The Performance Evaluation of NOMA for 5G Systems Using Automatic Deployment of Multi Users

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Abstract—Non-Orthogonal Multiple Access (NOMA) in the fifth generation (5G) system is one of the optimistic technologies for wireless radio access networks. Compared to orthogonal multiple accesses (OMA) reduce the spectral efficiency; NOMA provides the best solution by increasing the data rates. This study evaluates NOMA with a downlink in the automatic deployment of multi-users. The outage performance and ergotic sum-rate gain give the NOMA better performance can be concluded at the final results. NOMA provides the Quality of Service (QoS) to the multi-users by considering the power allocation and data rate factors. Here is considered the outage probability will be 1 when it identifies the different user and allocates the data rate and power.

Keywords—NOMA; OMA; ERGOTIC SUM RATE; Bits per Channel Use (BPCU); Outage performance; Successive Interference Cancellation (SIC); Channel State Information (CSI)

I. INTRODUCTION

THE telecommunication domain has evolved and we have witnessed the dynamics from 1G to 5G [1]. The Frequency Division Multiple Access (FDMA) is used in the 1G system. The Time Division Multiple Access (TDMA) is used in the 2G network. The third generation is used Code Division Multiple Access (CDMA) system. The Orthogonal Frequency Division Multiple Access (OFDMA) is used in 4G [2]. The system capacity can be improved by multiple access techniques like OMA and NOMA [3]. The performance of NOMA can be considered using spectral efficiency when compared to conventional OMA. In NOMA there are two techniques one is Power domain NOMA and Code domain NOMA [4, 5].

In wireless cellular networks, the analog signals are represented by images and sounds, converted into digital signals represented by a suitable number of bits.

The 5G wireless campaigns are interconnected by the radio waves with an antenna array and low and low power transmitter in the ended frequency channels assigned by
the transceiver from a public pool of frequencies, which are reprocessed in geologically detached booths.

To meet the effectiveness of the 5G system-wide research activities such as Relay beam forming is used, in this the

computationally algorithm is used which reduces the power in the 2D-search network of the transceivers transmit powers and semi-definite programming [6], Experimental inspection of NOMA as multi-user power allocation signaling overhead. In this adaptive modulation coding and frequency, domain scheduling is used which gives more than 30% higher in NOMA when compared to the OMA scheme [7], millimeter-wave multi-beam MIMO and tapered slot antenna give the good beam forming concert by the element spacing can be easily meet the requirements of half-wavelength in the H-plane [8], multiple inputs and multiple-outputs [9], reference signal received power and cell range expansion are used are introduced to avoid the imbalance between macrocells and pico cells [10], and to improve energy efficiency and the capacity to demand heterogeneous networks, the active or sleep for the base stations was designed [11].

Again in [12], Power allocation is a very important factor is considered in the NOMA technique. The power allocation should serve to the user depending upon the priority to emergency things and address them quickly. Using OMA (orthogonal multiple access) is not possible to address quickly. Further in [13], the authors propose high user connectivity and overall sum rate; flexible clusters sum-rate distributions for given SNR and desired QoS, and significantly low system complexity can be achieved through a massive MIMO-NOMA scheme. Hence this study is considered Power domain NOMA. In the case of OMA serves in time, frequency, and code domain but not in power levels.

Here NOMA gives the power allocation depends on the distance between Base Station (BS) to the users [14]. The [15] author focuses on power allocation and channel state estimation. The arrival of massive MIMO, mm-wave, and perfect antenna selection reduce the hardware cost utilizing power reduction and network capacity [16, 17]. Now the NOMA 5G in the cellular network gives the QoS in terms of ergotic data rate and increased spectral efficiency [18, 19].

In this study of NOMA is in target for the downlink scenario, the QoS is achieved in 5G through outage performance and ergotic sum rates. Here we consider the two types of conditions foremost it estimates the channel condition and it allocates the ergotic data rate to the number of users. Initially, it is developed for a high Signal to Noise Ratio (SNR) value and the case study has been developed for the multi-users. At the end of simulation results, NOMA gives a better performance when compared to the conventional orthogonal multiple access (OMA) technique in terms of ergotic sum rate.

