MASSIVE MIMO USING MRC TECHNIQUE MAKING CELL - FREE

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ABSTRACT:

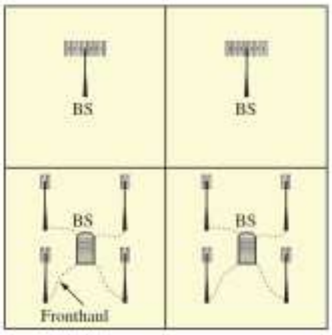
While demonstrating that partially or totally centralised signal processing at the Central Processing Unit (CPU) achieves improved Spectral Efficiency, this study promotes the use of maximum ratio combining at each Access Point (AP) (SE). A viable solution for meeting the rising user demand and high rate expectations in beyond-5G networks is cell-free massive MIMO. The fundamental concept is to enable multiple distributed access points (APs) to communicate with all network users, maybe by means of a single coherent signal processing system. The purpose of this article is to offer the first in-depth analysis of this technology under various levels of AP cooperation. With spatially correlated fading and unrestricted linear processing, the uplink spectral efficiency of four distinct cell-free implementations are specifically examined. It turns out that only by adopting MRC is it able to significantly outperform both small cell and conventional cellular massive MIMO networks. Because of this, it is the recommended method for running cell-free massive MIMO networks. Investigation into non-linear decoding also reveals that it only makes a little difference.

INTRODUCTION:

The cellular network structure shown in Fig. 1(a) is the conventional method for providing wireless communication services over a wide area. Each base station (BS) serves a unique set of user equipment (UEs).

Since this network topology has been used for many years, spectral efficiency (SE) has continuously increased thanks to smaller cell sizes and the use of more sophisticated signal processing techniques for interference reduction. Massive multiple-input multiple-output (mMIMO), which debuted recently, has emerged as the primary 5G physical-layer technology. By improving the BS hardware instead of setting up new BS stations, it can increase the SE over traditional cellular networks by at least 10 times. The small array of 100 or more antennas that each BS has, which is utilised for digital beamforming and, specifically, to spatially multiplex numerous user equipment (UEs) on the same time-frequency resource, is where the SE gain originates from. mMIMO differs from standard multi-user MIMO in that each BS has many more antennas than UEs in the cell. Without requiring any BS cooperation, each BS can employ individual signal processing techniques, such as MRC in the uplink, to minimise interference from both the same cell and other cells. As seen in Fig. 1, the mMIMO theory also permits deployments with spatially scattered arrays in each cell (a). This configuration is quite similar to the Coordinated Multi-Point (COMP) and Distributed Antenna System (DAS) setups with static, disconnected cooperation clusters. Cellular networks come in many different forms. Cell-free mMIMO, an alternative network architecture, was taken into consideration. A significant number of distributed single-antenna access points (APs) are to be set up and connected to a central processing unit (CPU), sometimes referred to as an edge-cloud processor or CRAN data centre. In order to serve the UEs jointly through coherent joint transmission and reception, the CPU manages the system in a Network MIMO mode with no cell borders. The operating mode with much more APs than UEs distinguishes

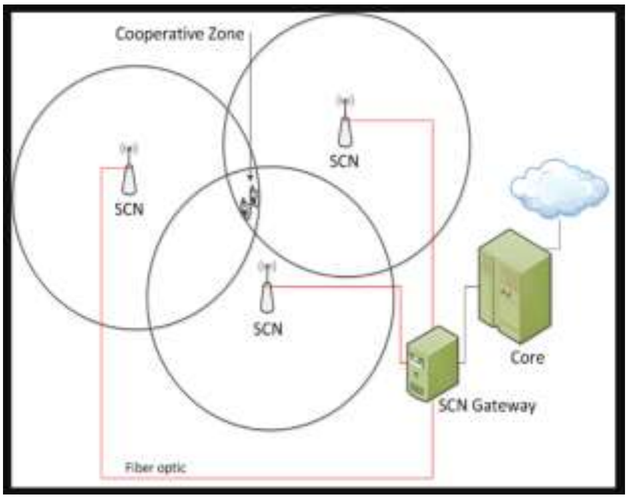
Cell-free mMIMO from regular Network MIMO. An major innovation from an analytical standpoint was the inclusion of incomplete channel state information (CSI), whereas perfect CSI was frequently assumed in the past, in the performance analysis. The study recommended using matched filtering or conjugate beamforming, also known as maximum ratio (MR) processing, locally at each AP while demonstrating that CPU processing that is partially or completely centralised can produce higher SE.



