Fractional Power Allocation Scheme for NOMA

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Abstract - Non-orthogonal multiple access (NOMA) has currently received significant consideration as a promising possibility for a fifth generation (5G) frameworks. NOMA is a basic empowering technology for 5G wireless networks to meet the heterogeneous requests on low inactivity, high dependability, enormous availability, and high throughput. NOMA is a upcoming downlink multiple access (MA) scheme accomplishes huge spectral proficiency by consolidating superimposed coding with successive interference cancellation (SIC) at the transmitter and receivers respectively. The NOMA scheme achieves a lower outage probability. Here we considered the probability of outage and bit error rate performance (BER) for downlink and uplink NOMA. Simulation results show that user channel gain and fractional power allocation of total power to user will play a vital role in the probability of outage, BER and sum rate capacity.

Keywords - NOMA, SIC, probability of outage, sum rate capcity, channel gain

INTRODUCTION

NOMA is an extra shape for giving a multi-client access scheme. NOMA utilizes the power domain to separate signals, a strategy that has not been utilized within 2G, 3G or 4G. NOMA is newly preferred for 3GPP LTE and is imagined to be a fundamental section of 5G mobile framework [5]. The main element of NOMA is to help multiple clients in the meantime/frequency/code, yet with various power levels, which yields a huge spectral proficiency gain over conventional orthogonal MA. NOMA allows each resource slot to be exploited by multiple users.

Conventional Orthogonal Multiple Access (OMA) facilitates restricting number of clients because as a result of restriction in the number of orthogonal resource blocks, that restrict the spectral proficiency as well as the capability of current networks. OMA serves one user in individual orthogonal resource slot. Spectral efficiency of OMA will be very poor where one user has poor channel condition and in turn reduces the throughput of the overall system.

NOMA does not compromise on fairness, as a result net throughput of NOMA can be noteworthy than OMA. NOMA enables massive connectivity which is key to support for connecting a larger number of users and distinct category of users and applications in 5G, diverse Non Orthogonal Multiple Access (NOMA) schemes being studied [4]. NOMA has been shown to be compatible with existing wireless systems and can be integrated with other communication technologies to further improve their efficiency. For instance NOMA can be blended with existing OMA techniques such as TDMA and OFDMA [6].

Power domain NOMA is measured as an efficient multiple access system for 5G Framework. NOMA enables simultaneously serving two users on the same OFDMA subcarrier [3]. NOMA relevant methods includes NOMA multiplexing in the multiple antenna domain, power domain NOMA, and code domain NOMA. The proposed Power NOMA scheme has been discussed in Section II, Downlink and Uplink NOMA is presented in section III and Section IV presents simulation outcome, Section V represents conclusion.

I. RELATED WORK

NOMA has immense potential towards enhancing the spectral efficiency in 5G networks and supporting massive connectivity. NOMA facilitates serving multiple users over the same frequency and time resources via power domain and/or code domain multiplexing that would enhance the system access performance.

OFDMA is broadly utilized and extremely fruitful for 4G and could be utilized as a 5G multiple access method. Although it does necessitate the utilization of OFDM and necessitating orthogonality among carriers and the utilization of a cyclic prefix has few disadvantages. Accordingly, other multiple access methods are being investigated example SCMA (sparse code multiple access) and NOMA. In SCMA, information symbols are straightforwardly mapped to multi-dimensional sparse codewords chosen from layer-precise SCMA codebooks. NOMA method has been established for probable utilization with 5G and other highly developed communications systems. The plan is that it will enhance spectral efficiency of the wireless radio access.

To derive the signal, SIC is utilized at the receiver. The channel benefits consisting of components along with the path loss and accepted SNR distinction between clients is converted into multiplexing gains. It is then easier to detach the higher level signals at the receiver and consequently cancel it to leave only low level signal. In this manner, NOMA utilizes the path loss differences among clients, despite the matter that, it requires additional handling power in the receiver. Instead power sharing decreases the power assigned to every client, both clients - those with large channel gains up and those with lower channel gains take advantage of being planned more frequently and by being allocated more bandwidth. This implies NOMA empowers system capacity and fairness of allocations to be enhanced for all clients. Notwithstanding this NOMA can assist a greater number of connections than other systems and this will result to be especially valuable in perspective of the enormous anticipated increment in network for 5G emerges.

II. METHODOLOGY

NOMA is capable of serving large no. of users by using less resource slots. A key feature of NOMA, it allocates more power to the weak users. Here the execution of the NOMA schemes in terms of outage probability and achievable sum rate for the optimum power allocation is evaluated.

