Non-Orthogonal Multiple Access (NOMA) for Downlink Multiuser System over Different Weibull Fading Scenario

Bharti Katiyar and Chetan Fadnis

Abstract—**Non-Orthogonal Multiple Access (NOMA) scheme for future radio along with Successive Interference Cancellation (SIC) for downlink multiuser over different Weibull fading scenario is being investigated in this paper and the results have shown significant improvement as compared to conventional Orthogonal Multiple Access. User Equipment (UE'i) in each cluster with a single antenna is allocated with dynamic power on the power domain NOMA basis with SIC at the receiver. We have utilized the closed-form expressions for the BER, spectral efficiency and throughput, in Weibull fading scenario and by employing the NOMA technique, the simulation results show the improvement in the performance of the system even in severe fading as compared to OMA techniques.**

Index Terms—**NOMA, OMA, Weibull fading channel, SIC, SINR, Bit Error Rate (BER), Spectral Efficiency, throughput.**

I. INTRODUCTION

5G isn't only the following advancement of 4G innovation; it's a change in outlook. Not exclusively is 5G transformative (giving higher transmission capacity and lower idleness than current-age innovation), all the more critically, 5G is progressive—since it is relied upon to empower in a general sense new applications with significantly more stringent prerequisites in latency and transfer speed. Today, a few models associations and forums, in particular IEEE, 3GPP, and ITU, [1] are chipping away at characterizing the engineering and institutionalizing different parts of 5G advances. In any case, little has been concentrated to investigate how 5G advancements can be valuable to strategic and person on call systems. It is critical to research how strategic and person on call networks can exploit 5G advancements to help huge data transfer capacity, huge detecting, and huge control type applications.

As the most up to date individual from the different access family, Non-Orthogonal Multiple Access (NOMA) [2] is imagined to be a fundamental segment of 5G NR systems. Moreover, NOMA further advances the range usage by enabling MU to transmit from a similar source to numerous gadgets at the same time. Especially, NOMA adequately uses Superposition Coding (SC) and progressive obstruction crossing out and multiuser decent variety to improve the range usage. By assigning more transmission capacity to clients with poor channel conditions, NOMA can accomplish a reasonable tradeoff between framework throughput and client fairness [3]. In general, NOMA schemes can be classified in two categories: power-domain multiplexing and code-domain multiplexing. In power-domain multiplexing, users are assigned diverse power coefficients as per them divert conditions with the end goal to accomplish a high framework execution. In general, information signals from various users are superimposed at the transmitter. To achieve a good trade-off between the throughput of the system and the user fairness, At the receiver side Successive Interference Cancellation (SIC) [4], [5] is applied so as to decode the signals, one by one until the desired user's signal is derived.

With the existing networks, implementing Power-domain multiplexing can be easily achieved along with remarkable advantage that it accommodates the signal in same bandwidth, with the perk of improved spectral efficiency [6]. Weibull distribution has enormous applications and fits in different domains easily, for a circumstance like rustic domains with less UE's or urban district with generally gigantic tele-density or crowded areas, yet it is undeniably missing from writing. A novel approach is suggested in [7], which also includes Weibull fading models.

In this paper, we give a brought together model framework to NOMA in Weibull fading for downlink situation alongside correlation among OMA and NOMA. NOMA schemes [8] and Interference cancellation [9] for NOMA are proposed to enhance the productive utilization of constrained system sources. In [10], it highlights a scope of key difficulties, opportunities and future research patterns identified with the design of NOMA, including the mathematical analysis, the structure of spreading sequences or codebooks, the receiver design. OMA based methodologies that utilization time, frequency, or code domain in a symmetrical way can't adequately use radio assets, constraining the number of clients that can be served all the while. In [11], it depicts the need to improve on spectral efficiency and also the issues in implementing the NOMA making it a key candidate. With the end goal to beat such disadvantages and to expand the different access effectiveness, NOMA system has been as of late proposed.

The reminder of this paper is organized as follows. Section II illustrates the channel model both for NOMA and OMA. Section III presents state-of-art research on NOMA with respect to SINR, spectral efficiency and throughput. The

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978-1-7281-4988-2/20/$31.00 ©2020 IEEE

numerical results along with simulations (Monte-Carlo) are presented in section IV and finally, section V concludes this paper.

