IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 14, Issue 6, Ser. I (Nov - Dec 2019), PP 59-65
www.iosrjournals.org

Spectral Efficiency of NOMA Scheme in combination with Transmit Antenna Selection

ArunmozhiS, E. Ramassamy, K.Alamelu, N. Elakkiya, K. Punithavathi
Dept. of Electronics and Communication Engg.Manakula Vinayagar Institute of Technology
Pondicherry, India.

Abstract—*The adeptness of non-orthogonal multiple access (NOMA) modelin combination with a Two-stage transmit antenna selection technique is addressed for the upcoming generation of cellular mobile communication. The primary goal of achieving low cost, low complexity with high diversity gain is significantly contributed by the merge of the recently proposed non-orthogonal multiple access (NOMA) and transmit antenna selection (TAS) techniques. The mobile traffic is on the increase exponentially and the demand is to have a considerable gain in the capacity and that of the end to end throughput. A multi-antenna base station is considered with single antenna users split into two multicast groups. The groups are selected such that one group is served unscrupulously and the other group is requiring a strict QoS with limited power and processing devices. The proposed scheme is to gratify the reliability and enhance the QoS of the proposed multicast groups. The spectral efficiency and energy efficiency of the multicast group is related with the traditional system and the performance of the multicast group is relatively better.*

Keywords—*NOMA,Multicast group,Transmit Antenna selection, Spectral efficiency.*

I. Introduction

The demand of the fifth Generation (5G) wireless communication in providing Machine-to-Machine (M2M) communications and the Internet-of-Things (IOT) apart from conventional voice and multimedia services is possible only with the advent of Novel multiple access techniques. Non-orthogonal multiple access (NOMA) is proposed recently as a Radio access technique which can aid in overcoming the bottlenecks in implementing next-generation wireless communications. Conventional orthogonal frequency division multiple access (OFDMA) is the standard which gave way for the orthogonal multiple access (OMA) technique suffers in achieving good spectral efficiency and increased latency. When the issue is on such latency, spectral efficiency and high reliability over massive connectivity then NOMA could offer a very good benefit. NOMA gives an added advantage in addressing the problem of accessing the same resource in different time, frequency and space by multiple number of users[1]. The key factor in the enhancement of spectral efficiency by NOMA is the advent of the Successive Interference Cancellation (SIC) which can be fixed or variable. There are other enabling techniques like multiple-input multiple-output (MIMO), cooperative communications, beam-forming, space–time coding, network coding, etc. When the enabling techniques are integrated with the NOMA there is evident improvement in the performance of the wireless network. The multiple users are superposed in the power domain in case of NOMA. Whereas the basic signals of the NOMA is similar to LTE-baseline which uses OFDMA or the conventional OFDM where Discrete Fourier transform is used. Successive Interference cancellation (SIC) is embracedduring the reception with the adaptability to accommodate future modifications. The downlink of a NOMA employing the SIC will enhance the capacity of the system and also aid in boosting the throughputperformance. This is possible even in case of reduced availability of the frequency-selective channel quality indicator (CQI) in the base station terminal.

In the multi-user scenario the NOMA has a key advantage in exploiting the power domain which is significant and has not been explored or conveniently utilized by the 3.5/4G systems. Also the usage of Dirty paper coding (DPC) technique or the use of SIC during reception is another added feature that makes NOMA more capable. NOMA takes advantage in scenario where the channel gains differ or to say the path loss between User equipment (UE), is considerably large, which is not apparent in OFDMA. Employing multiple antennas obviously enhances the achievable rates to a greater extend and the advantage of using large antennas is exploited by NOMA in [2]. NOMA/MIMO performs better when there is large number of UE by using the different fading channel gains and also improves the throughput gain. In case of Low number of UE the scheme is not significant when compared to single-user (SU)-MIMO approach. But in reality we are moving to a data traffic produced by more number of UE.

