjacent cells use same pilot sequence. If the product $\boldsymbol{x_i}\, \boldsymbol{x}_k^H = 0$ [24], so the interference is vanished due to mutual orthogonality between pilots vector in the entire networks, but as mentioned, number of pilot sequence is limited due to limited channel coherence time, so increasing pilot sequence will affects dramatically the network data rates. So that the pilot vectors are reused over the network leading to pilot contamination problem. Many solutions are provided to solve pilot contamination issue [25].

We aim to minimize the cross-interference that happens at the SCU coming from the macro cell's downlink power. The macro cell selects the transmitting antennas which have minimum interference effects on the SCU based on SCU's channel gain that received by macro antennas. The macro cell will have prior knowledge of the small cell user channel using the pilot sent by SCU to the macro cell. SCU's Channel gain received by macro cell antennas can, therefore, be characterized as:

$$|\boldsymbol{h}_{scu-mc}\, \boldsymbol{w}|^2 = min(|h_{scu-mc}^1|^2, \, |h_{scu-mc}^2|^2, \cdots, |h_{scu-mc}^M|^2) \tag{4}$$

where, $|h_{scu-mc}^M|^2$ is the channel gain from the SCU to Mth antenna of the macro BS. $\boldsymbol{w}$ is $1 \times M$ the transmit selection vector with $E\{\|\boldsymbol{w}\,\|\}^2 = 1$ [26].

The SCU sends an orthogonal pilot to the massive macro cell, the small cell user's pilot has to be orthogonal to all of the macro cell users' pilots. The massive macro cell, in turn, determines channel gains received by massive macro antennas from the SCU using the SCU's orthogonal pilot. Thus, the macro cell selects the antennas subset that receives minimum interference from the SCU. The macro cell uses this antenna subset for transmission to its MCUs. More precisely, the macro cell excludes number of antennas from transmission process that receives largest interference power from the small cell user's channel in order to reduce the cross-interference between the macro cell and the SCU. Table 1 shows the progression of the proposed selection scheme.

Table 1. Antenna selection scheme

Selection Scheme: Antenna Selection Based on The SCU Channel Gain

1: Set up selection Vector < $\boldsymbol{w}_i$ empty vector 1× M >

$$\boldsymbol{w} = [\,0\,,0,\cdots,0\,]$$

2: SCU channel estimation- A pilot is sent from SCU to the macro cell.

$$\boldsymbol{y_p} = \sqrt{p_k}\,\boldsymbol{h}_k\,\boldsymbol{x_k} + \sum_{\substack{i=1\\ i\neq k}}^{K} \sqrt{p_i}\,\boldsymbol{h}_i\,\boldsymbol{x_i} + \sum_{\substack{l=1\\ l\neq j}}^{\pounds}\sum_{i=1}^{K} \sqrt{p_{li}}\,\boldsymbol{h}_{li}\,\boldsymbol{x}_{li} + \boldsymbol{N}$$

3: SCU channel gain $\boldsymbol{h}_{scu-mc}$ is compared in each Antenna with other antennas.

$$|\boldsymbol{h}_{scu-mc}|^2 = min(|h^1_{scu-mc}|^2,\ |h^2_{scu-mc}|^2,\cdots,|h^M_{scu-mc}|^2)$$

4: Update < $\boldsymbol{w}_i$ >

$\boldsymbol{w} = \min(\boldsymbol{h}_{scu-mc}\ \mathbb{C}^{1\times(M-10)})$ exclude 10 antennas each time

5: Selection Phase: Macro cell selects subset of antennas with lowest SCU channel gain for transmission.

$$|\boldsymbol{h}_{scu-mc}\,\boldsymbol{w}|^2 = min(|h^1_{scu-mc}|^2,\ |h^2_{scu-mc}|^2,\cdots,|h^M_{scu-mc}|^2)$$

