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A REVIEW ON POTENTIAL SOLUTIONS OF NOMA

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Abstract- Improved spectral efficiency is one of the major concerns of 5G networks in contrast with 4G systems. It needs high information rate with reduced interference and increase in capacity. For implementing 5G wireless networks, Non Orthogonal Multiple Access (NOMA) is one of the productive multiple access schemes over Orthogonal Multiple Access (OMA) schemes that are existing in the previous generation cellular mobile networks. Its main objective is to serve multiple users in the power domain with better bandwidth utilization. By deploying Successive Interference Cancellation (SIC) at the receiver side, the user can decode its information without any interference. In this paper, we have discussed about the basic concepts of NOMA, usage of cooperative NOMA (C-NOMA) and Multi Input Multi Output (MIMO) -NOMA with beam forming.
Keywords: NOMA, Superposition Coding, SIC, MIMO-NOMA, C-NOMA.

I. INTRODUCTION

NOMA is one of the trending multiple access techniques for 5G cellular mobile networks. The basic concept behind NOMA is to serve multiple users in the same time slot or frequency with different power levels[1]. It uses the power domain or code domain for providing multiple access schemes, while the previous generation cellular mobile networks focused only on time, frequency or code domain. This scheme can serve more number of users through the non-orthogonal spectrum resource allocation technique. It allows the source to transmit signal to all other users simultaneously by using the bandwidth of the entire system, which improves the spectral efficiency. NOMA can accommodate Superposition Coding (SC) in the base station transmitter and SIC in the receiver side to enhance spectrum efficiency. Also, it has the ability to adapt transmission strategy depending on the traffic and user's Channel State Information (CSI). The strong user is associated with better channel conditions because mostly it is located closely to the base station transmitter. If the lowest transmit power is allocated to a strong user and highest transmit power is allocated to weak user, then the weak user will encounter good channel condition. At the receiver side, SIC will first decode the strongest signal in order to reduce the inter cell interferences. In both uplink and downlink transmissions and wireless power transfer networks, it can be used. In downlink, strong user will successively decode the signal first and cancel the signals of weak users. Similarly, in uplink, the weak user will decode the signal first and cancel out the strong user's signals[2].

II.CATEGORIZATION OF NOMA

NOMA is categorized into two major approaches: power domain NOMA and code domain NOMA (Fig 1). The power domain NOMA achieves multiple accesses in power domain, whereas the code domain NOMA attains multiple accesses in code domain.

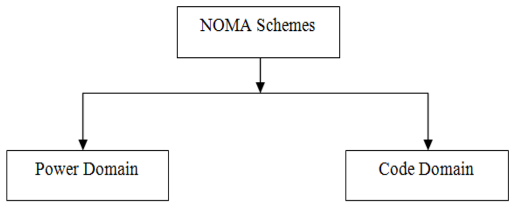

Fig 1: Basic categorization of NOMA

III.POWER DOMAIN

In power domain NOMA, different power levels are allocated to different users based on their channel state information to achieve maximum gain and SIC is used to reduce multi-user interferences[3]. Fig 2 illustrates the NOMA scheme through power domain multiple access with a SIC receiver in the downlink. At the receiver side, SIC is used to realize Multi-User Detection (MUD) and it is done at users with relatively high Signal-to-Interference Noise Ratio (SINR).

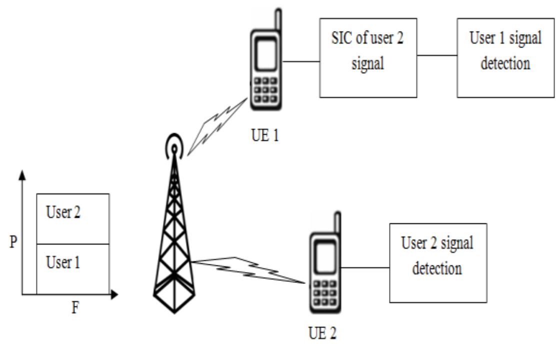

Fig 2: Power domain NOMA
(P- Power, F- Frequency)

IV.CODE DOMAIN

Code domain multiplexing is similar to Code Division Multiple Access (CDMA). It uses the entire time and frequency slots. It has the capability to provide good spreading gain and shaping gain with improved signal bandwidth[3]. Code domain NOMA is categorized into several approaches like low density spreading CDMA, low density spreading OFDM and parse code multiple access.