The achievement of good performance by the use of multiple antennas has to give a overhead of increased computational complexity and a lot of power consumption as claimed by [3]. In order to moderate the complexity involved in the computation of large number of antenna processing and also to diminish the undesired effects the concept of antenna selection is proposed in [4] which does not compromise on the diversity gain and required throughput. Consequently, the antenna selection in combination with NOMA techniques has lured researchers [5].By hiring the Transmit Antenna Selection (TAS) the evaluation of the outage performance for NOMA downlink was explored at the BS.

Further more efficient antenna selection schemes is proposed in [6] which shows a sum-rate maximization in downlink MIMO-NOMA networks. The usage of a joint antenna selectionatthe base station and also at the receiver end of each user in a MIMO-NOMA systems is persuading researchers to a greater extend. However conventional MIMO-OMA systems have already employed on joint antenna selection schemes but the extension of the technique for MIMO-NOMA systems directly is not possible. The main problem with the MIMO-NOMA is the presence of large number of inter-user interference. In the conventional MIMO-OMA systems the signals are transmitted without much interference unlike NOMA. A universalidealresultto the problems faced due to interference demands a wide research on the combinations of all sorts of antenna selection algorithms which is tedious. The search is not feasible when the numbers of antennas become massive. The design of low-complexity antenna selection algorithmover a MIMO-NOMA downlink situation is considered. The users are grouped into two and NOMA technique is adapted for communication within the group and when the communication is between different groups then the network switches to conventional OMA technique. To improve the QoS requirement the Two-stage antenna selection is utilized. The objective of the proposed system is to evaluate the spectral efficiency of Non-orthogonal multiple access (NOMA) joint with two-stage transmit antenna selection (TAS) technique.

II. Noma Architecture

The NOMA is proposed to have a good improvement in spectral efficiency and energy efficiency. Further the latency problem is optimized by the use of NOMA in the multiple access regime with an added advantage of having good reliability. The key advantage of NOMA is evident in case of large number of users. The Superposition coding (SC) is a well-known scheme for implementing non-orthogonal mechanism. The SC can realize the capacity requirements on broadcast channel. The important procedure of successive Interference cancellation in the receiver is elaborated.

A. Successive Interference Cancellation

As mentioned the superposed signals at the power level during transmission has to be decoded ate the receiver efficiently. Cover initially proposed the effective SIC technique. The SIC is an algorithm that utilizes the vital information on the observed signal when there is variation in the strength of the received signals.

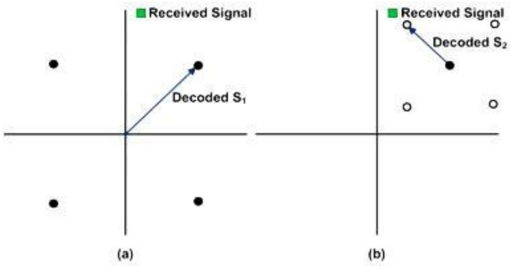

Fig. 1 SC decoding (a) decoding user 2 signal (b) decoding of user 1 signal.

There is a phenomenon of successive decoding of signal s in the SIC protocol. The receiver performs SIC in phases. First the decoding of user's 1 signal is done and then this decoded signal of user 1 is subtracted from the combined signal before thesecond user's signal decoding procedure is initiated. The principle is that while decoding the signals from other users but for the one that is being decoded are considered to be an interfering signal. This will give a benefit of the former signalbeing removed already. However, there is an overhead of ordering the users according to their signal strength which will increase the complexity of SIC. Priority is set for the stronger signal to decode first and the combined signals of all other weak signal is treated as interferer. Fig. 1elucidates the decoding procedure of the superposed signal at the receiving end. The user 1 constellation pointis first decoded from the overall signal that is received. The decoder then switches to the constellation point of user 2 and with the help of the user 1 decoded constellation point the decoding is done for user 2.Additionally, to comprehend the SIC performance with respect to a wireless communication system bothas a trivial scenario and in a OFDM or MIMO systems,the following is analyzed. The decoding procedure for the superposedsignals can be analyticallypresented as follows:

1) First a single-user decoder of user 1 g1: $C^T \rightarrow \{0,1\}^{2^{TR_1}}$user 1 signal $S_1(n)$ is decoded by treating user 2 signal $S_2(n)$ as noise.