6: Calculate $SINR_{scu}$

7: If $SINR_{scu} \geq \gamma_{scu}$

No

< go step 4 >

Yes

< End>

8: Calculate $SINR_{MCU}$

Scheme first step is sitting the selection vector (subset antennas) $\boldsymbol{w}_i$ to 0. The cross-interference channel gain, $|\boldsymbol{h}_{scu-mc}|^2$, of the SCU is calculated using its pilot which is sent to macro cell. Where, $\boldsymbol{h}_{scu-mc} \in \mathbb{C}^{M\times 1}$ is M -dimensional vector characterizing MIMO channel from the SCU to the macro cell's antennas. The scheme compares gain received by macro cell antennas to each other and excludes the top group antennas every time that have the largest interference power. Next step is comparing the resulting $SINR_{SCU}$ of the SCU to γ_{scu} , where γ_{scu} is the minimum threshold capacity of the SCU. The remaining antennas of the macro cell used to communicate with its MCUs. As mentioned in [4, 27], all massive antennas serve the MCUs at the same time using the precoding techniques which permit the macro cell to redistribute the transmitted power over remaining antennas in order to direct this power to each MCU.

3. SCU DATA RATE ANALYSIS

However, major interference comes from macro BS and its MCUs, but inter-cell interference from adjacent small cell BSs to our SCU cannot be neglected and should be taken into our accounts. Assume the channel between the SCU and the small cell is $h_{scu-sc} \in \mathbb{C}^{1\times 1}$, downlink received signal $y_{scu} \in \mathbb{C}^{1\times 1}$ at the SCU is:

$$y_{scu} = \sqrt{p_{sc}}\, h_{scu-sc}\, s_{sc} + \sum_{\substack{j=1\\ s\neq a}}^{S} \sqrt{p_{j-sc}}\, h_{j-scu-sc}\, s_{j-sc} + \sum_i^M \sqrt{p_{imc}}\, h_{i-mc}\, w_i\, x_i + n_{SCU} \quad (5)$$

where, p_{SC} ,p_{j-sc} are the transmitted power from the small cell to its SCU, $n_{SCU} \in \mathbb{C}^{1\times 1}$ is small cell's white Gaussian noise with variance σ^2 , p_{mc} is downlink power to the MCUs, h_{i-mc} is the channel from m^{th} macro antenna to SCU antenna. $h_{j-scu-sc}$ is the inter-cell interference channel from j^{th} SCU to our SCU antenna. s_{sc}, s_{j-sc} and $x \in \mathbb{C}^{1\times 1}$ are the transmission data signal from the SC and the macro cell respectively. The first term is the desired signal, second and third term are interference signal from adjacent small cells BSs and the macro cell.

The small cell can estimate SCU channel response h_{scu-sc} using minimum mean square error (MMSE) [27] to detect the SCU signal, the detection vector $\hat{h}_{scu-sc}$ as:

$$\hat{h}_{scu-sc} = h_{scu-sc}\left(h^*_{scu-sc}\, h_{scu-sc} + \frac{1}{p_{sc}}\, I_1\right) \quad (6)$$

SCU signal power calculated as:

$$P = \left|h_{scu-sc} \times \hat{h}_{scu-sc}\right|^2 \quad (7)$$

As mentioned, the interference power that adversely affects the transmission between the SCU and small cell BS coming from macro cell and its MCUs, the expected interference is calculated as:

$$I = \sum_k \left| \boldsymbol{h}_k \times \hat{h}_{scu-sc} \right|^2 \tag{8}$$

The signal-to-interference-plus-noise ratio $SINRscu$ of the small cell user according to (7) and (8):

$$SINR_{SCU} = \frac{p_{SC} * |h_{scu-sc} \times \hat{h}_{scu-sc}|^2}{p_{mc} \sum_{i=1}^{K} |\boldsymbol{h}_{i-mc} \times \boldsymbol{w}_i \times \hat{h}_{scu-sc}|^2 + |n_{SCU} \times \hat{h}_{scu-sc}|^2} \tag{9}$$

