Comparative Study the Effect of Antenna Selection on Capacity and Energy Efficiency of 5G Systems

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Abstract. As a result of the rapid growth in wireless communications and the increase in the number of users of cellular phones around the world, massive multi-output, and multi-input (massive MIMO) systems have been used. The main drawback of such a system is the increase in the number of antennas and the amount of energy consumed. To mitigate that the number of active antennas can be reduced to save some energy. In this paper, we will study different algorithms for choosing the suitable antennas in MIMO systems, subject to keeping an acceptable level of bit rate and energy efficiency in the system. The study will also consider the amount of complexity for each algorithm based on the consumed time to perform each algorithm in MATLAB.

1. Introduction

The mobile systems has began for more than a few decades. Over the past two decades, the world has witnessed a gradual development of wireless communications towards the second, third and fourth generation wireless networks. Introducing digital modifications. Effective Frequency Reuse, packet-based Internet penetration.

Multi-output multi-input (MIMO) system technology is the most interesting type of wireless access to meet the 5G systems and beyond need [1]. Massive MIMO systems are an extension of the traditional MIMO technology that involves the use of hundreds or even thousands of antennas connected to the base station to improve spectral efficiency and throughput. The increase in capacity, throughput, and spectrum efficiency in large MIMO systems has made it a critical issue and has made a critical technology for emerging wireless standards [2].
Figure 1. Global mobile data traffic and growth in connected devices from 2017 to 2022.

The main advantage of massive MIMO technology is that each user should only obtain a dedicated signal with the least interference or the least amount of interference potential from other stations [3]. Despite the significant advantages of massive MIMO, when it comes to power consumption, it is well known that BSs with a large number of active antenna elements suffer from an extremely high-power consumption since each antenna is connected to a separate power-demanding radio frequency (RF) chain. RF chains are responsible for 50%–80% of the total transceiving power consumption of communications systems [4].

One way to maintain the advantages offered by MIMO while reducing the energy consumption, cost, and hardware complexity is via using antenna selection (AS) techniques, However, unlike conventional MIMO systems where the AS is carried out with the main focus being on enhancing the performance, there has been a large number of researches on the selection of antennas in recent years [5-9]. In [5,6] the authors proposed an algorithm for selecting the receiving antenna in multi-input and multi-output systems. The researchers suggest two algorithms for selecting antennas, which are the Fast and Global The results showed that the proposed algorithms indicated that the capacity obtained is near ideal and close to the ideal case, but needs high memory due to the computational burden, i.e., it is complicated in terms of computation, and also showed that the global method is appropriate in the case of the number of selected antennas less than the number Antennas available. In [7] the researchers proposed an increase in the data rate through the use of Convex Optimization to determine the optimal antennas on a large scale in MIMO systems. The simulation results of the proposed method confirmed that it works well and its performance is close to the optimal selection algorithm and can reduce the cost by reducing the frequency chains And an increase in system efficiency. In [8], the researchers proposed a binary switching architecture for the solution that is simpler and sub-optimal but provides better signal quality, compared to a full switching network. To evaluate the proposed technique, compare the amplitude of the aggregate when using multiple dual switches with the full switching performance. It was found that the proposed dual switching gives a competitive performance close to the full switching. The results indicate that massive MIMO devices can be simplified by reducing the number of RF chains and simply selecting an antenna through binary switching architecture. The complexity is less and the loss in signal quality is less, but in return the number of RF is complete, that is, without reducing the RF, which is of a high cost.

As for the source [9], the authors selected the antennas and their effect on the channels, and the results showed that it is possible to reduce the complexity significantly in the devices and the energy consumption can be reduced without a significant deterioration in the performance of the system. In [10] the authors source a proposal for a sub-diagram and binding for the selection of antennas for an increase in capacity which can be achieved using dirty paper coding.

In this paper, four algorithms will be studied and compared and their effects on the selection of antennas in the fifth generation massive MIMO systems in terms of capacity and energy efficiency where the research paper is organized as follows on the system model in the Second Section, and in the Third Section the effect of the antenna selection in the fifth generation on the capacity will be discussed, while in the Fourth Section the study of the effect of the antenna selection on energy efficiency. After that, a summary of the results will be presented.