Also, outage performance is considered, which gives the QoS for NOMA in a 5G cellular system. The below results concludes the performance depends on the power allocation and data rates. Here it included the outage probabilities will be 1 when it identifies the different users and allocates data rates and power. Here multiple access considered in NOMA is the same as conventional orthogonal multiple access (OMA) techniques.

II. NOMA DOWNLINK SCENARIO

The below Fig 1, represents the downlink NOMA network, which consists of Base Station(BS) which radiates the desired signal and different power allocation coefficients to the number of users.[20] The users at the receiver should performance the successive interference cancellation (SIC) to get back the signal transmitted from the BS. Depending upon the channel state information (CSI), the user is allocated different power [21].

The user which is at the far should allocate more power; on the other hand, the near user should allocate less power. [22] The user at the far treats the low signal as noise and it gets back the original signal without performing SIC. But the nearest user treats higher signal power undergoes the SIC operation. The signal transmitted from the BS can be represented as

$$s = \sum_{i=1}^{L} \sqrt{q_i P_s x_i} \qquad (1)$$

Where,
x_i = information of i (x_i)
P_s = Transmission power at the BS
l^{th} = Users
h_i = Channel co-efficients
q_i = Power allocations co efficient for user i subjected to $\sum_{i-1}^{L} q_i = 1$ and $q_1 \geq q_2 \ldots \geq q_L$
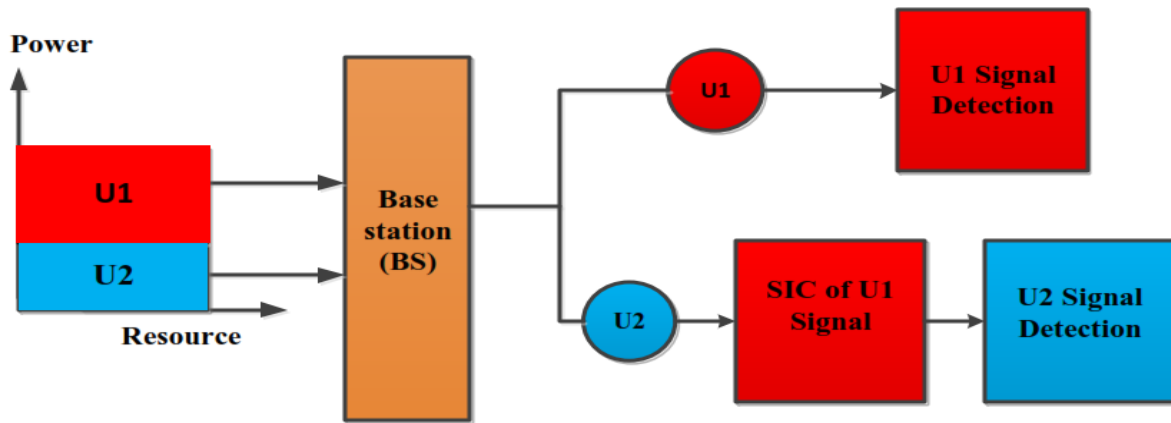

Fig. 1. The above figure depicts a NOMA downlink system

The channel gains are ordered
$|h_1|^2 \leq |h_2|^2 \leq \ldots \ldots \ldots \leq |h_L|^2$, where h_l is the channel co-efficient. The signal which is received i.e. l^{th} user can be represented as

$$y_l = h_l s + n_l = h_l \sum_{i=1}^{L} \sqrt{q_i P_s x_i} + n_l \qquad (2)$$

Where, n_l is the Additive White Gaussian Noise (AWGN)

A. SNR EXPLORATION

The equation (2) is the signal to noise ratio of the lth user to detect j^{th} user $j \leq l$.