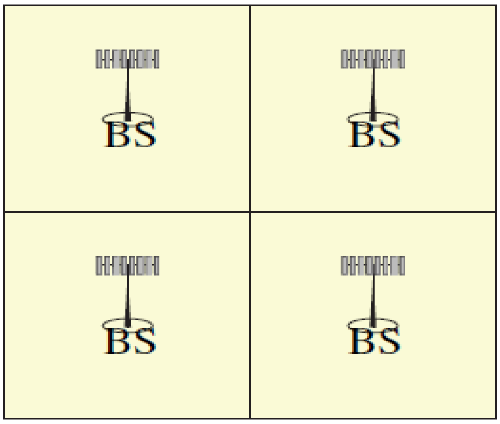
(a) Cellular network with mMIMO BSs having either co-located arrays (top) or distributed arrays (bottom).

EXISTING METHOD:

Both small cell systems and cellular networks are currently used approaches. We assume that in small cell systems, just one AP serves each user. The accessible AP with the greatest average received useable signal power is chosen for each user. An AP becomes unavailable if another user has previously selected it. User by user, in a random order, the APs are chosen.We take into account a time scale that is brief enough to prevent handovers between Aps. Small cell systems prevent the channel from hardening.

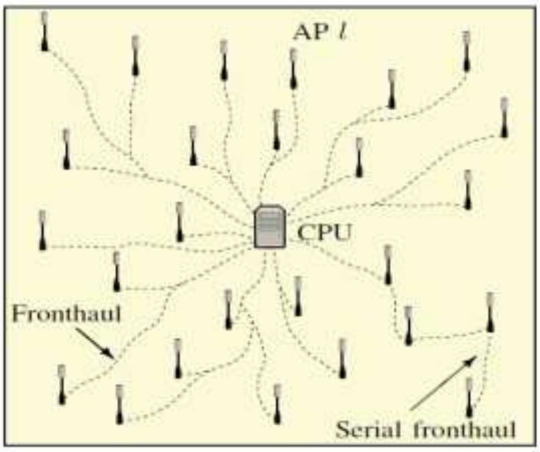


As indicated in the picture, the cellular network has four square cells inside a 1 km by 1 km area. The uniform linear arrays are half-wavelength spaced on the multi-antenna APs, and the gaussian local scattering model with a 15° angular standard deviation is used to construct the spatial channel correlation.



PROPOSED SYSTEM:

The Cell-Free mMIMO network is made up of N antennas on each of L geographically dispersed APs. As seen in figure, fronthaul connections are used to connect the APs to a CPU (b). In a cell-Free system, unlike cellular wireless networks, we do not segment the network into cells or assign users to specific base stations. Instead, we suppose that a region is covered by K randomly distributed single antenna users, M randomly distributed single antenna APs, and these APs are connected to a CPU via fronthaul links.



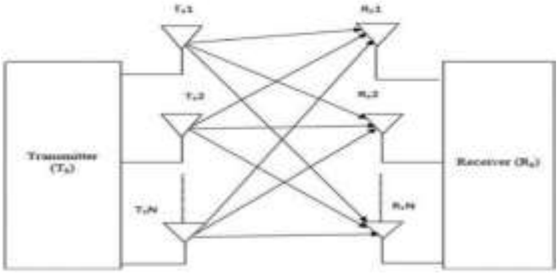
(b) Cell-free mMIMO network.

Figure illustrates a cell-free system as an example. In contrast to a traditional cellular network, each user in a cell-free system is not served by a single base station. For each OFDM subcarrier, a flat fading channel model is used. For ease of use, the OFDM subcarrier index has been left out. The whole region is thought to be small enough for the largest propagation time difference between any two APs reaching a user to be less than the length of the OFDM cyclic prefix.Given by is the channel coefficient between AP m and user k.

$$g_{mk} = \sqrt{\beta_{mk}}\ h_{mk}$$

where β_{mk} is the large scale fading coefficient This takes into consideration shadowing and path loss. This coefficient is easily measured and tracked because it fluctuates slowly.

The second factor h_{mk}~ C N(0; 1) is the small scale fading coefficient. We suppose that these coefficients are independent, i.i.d. random variables that remain constant over the course of a coherent interval. For an OFDM wide-band system β_{mk} is not frequency-dependent , while h_{mk} has frequency dependency and a Nyquist sampling interval that is proportional to the channel delay spread in frequency. We denote by $G \in C^{mxk}$, $[G]_{mk} = g_{mk}$ between all APs and users, the channel matrix. We also assume that the channel coefficients for uplink and downlink are the same, or channel reciprocity. We concentrate on the case of users who move at less than 10 km/h. In other words, as this is often the case in real-world circumstances, we presume that the majority of our users are pedestrians.