The spectral efficiency is [28],

$$SE_{SC} = log_2(1 + SINR_{SCU}) \tag{10}$$

4. RESULTS AND DISCUSSION

In this subsection, we investigate the antenna selection scheme based on the SCU channel gain in the heterogeneous networks, the scheme is investigated for different transmission scenarios. We assume that the channel vectors $\boldsymbol{h}_{scu-mc}$, $h_{scu-sc}$and $\boldsymbol{h}_{i-mc}$ are estimated by the receivers and the channel vectors are assumed to be of Rayleigh distribution. The simulation results show $SINR_{SCU}$ for each transmission scenario. The simulation results illustrate the scenario depicted in Figure 1, where a macro cell overlay one small cell. There are 10 active MCUs served by the macro cell, where the MCUs are uniformly distributed in the whole-cell and each small cell has only one user uniformly distributed within 10 meters. There are 4 sectors for each macro cell, number of small cell BSs is distributed in each sector, the major interference to our SCU comes from closest macro cell and one SC from each sector (will be explained later). Table 2 shows the hardware parameters used.

One of the solutions of pilot contamination problem is the pilot reuse factor f, the pilot sequences can be distributed among the UEs and reused across cells. The pilot reuse factor means times more pilots than UEs per cell and the same subset of pilots is reused in a fraction 1/f of the cells (f ∈ {1, 2, 4}). If $f = 4$ this guarantee a very small effect of pilot contamination on user channel estimation, pilot reuse factor follows the same concept of frequency reuse in GSM [24].

Table 2. Network parameters

Parameters	Values
Number of macro cells	8
Number of sectors for each macro cell	4
Number of antennas of macro Cell BS, M	100
Number of MCUs, K	10
Pilot reuse factor	2
Number of SCU for each SC	1
Macro cell transmit power	43 dBm
Small cell/SCU transmit power	23 dBm

The path loss for the macro cell and the small cell is calculated using Hata-Okumura model [29]. The small cell and the SCU are outdoor settlings at 300 meters from the macro cell user. We compare channel gain scheme with the selection scheme presented in [13]. The selection scheme used in [13] based on convex optimization is used to select a subset of antennas to reduce only the number of the macro cell's RF chains. The work in [13] assumes only massive BSs in the network. In our study, the macro cell receives the SCU's pilot to calculate the cross-channel of the SCU and directly excludes several antennas which have largest interference gain on the SCU and compare the proposed channel gain scheme with the convex optimization. The convex optimization problem can be formulated as [13],

Minimize $E\{log_2|I_M + \boldsymbol{h}_{scu-mc}\, \boldsymbol{w}\, \boldsymbol{h}_{scu-mc}|\}$

Subject to $\boldsymbol{w}_i \in \{0, 1\}$ (11)

$\sum_{i=1}^{M} \boldsymbol{w}_i = B$

where B is the number of excluded antennas in each time. The optimal selection algorithm is an exhaustive search over all possible antenna combinations. For massive MIMO where M can be more than one hundred, the exhaustive search will take a very long time to be done due to an extremely large number of possible antenna combinations.

Based on the proposed scenario depicted in Figure 1, we study the effect of antenna selection on the downlink performance, where the downlink of the macro cell interferes with the link between the SC to its SCU. The simulation results compare between two algorithms, the antenna selection based on SCU channel gain and the convex optimization selection based on the SCU channel gain. The performance results of the antenna selections for 9 selection scenarios are shown in Table 3. As we mentioned the number of massive antennas is 100 antennas, we exclude 10 antennas each time to clarify the different performances of each scenario. The performance of the spectral efficiency of the SCU is increased by about 4% when using channel gain selection scheme where 90 macro cell antennas are interfering with the SCU. The spectral efficiency continues to increase when we exclude more antennas.

Table 3. SCU bit rate (bit/s/Hz), and execution time (sec.)