$$\text{SINR}_{j \to l} = \frac{q_l \gamma |h_l|^2}{\gamma |h_l|^2 \sum_{i=l+1}^{L} qi+1} \qquad (3)$$

Where $\gamma = \frac{Ps}{\sigma 2}$ denotes the SNR. In order to obtain the desired signal SIC process is derived.

$$\text{Therefore. } \text{SINR}_l = \frac{q_l \gamma |h_l|^2}{\gamma |h_l|^2 \sum_{i=l+1}^{L} qi+1} \qquad (4)$$

The signal to noise ratio of the user can be represented by,
$$\text{SINR}_L = q_l \gamma |h_l|^2 \qquad (5)$$

B. SUM ERGOTIC RATE EXPLORATION

This case gives sum ergotic rate, the below expression gives NOMA data rates of lth users

$$R_l^{NOMA} = \sum_{i=1}^{L} \log_2[1+\text{SINR}_l]$$
$$= \log_2[1+q_l \gamma |h_l|^2] + \sum_{i=1}^{L} \log_2 \left[1 + \frac{q_l \gamma |h_l|^2}{\gamma \sum_{i=1}^{l-1} qi|h_l|^2+1} \right] \qquad (6)$$

III. FRAME-WORK

The complete framework of the system is explained in Fig 2. It consists of the automatic deployment of a multi-users downlink scenario with a single base station and two users. Here NOMA is considered depends on some protocols like path loss, transmission power, and power allocation coefficients. If NOMA finds the exact user and allocate more power too far and user with SIC to the nearest user, then the performance of NOMA is considered based on ergotic data rate and outage performance with a high SNR value [23].

IV. NOMA CHANNEL GAINS

The ergotic sum rates and outage probability tell the channel gains. The channel is uncorrelated and not in a normal distribution with equal variance and zero means. [24] So Rayleigh distribution is not suitable. The cumulative density function calculates the probability for unordered channel gain and is given by,

$$S|\tilde{h}|^2(y) = \frac{2}{P_B^2} \int_0^{P_B} [1 - e^{-[1+z^\beta]y}] z\, dz \quad (7)$$

If the value of β goes on increases then it's difficult to estimate the probability. [25] So Chebyshev's theorem can be applied to find large numbers. It is used to find the interval between [-1, 1], so the above equation can be altered as,

$$S|\tilde{h}|^2(y) = \frac{1}{2} \int_{-1}^{1} \left(1 - e^{-\left(1+\left(\frac{P_B}{2}x+\frac{P_B}{2}\right)\beta\right)y}\right)(x+1)dx$$

By the implementation of Chebyshev's theorem, the expression can be re-written as,

$$S|\tilde{h}|^2 \cong \frac{1}{P_B} \sum_{n=1}^{N} W_n g(\theta_n) \quad (8)$$

Where,

$$W_n = \frac{\pi}{N}, \qquad \theta n = \cos\left[\frac{2n-1}{2N}\pi\right]$$

The PDF expression gives as,

$$f|\tilde{h}|^2(y) \cong \frac{1}{P_B} \sum_{n=1}^{N} \gamma_n e^{-c_n y} \quad (9)$$