MASSIVE MIMO MODEL:

The Mx1 received vector y at the BS is

$$y = \sqrt{p_u}\ [g_1\ g_2\ g_3\ \ldots\ldots g_k] \begin{bmatrix} x_1 \\ \vdots \\ x_k \end{bmatrix} + \begin{bmatrix} n_1 \\ \vdots \\ n_2 \end{bmatrix}$$

$$y = \sqrt{p_u}\ \text{G x + n}$$

Where n= $\begin{bmatrix} n_1 \\ \vdots \\ n_m \end{bmatrix}$ is a vector of additive iid zero mean gaussian noise samples and the noise variance is set to 1, without loss of generality.

Let g_{mk} denote the Mx1 channel vector between BS and user K

$g_k = \begin{bmatrix} g_1 k \\ \vdots \\ g_m k \end{bmatrix}$ The expectation of the channel is given by

$E\{|g_{mk}|^2\} = \beta_k$ where β_k models the geometric attenuation and shadow fading and it is a largest scale fading factor

.

CHANNEL ESTIMATION:

By considering the Massive MIMO model the channel estimation model is given by

$y_{m\times k} = \sqrt{p_p}\ G_{m\times K}\ \emptyset_{K\times K} + N_{m\times k}$ where K= number of pilot transmission

The pilot power p_p=k p_u and the pilot matrix is chosen as $\emptyset\ \emptyset^H$=I this is known as an orthogonal pilot matrix.

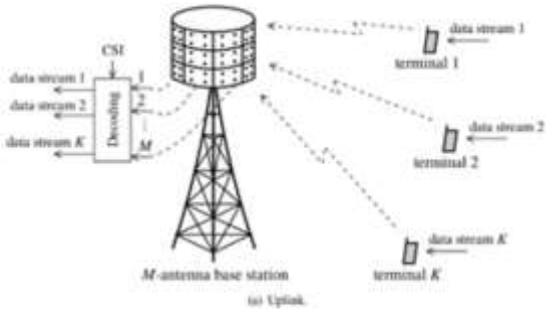
The channel estimation can now be obtained as

$$\hat{G}=Y\frac{1}{\sqrt{P_P}}\emptyset^{H}=(\sqrt{P_P}\,G\,\emptyset+N)\frac{1}{\sqrt{P_P}}\emptyset^{H}$$

$$\hat{G}=G+N\frac{1}{\sqrt{P_P}}\emptyset^{H}$$

$$\hat{G}=G+E$$

and the variance of channel estimation error is $\frac{1}{k\,p_u}$



The uplink transmission of data is shown in the above figure.

Now in the Massive Receiver let us consider the user 1 as the desired user, the received signal can be spilt into desired signal and interference

$$y=\sqrt{p_u}\,g_{1\,x_1}+\sqrt{p_u}\sum_{i=2}^{k}g_{1\,x_i}+n$$

Here the interference is added at the receive signal and those interference is removed by using the matched filter receiver or maximal ratio combiner for user 1

$$r_1=\frac{g_1{}^{H}}{\|g_1\|}y$$

$$r_1=\frac{g_1{}^{H}}{\|g_1\|}(\sqrt{p_u}\,g_1x_1+\sqrt{p_u}\sum_{i=2}^{k}g_i\,x_i+n)$$

$$r_1=\sqrt{p_u}\|g_1\|x_1+\sqrt{p_u}\sum_{i=2}^{k}\frac{g_1{}^{H}}{\|g_1\|}g_ix_i+\frac{g_1{}^{H}}{\|g_1\|}n$$

The SINR for Massive MIMO is calculated as

$$\text{SINR}=\frac{p_u\|g_1\|^2}{p_u\sum_{i=2}^{K}\in\left\{\left|\frac{g_1^H}{\|g_1\|}g_i\right|^2\right\}+\in\left\{\left|\frac{g_1^H}{\|g_1\|}n\right|^2\right\}}$$

