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# Performance of antenna selection schemes for massive multiple-input multiple-output systems under Non-orthogonal multiple access cooperative communication

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Non-orthogonal multiple access (NOMA) has emerged as a promising technology for 5G systems. The most important characteristic of NOMA is that other users' messages is available to the users with better channel conditions. In this work, a modified antenna selection scheme called Double threshold generalized selection combining (DT-GSC) to save power in receivers used for massive multiple-input multiple-output (MIMO) applications are proposed. The diversity combiner selects the paths above two threshold values set at the combiner, the input and the combiner's output. These threshold values are selected based on the practical communication scenario. The average number of combined branches and estimated path are shown mathematically. The bit error performance of DT-GSC and maximal ratio combiner (MRC) are plotted. Through numerical examples it is evident that the new combining technique performs better compared to the existing ones. This combining technique is beneficial in the massive MIMO base station and user equipment with multiple antennas or cooperative communication set up with users employing the MRC scheme. Simulation results are presented to demonstrate the performance of the proposed technique.

**Keywords*:*** Cooperative communication, Massive multiple-input multiple-output (MIMO), Non-orthogonal multiple access (NOMA), Double thershold generalized selection combining (DT-GSC)

## 1 Introduction

One of the emerging and promising technologies of the Internet of Things (IoT) is vehicle-to-everything (V2X). The V2X enable communications among many applications related to vehicles, vehicle traffic, drivers, passengers, and pedestrians. This will provide a safer and more efficient driving experience for our future life. The mission-critical services which play a vital role in the future life is supported by V2X communications. These services typically require low latency and high reliability[1]. To overcome the above challenges, several solutions, such as hybrid analog-digital precoding schemes[2] and spatial modulation[3,4] have been proposed. In this perspective, Antenna selection (AS) can be considered as an alternative to reduce the complexity in small and large- scale MIMO systems operating below 6 GHz[5,6] . This work mainly focusses on this area. In Wideband Code Division Multiple Access (WCDMA) RAKE receiver can increase the reliability of wideband systems by coherently combining multiple resolvable paths[7,8]. To achieve less power consumption and to reduce hardware complexity, the mobile terminal should select a set of paths for the reception. A finger assignment scheme's performance gives low complexity and reduces the soft handover overhead (SHO)[9]. When the received signal is of poor quality in the SHO region, the receiver search for the additional multipath from the target base station and select the strongest path among the serving and target base stations. The analysis in this work is limited to two base stations[10,11]. Low complexity diversity combining schemes, such as generalized selection combining (GSC), has been deeply explored over the last decades[12,13]. The finger selection algorithm for UWB can be found in the literatures[14,15]. Finger delay problems and suboptimal finger placement were analysed in the literature[16]. Thus, the next generation wireless networks can adopt NOMA techniques to improve the system spectral efficiency of the system. To optimize the performance of NOMA, all the users are allowed to share each resource element (in time or frequency domain) and the allocated power through iterative water-filling[17,18].

All the combining schemes except the literature[2] are based on available paths irrespective of the base stations and do not consider network overhead. Here we consider the massive antenna base station case, in

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which double threshold GSC is used. In MRC, all antenna outputs are selected for combining. Therefore power consumption is more. Whereas in threshold GSC combining only selected antennas based on the threshold is used for combining.

In input double threshold GSC, the received SNR is compared between two thresholds. If the received SNR is less than the preset threshold (first), another checking is done with a threshold (second), which is slightly less than the previous threshold. And this system is arranged so that the number of paths used for combining should not exceed two branches. This is essential for power saving and reduces complexity. The second threshold is chosen in such a way that the combiner should give the required performance.

In this contribution, the performance of the cooperative NOMA system under the massive MIMO scenario is studied. In massive MIMO systems, double threshold generalized selection combining is done instead of maximal ratio combining in the antenna selection process.