A. Unordered downlink NOMA

NOMA downlink shown in fig.1, the base station creates a superposed signal containing data of both the user

$$X = \sqrt{P_1 \rho_s}\, X_1 + \sqrt{P_2 \rho_s}\, X_2 \qquad (1)$$

Where $\rho_s = \frac{P}{\sigma^2}$, P = Total transmission Power,

$\sqrt{P_1 \rho_s}$ = Fraction of P to user 1 ,

$\sqrt{P_2 \rho_s}$ = Fraction of P to user 2.

At the receiver first the user with the higher transmit power is recognized and decrypted, after decoding this signal will be eliminated from the composite signal to ease the decoding of remaining user. Then, the corresponding signal is removed from the received signal.

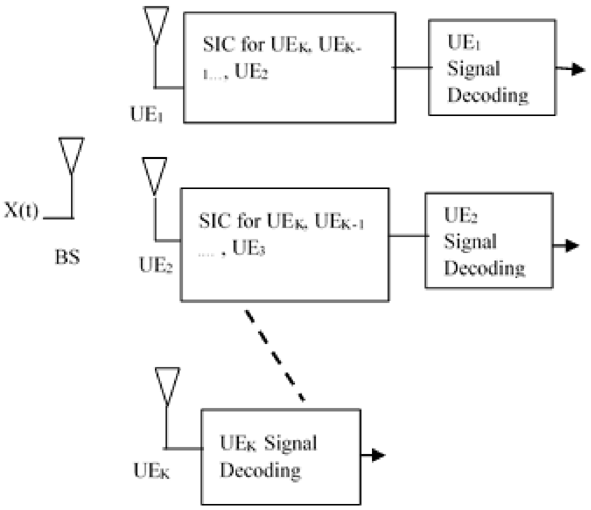

Fig 1. Downlink NOMA

In case of unordered NOMA User1 received signal is given by

$$Y_{11} = \left(\sqrt{P_1 \rho_s}\, X_1 + \sqrt{P_2 \rho_s}\, X_2\right) h_1 + N1 \qquad (2)$$

Decoding of user1 at user1, SNR is

$$SNR_{11} = \frac{P_1 \rho_s |h_1|^2}{P_2 \rho_s |h_1|^2 + 1} \qquad (3)$$

At user2 received signal is given by

$$Y_{12} = \left(\sqrt{P_1 \rho_s}\, X_1 + \sqrt{P_2 \rho_s}\, X_2\right) h_2 + N2 \qquad (4)$$

Decoding of user1 at user2 SNR is

$$SNR_{12} = \frac{P_1 \rho_s |h_2|^2}{P_2 \rho_s |h_2|^2 + 1} \qquad (5)$$

After decoding first user and cancelling interface the received signal at user2 is

$$Y_2 = \left(\sqrt{P_2 \rho_s}\, X_2\right) h_2 + N1 \qquad (6)$$

SNR for decoding user2 is

$$SNR_{22} = P_2 \rho_s |h_2|^2 \qquad (7)$$

For user1 the probability of outage occurs when $SNR_{11} < R_1$Where R_1 is ratio of P_1 to P_2. For user1 the probability of outage is given by

$$User1\ Probability\ of\ outage = 1 - \exp\left(-\left(\frac{R_1}{(P_1 - P_2 R_1)\rho_s \delta_1^2}\right)\right) \quad \text{Where } \delta_{1} = E|h_1|^2 \qquad (8)$$

For user2 the probability of outage occurs when $SNR_{22} < R_2$ where R_2 is ratio of P_2 to P_1. For user2 the probability of outage is given by

$$User2\ Probability\ of\ outage = 1 - \exp\left(-\frac{1}{\delta_2^2} \max\left(\left(\frac{R_1}{(P_1 - P_2 R_1)\rho_s}, \frac{R_2}{(P_2)\rho_s}\right)\right)\right) \qquad (9)$$

Where $\delta_{2} = E|h_2|^2$

B. Ordered downlink NOMA

The decoding order is fixed users are order such as weakest user first or stronger user. Each user is given a token user1 is decoded first and then the user2. Decoding protocol does not depend on the channel gain of user1 is $min\{|h_1|^2, |h_2|^2\}$ and Channel gain for user 2 is $max\{|h_1|^2, |h_2|^2\}$

$$User1\ Probability\ of\ outage = 1 - \exp\left(-\left(R_1/(P_1 - P_2 R_1\right)\rho_s \delta_3^2\right) \qquad (10)$$