V.SUPERPOSITION CODING (SC):

The superposition coding is used to transmit signals to a number of receivers from a single source at the same time. The user nearer to the base station will get more gain without interference compared to the far away user[4]. In a two user scenario, the source needs to encode information ... r decodes the received encoded information, the interference from nearby users might be present. But the nearby users have a high link capacity gain with the base station, so it can decode the received information packet by subtracting the far user signals from the received signals. Fig 3 represents the two user SC (N-near the user, F-far user).

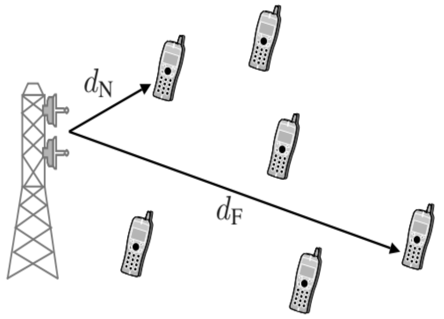

Fig 3: SC for two users

The superposition coding is an acknowledged non orthogonal scheme. Capacity of scalar Gaussian broadcast channel can be achieved with SC[5]. In order to elaborate the performance of superposition coding, fig 4 represents the signal constellation diagram of user 1 with higher transmitting power and user 2 with lower transmitting power and the constellation of user 1 is superimposed by user 2.

VI.SUCCESSIVE INTERFERENCE CANCELLATION (SIC)

The SIC is the most powerful interference cancellation-based scheme in terms of Bit-Error-Rate (BER) performance. The concept behind this scheme is that the users can decode the received signal efficiently. In SIC, users are aligned with respect to their signal strength. The receiver decodes the strongest signal first and cancelled it from the combined signal and later it decodes the signal which is having the weakest signal strength[6]. The SIC aims to improve system capacity and performance gain. Fig 5 illustrates the decoding of superimposed signals. As shown in the figure, after decoding the constellation point of user 1, constellation of user 2 will be decoded with respect to the user 1's decoded constellation point.

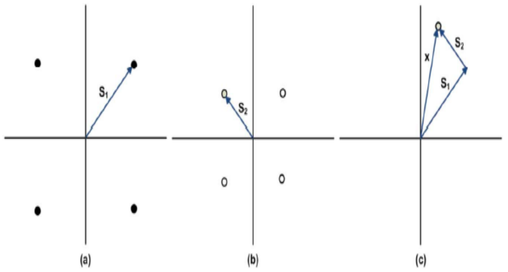

Fig 4: Encoding in SC (a) User 1's constellation (b) User 2's constellation (c) Superimposed signal constellation diagram [2]

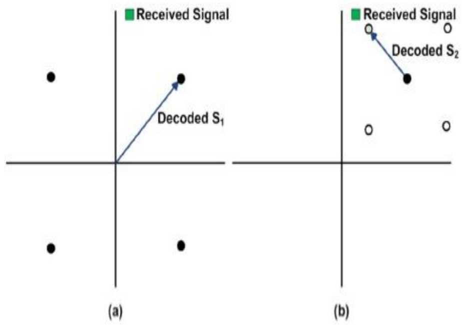

Fig 5: Decoding in SC (a) Decoding user 1 (b) Decoding user 2 [2]

VII.EFFECTIVE SOLUTIONS FOR NOMA

For enhancing the encapsulation process of NOMA in 5G network, few effective methods or schemes can be combined with NOMA to overcome the existing issues. The collaborative schemes of NOMA are MIMO-NOMA with beam forming and C-NOMA, which enables to combat fading, path loss and to gain improved capacity.

VIII.NOMA-MIMO WITH BEAM FORMING

To achieve high spectrum efficiency and high throughput gain at downlink side, combined MIMO-NOMA[7] can be implemented which consists of two or more base stations and multiple user equipment (i.e., mobile users in wireless cellular mobile communication systems). In MIMO (Multi Input Multi Output), the directional communication can be implemented using beam forming signal processing technique. System capacity can be enhanced using the conventional multi user directional beam forming technique in MIMO systems. Under multi user beam forming scheme, each user is supported with single beam forming signal that is orthogonal to other channel users to alleviate the interference from other users and to enhance the sum capacity of the system.