## 2 Materials and Methods

Traditional cooperative relaying systems are considered in Fig. 1(a), where signals from the base station pass through the relay and reach the destination, in addition to the line of sight component (LOS). Now consider a cooperative non-orthogonal multiple access (NOMA) cooperative scenario in which users communicate with a base station (BS) with many antenna arrays. At the base station, signals coming through various paths are combined using double threshold generalized selection combining (DT GSC). In the normal mode, MRC is used but here, to save the power, only certain antennas whose received SNR value greater than the input threshold are selected for combining purpose. Again if the combiner output should satisfy some minimum output threshold also to ensure the quality of operation. So two thresholds are chosen, one at the input side and the other at the combiner's output side. This scheme is known as a double threshold generalized selection combining.

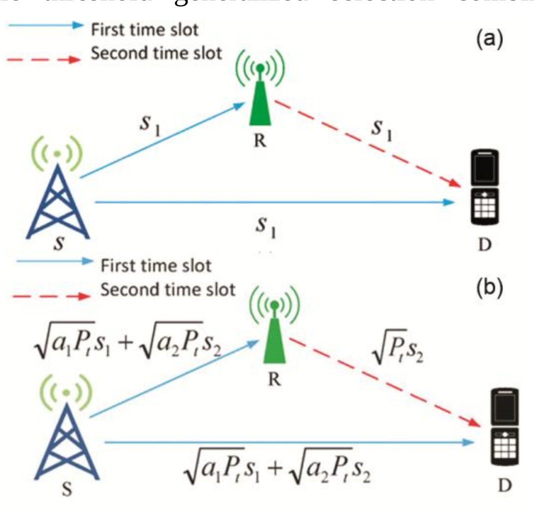


Fig. 1 — (a) Traditional cooperative relaying system, and (b) NOMA based cooperative relaying system.

Consider the communication scenario as in Fig. 1(b). Here a source (S) communicates with the destination (D) through the direct link and the strongest N indirect links. According to this selection scheme the destination receives N+1 copies of the source signal. Out of these received signals, the first one is from the source through direct link. The rest of the N copies are from the N strongest paths. The channel coefficients between the source S and the i[th] relay $R_i$ ($h_s$,$R_i$), between $R_i$ and D ($h_{Ri}$, D) and between S and D ($h_s$, D) are flat Rayleigh fading coefficients. Also, $h_s$, $R_i$, $hR_i$, D and $h_s$, D are mutually independent. In this work, it is also assumed that additive white Gaussian noise (AWGN) terms of entire links have zero mean and variance $N_0$.

From Fig. 2, let $s_1 = x_1$ , $s_2 = x_2$, and $\rho_1 = \rho_s$

The base station constructs a superposed signal containing data of both users.

$$x_s = \sqrt{a_1\rho_s x_1} + \sqrt{a_2\rho_s x_2} \quad \dots (1)$$

where, the quantity $\rho_s$ denotes the total transmit SNR, $\rho_s = \frac{P_s}{\sigma^2}$ , $P_s$ = total transmit power $a_1$, $a_2$ are a fraction of power allocated to user 1, 2

In order to satisfy total power constraint, $a_1, a_2$ must satisfy

$$a_1 + a_2 = 1 \quad \dots (2)$$

At user 1, the received signal is

$$y_1 = h_1\left(\sqrt{a_1\rho_s x_1} + \sqrt{a_2\rho_s x_2}\right) + n_1$$

$$= h_1\sqrt{a_1\rho_s x_1} + h_1\sqrt{a_2\rho_s x_2} + n_1 \quad \dots (3)$$

SINR or decoding $x_1$ at $u_1$ is

$$\gamma_{u_1}^{x_1} = \frac{a_1\rho_s|h_1|^2}{a_2\rho_s|h_1|^2+1} = \frac{a_1\rho_s\beta_1}{a_2\rho_s\beta_1+1} \quad \dots (4)$$

where, $\|h_1\|^2 = \beta_1$

The achievable rate of user 1 is

$$log_2\left(1+\gamma_{u_1}^{x_1}\right) = log_2\left(1+\frac{a_1\rho_s\beta_1}{a_2\rho_s\beta_1+1}\right) \quad \dots (5)$$