2. System Model
The base station is equipped with (Nt) from the antennas and the mobile station with (Nr) from the antennas, and the number of the selected antennas is (Ns). We assume that the channel is of the type of Rayleigh, and that the data is sent through the (dawn link) and the channel is similarly treated, which sends two experimental signals on The downlink in the system model, and the encoding of the transmitted signal used is of the MF type, and the signal is detected by the linear detectors of the
(MRC) type to clarify where \( N_r \leq N_t \) (and the \( H \)) represent the channel coefficient between the number of antennas. Reported through the following matrix. In this paper the transmitted power \( P_t = 0.1 \) watt. The received signal can be given by the following equation:

\[
y = H x + n
\]  \hspace{1cm} (1)

Where \( y \in c^{N_r \times 1} \) represents the received signal by \( N_r \) and \( x \in c^{N_t \times 1} \) represents the symbol vector for the transmitted information and \( n \in c^{N_r \times 1} \) represents the AWGA noise vector in the receiver and \( H \in c^{N_t \times N_r} \). The channel matrix, which is a compound random variable, is formed by multiplying the number of transmitting antennas by the number of receiving antennas. One equation can be illustrated as follows:

\[
\begin{bmatrix}
y_1 \\
\vdots \\
y_{N_r}
\end{bmatrix} =
\begin{bmatrix}
h_{11} & \ldots & h_{1,N_t} \\
\vdots & \vdots & \vdots \\
h_{N_r,1} & \ldots & h_{N_r,N_t}
\end{bmatrix}
\begin{bmatrix}
x_1 \\
\vdots \\
x_{N_t}
\end{bmatrix} +
\begin{bmatrix}
n_1 \\
\vdots \\
n_{N_r}
\end{bmatrix}
\]  \hspace{1cm} (2)

| Components                               | symbol | Assumed value |
|------------------------------------------|--------|---------------|
| Number of transmitted antennas          | \( N_t \) | 16            |
| Number of received antennas              | \( N_r \) | 2             |
| Number of transmitted antenna selections | \( N_s \) | 4             |
| Number of receiver antenna selections    | \( L_r \) |               |
| Signal to noise ratio                    | \( \gamma \) | 6dB           |
| Channel matrix                           | \( H \) | Complex number |
| Sub-channel matrix                       | \( H_{sub} \) | Complex number |
| Energy efficiency                        | \( EE \) | bit/joule     |
| capacity                                 | \( R \) | bit/sec/Hz     |

Where the base station is equipped with 16 antennas, considering that the base station in the fifth generation contains a large number of antennas and the mobile station is equipped with 4 antennas because most of the mobile devices in the fifth generation contain 5 antennas and thus becomes the channel array (16×4), unlike the fourth generation which was the maximum of the channel array was made up of (4×2), (8×2), (2×2)…etc, as for the value of (SNR=6db) only this value was taken only for comparison between algorithms and also for power.

3. Algorithms of selecting antennas

There are many algorithms in the literature to select antennas. It has been assumed consider four algorithms in our study: optimal algorithm antenna selection, random antenna selection (RAS), norm-based antenna selection (NBS), greedy algorithm antenna selection.

3.1 Random Antenna Selection (RAS)

This algorithm, as expressed via the flow chart in Figure 2, is considered one of the algorithms in which the antenna is randomly selected, and although it is the least time-consuming algorithm, it is also considered the least accurate and the least bit rate performing.

\[
R_{dl} = \left| \log_2 \left( I_{N_r} + \frac{Y_{dl}}{N_t} H H^H \right) \right|
\]  \hspace{1cm} (3)

\( H^H \): transpose Hermitia for channel matrix.

