



## An Improved Resource Allocation Scheme for 5G NOMA System

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### ABSTRACT

As a result of increasing demand on telecommunications services, networks suffer low speed and high latency. These seriously affect the performance of the network due to the presents of high burden on the existing multiplexing techniques such as Orthogonal Multiple Access (OMA) to deliver high speed data rates. Hence, the ever increasing demand for high speed and low latency data communications by mobile users define future features of networks to ease the burden on the existing multiple access techniques by significantly offering high data rates through multiplexing of multiple users over the same channel at the same time and frequency using Non Orthogonal Multiple Access (NOMA) in 5G systems. The research developed an improved resources allocation scheme for NOMA fifth Generation (5G) systems. The multiplexing of users on the same frequency band in NOMA makes it possible to have higher sum rate than the conventional OMA technique. This high sum rate can only be guaranteed through the use of efficient resources allocation scheme, so as to avoid high rate of interference and decoding errors. The research focuses on improving sum rate and coverage probability while considering the requirement for green communication in 5G. A multiple user's downlink NOMA system with  $N$  sub-channels and 32 users which are uniformly distributed in a circle of diameter 500 meters is considered in this work.

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### INTRODUCTION

The exponential increase in the number of mobile subscribers and the emergence of various imagining and objects orientated technologies such as: virtual reality, augmented reality, Artificial Intelligence (AI), Three-Dimensional (3D) media Ultra-high Definition Transmission Video (UDTV), Internet of Things (IoT), Intelligence Transport Systems (ITS) in the society have increase the demand for date rate significance on wireless communications networks [1]. It is forecasted that there will be over 100 billion subscribers by the year 2025 and about 7.6 percent of the subscribers would use their devices to download and upload information via wireless communication networks [2]. Current networks are run using LTE platform. Running the networks on this platform will not be able to cope with the rate increment in data demands [3]. To withstand harsh and strict conditions, pursuit for higher sum rate, handle more data, increase capacity, spectral, and energy efficiency in 5G systems at a minimal cost, NOMA is considered due to its capability to handle multiple users over the same channel at the same time and frequency resource concurrently [4]. NOMA technique allows resource to be assigned

concurrently to multiple users, unlike OMA, where single radio resource (i.e. frequency or time) is assigned to only one user [5]. Current researches have verified that NOMA can increase the overall sum rate of macro cell significantly in downlink scenario. These techniques require a combination of serial interference cancellation or maximum probability of demodulation to achieve the ultimate capacity limit in the system.

NOMA has drawn a lot of interest in literatures recently, for example, MIMO-NOMA was considered in [6]-[7], cooperative NOMA in [8], fairness for NOMA in [9], millimeter wave for downlink NOMA in [10]. Furthermore, the authors in [11] analyzed NOMA with equal subcarrier power allocation (ECPA) and Average Channel based Power Allocation (ACPA) in a scenario with users' target rate and the authors showed analytically, that NOMA was better than OFDMA in terms of the achievable sum rate and the coverage probability. The authors in [11] and [12] showed how NOMA could improve the capacity and sum rate of the network over orthogonal multiple access techniques (OMA). [12] Presented a number of power allocation techniques: equal and proportional power allocation (equal), Hierarchical Pairing Power Allocation (HPPA), and proportional

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power allocation (proportional). The HPPA achieved the best performance but users suffered high inter and multi interference. The equal had the lowest interference rate but have poor performance. The proportional was the midpoint between the two, but required computation to determine specific parameters to achieve the best performance. Others works on NOMA, such as [13] and [14] did not consider multiple users at all.

In this paper, a sub-channel based NOMA system with multiple users was considered. The system spectrum was divided into sub-channels and power was then allocated to each sub-channel based on the user's requirement so as to maximize the sum rate and also to reduce power consumption. The rest of this paper is organized as follows. Section II discusses the system model of a NOMA system with

$$Y_{i,S}^u = \sum_{U=1}^U (P_{i,S}^u h_{i,S}^u X_{i,S}^u + N_{i,S}^u) \quad (1)$$

Where:  $h_{i,S}^u$  Represent the channel gain between the BS and the user and  $N_{i,S}^u$  Represent the additive white Gaussian noise.

In this model, user pairs are allocated to sub-channels so as to mitigate the effect of multi-users interference which occurs as a result of multiplexing

$$R_s = \sum_{n=1}^N R_n \quad (2)$$

where:

$R_s$  is the total sum rate of the system.

$R_n$  is the total sum rate of a subchannel n.

N is the total number of sub-channels in a system.

$R_n$  is given as follows:

$$R_n = B \log_2((1 + L_S) + (1 + H_S)) \quad (3)$$

Where: B is the bandwidth of a sub-channel n and  $H_S$  and  $L_S$  are the SINR of the strong and weak user in a pair S.

