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SUM CAPACITY ANALYSIS OF NOMA WITH BEAM SPACE BEAM FORMING

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ABSTRACT: In this paper, proposed a non-orthogonal multiple access (NOMA) network based on Beam Space Beam Forming that has been aimed at finding capacity performance in the MU wireless network for down link transmission. The comparative performance analysis of the proposed network model based on the multiple access schemes that include NOMA and OMA. As the key feature of NOMA is to serve the multiple users at the same time/frequency/code, but with different power levels, that provides a notable gain in sum capacity over preceding OMA. Keeping this feature in mind the power allocation strategy is implemented, to assign power to multiple users simultaneously. To exhibit improvement in the sum capacity, an algorithm is proposed, which is a distance detector with a memory which identifies the users in the current position and then differentiates them as a near and far user. Secondly, this detector then assigns powers to the user's as per the NOMA fundamentals. This algorithm selects two users; the selected users will have a large channel difference between them. That reduces the interference from adjacent user. To expand the sum capacity in multiuser multiple input multiple output NOMA network, beam space beam forming is in cooperated. The users in same beams with NOMA fundamentals will have high correlation between them that will reduce the inter-beam interference. The user pairing and power allocation methodology ensures that each user assigned power as per NOMA principle to maximize the sum capacity of users and will reduce the amount interference from adjacent beams and users. The capacity comparison exhibits that the multi-user multiple input multiple output NOMA with Beam Space Beam forming performs better than the conventional Beam Forming.

Keywords: Non-Orthogonal Multiple Access (NOMA), Sum Capacity, Multi-User (MU), Multiple Input Multiple Output (MIMO), Radio Access Technology, Beam Space Beam Forming, User Pairing, Distance Detector Algorithm.

INTRODUCTION

Due to the advancement in smart phone broadband systems the traffic load on traditional cellular networks is predicted to expand 1000 times in the following 10 years. To overcome the issue of system's capacity and coverage as a result of growing data traffic in cellular networks i.e. forwarding the boundaries of the passive wireless technology to maneuver into future 5G cellular networks by the planning of RATs. They are usually categorized by the multiple access schemes like, OMA and NOMA. With these schemes the system resources can be shared concurrently. This research is to analyze the down link sum capacity performance of 5G NOMA proposed network and address its challenges. The contributions of this research are; Theoretical capacity performance comparison of both NOMA and OMA schemes. Note that the individual users and sum capacity evaluation and comparison. The stationary and non-stationary users with their power co-efficient with user pairing algorithm the sum capacities are analyzed. To further extend the research, Beam space beam forming is in-cooperated in NOMA, to maximize the sum capacity performance of MU-NOMA network with the help of proposed distance detector algorithm. Recently, (Ali et al, 2012; Khan and Rizvi, 2013) wireless communications has drilled an enormous insurgency while a couple of decades prior usages of cell phones were limited to text messages and voice calls. With 3G, the use if data traffic increased and later with 4G, further expansion in data traffic. Due to this versatile broadband and information situated gadgets are invented (Liu and Zhang, 2016; Lei, 2016). These gadgets are to be fault for a quick development in versatile information (Khan *et al.*, 2016). Also, the quantity of workstations and tablets portable associated is expanding exponentially too that implies there will be more development in versatile information in future. In future, individuals are relied upon to be encompassed by shrewd articles in homes, workplaces, avenues, and urban areas; so in the savvy world (Timotheou and Krikidis; Wang *et al.*, 2016; Wei *et al.*, 2016). As it is as of now realize that the radio assets in the wireless range and transmit powers are constrained and current wireless technologies are not ready to oblige so the expansion in the rush hour gridlock request inside the accessible assets as the mobile networks need to manage the increment of the quantity of associated gadgets and furthermore the requests of clients for higher rates to permit redirections like ongoing video spilling and web based games. (Khan *et al.*, 2018), Therefore, mobile networks have to make progress in the wireless communications systems in order to meet the required demands for that new technologies are needed to make progresses in channel capacity performance of the system.