II. Channel Model

A. Scenario

- In Orthogonal Multiple Access scheme, user 1 uses α Hz and remaining $(1-\alpha)$ Hz is assigned to user 2.
- In Non-Orthogonal Multiple Access scheme, entire frequency band (say 1Hz) is simultaneously used by two users. Combined signal of users UE_i (i=1 ,2) equipped with single antenna, multiplexed in power domain subject to the total power P, is transmitted from single BS antenna as shown in Fig. 1.

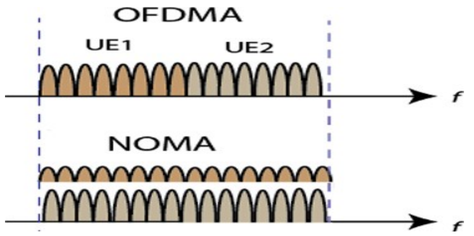

Fig. 1. Frequency Sharing in OMA and Power sharing in NOMA

B. System Model

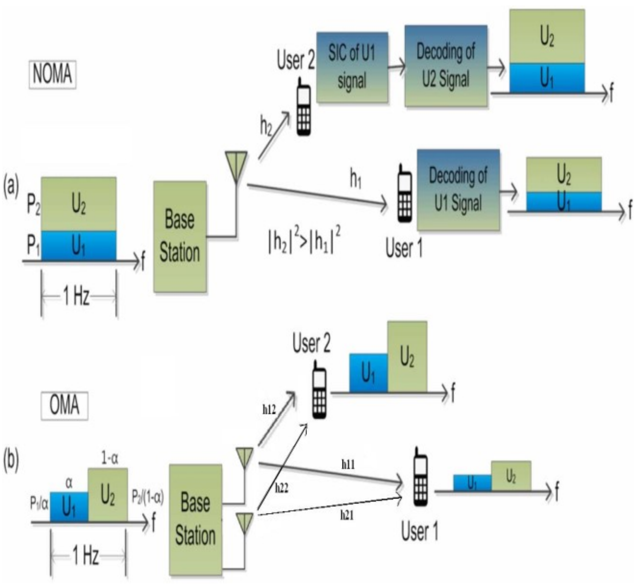

Fig. 2. a) NOMA scheme, b) OMA scheme

Fig. 2a represents, system model for two users, each equipped with single antenna. In NOMA scheme, the received signal at the BS is represented as

$$y_1 = h_1 x + n_1 \tag{1}$$

$$y_2 = h_2 x + n_2 \tag{2}$$

where x is the combined signal of users UE_i (i=1, 2)

$$x = \sqrt{P_1}\, x_1 + \sqrt{P_2}\, x_2 \tag{3}$$

Fig. 2b represents, system model for two users OMA scheme, the received signal at the BS is represented as

$$y_1 = h_{11} x_1 + h_{12} x_2 + n_1 \tag{4}$$

$$y_2 = h_{21} x_1 + h_{22} x_2 + n_2 \tag{5}$$

III. Problem Formulation

We consider the practical SIC schemes based on Zero-Forcing (ZF) and the Minimum Mean Squared Error (MMSE) criteria. The UE2 detects the signal without Successive Interference Cancellation directly assuming that the power is higher as compared with UE1 ($P_2 \gg P_1$). For UE1, the received signal y_1 is

$$y_1 = h_1 (\sqrt{P_1}\, x_1 + \sqrt{P_2}\, x_2) + n_1 \tag{6}$$

where $h_1\sqrt{P_2}\, x_2$ is the channel interference. Weight factor for the Weibull channel coefficient h_2 based on ZF or MMSE criteria with the estimated channel coefficient $\widetilde{h_2}$

$$\hat{h}_2|_{ZF} = \left(\tilde{h}_2^H \tilde{h}_2\right)^{-1} \tilde{h}_2^H, \hat{h}_2|_{MMSE} = \left(\tilde{h}_2^H \tilde{h}_2 + \sigma_{n_1}^2 I\right)^{-1} \tilde{h}_2^H \tag{7}$$

where H in the superscript denotes Hermitian transpose and $\sigma_{n_1}^2$ is variance of noise n_1. The desired information can be derived by subtracting the estimated signal from signal at receiver and updating the same. Decoding the signal at UE2, the resultant signal from UE1 is used. We have assumed that the channel gain of UE2 is higher than UE1, therefore SIC is not employed for UE1, and signal is derived directly.