Where δ_3 *is Hormonic mean of* δ_1 *and* δ_2

$$User2\ Probability\ of\ outage = 1 - \exp\left(-\left(\frac{\varphi}{\rho_s \delta_1^2}\right)\right) - \exp\left(-\left(\frac{\varphi}{\rho_s \delta_2^2}\right)\right) + \exp\left(-\left(\frac{\varphi}{\rho_s \delta_3^2}\right)\right) \qquad (11)$$

Where $\varphi = \max\left\{\left(\frac{R_1}{(P_1 - P_2 R_1)}, \frac{R_2}{(P_2)}\right)\right\}$

C. Unordered Uplink NOMA

Fig. 2 represents uplink NOMA where base station receives the superimposed signal comprising of symbols of both the users

$$Y_{BS1} = h_1\left(\sqrt{P_1\rho_s}\,X_1\right) + \left(\sqrt{P_2\rho_s}\,X_2\right)h_2 + N_{BS} \quad (12)$$

Decoding of user1 at Base, SNR is

$$SNR_{BS1} = \frac{P_1\rho_s|h_1|^2}{P_2\rho_s|h_2|^2 + 1} \quad (13)$$

After decoding first user and cancelling interface the received signal at user2 is

$$Y_{BS2} = \left(\sqrt{P_2\rho_s}\,X_2\right)h_2 + N_{BS} \quad (14)$$

SNR for decoding user2 at base station is

$$SNR_{BS2} = P_2\rho_s|h_2|^2 \quad (15)$$

$User1\ Probability\ \ of\ outage\ =$

$$1 - \{\exp(-\frac{\left(\frac{R_1}{P_1\rho_s\delta_1^2}\right)}{1+\left(\frac{R_1P_2\delta_2^2}{P_1\delta_1^2}\right)}\} \quad (16)$$

Outage probability does not occur for user2 when $SNR_{BS1} \geq R_1\ and\ \ SNR_{BS2} \geq R_2$.

$User2\ Probability\ of\ outage\ =$

$$1 - \exp\left(-\left(\frac{R_1}{P_1\rho_s\delta_1^2} + \frac{R_1}{P_2\rho_s\delta_2^2} + \frac{R_1R_2}{P_1\rho_s\delta_1^2}\right)\right)/\left(\frac{R_1}{P_1\delta_1^2}\right) \quad (17)$$

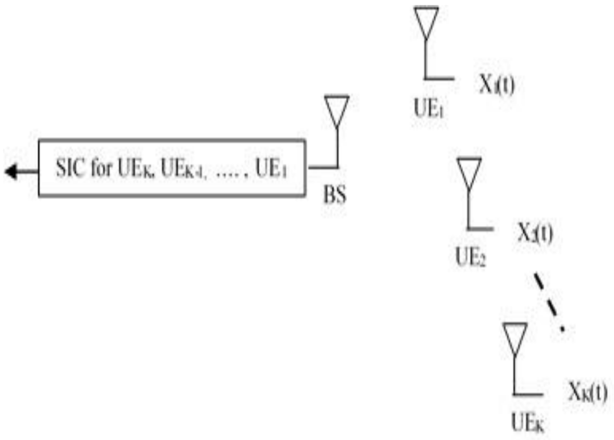

Fig. 2. Uplink NOM

D. Optimal power allocation

Power domain NOMA works effectively when two or a few clients share the similar resource block. As more number of users are utilizing similar resource slot, multiple clients are separated in the power domain. Hence, optimal power allocation should be done to maximize the sum rate capacity of downlink NOMA.

The sum rate capacity of downlink NOMA is given by

$$C_{user1}^{X_1} + C_{User2}^{X_2} = \log_2\left((1+\rho_s\ |h_1|^2)\left(\frac{1+P_2\rho_s|h_2|^2}{1+P_2\rho_s|h_1|^2}\right)\right) \quad (18)$$

The first term$(1+\rho_s|h_1|^2)$ is constant and the second term $\frac{1+P_2\rho_s|h_2|^2}{1+P_2\rho_s|h_1|^2}$ should be maximum for optimal power allocation which intern improves the sum rate.