2) the User 2 operates on the signal in the following manner to decode its signal correctly from its received signal $Y_2(n)$:

Step 1) user 1's message $S_1(n)$ is decoded by the single-user decoder $g1{:}C^T \rightarrow \{0,1\}^{2^{TR_1}}$

Step 2) The value$\sqrt{P\beta_1 h_2 S_1(n)}$is subtracted from the received signal $Y_2(n)$

$$Y_2'(n) = Y_2(n) - \sqrt{P\beta_1 h_2 S_1(n)} \tag{1}$$

where h_2 is the complex channel gain at user 2.

Step 3) With the aid of single-user decoder denoted by g2: $C^T \rightarrow \{0,1\}^{2^{TR_1}}$on $Y_2'(n)$ the User 2 information is obtained.

B. Two Stage TAS Based NOMA

The Two stage based NOMA is preferred to meet out the QoS requirements of User 2 meanwhile there is no compromise on the overhead of User 1 and the end to end network performance is enhanced. The proceduremeasures the quality of the channel at the BS to U2 link and BS to U1 link. In the phase I, the Base Station picks a set of antennas S_r which can ensure the QoS requirement of User 2. In the next phase II, The Base station selects the best antenna for user 1 to trnasmit from another set of antennas S_r.For the successful delivery to user2 the constraint onthe channel quality $h_{i2}>\widehat{\gamma_2}\,\rho(a_2-a_1\widehat{\gamma_2})$ has to be satisfied. Hence, the antenna set S_r can be defined as

$$\mathcal{S}_r = \left\{1 \le i \le N_A{:}\, h_{i2} > \frac{\hat{\gamma}_2}{\rho(a_2-a_1\hat{\gamma}_2)}\right\} \tag{2}$$

The best antenna from the set in S_r is used by the U1, the expression can be shown in (3):

$$i^* = \arg\max_{i\in\mathcal{S}_r}(h_{i1}) \tag{3}$$

By employing the two-stage TAS scheme the Probability of outage can be evaluated at the U2 and can be expressed as$\varepsilon_2=P_r(|S_r| = 0)$, the value $|S_r|$ denotes the number of antennas in S_r. The expression (2) will help id yielding the closed form expression of $\varepsilon_2$similar to that of the traditional TAS. The outage probability at the user 1 end can be shown as :

$$\epsilon_1 = \Pr\left(|\mathcal{S}_r| > 0\right)\left[1 - \Pr\left(h_i \cdot 1 \ge \frac{\hat{\gamma}_2}{\rho(a_2-a_1\hat{\gamma}_2)}, h_i \cdot 1 \ge \frac{\hat{\gamma}_1}{\rho a_1}\right)\right] + \varepsilon_2 \tag{4}$$

The next stage is to develop a closed form expression for ε_1. Theprobability of outage represented by$P_{i,out}$is got from the selection of the i^{th} antenna in S_r, given as:

$$\begin{aligned} P_{i,\,out} &= 1 - \Pr\left\{h_{i1} \ge \frac{\hat{\gamma}_2}{\rho(a_2-a_1\hat{\gamma}_2)}, h_{i1} \ge \frac{\hat{\gamma}_1}{\rho a_1}\right\} \\ &= 1 - \exp\left(-\max\left(\frac{\hat{\gamma}_2}{\sigma_1^2\rho(a_2-a_1\hat{\gamma}_2)}, \frac{\hat{\gamma}_1}{\sigma_1^2\rho a_1}\right)\right) \end{aligned} \tag{5}$$