The noise samples are distributed as cN(0,1) it is given by

$\frac{g_1{}^{H}}{\|g_1\|}n\sim$ cN(0,1) The expectation for this is given by

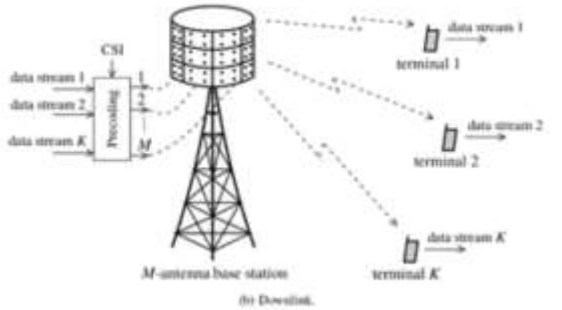
$$\in\left\{\left|\frac{g_1^H}{\|g_1\|}n\right|^2\right\}=1$$

Let us consider the coefficients of g_i are distributed as cN(0,β_i) then it follows as $\frac{g_1^H}{\|g_1\|}g_i\sim$ cN(0,β_i) the expectation is given as $\in\left\{\left|\frac{g_1^H}{\|g_1\|}g_i\right|^2\right\}=\beta_i$. Therefore the SINR can be obtained as SINR $=\frac{p_u\|g_1\|^2}{p_u\sum_{i=2}^{k}\beta_i+1}$ where p_u is the power scaling, the $p_u=\frac{E_u}{m}$ as the power of each user is decreased inversely as number of antenna by considering this power scaling factor the SINR scales as

$$\text{SINR}=\frac{E_u\frac{\|g_1\|^2}{m}}{E_u\left(\frac{1}{m}\sum_{i=2}^{k}\beta_i\right)+1}$$

Therefore , Massive MIMO is able to suppress the MUI and by using only the MF it has a very low complexity.

One can also maintain constant SINR even with power decreasing as $p_u=\frac{E_u}{m}\alpha\frac{1}{m}$, here the power of users can decrease as $\frac{1}{m}$ which is the major advantages of Massive MIMO. The receive beamforming is a fundamental operation in wireless communication. This is required to maximize the SNR for each user and suppress the interference.



The downlink transmission of data is shown in the above figure. As the Massive MIMO operates in the TDD mode thus, channel estimate in the UL can be used in the DL. This is termed as Channel Reciprocity. Let W denote the receiver combiner or beamformer.

The output of the beamformer is

$$\tilde{y}=[w_1^*, w_2^*, \dots \dots . w_l^*]\begin{bmatrix} y_1 \\ \vdots \\ y_l \end{bmatrix}$$

The receive combiner or beamformer that maximizes the SNR is w=$\frac{1}{\|h\|}$ which is termed as maximal ratio combiner (MRC)

In order to supress the multiuser interference to zero we are sing the channel diagonalization.

H_iF_j =0 , i≠j Where the channel from BS to the Jth user is denoted by $H_j$and associated precoder by F_j.

In block diagonalization the property is F_j has to lie in the null space of $\widetilde{H_J}$

$$\widetilde{H_J}F_i = \begin{bmatrix} H_1 \\ \vdots \\ H_{j-1} \\ H_{j+1} \\ \vdots \\ H_k \end{bmatrix} F_j = \begin{bmatrix} H_1F_j \\ \vdots \\ H_{j-1}F_j \\ H_{j+1}F_j \\ \vdots \\ H_kF_j \end{bmatrix} = 0$$

When we consider the imperfect channel information that is the channel state information is uncertainty.

The matched filter receiver for user 1 with CSI uncertainty is

$$r_1=\widehat{g_1^H}\mathrm{y}$$

$$r_1=\widehat{g_1^H}\left(\sqrt{p_u}\, g_1x_1 + \sqrt{p_u}\, \sum_{i=2}^{k} g_ix_i + n\right)$$

Where y is the received signal of the Massive MIMO system model.

The output of the CSI uncertainty is

$$r_1=\sqrt{p_u}\, \widehat{g_1^H}\, g_1x_1+\sqrt{p_u}\, \sum_{i=2}^{k} \widehat{g_1^H}\, g_ix_i+\widehat{g_1^H}\mathrm{n}$$

$$r_1=\sqrt{p_u}(g_1 + e_1)^H g_1x_1+\sqrt{p_u}\, \sum_{i=2}^{k} \widehat{g_1^H}\, g_ix_i+\widehat{g_1^H}\mathrm{n}$$

$$r_1=\sqrt{p_u}\|g_1\|^2x_1+\sqrt{p_u}e_1^H g_1x_1+ \sqrt{p_u}\, \sum_{i=2}^{k} \widehat{g_1^H}\, g_ix_i + \widehat{g_1^H}\mathrm{n}$$

$$\mathrm{SINR} =\frac{p_u\|g_1\|^4}{p_u\epsilon\{|e_1^H g_1|^2+p_u\sum_{i=2}^{k}\epsilon\left\{\left|\widehat{g_1^H} g_i\right|^2\right\}+\epsilon\left\{\left|\widehat{g_1^H} n\right|^2\right\}}$$