MATERIALS AND METHODS

In the power domain, both multiple access can hold multiple users. Therefore different users will be allocated different power levels in multiple access schemes. Users in NOMA network will receive same signal that contains the data for all users. Every user deciphers the most grounded signal first, and then subtracts the decipher signal from the received signal. SIC receiver iterates the subtraction until it finds its own signal. User which is near to the BS can cancel the signals of the farther user. Since the signal of the farthest user contributes the most of the received signal, it will decipher its own signal first. (Benjebbour *et al*., 2013; Ding *et al.*, 2015), proposed the network of power domain down link NOMA for two users, which is illustrated in Fig 1. The BS will transmit the messages of both $user_1$ and $user_2$, i.e., s_1 and s_2 , with powers coefficient p_1 and p_2. The signal which is transmitted is represented by;

$$x = \sqrt{p_1}s_1 + \sqrt{p_2}s_2 \quad (1)$$

where transmit power is $p_1 + p_2 = 1$. The signal received at $user_n$ is given by;

$$y_n = h_n x + v_n \quad (2)$$

where, h_n denotes the complex channel coefficient including the joint effect of large scale fading and small scale fading. Variable, v_n denotes the AWGN, the circularly symmetric complex Gaussian distribution with mean zero and variance

MIMO NOMA with beam space beam forming: For implementing MU-MIMO NOMA, the two key factors for pairing up the users are the correlation and channel gain. Therefore the users are paired in a way that they have high correlation and high channel gain differences to avoid inter-beam interference by doing this NOMA principle fulfilled (Islam *et al.*, 2016. In the last scenarios limited number of users assumed and NOMA principle was implemented over them.

Here in this proposed network design BS is centrally located, with ULA beams at equal distance d=0.5. It is assumed that single antenna per user and two users are assumed to be in a cluster i.e. beam that will share one beam vector. By sharing the beam vector, the interference parameter will rise for that clustering is done. (Benjebbour *et al*., 2013) The two paired user that are kept in a cluster are selected in a way that they have high channel gain difference and high correlation that will ensure they share same beam vector and NOMA is applicable (Ding *et al*., 2017; Ding *et al*., 2014). For NOMA user pairing the proposed distance detector algorithm is used. With which the powers are assigned to the users in pair.

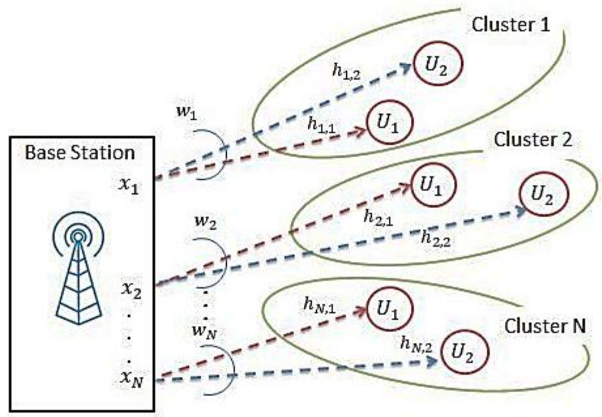

Figure-1. Down Link NOMA with Beam Space Beam Forming

The beam vector generated in this is assumed to be identity matrix, whose length represents the N vector of clusters. By doing this the inter cluster interference will be zero (Higuchi and Benjebbour, 2015). In a cluster, the near user with large channel gain and the far user with small channel gain. Their respective received signals in the nth cluster (1≤ n ≥ N) can be calculated as;

$$y_{k,n} = h_{k,n} \sum_{i=1}^{N} w_i x_i + n_{k,n} \quad (3)$$

Where $n \in 1,2$ and $k \in 1, \dots k$. The $x_{i.}$ consist of the transmitted signal of both bear and far users i.e. $x_i = \sqrt{p_{i,1}}s_{i.1} + \sqrt{p_{i,2}}s_{i.2}$. These $s_{i.1}$ and $s_{i.2}$ are the near far user signals respectively. $p_{i,1}$ and $p_{i,2}$ are the power coefficients of near far users. $h_{k,1}$ and $h_{k.2}$ are the channel vectors of both near far users in k^{th} cluster, respectively. The channel assumed is Rayleigh Fading with zero mean and unit variance. w_i is the beam space BF vector of the k^{th} cluster $k_{k,1}$ and $k_{k,1}$ are the AWGN vectors (Haci, 2018) .

The received SINR of the strong and weak users in the k^{th} cluster can be formulated as;

$$y_{k,1} = h_{k,1} w_k x_k + h_{k,1} \sum_{i=1, i\neq n}^{K} w_i x_i + n_{k,1}$$

$$= h_{k,1} w_k \sqrt{p_{i,1}} s_{i.1} + \sqrt{p_{i,2}} s_{i.2} + h_{k,1} \sum_{i=1, i\neq n}^{K} w_i x_i + n_{k,1} \quad (4)$$