Since the above expression is a linear exponential function to analyze the performance factor.
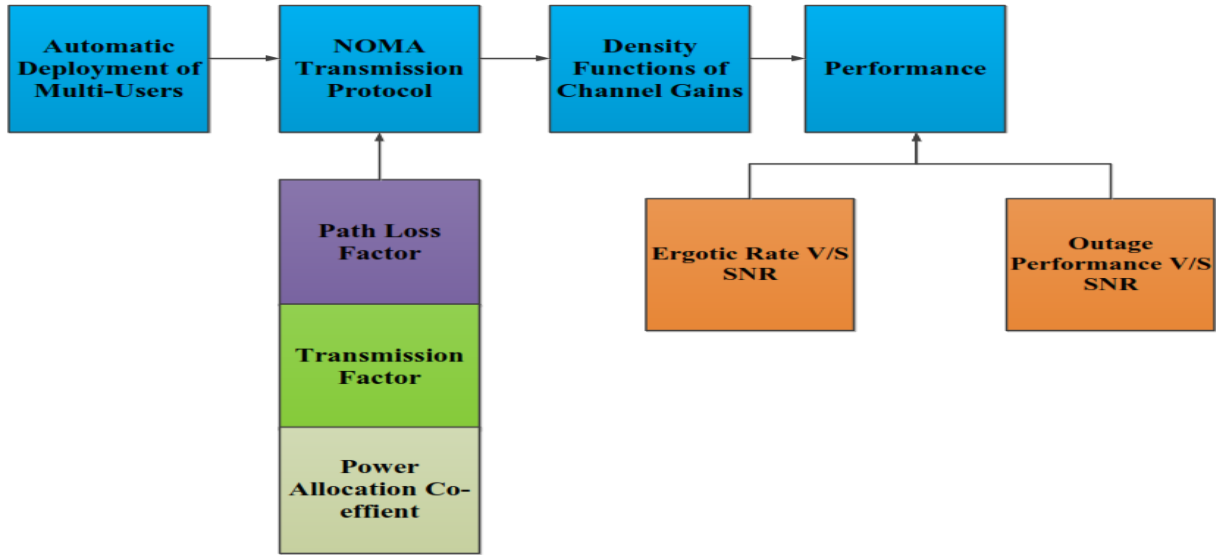

Fig. 2. NOMA network topology

V. NOMA PERFORMANCE

The outage probability tells the scope of NOMA, which measures the user's QoS. Here it is taken two conditions one is users are greater than the numbers of the message and vice-versa. Let E denotes the event and $\bar{E}$ denotes the inverse of the event. If l^{th} user not fined the, then the outage probability can be expressed as [26-27],

$$P_l = 1 - P[\bar{E}_{l,1} \cap, \bar{E}_{l,2} \cap \text{------} \bar{E}_{l,l}]$$

The compliment i.e. $\{q_l \gamma |h_1|^2 > \phi_l\}$

$$\bar{E}, x_i = \frac{q_l \gamma |h_1|^2}{\gamma |h_1|^2 \sum_{i=l+1}^{L} ai+1} > \phi_{x_i} \quad (10)$$

$$\bar{t}\left(\gamma|h_1|^2\left[t_{x_i} - \phi_{x_i}\sum_{i=x_i+1}^{M} Pi\right] > \phi_{x_i}\right)$$

Where

$$\phi_{x_i} = 2^{\bar{R}_{x_i}} - 1$$

The below is the following condition

$$t_{x_i} > \phi_{x_i}\sum_{i=x_i+1}^{M} t_i$$

Here, $\psi_{x_i} \triangleq \dfrac{\phi_{x_i}}{\rho\left(t_{x_i} - \phi_{x_i}\sum_{i=x_i+1}^{M} Pi\right)}$ for $x_i < M$,

$$\psi_M = \frac{\phi_M}{\tau_M} \;\&\; \psi_l^* = \max\{\varphi1 - - - -\varphi l\}$$

Therefore the outage probability can be expressed as

$$P_l = 1 - P[|h_1|^2 > \phi_l^*]$$

$$= \int_0^{\psi_l^*} \frac{M! \left[S|\tilde{h}|^2(y)^{l-1}\right] [1 - S|\tilde{h}|^2(y)]^{M-l} S|\tilde{h}|^2(y)}{(l-1)! \; (M-l)!}$$

$$(11)$$

The channel gain can be approximated by

$$S|\tilde{h}|^2(y) = \frac{1}{P_b} \sum_{n=1}^N \beta_n \, y$$

Where

$$\rho \to \infty \,, \Psi_l^* \to 0$$

So the probability for high SNR can be represented as

$$P_l^{out} = \tau l \int_0^{\psi_l^*} [(nx)^{l-1}(1-nx)^{M-l} \frac{1}{P_b}] * \sum_{n=1}^N \beta_n (1 - C_n x) \, dx \qquad (12)$$

The NOMA diversity can be represents as

$$P_l^{out} = \frac{1}{\rho^l} \qquad (13)$$

The above expression tells the of lth user with l diversity order. Section 7 tells lth user with diversity l. The BS allocates the message to the random users; the diversity order is described as one. NOMA boosts the spectral efficiency since it is serving in time, frequency, and code.