B is given as:

$$B = \frac{W_T}{N} \quad (4)$$

Where:  $W_T$  is the total bandwidth of the system and N is the total number of subchannels in a system.

$$H_S = \frac{P_{H,S} |h_{H,S}|^2}{|h_{H,S}|^2 + B N_0} \quad (5)$$

$$L_S = \frac{P_{L,S} |h_{L,S}|^2}{P_{H,S} |h_{L,S}|^2 + B N_0} \quad (6)$$

Where:

B is the bandwidth of a sub-channel.

$N_0$  is noise power spectral density.

$P_{H,S}$  and  $P_{L,S}$  are allocated power of the stronger and weak users which are given as:

multiple users, Section III presents the pairing and power allocation concept. The simulation scenarios and results are presented in section IV, and finally, Section V concludes the paper.

### SYSTEM MODEL

Considering a single cell downlink NOMA system with U users, users are grouped into S pairs based on their channel gain. The channel gain of users with better condition is denoted as  $|h_{H,S}|^2$  while that of worst condition is given as  $|h_{L,S}|^2$ . Suppose a given Base Station (BS) is transmitting a signal  $X_{i,S}$  to U-th users ( $U = \{1, 2, \dots, u\}$  and  $i = \{H, L\}$ ) with transmit power  $P_{i,S}^u$ , the received signal by the user U at a pair S is given as [12]:

a large a number of users in the same channel. This reduce complexity in receiver design. Users with dissimilar channel condition (that is strong and weak user) are paired and assign to a sub-channel so as to reduce the effect of inter user interference which occurs as a result of pairing users with similar channel condition. The model equations are:

$H_S$  and  $L_S$  are given as:

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$$P_{H,s} = \frac{-\left( BN_0(|h_{H,s}|^2 + |h_{L,s}|^2) \right)}{2|h_{H,s}|^2|h_{L,s}|^2} + \frac{\sqrt{+4|h_{H,s}|^2|h_{L,s}|^2 BN_0(|h_{H,s}|^2 P_s) + ((N_0 B)^2) (|h_{H,s}|^2 + |h_{L,s}|^2)^2}}{2|h_{H,s}|^2|h_{L,s}|^2} \quad (7)$$

$$P_{L,s} = \frac{BN_0(|h_{H,s}|^2 + |h_{L,s}|^2) + 2P_s|h_{H,s}|^2|h_{L,s}|^2}{2|h_{H,s}|^2|h_{L,s}|^2} - \frac{\sqrt{4|h_{H,s}|^2|h_{L,s}|^2 BN_0(|h_{H,s}|^2 P_s) + ((N_0 B)^2) (|h_{H,s}|^2 + |h_{L,s}|^2)^2}}{2|h_{H,s}|^2|h_{L,s}|^2} \quad (8)$$

$|h_{H,s}|^2$  and  $|h_{L,s}|^2$  are the channel gains of the strong and the weak users in a pair.

$$|h_{L,s}|^2 = |h_{H,s}|^2 = \xi |h_{U,s}|^2 d^{-\nu} \quad (9)$$

where:

$|h_{U,s}|^2$  is Rayleigh fading factor.

$\xi$  represent log-normal shadowing factor.

$d^{-\nu}$  denotes distance between user and the base station.

$\nu$  stands for the path loss exponent.

$U$  means number of users.

The power allocation, is presented as:

$$P_n = \frac{G_{g,n} P_t}{\sum_{n=1}^N G_{g,n}} \quad (10)$$

#### USER PAIRING AND POWER ALLOCATION CONCEPT.

The scheme adopts sub-channel allocation to reduce the effect of multi-user interference and receiver design complexity. It also pairs users with dissimilar channel conditions (that is strong and weak

user) to mitigate the effect of inter-user interference. For proper illustration of the procedure, four users are considered and the process of pairing, sub-channeling, power allocation and decoding process is shown in Figure 1.