At user 2

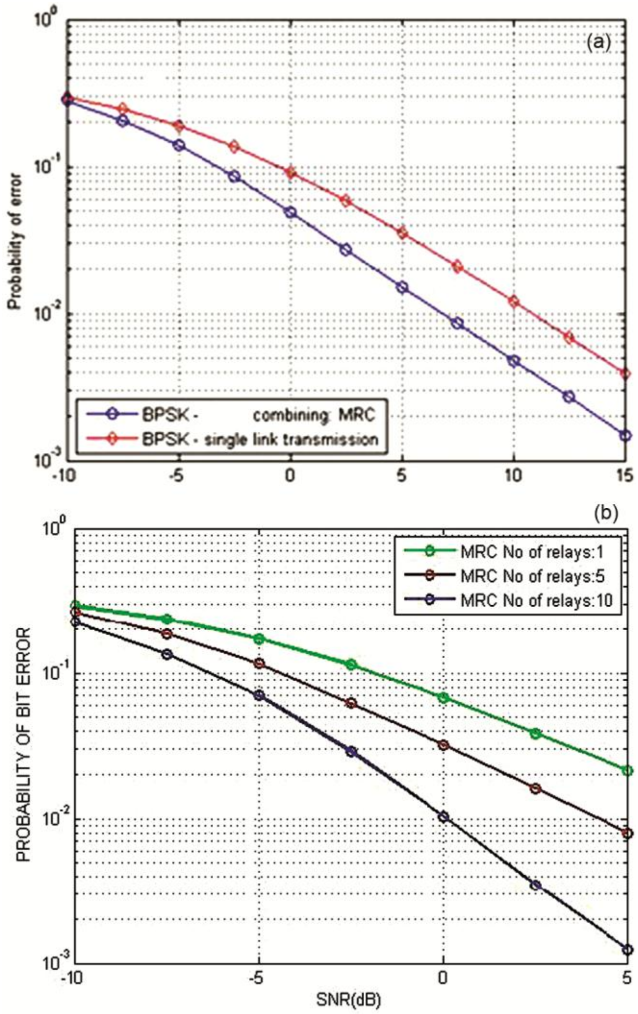


Fig. 2 — (a) Performance analysis of MRC with single relay, and (b) performance analysis of MRC by changing the number of relays.

$$y_2 = h_2\left(\sqrt{a_1\rho_s x_1} + \sqrt{a_2\rho_s\beta_2}\right) + n_2 \quad \dots (6)$$

SINR for decoding $x_1$ at user 2

$$\gamma_{u_2}^{x_1} = \frac{a_1\rho_s\beta_2}{a_2\rho_s\beta_2+1} \quad \dots (7)$$

The sum rate of NOMA for $\beta_2 \geq \beta_1$ can be evaluated as

$$C_{u_1}^{x_1} + C_{u_2}^{x_2} = log_2\left(1 + \frac{a_1\rho_s\beta_1}{1 + a_2\rho_s\beta_1}\right) + log_2(1 + a_2\rho_s\beta_2) \geq log_2(1 + a_2\rho_s\beta_2) \quad \dots (8)$$

where, $\beta_1$ and $\beta_2$ are channel gains.

### 2.1 Performance analysis

In this section, the probability of error, outage probability and channel capacity of the threshold MRC scheme are studied.

### 2.2 Probability of error

The average error probability over slow flat fading channels is calculated by averaging the conditional error probability in AWGN, $P(e/\gamma_{ub})$. Mathematically, $P(e)$ is given by the expression

$$P(e) = \int_0^{\propto} P\left(\frac{e}{\gamma_{ub}}\right) f\gamma_{ub}(\gamma_{ub})d\gamma_{ub} \quad \dots (9)$$

where, $f\gamma_{ub}(\gamma_{ub})$ is the probability density function (PDF) of the upper bound total SNR of the combiner. Practically, $P(e/\gamma_{ub})$ is in the form of $A\, erfc(\sqrt{B\gamma_{ub}})$

for eg. $P(e/\gamma_{ub}) = 0.5erfc\left(\sqrt{\gamma_{ub}}\right)$ … (10)