III. RESULTS AND DISCUSSION

Outage for Unordered Downlink NOMA

Fig 3. Represents the outage probability of unordered Downlink NOMA. Simulation results show that at clip rate 10-1 user1 is having a poor channel gain with 90% power allocation of total power, the probability of outage is 11dB and user2 is having a good channel gain with 10% power allocation of total power, the probability of outage is 13dB. At clip rate 10-1 user1 is having a good channel gain with 90% power allocation of total power the probability of outage is 4dB and user2 is having a poor channel gain with 10% power allocation of total power the probability of outage is 20dB. For user1 having a good channel gain the probability of outage is improved, but probability of outage for user2 is large. Therefore there is no guarantee that user2 is decoded correctly. For unordered downlink NOMA it is optimal to choose user1 with poor channel gain and allocate more power to user1 and decoding should be done first for weaker user.

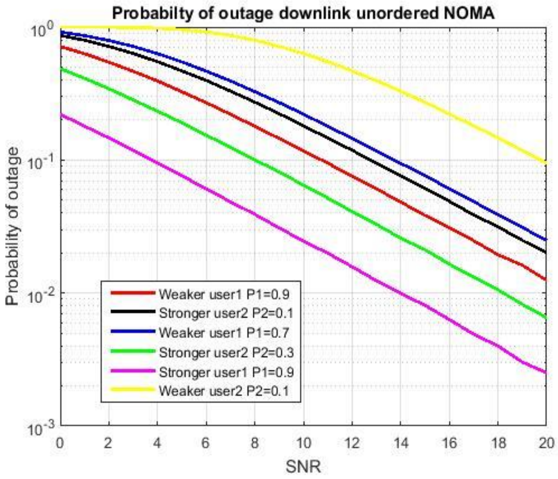

Fig 3. Probability of outage for unordered downlink NOMA

A. *Outage for downlink Ordered NOMA*

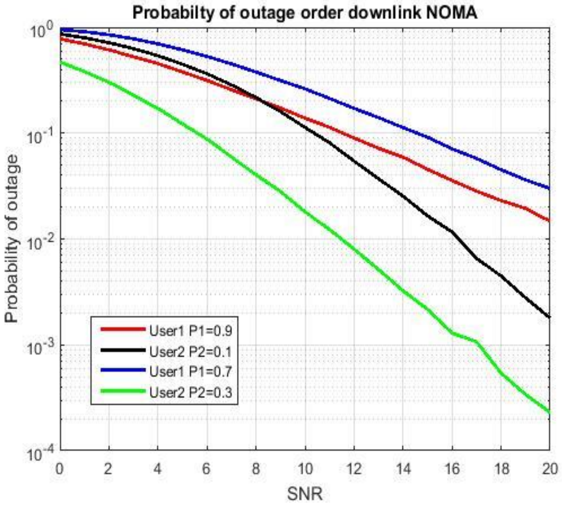

Fig 4. Probability of outage for ordered downlink NOMA

Fig 4. Represents the outage probability of ordered Downlink NOMA. Here we consider the user with poor channel gain as weaker user and user with good channel gain as stronger. Simulation results show that at clip rate 10-1, user1 with 90% power allocation of total power, the probability of outage for is 12dB and user2 with 10% power allocation it is 10dB. At clip rate 10-1 user1 with 70% and user2 with 30% of power allocation of total power the probability of outage is 15dB and 8dB respectively. Hence for ordered downlink NOMA it is optimal to allocate more power to weaker user.

B. *Outage for unordered Uplink NOMA*

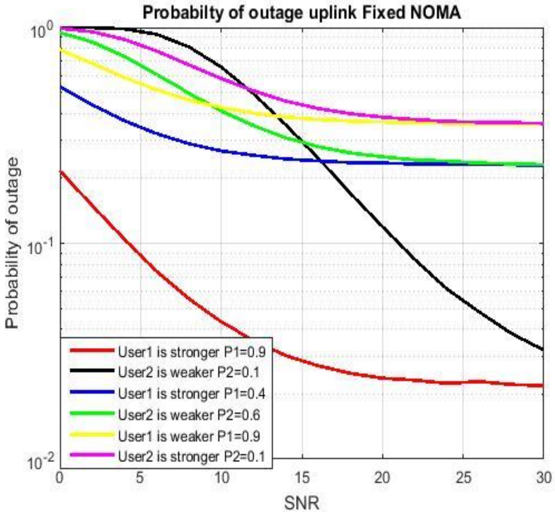

Fig 5. Probability of outage for uplink NOMA

Fig 5. Represents the outage probability of unordered uplink NOMA. Simulation results show that user with good channel gain and allocating large fraction power of total transmission power is having a less probability of outage. If a stronger user is decoded correctly, then we decode weaker user with less probability of error. The probability of outage is more when we allocate large fraction power to the weaker user.