From the law of total probability and ordered statistics, the value ε_1 can be shown as:

$$\varepsilon_1 = \varepsilon_2 + \sum_{l=1}^{N_A} \Pr\left(|\mathcal{S}_r| = l\right) \prod_{i=1}^{l} P_{i,out} \tag{6}$$

Where

$$\begin{aligned} \Pr\left(|\mathcal{S}_r| = l\right) = \binom{N_A}{l} \prod_{j=1}^{l} \exp\left(-\frac{\hat{\gamma}_2}{\sigma_2^2\rho(a_2-a_1\hat{\gamma}_2)}\right) \\ \times \prod_{k=l+1}^{N_A} 1 - \exp\left(-\frac{\hat{\gamma}_2}{\sigma_2^2\rho(a_2-a_1\hat{\gamma}_2)}\right) \end{aligned} \tag{7}$$

whenthe value $\rho \rightarrow \infty$, the exponential approximation is used and the asymptotic expression of ε_1^{∞}can be obtained as:

$$\begin{aligned} \varepsilon_1^{\infty} \simeq \frac{1}{\rho^{N_A}}\Bigg[\left\{\frac{\hat{\gamma}_2}{\sigma_2^2(a_2-a_1\hat{\gamma}_2)}\right\}^{N_A} + \sum_{l=1}^{N_A}\binom{N_A}{l} \\ \cdot\left\{\frac{\hat{\gamma}_2}{\sigma_2^2(a_2-a_1\hat{\gamma}_2)}\right\}^{N_{\Lambda}-l}\left\{\max\left(\frac{\hat{\gamma}_2}{\sigma_1^2(a_2-a_1\hat{\gamma}_2)}, \frac{\hat{\gamma}_1}{\sigma_1^2 a_1}\right\}\right\}'\Bigg] \end{aligned} \tag{8}$$

Full diversity gain of order NA in both User 1 and 2 is obtained from the above equation (8).

The consideration here is that a single-cell downlink scenario has N users U_i, with $i\in N = \{1,2, \dots, N\}$, and the cell has only one BS. Each user has only one antenna. A similar uplink scenario can be simulated for the implementation of NOMA. There is always a simultaneous transmission form the BS to all users. Thepower constraint on the total power P is taken into account. The channel sorting is done as shown $0 < |h|^2 \le |h_1|^2 \le \dots \le |h_i|^2 \dots \le |h_N|^2$, i.e, the user always holds the weakest instantaneous channel. The superposition of user data or signal is done is done at the BS with a fractional share of power to each user. $P_i = \beta_{iP}$ denotes the fractional power allocated to each user. The weaker user's signals are decoded at the receiver. For example, $U_i$has the potential to decode the signals for each U_m with $m <i$. the subtraction takes place in the next stage where the weaker user's signal are removed from the received signal to obtain the signal of user U_i, considering the Ui is the stronger users and other signals as interference.

The equation (9) depicts the received signal at user U_i.

$$y_i = h_i x + w_i \tag{9}$$

The data rate of user U_N is given by (10).

$$R_N = \log_2\left(1 + \beta_N P|h_N|^2/\sigma_n^2\right) \tag{10}$$

Joint Antenna Selection beingemployed in the base station and user interface simultaneously for MIMO-NOMA systems is to be explored.

The instantaneous channel gains are deeply affected by the selection of different antennas and it also changes the order of the instantaneous gains. This pictures that the signal-to-interference-plus-noise (SINR) of many users are greatly affected by the decoding order which is largely affected by the antenna selection process. This complicates the antenna selection for MIMO-NOMA system non-trivial.