The SINR can be simplified as

$$\mathrm{SINR}=\frac{p_u\|g_1\|^2}{p_u\times\frac{1}{kp_u}+p_u\sum_{i=2}^{k}\frac{\left(\beta_1+\frac{1}{kp_u}\right)\beta_i}{\beta_1}+\frac{\left(\beta_1+\frac{1}{kp_u}\right)}{\beta_1}}$$

The power scaling is given by $p_u=\frac{E_u}{\sqrt{m}}$ and the simplified SINR by considering the power scaling is given by

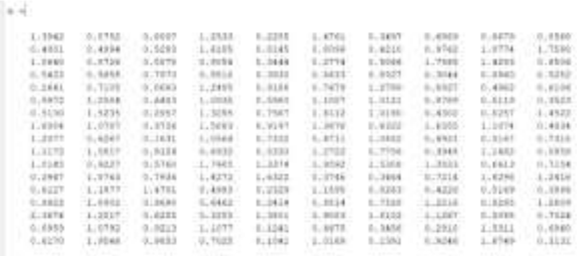
$$\mathrm{SINR}=\frac{\frac{E_u}{\sqrt{m}}\|g_1\|^2}{\frac{1}{k}+\sum_{i=2}^{k}\frac{1}{k}\frac{\beta_i}{\beta_1}+1+\frac{\sqrt{M}}{k\beta_1E_u}}$$

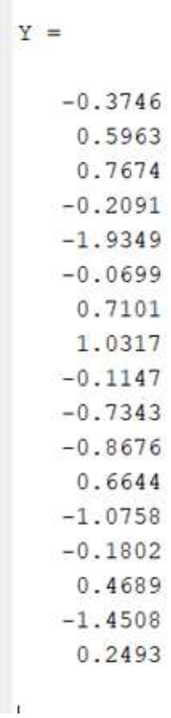
$$\mathrm{k}\beta_1{E_u}^2\frac{\|g_1\|^2}{m} \qquad \mathrm{k}{\beta_1}^2{E_u}^2$$

In order to keep INR constant the transmit power only decreases as.$p_u\alpha\frac{1}{\sqrt{m}}$

RESULTS:

INPUT DATA:

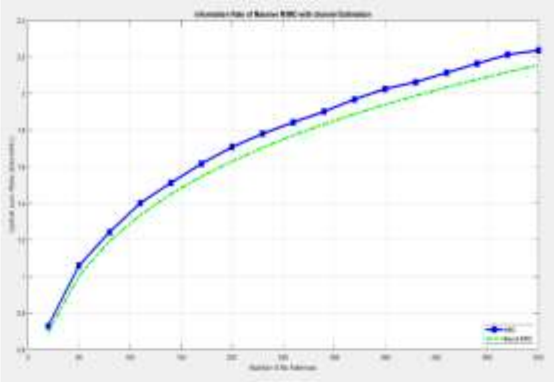




```
Y =

   -0.3746
    0.5963
    0.7674
   -0.2091
   -1.9349
   -0.0699
    0.7101
    1.0317
   -0.1147
   -0.7343
   -0.8676
    0.6644
   -1.0758
   -0.1802
    0.4689
   -1.4508
    0.2493
```

Massive MIMO channel estimation with imperfect CSI:



CONCLUSION:

We examine the effectiveness of MIMO systems using the MRC technique in this research and obtain an expression for SINR. In addition, we created three graphs, which are mentioned in the result section. After analysing the data, we may draw the conclusion that adding more antennas improves the performance of MIMO systems. A MIMO system that has some number of antennas on both sides would operate well. Both when a base station transmits to many mobile devices and when a base station receives from multiple mobile devices, the performance will be the same.

However, since just one receiving or transmitting antenna will be used, it will take longer to combine or broadcast than if there were two or three. Finally, using the same or even number of transmitting and receiving antennas is advised because their performance is superior to using variable numbers of antennas.

FUTURE SCOPE:

The radio stripes architecture with a sequential fronthaul between the Aps is the paper's future area of interest. Thus, employing this design allows us to drastically cut back on fronthaul signalling without sacrificing communication performance.

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