Review of Non- Orthogonal Multiple Access-Multiple Input Multiple Output (NOMA-MIMO) Model

Kenechukwu Anolue, SabinusIhedoro

Abstract: In recent times, we have seen a great need for mobile internet. This need increases as technology tries to make life better and solve world problems especially now there has been great push for internet of things. This raises the need for enhanced spectral efficiency to accommodate all internet needs, and most especially increase efficiency. The combination of Non-orthogonal multiple access with Massive Multiple Input Multiple Output will go a long way in solving this. NOMA has been proved to be the need technology for better Spectral efficiency, as it saves resources, and uses power efficiently in decoding information which is a sharp difference from the normal Orthogonal Multiple access we are used to, when coupled with MIMO, it shows a great throughput rate, which is very essential in mobile internet. Developing 5G is not left out, as it has been proved to show positive impact on it. We discuss the characteristics of NOMA, its model, mathematical analysis using a single antenna for downlink (as it covers both FTP download, and HTTP) transmission, and went on to prove its increased throughput in MIMO technology. This paper also shows the application on 5G technology, as other forms of NOMA are highlighted too.

Keywords:NOMA, MIMO,5G, SoDeMa, OMA, Throughput, SIC, IRC.

1. INTRODUCTION:

Over the years, there has been geometric increase in number of mobile phone users all over the world, also coupled with the recent push/desire of Internet of Things(IOT) in all life's sector, we discover communications is essential for daily life activities.
To meet up with demands for future radio access, small cells have been deployed, antennas have been combined together and distributed sparsely, each advancement improves spectral efficiency. Basically, improving wireless communication means to improve its throughput (bit/s), which is a product of bandwidth and spectral efficiency, the improvement of any of them or the two will result to a better throughput and a better way of increasing spectral efficiency is using multiple antennas (MIMO). Multiple Input Multiple Output has been developed and used over the years to solve fading problems, and was later advanced to MU-MIMO (Multi user MIMO) recently, there has been a paradigm shift in research from the usual Orthogonal Multiple Access (OMA) technologies to the Non-Orthogonal Multiple Access (NOMA) technologies for Massive MIMO to get the full benefits that was speculated for Massive MIMO, as NOMA has already been proved to be better than OMA analytically [4]. Orthogonal technologies are the OFMD, CDMA, TDMA which covers the 4G, 3G and GSM, which is currently in use for M-MIMO, while the NOMA technology looks to perfect 5G, and may serve as an aid for future technologies to come. This will reduce delays, accommodate a larger population, satisfy traffic demands reduce time lag in communication, increased spectral efficiency, robust and Lesser fading. NOMA allows frequency time and capacity resources to be shared in power and code domains. The power domain multiplexing is a major difference between OMA and NOMA since OMA allows variations in code multiplexing while NOMA maximizes the power Multiplexing in different variations. In this paper, we will look into power multiplexing and see its positive effect on interference, sum rate and capacity.

2.SYSTEM MODEL

In NOMA massive MIMO, tens of antennas on a base station serves hundreds of users at the same frequency resources with different power ratios. NOMA requires Successive Interference Cancellation (SIC) with a power allocation scheme that allocates more power to users with better channel gain. A superposition coding is formed in the power domain, where the separation is done with the SIC coupled with channel codes. The SIC is combined with another approach, Interference rejection combining (IRC) for cancelling interference due to difference in precoding ratios, this IRC is introduced because of Massive MIMO is involved.
The SIC receiver decodes the received signal for interference cancellation, it is used for intra-beam user multiplexing applying the same precoding weights. The IRC doesn't consider the channel gains and therefore is used for inter-beam user multiplexing. The random beamforming is required to increase the performance of the IRC.