III. System Model

The system model analyzes the downlink scenario with a base station (BS) broadcasting to two multicast groups of users U1 and U2 as shown in Fig. 2. There are NA antennas in the base station and the set is given as N = {1, 2, . . .,NA}. The transmit antenna selection is performed among the set to maximize the system throughput. All the users in the groups are assumed to have single antenna and hence could perform only half duplex communication. The group of users classified as U2 are related to low-rate delay-sensitive applications and the devices are low power devices and limited processing capable devices, whereas the other group U1 is linked to high-rate delay-tolerant applications. The user 1 group can afford opportunistic connectivity and the devices are operating like the multimedia application devices which require more power comparatively. On the other hand, the user 2 group consistsof low power IOT sensors or healthcare devices. A quasi-static Rayleigh fading channels are considered for analysis. The data is transmitted from BS as a broadcast signal and both users receive the data. The broadcast is ceased only if any of the user from any of the group U1 ∈ U1 and U2 ∈ U2, decodes their respective data successfully. Every group has a coordinator who can locally communicate among the user groups and also with the BS. The BS sets its priority is successful delivery of information to both the user groups in spite of the disparity of procedures among them. The coordinator selection determines the number of BS transmissions.In case, the BS chooses the worst channel condition is as a coordinator then the BS is forced to communicate coded packets to confirm the effective decoding by all the users of the group instead of trusting on the coordinator’s backing. Thegroup which are not delay tolerant chooses a coordinatorsuch that it can be synced by BS without much delay in service.

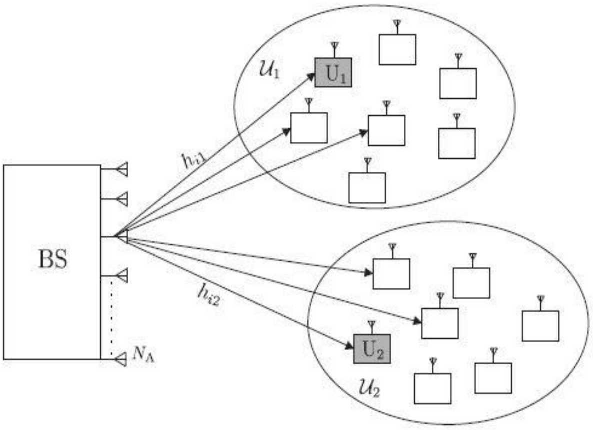

Fig. 2 Network showcasing the base station BS and the multicast groups U1 and U2, with the selected coordinators U1 and U2.

For a delay tolerant group, the BS can select a user whose channel conditions is the best. In [10] there is a detailed information on the severalapproaches for selecting coordinators from the information of their channel state (CSI). The channel gains h_{i1} and h_{i2} denotes the coefficient between i^{th} antenna of the BS and the coordinators of each group. As usual these coefficients are also modelled as zero-meancomplex Gaussian random variables. But the distribution is considered as independent and not identical. σ_{21} and σ_{22} denote the variances corresponding the user group 1 and 2. The frame to frame change in the channel coefficient is modelled by the quasi-static assumption.

IV. Simulation And Results

The implementation of the NOMA along with the Two stage transmit antenna selection scheme is simulated with the help of Monte Carlo simulation. The system model discussed above is used for the simulation and the performance is compared with the traditional OMA scheme. Also the performance is evaluated over the conventional antenna selection over the NOMA instead of Two-stage selection scheme. The table I gives the simulation parameters used. Fixed values to the different variables are set.

TABLE I. SIMULATION PARAMETERS

Parameters	**Values**
User, u	1,2
Variance of Gaussian Random Variable 1 , σ_1^2	2.9155
Variance of Gaussian Random Variable 2, σ_2^2	0.1715
Power allocation coefficient, $\mathbf{a_1}$	0.2
Power allocation coefficient, $\mathbf{a_2}$	0.8
Number of coded packets, $\boldsymbol{\tau_u}$	1
SNR threshold for User 1, γ_1	5.782dB
SNR threshold for User 1, γ_2	-0.983 dB

In Fig. 3, it is observed that the Energy efficiency of MIMO-NOMA(Two stage-TAS) is high at high signal to noise ratio (SNR) than MIMO-NOMA(Conv-TAS) and MIMO-OMA. In Fig. 4, the depiction is that the Energy efficiency of MIMO-NOMA (Two-stage-TAS) reduces when the number of users increases but with very high difference from MIMO-NOMA (Conv-TAS) and MIMO-OMA.