Therefore the probability of error at a specific SNR at the combine output is given as

$$P(e/\gamma_{ub}) = Aerfc\left(\sqrt{B\gamma_{ub}}\right) \quad \dots (11)$$

Hence, the unconditional probability of error can be written as

$$P(e) = A\int_0^{\propto} erfc\left(\sqrt{B\gamma_{ub}}\right) f\gamma_{ub}(\gamma_{ub})d\gamma_{ub} \quad \dots (12)$$

### 2.3 Outage probability

The mutual information between the source and destination, when the thresholded MRC scheme is used, is given as

$$I = \frac{1}{(N+1)} log_2(1 + \gamma_{ub}) \quad \dots (13)$$

where, $\frac{1}{(N+1)}$ factor is included because we need $N+1$ time slots (or orthogonal channels) for transmitting the data. The outage probability is given by

$$P_{out} = P_r(I \leq R) = P_r\left(\gamma_{ub} \leq 2^{\frac{N+!}{R}} - 1\right) \quad \dots (14)$$

### 2.4 Channel capacity

In Shannon's sense, the channel capacity is an important performance metric. Channel capacity provides the maximum achievable transmission rate under which the errors are recoverable. The average channel capacity is expressed as

$$C = \frac{BW}{(N+1)}\int_0^{\propto} log_2(1 + \gamma_{ub}) f_{\gamma_{ub}}(\gamma_{ub})d\gamma_{ub} \quad \dots (15)$$

## 3 Results and Discussion

This section shows the analytical bit error rate (BER) results for binary phase-shift keying (BPSK) modulation, outage probability and performance comparison between MRC and DT GSC. To evaluate the proposed DT GSC scheme's performance, we have simulated a massive MIMO NOMA cooperative communication system using Matlab and Monte Carlo simulations to validate the accuracy.

From Fig. 2(a), the performance of the MRC with the BPSK modulation scheme with a single relay is observed. The performance of the receiver with MRC is better compared to single link transmission. Cooperation provides multiple copies of the transmitted signal at the destination. With MRC, which maximize the SNR of the received signal. In Fig. 2(b), the performance of MRC with a varying number of relays are shown. As the number of relays increases, cooperation becomes better, leading to improved performance at the receiver end.

Figure 3(a) shows the performance of selection combining (SC), where only one antenna with high SNR is selected for the reception. Double threshold generalized selection combining (DT GSC), where a set of antennas with highest SNR and MRC (using all antennas) with a varying number of relays are shown. As the number of relays increases, cooperation becomes much better and leads to better performance. From Fig. 3(b), the outage probability versus threshold of MRC and DT GSC schemes are plotted. DT GSC performs almost similar to MRC. In MRC, power consumption becomes more because of the hardware complexity.

From Fig. 4(a), the downlink performance of NOMA with two users is shown. In ordered NOMA, the weaker user is decoded first. From Fig. 4(b), the downlink performance of the fixed NOMA system is shown. Here the decoding order of the user is fixed. The outage occurs when the data rate of the user is less than the desired rate.