The summation part in eqn: 12 represent the inter-cluster interference and $h_{k,1} w_k \sqrt{p_{i,2}} s_{i.2}$ is the inter-user interference. The both interference can be removed. Therefore the $y_{K,1}$ becomes;

$$y_{k,1} = h_{k,1} w_k \sqrt{p_{i,1}} s_{i.1} + n_{k,1} \quad (5)$$

The received $SINR_{K,1}$ is expressed as;

$$SINR_{K,1} = \frac{|h_{k,1}|^2 \propto_k \sqrt{p_{i,1}}}{\sigma_k^2} \quad (6)$$

On the other hand, for finding the SINR of the far user, the received signal can be calculated as;

$$y_{k,2} = h_{k,2} w_k x_k + h_{k,2} \sum_{i=1, i \neq n}^{K} w_i x_i + n_{k,2}$$
$$= h_{k,2} w_k \sqrt{p_{i,1}} s_{i.1} + \sqrt{p_{i,2}} s_{i.2} + h_{k,2} \sum_{i=1, i \neq n}^{K} w_i x_i + n_{k,2} \quad (7)$$

The received SINRk;2 is expressed as;

$$SINR_{K,2} = \frac{|h_{k,2}|^2 \propto_k \sqrt{p_{i,2}}}{\sigma_k^2} \quad (8)$$

For this new NOMA proposed network the power allocation formulation will remain same for NOMA users i.e. eqn: 9 but the new rate equations of the userk are formulated with
consideration of inter-beam interference that are;

$$R_{n,i} = log_2(1 + \frac{P_{n,i} \; P_i \; |h_{n,1}|^2}{\sum_{r=1}^{N} P_{r \neq i} \; |h_{n,i}|^2 + (N_{n,i}) + (I_{n,i})}), \; b/s/Hz \quad (9)$$

where $I_{k,n}$ is the inter beam interference power received by the $users_n$ and $P_{k,n}$ is the total power transmitted per cluster.

$$I_{k,n} = \sum_{j=1, j \neq n}^{N} \sum_{k=1}^{k} c_{j,k} \, p_k D_k(\theta_n) dist_n^{\propto} \quad (10)$$

$$P_k = \left\{ \frac{P_t}{K_s}, if \sum_{n=1}^{N} c_{n,1} = 1 \right\}$$
$$P_k = \left\{ 0, if \sum_{n=1}^{N} c_{n,1} = 0 \right\}$$

where, P_t is the transmitted power which is fixed and k is the number of beams assigned.

RESULTS AND DISCUSSION

Multiple User Sum Capacity Performance: In this section the NOMA users with Beam space beam forming are compared with the users on which simple beam forming that is each user will get one beam for doing fair simulations the NOMA beams are halved. In this simulation is it assumed that there are n-users, and two users are present in one beam for the case of NOMA and Beam space beam forming is applied on it. For the conventional beam forming single user gets single beam. In fig: 2 the plot of sum capacities clearly shows that NOMA performance is better than conventional beam forming. And the performance if the network will become static after the reaching a point where the number of beams and the users becomes equal. That is what is called conjunction in a network.

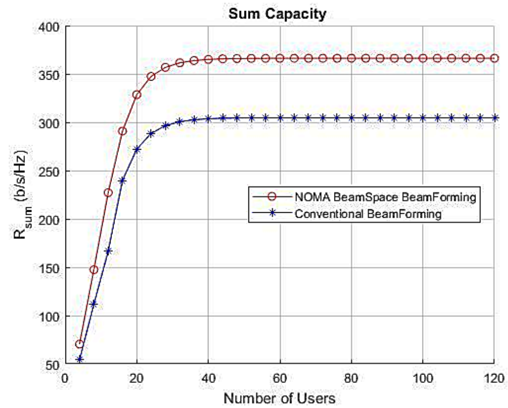

Fig. 2. Capacity of Users in NOMA with Beam Space Beam Forming

Sum Capacity Performance with Multiple Beams: In this simulation it is assumed that the number of users is fixed and beams are varied. Two users are present in one beam for the case of NOMA and Beam space beam forming is applied on it. For the conventional beam forming single user gets single beam. In fig: 3 the plot of sum capacities clearly shows that NOMA performance is better than conventional beam forming but the trend of the plot is decreasing as the number of users are less than the beams. In this plot at every point the network capacity performance will be different similar to the real time scenarios. Similarly for finding out the average rate performance per user the NOMA performs better. Both graph have a decreasing trend as by increasing the number of beams and users remains constant then the additional beams will not be assigned to any user therefore the performance of the overall will degrade. The fig: 4 explain this phenomenon.