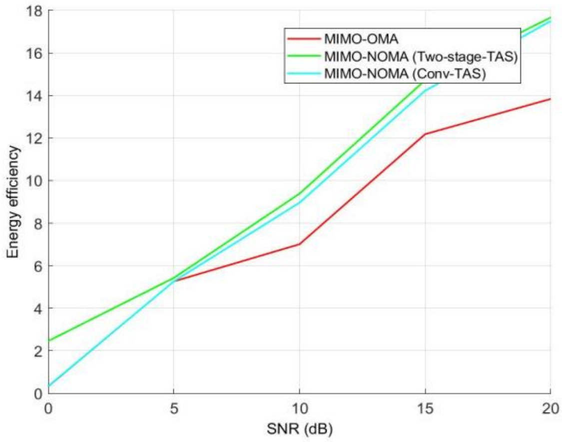

Fig. 3. Energy efficiency comparison among NOMA(Conv-TAS), NOMA(Two-stage-TAS) and OMA with respect to SNR(dB)

Fig. 5 illustrates the spectral efficiency of all the systems vary with very slight difference with respect to SNR of each systems. The curve shows that the spectral efficiency of proposed NOMA architecture is superior than other systems. The Twostage TAS is performing better in case of higher SNR regime whereas the low SNR is not of much advantage.

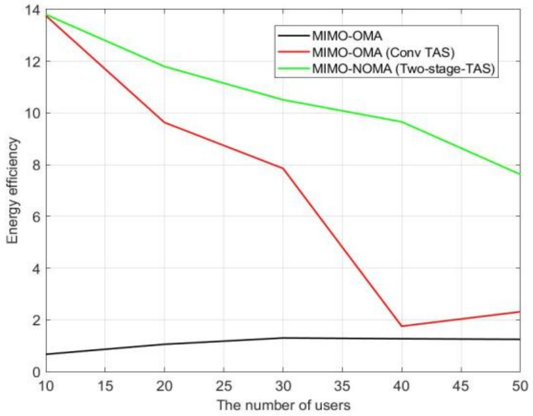

Fig. 4. Energy efficiency comparison among NOMA(Conv-TAS), NOMA(Two-stage-TAS) and OMA with respect to the number of Users

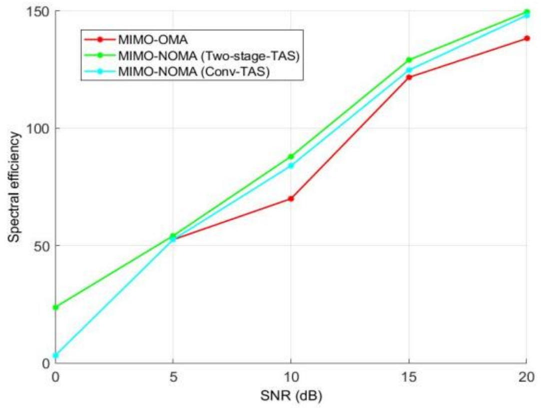

Fig. 5. Spectral efficiency comparison among NOMA(Conv-TAS), NOMA(Two-stage-TAS) and OMA with respect to SNR(dB)

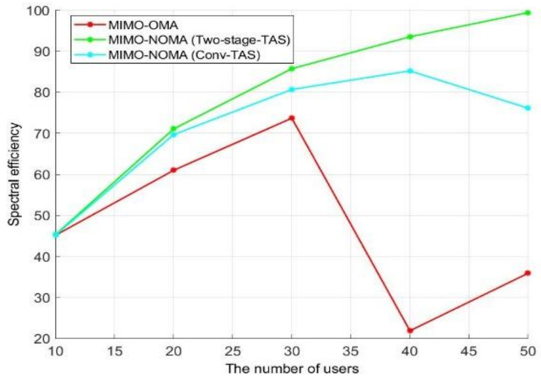

Fig. 6. Simulation results and the Spectral efficiency comparison among NOMA(Conv-TAS), NOMA(Two-stage-TAS) and OMA with respect to the number of Users

It is observed that MIMO-NOMA(Two stage-TAS) outperforms MIMO-NOMA(Conv-TAS) and MIMO-OMA with high spectral efficiency even with more number of users. Two-Stage TAS methodology is best suited in scenarios when there is need to adapt to different QoS requirements.