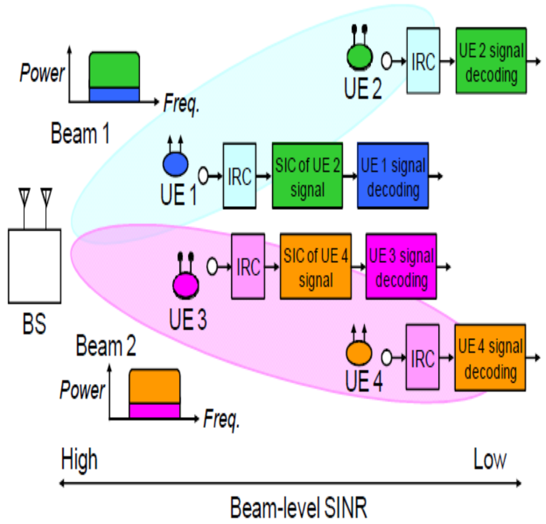

Fig 6: NOMA-MIMO with SIC-IRC receivers [7]

Fig 6 illustrates one type of combining NOMA-MIMO with random opportunistic beam forming. Here, at the transmitter side, multiple users are superimposed with single beam and at the receiver side, users uses two interference cancellation approaches. In a group of users with the same pre-coding weights, SIC technique is used to reduce intra-beam interference. Similarly, in a group of users with different pre-coding weights, Interference Rejection Combining (IRC) technique is used to reduce inter-beam interference. It is also called as interference suppression technique. By using IRC, there will be no need to decode other user equipment groups in other beams.

By combining both NOMA and multi user beam forming techniques, we can achieve enhanced total system capacity and reduced interferences [8]. This combined scheme can support two users with single beam forming signal. Based on user's correlation and variation in channel gain, NOMA with multi user beam forming technique can be developed by using grouping and power granting algorithm stated in Kimy et al. [8] to reduce the interferences. (i.e., intra-beam interference and inter-beam interference). NOMA with multi user beam forming has achieved the enhancement of total system capacity compared to conventional beam forming scheme by using optimal and reduced complexity sub

nsmit power

constraint[9]. It also considers the weak user's capacity to ensure user fairness.

Consider two user NOMA with beam forming consisting of N clusters (i.e., two users in each cluster). By keeping the weak user's capacity at least equal to the conventional multi user beam forming system capacity, power allocation scheme of N^{th} cluster enhanced the total capacity. This clustering algorithm is based on correlation between channels and zero forcing pre-coding matrices. From this approach, two users in a cluster can achieve similar benefits from zero forcing pre-coding matrices. But, whenever there is not enough user sets with high channel correlation, the performance of the system will be degraded due to increased interference among multiple users. To overcome this problem, researchers have investigated and designed a pre-coding matrix for MIMO-NOMA with beam forming which achieved a higher total data rate[10] in the vision of multi user interference. Also in a basic NOMA downlink, researchers have designed pre-coding and detection matrices for all users with a fixed power granting scheme[1]. MIMO-NOMA can result in better outage performance when compared to conventional MIMO with Orthogonal Multiple Access (OMA). In single antenna system, the strong user (user which has high channel gain) is creditable for successive interference cancellation and decoding. But in MIMO systems, pre-coders normally affect the signal to interference noise ratio of strong as well as weak users. From this, it is seen that the weak user's capacity is limited by the decoding performance of strong as well as weak users. So in each cluster, the same pre-coder for both strong and weak user is not adequate. Sun et al. [11] have used different pre-coders for a cluster with two users to further enhance the total system capacity.

IX.COOPERATIVE NOMA

C-NOMA relies on cooperation among NOMA users, i.e., users with strong channel conditions act as relays. The cooperative NOMA transmission makes use of prior data available in NOMA systems. Receivers are employed with successive detection scheme in which users with perfect channel conditions should help the users with poor channel conditions that are connected to the base station in decoding their messages and hence these users with perfect channel condition can play a role of relays to provide better reliability over reception[12]. Further betterment of transmission reliability for a user with bad channel conditions can be aided with dedicated relays. In Coordinated Direct and Relay Transmission (CDRT), NOMA is introduced and it plays a vital role in gathering the side information. Base Station (BS) performs two communications simultaneously as shown in fig 7: one is direct transmission with User Equipment 1 (UE1) and second communication is through a relay with User Equipment 2 (UE2). The side information is obtained with less complexity based on the basic NOMA property, which enables non orthogonal CDRT with achievable excellent sum capacity compared to non-coordinated direct and relay transmission[13]. Multiple users with multiple antennas can be served using dedicated relays as shown in fig 8, by introducing NOMA in multiple-antenna with Amplify-and-Forward (AF) cooperative protocol which increases the system performance. In this method, the Base Station (BS) and the mobile users (MU) are equipped with multiple antennas. With the requirement of increasing number of antennas, research is going on for incorporating more antennas in a smaller space. This increases mutual coupling leading to performance degradation. To avoid this, there exists a few mutual coupling reduction methods like introduction of decoupling slots and defective ground structure, which plays a vital role in reducing the interference and improving spectral efficiency[14][15]. To avoid system complexity, the relay node is considered as a single-antenna device.