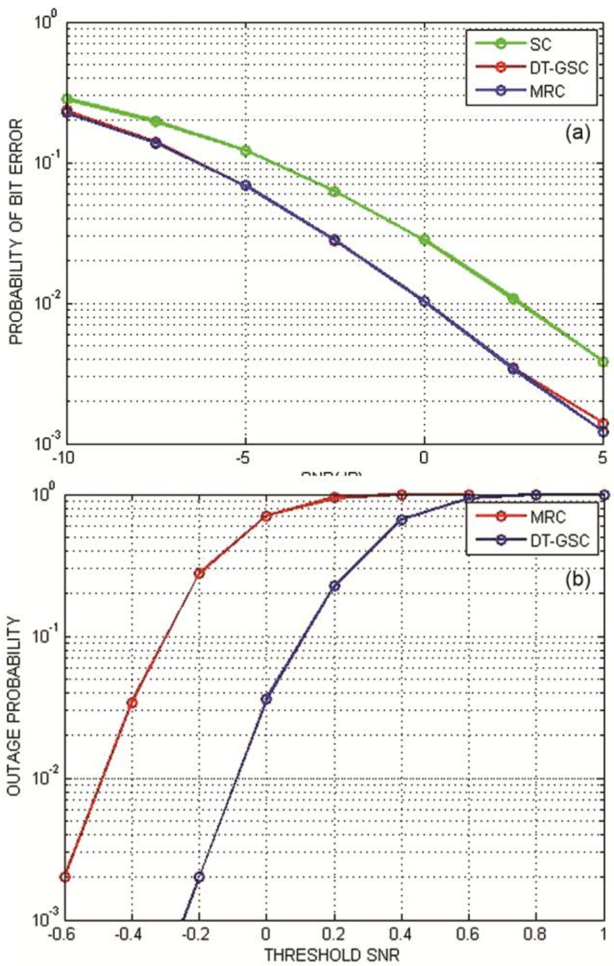


Fig. 3 — (a) Performance of SC, MRC and DT-GSC, and (b) outage probability vs. SNR threshold.

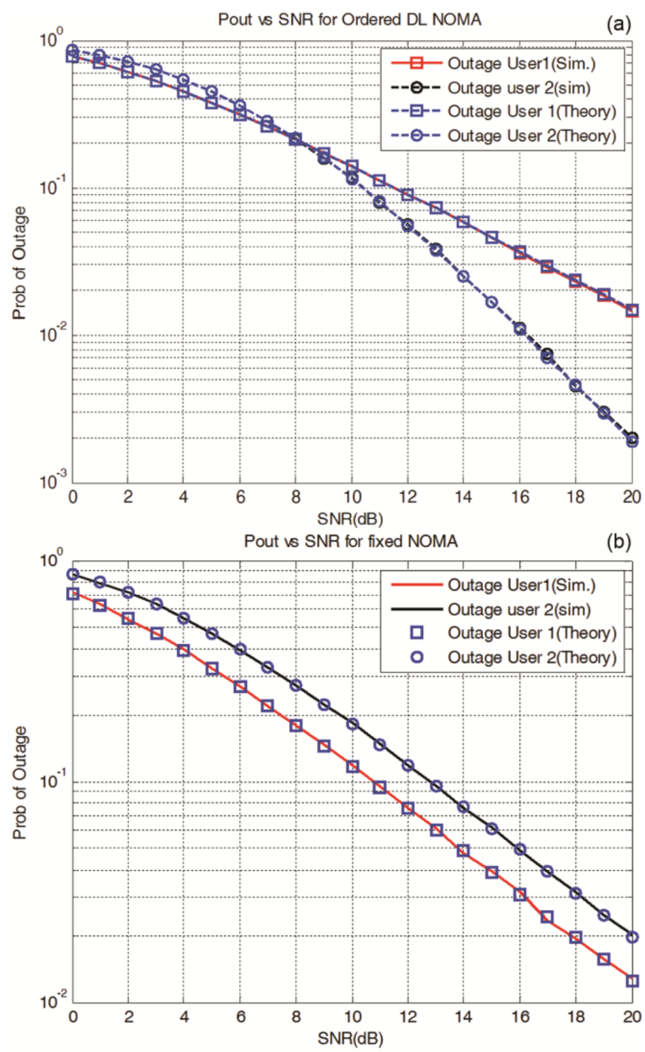


Fig. 4 — (a) Ordered downlink NOMA performance, and (b) performance of fixed NOMA system.

## 4 Conclusion

The analysis for the double threshold generalized selection scheme for massive MIMO NOMA cooperative diversity networks over Rayleigh fading channels has been performed. This is an efficient scheme that can be used to save power at the destination. Results indicate that the performance of the proposed DTGSC scheme approaches to MRC. The SNR threshold employed at the combiner input side determines the error performance of the system. The threshold should not be too high or too low. If the threshold is too high, it leads to the outage of the signal and, if the threshold is too low, it leads to poor performance. Depending on the application used at the destination, the value of threshold varies. At medium and high SNR, Cooperative diversity network has high channel capacity comparable to direct transmission. Also the downlink performance of ordered and fixed NOMA systems is studied. In future, this can be extended to more than two users, especially in IoT networks.

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