Optimal Power Allocation for NOMA

Fig 6 shows the sum rate capacity for random power allocation NOMA and optimal power allocation NOMA. Simulation results show that sum rate capacity with optimal power allocation NOMA is improved compared to random power allocation NOMA. Increasing the channel gain improves the sum rate channel capacity. Channel capacity gain is directly proportional to ratio of channel powers of near user to far user. If both the users having similar channel condition no channel capacity gain is achieved.

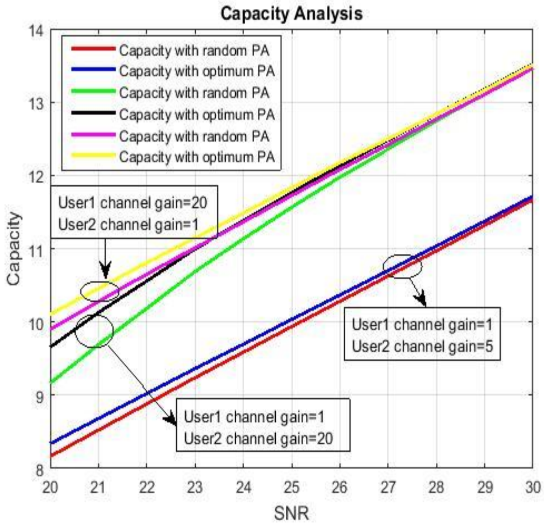

Fig 6. Channel Capacity V/S SNR

NOMA Downlink BER Performance

Fig. 7 represents the BER performance of downlink NOMA. In downlink NOMA weaker user will be decoded optimally. At a clip rate of 10-1 BER rate for weaker user is 5dB and stronger user is 15dB.

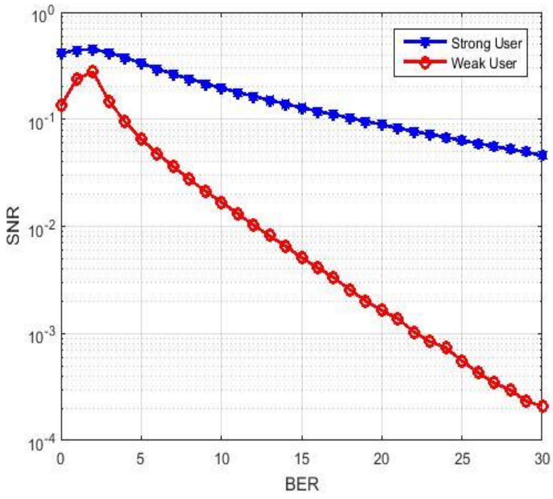

Fig 7. BER V/S SNR Downlink NOMA

C. *NOMA Uplink BER Performance*

Fig. 8 represents the BER performance of uplink NOMA. In uplink NOMA BER will be feasible in the range of 7dB to 18dB.

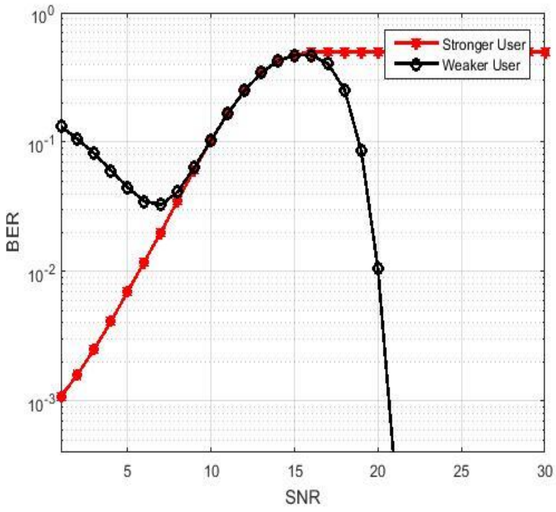

Fig 8. BER V/S SNR Uplink NOMA

V. CONCLUSION

NOMA is the one of the key principle for design of radio access techniques for 5G wireless networks. NOMA ensures that the user with worst channel conditions is served. Simulation results conclude that the probability of outage, BER and sum rate capacity depends on the user channel gain and fractional power allocation of total power to the user. In downlink NOMA decoding of weaker user first is optimum and in uplink NOMA decoding of stronger user first gives improved outage probability and BER.

Acknowledgment

I express my special thanks of gratitude to Dr. Rajendra R. Patil, Professor and HOD, Dept. of ECE, GSSSIETW, Mysuru India, for his support guidance and suggestion.

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