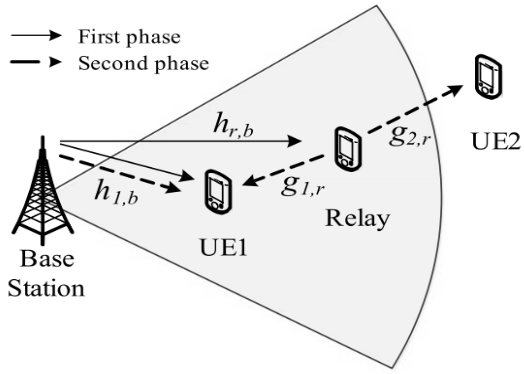

Fig 7: UE1 with direct transmission and UE2 transmission via relay [13]

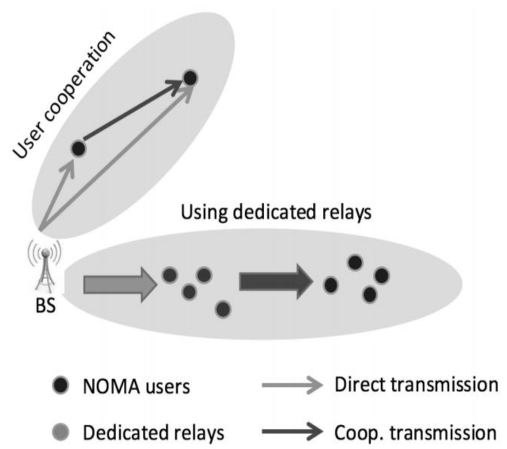

Fig 8: C-NOMA with dedicated relays [16]

It can be implemented to cellular communication or wireless sensor networks where transmission of data is from the multiple-antenna source node to multiple-antenna access points with the help of mobile relay, which is restricted to a single-antenna device because of its size and power constraints. By introducing a transmit antenna selection method at BS and MRC combining scheme at mobile users, simultaneous communication of the base station with multiple mobile users via relay node can be made possible[16]. In cooperative NOMA, wireless power transfer method is applied where near users are energy constrained and energy will be harvested from received RF signals. Far NOMA user's reliability can be improved without exhausting the battery of near users, by applying Simultaneous Wireless Information and Power Transfer (SWIPT) to near NOMA users. The collaboration of cooperative NOMA and SWIPT results in spectral efficiency and energy efficiency and hence it is called as cooperative SWIPT-NOMA protocol (multiple access protocol). To analyze the impact of randomly deployed user location, stochastic geometry is used in the above protocol. The users are deployed in two groups with random and spatial consideration in addition to homogeneous Poisson point processes where the near users are clustered together and deployed randomly close to the base station, whereas far users are clustered into another group and deployed close to the edge of the BS cell. NOMA is restricted to co-channel interference and NOMA is combined with a conventional OMA system which is most important to realize a hybrid MA network. Specifically, this hybrid MA scheme can effectively minimize the complexity of the system since some users are clustered together for the effective implementation of NOMA. The three tactful user selection schemes used to investigate the selected NOMA user's performance based on locations of users are:

1) Random Near user selection and Random Far user selection (RNRF), in which the near and far users are randomly selected from two groups.

2) Nearest Near user selection and Nearest Far user selection (NNNF), in which near user and far user closest to the BS are selected from two groups.

3) Nearest Near user selection and Farthest Far user selection (NNFF), where a near user close to the BS is selected and a far user far from the BS is selected[17].

X.CONCLUSION

In this paper, we have reviewed the concepts of NOMA and future scope of NOMA in 5G networks. NOMA in 5G network enables to achieve high data rate and better capacity over orthogonal multiple access schemes that are existing in previous generation cellular mobile networks. By using NOMA scheme, we can serve multiple users simultaneously at power domain. It can also be implemented in uplink as well as in downlink transmissions. Introduction of superposition coding at sender and SIC at receiver reduces the interference. Cooperative communication and MIMO beam forming in NOMA results in efficient utilization of spectrum, reduced path loss and fading effects.