VI. NOMA ERGOTIC SUM RATE

In this part, we are looking out for the ergotic sum rate of NOMA. This will gives a sum rate concerning the channel gains [28-30]. The ^{lth} user NOMA downlink represented by,

$$R_l^{NOMA} = \log_2[1+SINR_l] = \log_2\left[1 + \frac{q_l\gamma|h_l|^2}{\gamma|h_l|^2 \sum_{i=l+1}^L qi+1}\right]$$

The NOMA downlink sum rate can be expressed as

$$R_{SUM}^{NOMA} = \sum_{l=1}^L \log_2[1+SINR_l] = \sum_{l=1}^L \log_2\left[1 + \frac{q_l\gamma|h_l|^2}{\gamma|h_l|^2 \sum_{i=l+1}^L qi+1}\right] + \log_2[1 + q_L\gamma|h_L|^2] \qquad (14)$$

The equation (14) can be re-written by considering equation (9)

$$R_{SUM}^{NOMA} = \sum_{l=1}^L \int_0^\infty \log_2\left[1 \frac{q_l\gamma|h_l|^2}{\gamma|h_l|^2 \sum_{i=l+1}^L qi+1}\right] f|h_l|^2(y)dy$$

$$+ \int_0^\infty \log_2[1 + q_L\gamma|h_L|^2]f|h_L|^2(y)dy \qquad (15)$$

The **second term** of equation (15) can be rewritten as

$$\frac{\rho q_L}{\ln 2} \int_0^\infty \frac{1 - F|h_L|^2(y)}{1+q_L\gamma} \, dy$$

The Cumulative Density Function (CDF) can be expressed as

$$F|\bar{h}|^2(y) = \frac{1}{P_B} \sum_{n=1}^N \gamma_n e^{-cny}$$

So the CDF is used for largest order statistics can be given as

$$F|\bar{h}|^2(y) = \left[F|\bar{h}|^2(y)\right]^L$$
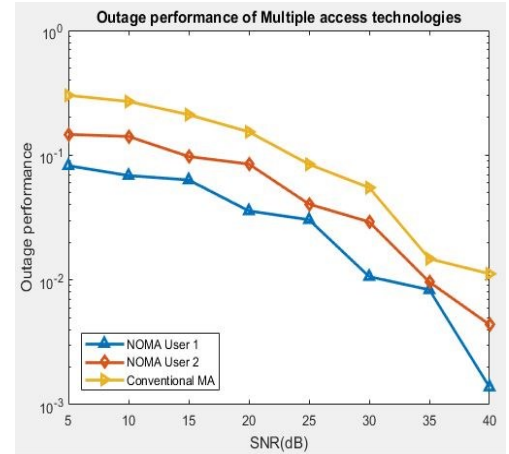
When $\gamma \to \infty$,
we can obtain sum rate for the high SNR downlink NOMA
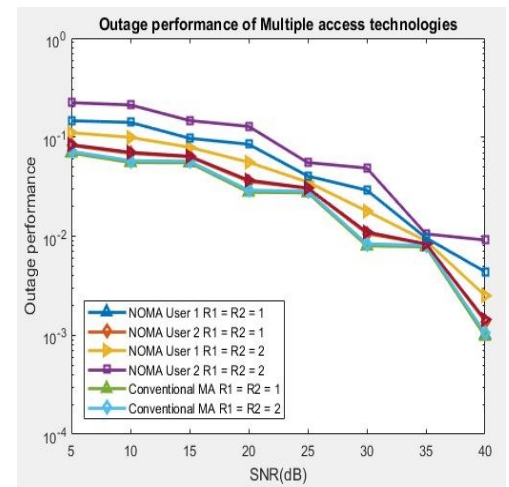
$$R_{SUM}^{NOMA} = \sum_{l=1}^L \log_2\left[1 + \frac{q_l}{\sum_{i=l+1}^L qi}\right] + \log_2[\gamma|h_L|^2]$$