From (6), SINR for UE1, implementing NOMA technique, under Weibull fading channel can be derived as

$$SINR = \frac{|h_1|^2 P_1^2}{|h_1|^2 P_2^2 + \sigma^2} \tag{8}$$

Rearranging (8), we have with $SNR_i = \frac{P}{\sigma^2}$

$$SINR = \frac{P_1}{P_2 + \frac{1}{SNR_i h_1^2}} \tag{9}$$

Here Weibull channel coefficient h_1 can be expressed in terms of its variance σ_W^2

$$h_1^2 = \sigma_W^2 = \Omega^{1/\beta}\left[\Gamma\left(\frac{2}{\beta}+1\right) - \left(\Gamma\left(\frac{1}{\beta}+1\right)\right)^2\right] \tag{10}$$

Under OMA, SINR for user 1, using (4) is represented as

$$SINR = \frac{|h_{11}|^2}{|h_{12}|^2 + \frac{1}{SNR_i}} \tag{11}$$

Here h_{11}, h_{12} are Weibull fading channel matrix coefficient.

In (12) and (13), data rates that can be achieved for user 1 and user 2 respectively are shown

$$R_1 = log_2\left(1 + \frac{|h_1|^2 P_1}{|h_1|^2 P_2 + \sigma_n^2}\right) \tag{12}$$

$$R_2 = log_2\left(1 + \frac{|h_2|^2 P_2}{\sigma_n^2}\right) \tag{13}$$

In (14) and (15), respectively, data rates that can be achieved for user 1 and user 2, in case of OMA are given by

$$R_1 = \alpha log_2\left(1 + \frac{|h_{11}|^2 P}{\sigma_n^2}\right) \tag{14}$$

$$R_2 = (1-\alpha) log_2\left(1 + \frac{|h_{22}|^2 P}{\sigma_n^2}\right) \tag{15}$$

The k^{th} user in the l^{th} cell experiences Ergodic uplink achievable rate, which is expressed in general form as

$$R_{lk} = \mathbb{E}\{\log_2(1 + \mathrm{SINR}_{lk})\} \tag{16}$$

and the K users in the l^{th} cell, has a cumulative spectral efficiency which is given by

$$SE_l = \sum_{k=1}^{K} R_{lk} \tag{17}$$

According to BER, throughput for OMA and NOMA system can be evaluated using the relation in (18), where C is the desired throughput [7].

$$C = \frac{(1-BER)*n_{bit/packet}}{T_{packet}(s)} \tag{18}$$

IV. NUMERICAL RESULTS

We provide the link level simulation with the BER performance for NOMA and OMA. From Fig. 3, BER performance becomes worst in severe fading in OMA, which is improved a little by employing NOMA technique. Although the results shows that with increasing severity index β, for NOMA BER is increasing, still it is lower than the values that in case of OMA. Fig. 4 and Fig. 5 depicts that the spectral efficiency and throughput in Weibull fading scenario is high in case of NOMA, as compared with OMA.

For two user scenarios, generalized capacity comparison of NOMA and OMA is depicted in Fig. 6. It is evident that for NOMA, achievable rate is outside the OMA capacity region, thus enhanced capacity for NOMA can also be claimed.

Table I summarizes the Monte-Carlo simulation parameters as per LTE specifications.

TABLE I
PARAMETERS VALUES

Parameters	Value
Bandwidth	1.4 MHz
Subcarriers per resource block	12
T_{packet}	0.5ms
Number of bits per packet ($n_{bit/packet}$)	864
Channel	Weibull
Modulation	BPSK
Power for NOMA	P1=80, P2=20