V. Conclusion

The requirement for low latency, high spectral and energy efficiency without diminishing the QoS requirement is addressed by the combination of a NOMA scheme with antenna selection. Further the two stage antenna selection gives and added advantage in maintaining the QoS requirement. The design parameters of the NOMA are the choice from the theoretical expression obtained for the desired QoS parameter. Theinfluence of TransmitAntenna selection on the performance of NOMA and conventional Orthogonal Multiple Accessing is analyzed. Over all network performance is significantly improved by adapting to the two-stage TAS criterion in combination with the NOMA and the comparisonwith the conventional TAS scheme depicts a very good advantage of the proposed scheme. The TS-TAS excellently exploits the benefits of multiple antennas. Further performance improvement can be achieved with significantly low power for transmission and network throughput by exploring NOMA-based RLC schemes.

References

[1] Amjad Saeed Khan, Ioannis Chatzigeorgiou, Sangarapillai Lambortharan, Gan Zheng “Network-Coded NOMA with Antenna Selection for the support of Two Heterogeneous Groups of Users” IEEE Transactions On Wireless Communications, Vol. 18, No. 2, pp.1332-1345, February 2018.

[2] X. Liu and X. Wang , “Efficient antenna selection and user scheduling in 5G massive MIMO-NOMA system” in Proc. IEEE Vehicular Technology Conference (VTC Spring), Nanjing, China, pp. 1-5, May 2016.

[3] Shahab Sanayei and Aria Nosratini, “Antenna Selection in MIMO Systems” IEEE Communications Magazine, pp.68-73, November 2004.

[4] Neelesh B. Mehta and Salil Kashyap, Andreas F. Molisch, “Antenna Selection in LTE: From Motivation to Specification” IEEE Communications Magazine, pp. 144 – 150, October 2012.

[5] V Y Zhang, J. Ge, and E. Serpedin, “Performance analysis of nonorthogonal multiple access for downlink networks with antenna selection over Nakagami-m fading channels,” IEEE Transactions on Vehicular Technology, vol. 66, no. 11, pp. 10590-10594, Nov. 2017.

[6] Yuehua Yu He Chen, Yonghui Li, Zhiguo Ding, Lingyang Song, and Branka Vucetic, "Antenna Selection in MIMO Non-Orthogonal Multiple Access Systems" IEEE Transactions on Vehicular Technology, Vol. 67, Issue 4, April 2018.

[7] I. Chatzigeorgiou, I. J. Wassell, and R. Carrasco, "On the frame error rate of transmission schemes on quasi-static fading channels," in Proc. 42nd Conf. Inf. Sci. Syst., Princeton, NJ, USA, pp. 577-581, March 2008.

[8] T. Cover, "Broadcast channels," IEEE Trans. Inf. Theory, vol.18, no. 1, pp. 2-14, January 1972.

[9] S. Vanka, S. Srinivasa, Z. Gong, P. Vizi, K. Stamatiou, and M. Haenggi, "Superposition coding strategies: Design and experimental evaluation," IEEE Tansanctions on Wireless Communications, vol. 11, no. 7, pp. 2628-2639, 2012.

[10] Z. Ding, R. Schober, and H. V. Poor, "Impact of user pairing on 5G nonorthogonal multiple –access downlink transmissions", IEEE Transactions on Vehicular Technology, vol. 65, no. 8, pp. 6010-6023, August 2016.