REFERENCES:

[1] Z. Ding, F. Adachi, and H. V. Poor, "The Application of MIMO to Non-Orthogonal Multiple Access," *IEEE Trans. Wirel. Commun.*, vol. 15, no. 1, pp. 537–552, 2016.

[2] S. M. R. Islam, N. Avazov, O. A. Dobre, and K. S. Kwak, "Power-Domain Non-Orthogonal Multiple Access (NOMA) in 5G Systems: Potentials and Challenges," *IEEE Commun. Surv. Tutorials*, vol. 19, no. 2, pp. 721–742, 2017.

[3] L. Dai, B. Wang, Y. Yuan, S. Han, C. L. I, and Z. Wang, "Non-orthogonal multiple access for 5G: Solutions, challenges, opportunities, and future research trends," *IEEE Commun. Mag.*, vol. 53, no. 9, pp. 74–81, 2015.

[4] T. Cover, "Broadcast channels," *Inf. Theory, IEEE Trans.*, vol. 18, no. 1, pp. 2–14, 1972.

[5] S. Vanka, S. Srinivasa, Z. Gong, P. Vizi, K. Stamatiou, and M. Haenggi, "Superposition coding strategies: Design and experimental evaluation," *IEEE Trans. Wirel. Commun.*, vol. 11, no. 7, pp. 2628–2639, 2012.

[6] N. I. Miridakis and D. D. Vergados, "A survey on the successive interference cancellation performance for single-antenna and multiple-antenna OFDM systems," *IEEE Commun. Surv. Tutorials*, vol. 15, no. 1, pp. 312–335, 2013.

[7] K. Higuchi and Y. Kishiyama, "Non-orthogonal access with random beamforming and intra-beam SIC for cellular MIMO downlink," *IEEE Veh. Technol. Conf.*, 2013.

[8] B. Kimy *et al.*, "Non-orthogonal multiple access in a downlink multiuser beamforming system," *Proc. - IEEE Mil. Commun. Conf. MILCOM*, pp. 1278–1283, 2013.

[9] Q. Sun, S. Han, C.-L. I, and Z. Pan, "On the Ergodic Capacity of MIMO NOMA Systems," *IEEE Wirel. Commun. Lett.*, vol. 4, no. 4, pp. 405–408, 2015.

[10] J. Kim, J. Koh, J. Kang, K. Lee, and J. Kang, "Design of user clustering and precoding for downlink non-orthogonal multiple access (NOMA)," *Proc. - IEEE Mil. Commun. Conf. MILCOM*, pp. 1170–1175, 2015.

[11] Q. Sun, S. Han, Z. Xu, S. Wang, I. Chih-Lin, and Z. Pan, "Sum rate optimization for MIMO non-orthogonal multiple access systems," *2015 IEEE Wirel. Commun. Netw. Conf. WCNC 2015*, pp. 747–752, 2015.

[12] Y. Liu, Z. Ding, M. Eikashlan, and H. V. Poor, "Cooperative non-orthogonal multiple access in 5G systems with SWIPT," *2015 23rd Eur. Signal Process. Conf. EUSIPCO 2015*, vol. 19, no. 8, pp. 1999–2003, 2015.

[13] J. Bin Kim and I. H. Lee, "Non-orthogonal multiple access in coordinated direct and relay transmission," *IEEE Commun. Lett.*, vol. 19, no. 11, pp. 2037–2040, 2015.

[14] R. Darwin, G. Ishwarya, **"**Dual Band Mimo Antenna Using Decoupling Slots For WLAN Applications," *Journal of Advanced Research in Dynamical and Control Systems*, Special Issue, pp. 1138-1147, 2017.

[15] L. Charliene Karunya, R. Darwin, "Multiple Input Miniaturized Fractal Antenna for Terrestrial Services", *IEEE Xplore, International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, pp. 2444-2447, 2016.

[16] J. Men and J. Ge, "Non-Orthogonal Multiple Access for Multiple-Antenna Relaying Networks," *IEEE Commun. Lett.*, vol. 19, no. 10, pp. 1686–1689, 2015.

[17] Y. Liu, Z. Ding, M. Elkashlan, and H. V. Poor, "Cooperative Non-orthogonal Multiple Access with Simultaneous Wireless Information and Power Transfer," *IEEE J. Sel. Areas Commun.*, vol. 34, no. 4, pp. 938–953, 2016.