Sum Capacity Performance with Resources Availability: This section is like wise to the previous scenarios but the plot is plot for doing the analysis on the resources availability to the NOMA users with Beam space beam forming are compared with the users on which simple beam forming that is each user will get one beam for doing fair simulations the NOMA beams are halved. In fig: 6 the plot of sum capacities clearly shows that NOMA performance is better than conventional beam forming. And the performance if the network will have decreasing trend as after usage of all the maximum number of resources the left users will not get the any further resources. This is explained in fig: 5 in which the average rate is plotted verses the varying number of users with fixed number of beams.

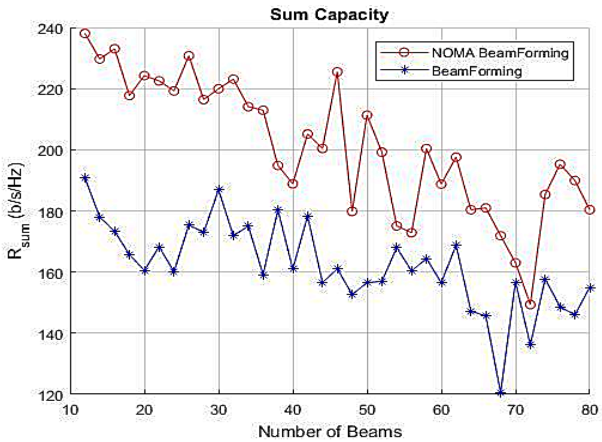

Figure-3. Capacity of Users in NOMA with Beam Forming

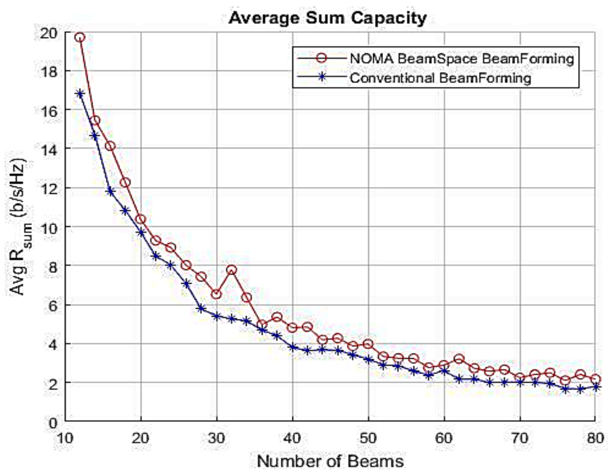

Figure-4. Average Capacity of Users in NOMA with Beam Forming

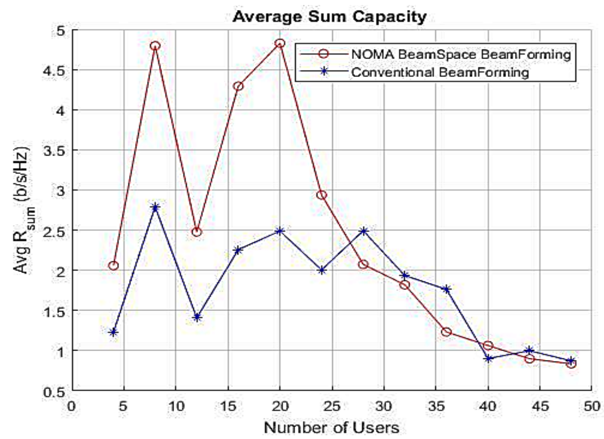

Figure-5. Average Capacity Performance with resources in NOMA Beam Space Beam Forming