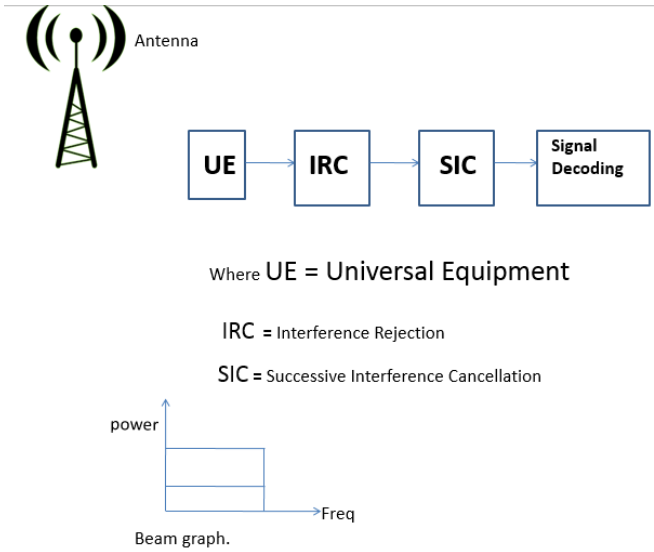

Fig 1: Block Diagram showing NOMA transmission in DL mode

3. NOMA/MIMO ANALYSIS

In this analysis, we consider throughput form its combination, and also give results of its channel capacity. Let overall transmission bandwidth be considered as 1GHz for easy computation. For single antenna transmission with two User Equipment (UE).
Transmission power- Pi, where i denotes users.
Superposition occurs in NOMA, and we have that the transmitted signals (x), are superimposed so that,

$$x = \sqrt{p_1}x_1 + \sqrt{p_2}x_2 \qquad (1)$$

Received signal

$$y_i = h_i x + N_{o,i} \qquad (2)$$

h_i is the channel coefficient between the UE and the Base Station (BS), $N_{o,i}$ represents power density. The decoding order occurs in an order of increasing channel gain[3], this makes it possible for a user to cancel interference from another user who have a lesser decoding order, i.e. if UE1 with channel gain $|h1|2 / N_{o,1}$> $|h2|2 / N_{o,2}$, it cancels the interference because it has a greater channel gain between the two, and therefore can decode signal x_1 without interference from x_2. The throughput for the users are given as;

$$R_1 = Log_2\left(1 + \frac{p_1|h_1|^2}{N_{0,1}}\right) \qquad (3)$$

$$R_2 = Log_2\left(1 + \frac{p_2|h_2|^2}{p_1|h_1|^2 + N_{0,2}}\right) \qquad (4)$$

If Pi is controlled with ratios summed to 1, the throughput can be easily adjusted for each UE [2]. This power allocation determines the throughput of each UE, and it is a major merit over OMA.
For ease of power allocation, we use Tree-Search based Transmission Power Allocation (TTPA) [6], this power allocation reduces the complexity of power allocation on NOMA models, and it is preferred over fractional Transmission Power Allocation (FTPA).
For Multi antenna transmission with two User Equipment (UE) or more; following assumptions are made; Links between the BS and the user are independent and identically distributed (i.i.d), Number of antennas for the UE is equal or larger than that at the BS, Downlink MIMO system is considered for this paper.

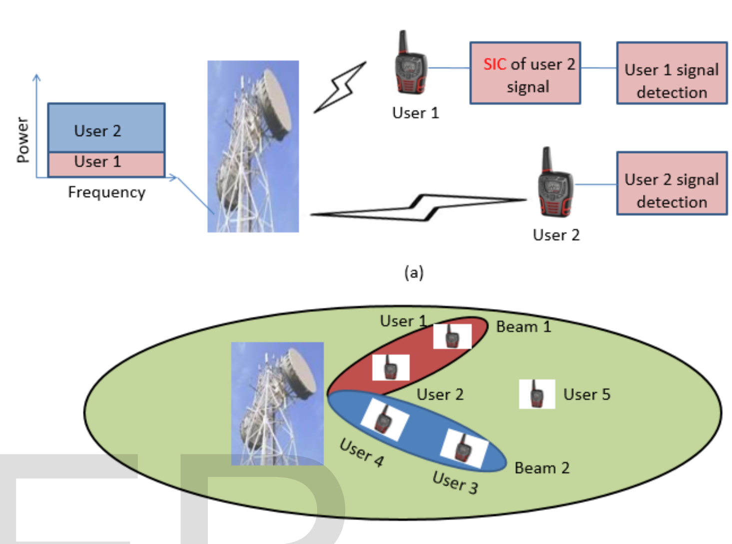

Fig 2: Diagram showing NOMA MIMO System in different beams and clusters.