$$= \log_2[\gamma|h_L|^2]$$
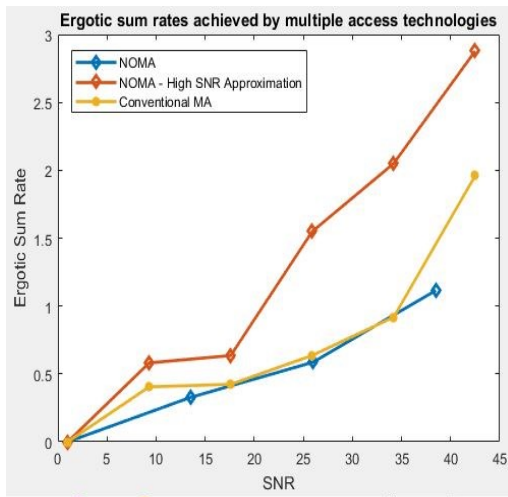
Through this NOMA, the users are served concurrently.

(a)   Bits per Channel Use (BPCU) for user1 and user2
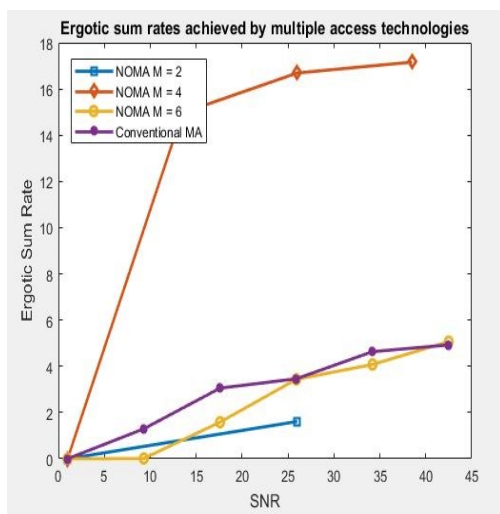

(b)Wrong choice of data rates and power

Fig 3. Outage performance of multiple accesses

(a)　　Ergotic sum rates with high SNR value

(b)　　Ergotic sum rates with conventional OMA

Fig 4. Ergotic sum rates achieved by multiple accesses

VII. SIMULATION RESULTS

The present work is simulated using MATLAB tool. Fig.3. (a) gives the outage performance of NOMA for downlink power co-efficient such as $a_1=2/5$ and $a_2=a_1-1$ with automatically deployed users with N=10, M=6, β=2, and P_B=5m. Here we have obtained the 0.1 target data rates for weak user1 in terms of Bits per Channel Use (BPCU) and 0.5 BPCU for strong user2. The conventional OMA scheme gives the targeted data rates with the addition of user1 and user2 (0.6 BPCU). Fig.3. (b) gives the outage probability will be always one for wrong choice of data rates and power. Fig. 4 gives the ergotic sum rates v/s high SNR and gives the comparison with conventional OMA scheme.

VIII. CONCLUSIONS

In this work, the NOMA technique is introduced to the efficient utilization of network sources. The conventional OMA scheme is used earlier for code, time, and frequency in an orthogonal division manner it is failed to share all the above

for the number of users efficiently. The NOMA technique gives better performance in both ergotic sum rates and outage performance with high SNR value. Here we are taken the diversity order always 1 when it allocates the different user and allocation the data rate and power. There are many other challenges like dynamic pairing is required among the channels to get more benefits from NOMA.

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