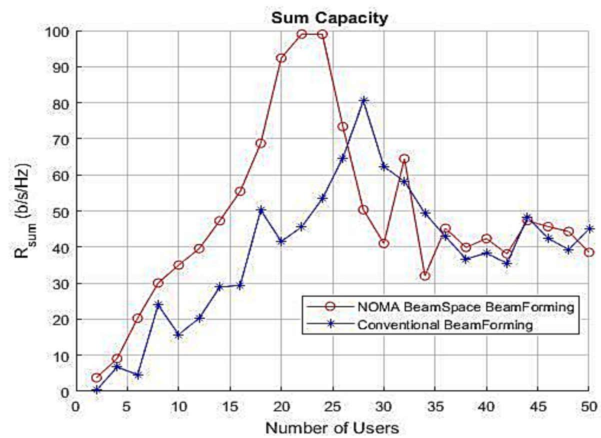

Figure-6. Capacity Performance with Resources in NOMA Beam Space Beam Forming

Conclusion: In this paper, 5G networks assuring multiple access scheme is discussed. This research empowers the idea of multiple users using single BS. The core challenge in this research was to achieve best possible capacity performance with the angle of the users generated at. Now, the designed network is able to show the capacity of users with new power equations that shows more improved results. Fundamentals of NOMA are presented in this research and also demonstrated that the NOMA out performs OMA in sum capacity. From a generic network model to a real-time network model in it is presented that the NOMA performance is superior than OMA. With MU-NOMA with Beam Space Beam Forming, the relation of paired NOMA is inversely proportional to the numbers users and the number of beams w.r.t the sum capacity. From this concludes that the sum capacity of users in a network will increase with the increasing number of the users. However, one challenge is present for successful implementation of NOMA that is power allocation optimization, particularly when there are multiple users are moving at different rates in the network. For enhancing the reliability of the proposed network, this research can be implemented with other techniques like other with coding schemes. The research demonstrated that NOMA is an invaluable multiple access scheme for future wireless networks. However, for the practical acknowledgment of the NOMA still much research exertion is expected to create propelled NOMA for preparing strategies. There are various fascinating research bearings that the research of this proposition can be expanded.

REFERENCES

Ali, S., E. Hossain and D.I. Kim (2016). Non-orthogonal multiple access (NOMA) for downlink multiuser MIMO systems: User clustering, beamforming, and power allocation. *IEEE access*, *5*, 565-577.

Benjebbovu, A., A. Li, Y. Saito, Y. Kishiyama, A. Harada and T. Nakamura (2013). System-level performance of downlink NOMA for future LTE enhancements. In *2013 IEEE Globecom Workshops (GC Wkshps)* (pp. 66-70).

Ding, Z., F. Adachi and H.V. Poor (2015). The application of MIMO to non-orthogonal multiple access. *IEEE Transactions on Wireless Communications*, *15*(1), 537-552.

Ding, Z., X. Lei, G.K. Karagiannidis, R. Schober, J. Yuan and V. Bhargava (2017). A survey on non-orthogonal multiple access for 5G networks: Research challenges and future trends. *IEEE Journal on Selected Areas in Communications*, *35*(10), 2181-2195.

Ding, Z., Z. Yang, P. Fan and H.V. Poor (2014). On the performance of non-orthogonal multiple access in 5G systems with randomly deployed users. *IEEE signal processing letters*, *21*(12), 1501-1505.

Haci, H. (2018). Performance study of non-orthogonal multiple access (NOMA) with triangular successive interference cancellation. *Wireless Networks*, *24*(6), 2145-2163.

Higuchi, K. and A. Benjebbour (2015). Non-orthogonal multiple access (NOMA) with successive interference cancellation for future radio access. *IEICE Transactions on Communications*, *98*(3), 403-414.

Islam, S.R., N. Avazov, O.A. Dobre and K.S. Kwak (2016). Power-domain non-orthogonal multiple access (NOMA) in 5G systems: Potentials and challenges. *IEEE Communications Surveys & Tutorials*, *19*(2), 721-742.

Khan, M.N., S.O. Gilani, M. Jamil, A. Rafay, Q.A. Awais, B.A. Khawaja and A.W. Malik (2018). Maximizing throughput of hybrid FSO-RF communication system: An algorithm. *IEEE Access*, *6*, 30039-30048.

Khan, M., S.K. Hasnain and M. Jamil (2016). *Digital Signal Processing: A Breadth-first Approach*. Stylus Publishing, LLC.

Khan, M.N. and U.H. Rizvi (2013). Antenna beam-forming for a 60 Ghz transceiver system. *Arabian Journal for Science and Engineering*, *38*(9), 2451-2464.

Liu, S. and C. Zhang (2016). Non-orthogonal multiple access in a downlink multiuser beamforming system with limited CSI feedback. *EURASIP Journal on Wireless Communications and Networking*, *2016*(1), 239.

Lei, L. (2016). *From Orthogonal to Non-orthogonal Multiple Access: Energy-and Spectrum-Efficient Resource Allocation* (Doctoral dissertation, Linköping University Electronic Press).

Timotheou, S. and I. Krikidis (2015). Fairness for non-orthogonal multiple access in 5G systems. *IEEE Signal Processing Letters*, *22*(10), 1647-1651.

Wang, J., H. Zhu, L. Dai, N.J. Gomes and J. Wang (2016). Low-complexity beam allocation for switched-beam based multiuser massive MIMO systems. *IEEE Transactions on Wireless Communications*, *15*(12), 8236-8248.

Wei, Z., J. Yuan, D.W.K. Ng, M. Elkashlan and Z. Ding (2016). A survey of downlink non-orthogonal multiple access for 5G wireless communication networks. *arXiv preprint arXiv:1609.01856*.