Let the number of antenna transmitting data at the base station be equal to M, N represents the number of antenna of each receiver, where (N≥M).
For the Kth user in the Mth clusters, where L is the number of users in each cluster which must not be less than two UE in each cluster.
Channel Coefficient [h1,ml ⋯hm−1,ml hm+1,ml ⋯hM,ml] is represented in matrix as Channel matrix; $H_{m,l} \epsilon \mathbb{C}^{N,M}$, while White Addictive Gaussian Noise; $n_{m,l} \epsilon \mathbb{C}^{N,1}$ for all user(m,l). precoding Matrices is designed as P= I_M, I_M is an M x M identity matrix, detection vector; $|v_{m,l}|2$ =1 .$v_{m,l}^H H_{m,k}$Pk = 0 for $k \neq m$, obeying the identity matrix.
In relation to equation (1), in matrix;

$$x = P\bar{s} \quad (4)$$

Where

$$s = \begin{bmatrix} \sqrt{\gamma_{1,1}}s_{1,1} + \cdots + \sqrt{\gamma_{1,L}}s_{1,L} \\ . \\ . \\ . \\ \sqrt{\gamma_{M,1}}s_{M,1} + \cdots + \sqrt{\gamma_{M,L}}s_{M,L} \end{bmatrix} \qquad (5)$$

$\gamma_{M,L}$ represents power allocation coefficient and $s_{M,L}$ represents the received signal of user (M,L). where $\sum_{l=1}^{L} \gamma_m = 1$.
In relation to equation (2), received signal;

$$y_{m,l} = H_{m,l} P\bar{s} + n_{m,l} \quad (6)$$

Applying detection vector $v_{m,l}$ on the received signals, we can easily obtain, and with $v_{m,l}^{H} H_{m,k}$Pk $= 0$ for $k \neq m$

$$v_{m,l} y_{m,l} = v_{m,l} H_{m,l} P_m \sum \sqrt{\gamma_{M,L}} s_{M,L} + v_{m,l} n_{m,l} (7)$$

According to channel gain ranking for SIC to be implemented,

$$|v_{m,1} H_{m,1} P_m|^2 \geq \ldots \geq |v_{m,L} H_{m,L} P_m|^2$$

$$R_{m,L} = \mathrm{Log}_2\left(1 + \frac{p\gamma_{m,l} \ |v_{m,l} H_{m,l} P_m|^2}{1 + p\sum_{k=1}^{L} \gamma_m |v_{m,l} H_{m,l} P_m|^2}\right) \quad (8)$$

Addition of more users should also be considered to the cluster; the throughput rate reduces since power ratio also reduces accordingly [4].

The sum Channel capacity for the Mth cluster can be obtained

$$S_{m,L} = \sum_{l=1}^{L} R_{m,L}$$

$$S_{m,L} = \sum_{l=1}^{L} \mathrm{Log}_2\left(1 + \frac{p\gamma_{m,l} \ |v_{m,l} H_{m,l} P_m|^2}{1 + p\sum_{k=1}^{L} \gamma_m |v_{m,l} H_{m,l} P_m|^2}\right)$$

(9).

4. NOMA FEATURES FOR 5G DEVELOPMENT

There has been a recent move from 3G to LTE, and LTE-A, 5G is in circulation now, but is yet to be rolled out in most part of the world. The 5G requirements [11] are; 1-10Gbps connections to end points in the field, 1 millisecond end to end round trip delay(latency), 1000x bandwidth per unit area, 10-100x number of connected devices, up to ten-year battery life for low power, machine -type devices.