\( I_{N_r} \): matrix Identical.
$R_{dl}^{\text{th}}$: The capacity is represented in the downlink

**Figure 2.** The flow chart of random select of antenna selection.

**Figure 3.** The flow chart of optimum antenna selection.
3.2 Optimal algorithm antenna selection
It is considered the best option for choosing the antenna as explained in Figure 3., but it has a very high complexity from a mathematical point of view as the bit rate formula is examined for a different group of antennas through the number of antennas in the reception and the number of antennas in the base station, and although it gives an ideal capacity, it takes a long period of time to choose an antenna. Suitable and for this reason, it has been used to compare it with other algorithms to obtain an algorithm of less complexity and close to the ideal case, and it can be expressed through the following relationship [12]

\[ R_{dl} = \max \left\{ \log_2 (INr + \frac{y_{dl}}{Nt} HH^H) \right\} \]  (4)

3.3 Norm-based antenna selection (NBS)
A display of the Norm-based algorithm is shown in the flow chart in Figure 4. The number of antennas selected in the base station must be less than the number of antennas in the base station itself. Symbolizes the base station number of antennas selected NS such that NS<NT And the LR number of receiver antenna selection LR<NR, the full channel matrix \( H \in \mathbb{C}_{NR \times NT} \) is virtual as the MIMO
communications is happening over \((LR \times NS)\)-element subset channel matrix \(H_{sub} \in C_{LR \times NS}\). In order to efficiently exploit the available resources, it is better to choose the antennas that have higher channel capacity. In general, increasing the channel gain has similar effect of having low noise, which leads to improving the system performance. This motivates the NBS algorithm that selects the antennas based on the related to the higher channel matrix subset norm. 

Let \(H_{sub} \in C_{LR \times NS}\) denote the subset candidates of the full channel matrix \(H\). The selected subset \(H_{sub}\) based on the NBAS criterion is found by solving the following optimization problem [11]:

\[
H_{sub} = \arg \max_{H_{sub}} \|H_{sub}\|_2^2 = \arg \max_{H_{sub}} \sum_{N_t=1}^{L_T} \sum_{N_r=1}^{L_R} |H_{sub}(N_r, N_t)|^2
\]

### 3.4 Greedy algorithm antenna selection

The following algorithm is proposed, which as shown in Figure 5, which is considered one of the algorithms of low complexity in mathematical terms, where the antenna is chosen in this algorithm based on the nature of the channel, that is, after the highest norm of the channel is calculated, these channels will be examined in terms of amplitude with the total rate. If the capacity is greater than the total capacity, then the antenna will be turned off, otherwise the antenna will be energized. When comparing this algorithm with the ideal algorithm, we notice that although it gives capacity less than the ideal capacity, it is close to the ideal case and has less complexity in terms of mathematics and execution time.[13]

### 4. Energy Efficiency

The transmitter and receiver circuits usually include the so-called RF frequency chains, as shown in the figure above such as Power amplifier, Digital to anlage converter, Anlage to digital converter, Low noise amplifier, Mixer, these components may be active or inactive, depending on the operating mode of the phone [15].

The energy efficiency of the bit /joule unit can be given in MIMO systems. Energy efficiency can be obtained using the following formula

\[
EE = \frac{\text{bit rate}}{\text{total power}}
\]

### 5. Results

In this section, it has been displayed a comparison between the different algorithms in terms of capacity, energy efficiency, and in term of complexity.

![Figure 6. The bit rate vs the number of the selected antenna in the four algorithms.](image-url)
In Figure 6. It has been shown that the optimum provides better performance in terms of bit rate with the number of selected antennas. Another insight from Figure 3 is that a comparison between Greedy & Norm, where the greedy can provide a better bitrate than the Norm at a low number of antennas, then it became harder for the greedy to stay better than the norm at a higher number of selected antennas. Lastly Random has the worst performance in terms of bit rate.

![Figure 6](image1)

**Figure 7.** The energy efficiency vs the number of the selected antenna in the four algorithms.

Figure 7 shows the performance of the four algorithms in terms of energy efficiency. The results reinforce the idea of having higher energy efficiency when the low antenna selection. At higher antenna selection, the EE decreases gradually.

![Figure 8](image2)

**Figure 8.** The consumed time with the number of antenna selection for the four algorithms.

From Figure 8, it is clear that the optimal algorithm consumes the highest time, which indicates that it has the highest complexity compare to other algorithms.
6. Conclusions
Through the comparison between the four algorithms under investigation, it was found that unlike the random and the norm algorithm, the optimal algorithm has the highest bitrate and energy efficiency with the cost of higher complexity. On the other hand, the Greedy algorithm can provide acceptable complexity with a valuable amount of bitrate and energy efficiency.

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