Interferer antennas & execution time	Channel-gain selection		Convex optimization selection	
	Spectral efficiency	Relative enhancement to 100 ants.	Spectral efficiency	Relative enhancement to 100 ants.
100 antennas	2.5829		2.5829	
90 antennas	2.6952		2.6952	
80 antennas	2.8224		2.8224	
70 antennas	2.9691		2.9691	
60 antennas	3.1409		3.1409	
50 antennas	3.3447	30%	3.3447	30%
40 antennas	3.6029	40%	3.6029	40%
30 antennas	3.9308	53%	3.9308	53%
20 antennas	4.3971	70%	4.3971	70%
10 antennas	5.1525	100%	5.1525	100%
Execution time for 9 steps of selection	0.0546 seconds		74.1180 seconds	

The improvement in spectral efficiency is noticeable when the macro cell uses 40 antennas for transmission and the spectral efficiency is increased by about 40%. A 100% improvement in spectral efficiency is noticed when only 10 antennas used by the macro cell for transmission to the MCU. Because of co-operation between the two tiers where the macro cell knows perfectly the SCU channel, the improvements in the spectral efficiency resulting from the SCU channel gain scheme is equal to the improvement due to the convex optimization scheme as shown in Figure 2. But it takes a very long time to execute the convex optimization due to an extremely large number of possible antenna combinations. The channel-gain scheme took only 0.0546 seconds to exclude 100 antennas to reach only 10 antennas (the whole scheme), so the execution time to exclude any number of antennas at one step will be $0.0546/9 = 0.0061$ seconds, whilst the convex optimization took about 74.1180 seconds. The channel-gain scheme improved the selection process by 1350-fold from the convex optimization which makes the new scheme suitable for the extremely large number of possible antenna combinations.

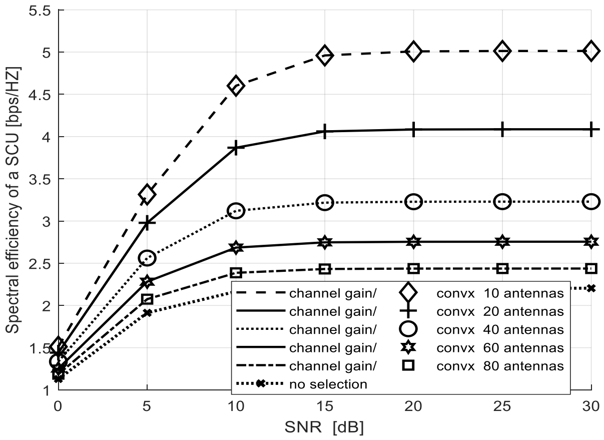


Figure 2. Spectral efficiency of a small cell user for various selection scenarios with channel gain/convex selection

Table 3 shows numerically the total improvement using antenna selection based on SCU channel gain scheme and the convex optimization scheme for SNR=10 dB and the execution time of the two schemes. If the macro cell uses 40 antennas for the transmission process, consequently, the bit rate of the SCU increased by 40%. For 500 MHz channel bandwidth as expected in 5G, the bit rate of the SCU will be about 1.8 Gbps.

Whereas the interference is decreased using the channel-gain selection scheme, higher-order modulation schemes could be used, and the data rate will be increased. The QPSK modulation scheme with 30 macro antennas interfered with the SCU outperforms the QPSK with 100 interferer antennas as shown in Figure 3. At Eb/N0=10, the bit error rate is improved by 65% when the number of antennas is reduced from 100 antennas to 30 antennas using QPSK and the channel-gain scheme. The BPSK modulation with the new scheme and 30 antennas can be used in deep fade environment or crowded user environments where BPSK with 30 antennas outperforms the QPSK with 100 interferer antennas by about 90% for 30 antennas and QPSK for 30 and 100 antennas.