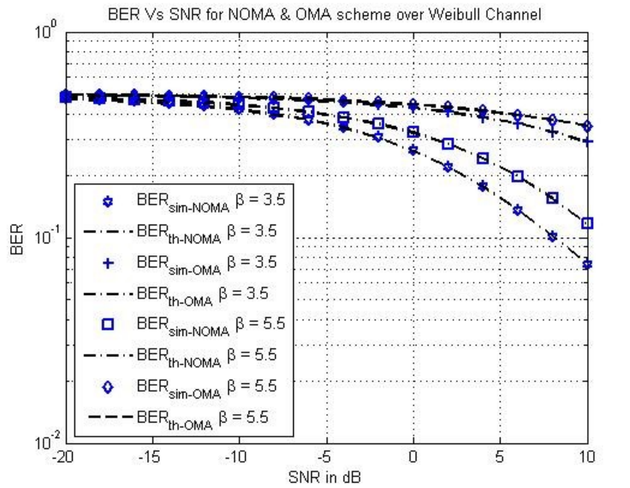

Fig. 3. BER V/s SINR for NOMA & OMA scheme over Weibull Channel

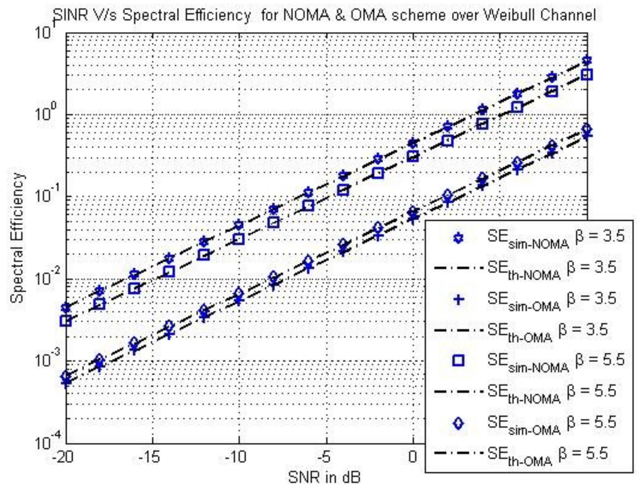

Fig. 4. SINR V/s Spectral Efficiency for NOMA & OMA scheme over Weibull Channel

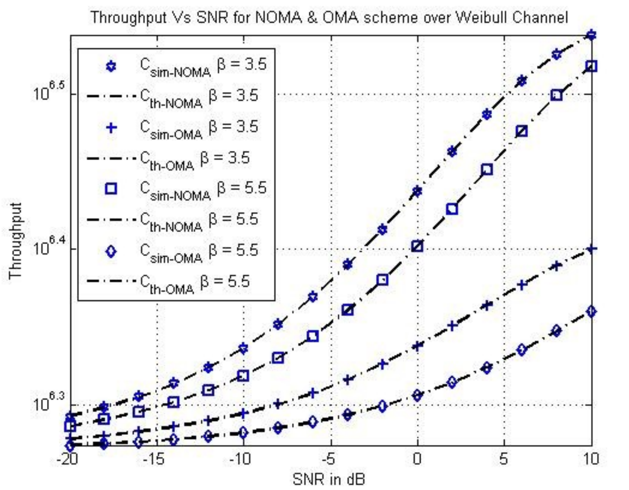

Fig. 5. Throughput V/s SNR for NOMA & OMA scheme over Weibull Channel

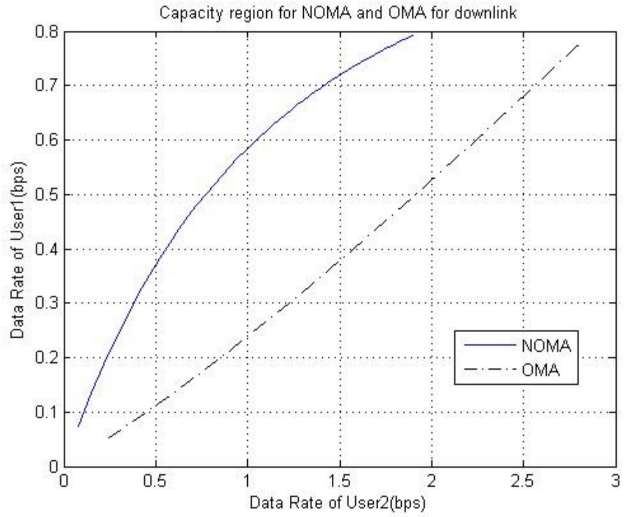

Fig. 6. Capacity for NOMA & OMA scheme over Weibull Channel

V. CONCLUSION

Non-orthogonal multiple access (NOMA) guideline develops as an answer for enhance the spectral efficiency while permitting some level of different access impedance at receivers. As needs be, clients are isolated in the power area. Such a power-area based various access conspire gives compelling throughput enhancements, contingent upon the channel conditions. In OMA, contrasts among channels and states of clients can't make full use of and derive benefit from its resource. It is very feasible for a client to be doled out with a huge frequency band while encountering disintegrating channel conditions. Such client cases restrain the adequacy of OMA based methodologies. In any case, as indicated by the NOMA standard, different clients who might be encountering better channel conditions can utilize these groups and increment their throughput. In addition, comparing clients who are the essential clients of these groups keep on utilizing these groups. In such arrangements, power level of clients is chosen in a manner to focus on a specific maximum error rate. The simulation results justify the key concept of NOMA and thus proves to be a promising candidate for 5G technology.

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