Massive MIMO is a good technology that will help in the development of 5G, Heterogenous Network (HetNet), is also a good technology in process, that combines other radio access technology in transmitting power.

In [5], a Software Developed Multiple Access (SoDeMa) was proposed for developing 5G. The Software Defined radio (SDR) was used as a concept in developing this scheme. SoDeMa just like HetNet combines both NOMA, MIMO and OMA technologies, and uses it for enhancing spectral efficiency. SoDeMa is made flexible for all Multiple access technology, which has its own specified purpose, small cells with even spread are also made available at different locations. It superimposes different access technology in different frames, which has its own different frequency, time, code and power resources as needed. This scheme is however seen as a good option to serve in any condition, or application needed. It is yet to be integrated in 5G, as more researches are made to determine its efficacy.

Pattern Division Multiplexing is a form of NOMA Scheme that uses code, and or Spatial Domain multiplexing, it is also used for uplink, and downlink transmission. Code multiplexing in this scheme aids in cancelation of interference, while spatial multiplexing is used to increase spatial diversity. Bit Division Multiplexing (BDM) also uses NOMA technology, here multiple user signals are superimposed in the bit domain, at different levels. It is used for downlink transmission.

5. CONCLUSION

This paper has explained what NOMA is all about, showing its mathematical relations with a single antenna, and MIMO combination. It also shows how NOMA can be integrated with MIMO to achieve a better system. The SoDeMa technology [5] developed through the idea of Software Defined Radio (SDR) for multiple access, is new and needs more research as this will aid HetNet maximize its full potential for 5G and future radio access technologies yet to come. Researches are going on currently to achieve a better system with NOMA as it has already been proved to be better than OMA.

REFERENCES

[1] S. Bhatia and Chandni, "A Review on NOMA Features for 5G Wireless Communication Network," International Journal of Trend in Research and Development, vol. 4, no. 3, p. 1, 2017.

[2] S. Yuya , Yoshihisa Kishiyama, Anass Benjebbour, Takehiro Nakamura, Anxin Li and Kenichi Higuchi, "Non-Orthogonal Multiple Access (NOMA) for Cellular Future Radio Access," IEEE, vol. 2, pp. 2-5, 2013.

[3] YANG LIU, GAOFENG PAN, HONGTAO ZHANG and MEI SONG, "On the Capacity Comparison Between MIMO-NOMA and MIMO-OMA," IEEE Access, vol. 4, pp. 2124-2125, 2016.

[4] A. Y. O. A. D. G. I. T. V. P. Ming Zeng, Capacity Comparison between MIMO-NOMA and MIMO-OMA with Multiple Users in a Cluster, arxiv, 2017.

[5] B. W. Y. Y. S. H. C.-L. I. a. Z. W. Linglong Dai, "Non-Orthogonal Multiple Access for 5G: Solutions, Challenges, Opportunities, and Future Research Trends," IEEE Communications Magazine, pp. 79-80, 2015.

[6] A. H. a. H. K. A. Li, "Investigation on low complexity power assignment method and performance gain of non-orthogonal multiple access

systems," IEICE trans. commun.

[7] W. Y.Liu, "Optimal joint rate and power allocation for layered multicast with superposition coding in cellular systems," ACM Wireless Network, vol. 19, p. 70, 2013.

[8] Z. D. a. H. V. Poor, "Design of massive-MIMO-NOMA with limited feedback," IEEE Signal Process, vol. 23, no. 5, p. 630, 2016.

[9] D. T. a. P. Viswanath, Fundamentals of Wireless Communication, Cambridge : Cambridge University Press, Cambridge, 2005.

[10] S. Han, "Energy Efficiency and Spectrum Efficiency Co-Design: From NOMA to Network NOMA," IEEE MMTC E-Letter, vol. 9, no. 5, p. 22, 2014.

[11] C. D. Dan Warren, Understanding 5G: Perspectives on future technological advancements in mobile., London: GSMA Intelligence, 2014.