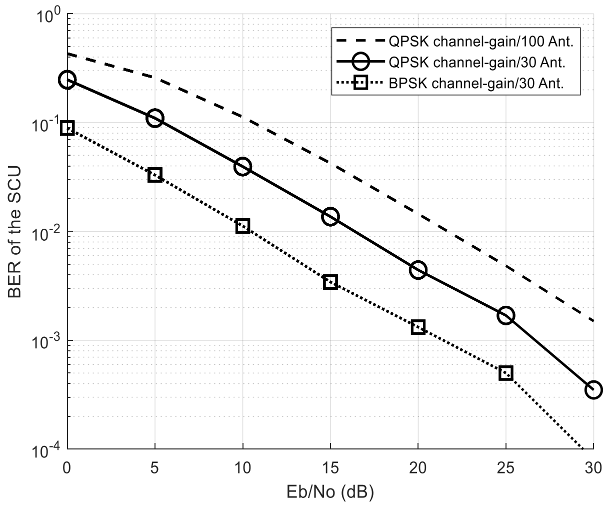
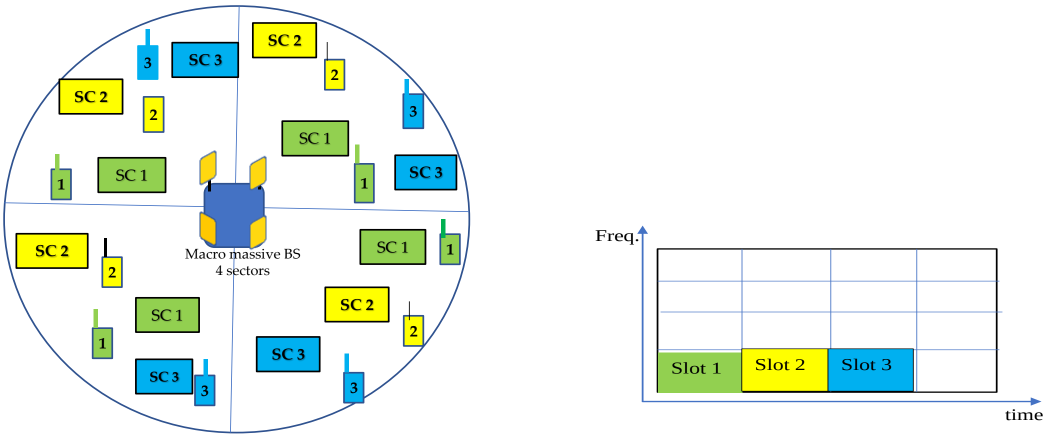


Figure 3. The bit error rate of a small cell user using BPSK for 30 antennas and QPSK for 30 and 100 antennas

As assumed before, the cell is divided into 4 sectors, each sector has its massive array which serves the MCUs located in this sector as shown in Figure 4(a). Increasing the number of small cells in each sector that uses the channel gain selection scheme can lead to switching off a large number of macro antennas, and this may adversely affect the number of macro cell users in this sector. To avoid this situation, on-work small cells will be separated onto OFDM slots as shown in Figure 4(b). OFDM frame is divided into slots separated in time. On-work SCs is divided over OFDM slots, so one SC will be served at that slot in that sector, all SCs within all sectors that have same slot label will be served at same time which ensures that macro cell will interfere with one small cell only in each slot in each sector. Accordingly, the macro cell will not have to turn off all of its antennas in the same slot, where each sector has only one small cell requiring only a limited number of antennas to be switched off for this time slot.

At time slot 1, the SCs labeled with 1 (green colored SCs) will be served in each sector, so that, there will be only one SC served in each time slot in each sector. At time slot 2 the yellow SCs labeled with 2 will be only served at each slot. This scheme can be used for any number of sectors.

The effect on overall cell spectral efficiency caused by excluding some antennas from the macro cell can be reduced by using sectorized technique [30]. The served number of the MCUs of massive MIMO cell is increased while using sectorized technique so that, overall cell spectral efficiency is increased. The number of served MCUs using 120 antennas (30 each sector) reaches about 54 users for one cell per time/frequency slot as shown in Figure 5. As mentioned, the cornerstone of the massive MIMO system is to serve multi-users at the same time slot, so that overall spectral efficiency is important metric that illustrates the significance of the system. In Figure 5, we marked the operating point that maximizes the performance for the corresponding values of MCUs (K) and the spectral efficiency, for maximum ratio combining (MR) processing [7].



(a) (b)

Figure 4. (a) A heterogeneous cell consists of one macro cell with 4 sectors overlaid with a number of small cells in each sector, (b) OFDM frame structure

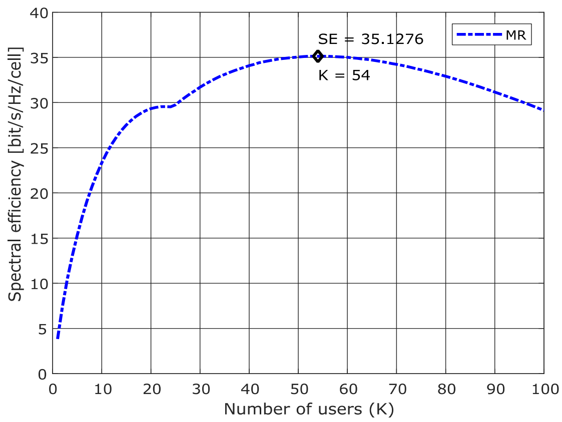


Figure 5. Number of served MCUs for one cell (4 sectors) with 30 antennas each sector (120 antennas for the entire cell)

Table 4 shows the spectral efficiency of the MCUs using antennas selection. As mentioned before, macro transmitted power is divided across the transmitting antennas. The transmitted power is fixed for the transmission period, fewer antennas mean more power for each antenna, so the bit rate increased when excluding more antennas [13]. Massive MIMO uses precoding techniques which permit the power to redistribute across transmitting antennas. Table 4 shows data rates of 10 MCUs which are served at same time and frequency resources using 100 antennas to 10 antennas. The data rate is increased when using only 40 antennas, the number of RF chains is decreased by 60% from the case of 100 antennas which saving more hardware power and less electronic noise emission which degrades overall system performance, hence we preserved the total network spectral efficiency and the total number of MCUs.

Table 4. MCUs bit rate (bit/s/Hz) with the active antennas

Active antennas	Spectral efficiency at SNR=10 dB (bps/Hz)
100 antennas	26.2453
90 antennas	26.2537
80 antennas	26.2677
70 antennas	26.2587
60 antennas	26.2779
50 antennas	26.2762
40 antennas	26.3115
30 antennas	26.3437
20 antennas	26.4615
10 antennas	26.2453

Spectral efficiency and the served number of the MCUs of massive MIMO cell is increased while using sectorized technique [30]. The number of served MCUs using 120 antennas (30 each sector) reaches about 54 users for one cell per time/frequency slot as shown in Figure 5. As mentioned, the cornerstone of the massive MIMO system is to serve multi-users at the same time slot, so that overall spectral efficiency is important metric that illustrates the significance of the system. In Figure 5, we marked the operating point that maximizes the performance for the corresponding values of MCUs (K) and the spectral efficiency, for maximum ratio combining (MR) [9] processing.

Remarkably, the optimized operating points are all in the range $M = K < 10$; so, it is not only possible to let K and M be at the same order of values, it can even be required. With MRC processing, the massive MIMO system operates efficiently also at $M = K = 100$ which gives $M = K = 1$; the data rate per terminal is quite small at this operating point but the sum spectral efficiency is not. Figure 5 shows that there is a wide range of K-values that provides almost the same sum performance, illustrating the ability to share the throughput between many or a few terminals by scheduling. In summary, the relation between K and M in Massive MIMO system is not a strict requirement. Massive MIMO system had an unconventionally large number of terminals, K, are served by large active antenna elements, M. It is not desirable to specify a certain ratio $M = K$, since it depends on a variety of conditions; for example, the system performance metric, propagation environment, and coherence block length.

5. CONCLUSION

We proposed an interference mitigation scheme using antenna selection based on the SCU channel gain, where the macro cell BS selects antennas subset for data transmission based on the SCU channel gain calculated from the SCU's pilot. The selected macro antennas have the smallest cross-interference gain on the SCU. The data rate of the SCU is increased by 40%, according to the selection scheme when 40 antennas are selected and the data rate of SCUs can reach about 1.8 Gbps. Our scheme needs only to know the channel gain received by each antenna and then excludes any number of antennas at a time according to the SCU spectral efficiency threshold. Thus, the scheme gives the same results obtained by the convex optimization scheme. However, the execution time of the channel gain scheme is lesser than convex optimization.

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