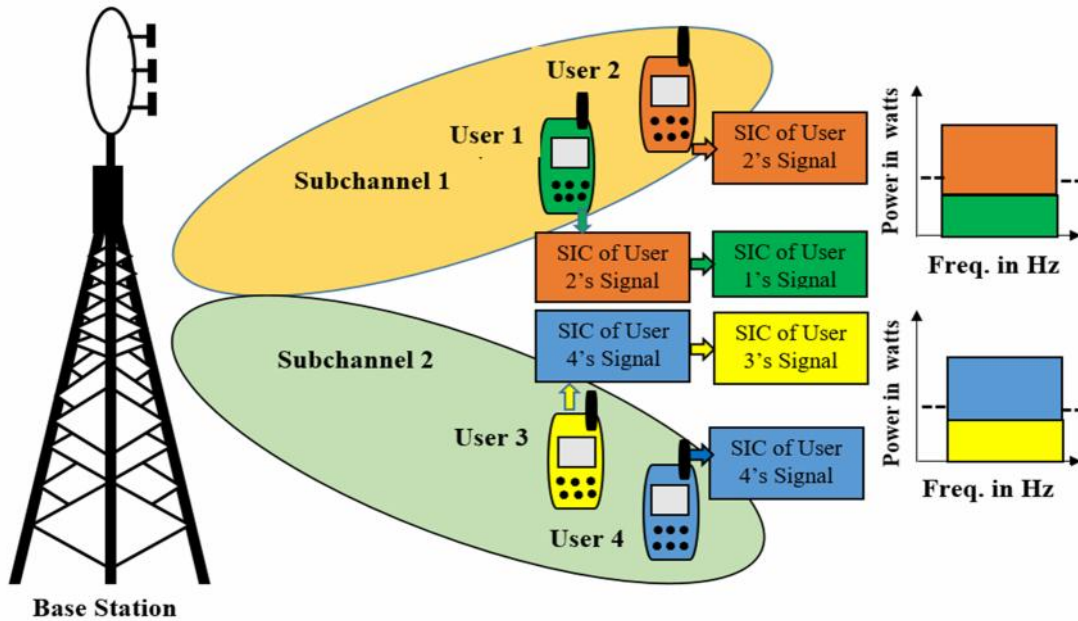


Figure 1. Resource and Power Allocation Procedure for Four Users.

The operational flowchart of the scheme is described in Figure 2. The developed scheme is made up of two main phases which are: the pairing and sub-channel allocation phase and power allocation phase. In pairing and sub-channel allocation phase, the channel gains of registered users are evaluated, users with dissimilar channel gains are paired and allocated

to an empty sub-channel so as to mitigate the effect of multi-user and inter user interference. While in the power allocation phase, the power required by the sub-channel base on its user pair is estimated and then allocated so as to reduce energy wastage to ensure conformity with the requirement for green communications in 5G networks.

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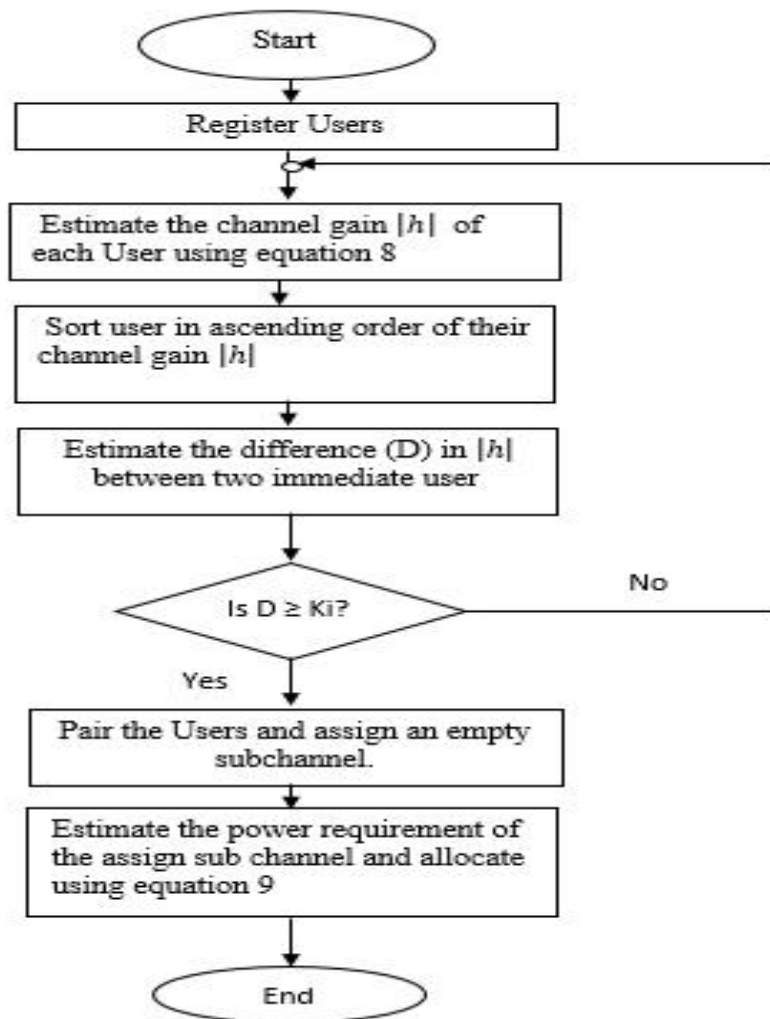


Figure 2. Flowchart of the Developed Scheme

## SIMULATION AND RESULTS

The scheme was developed in MATLAB simulation environment, using MATLAB R2017a

version. The parameters used for the simulation are presented in Table 1.

**Table 1:** Simulation Parameter Values of the Developed Scheme.

Parameter	Value
Number of Users(U)	32
Total Transmission Power ( $P_t$ )	30 dBm
Total Bandwidth ( $W_T$ )	5 MHz
Number of Subscribers ( $N_s$ )	512
Shadowing Standard Deviation	8 dB
Noise Power Density ( $N_o$ )	-174 dBm /Hz
Cell Diameter (D)	300m
Link space (ki)	0.2 to 1
Path Loss Exponent ( $v$ )	3
Minimum rate requirement ( $\Phi_{u,m}$ )	$0.6 \times 10^5$ bps

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In the simulation, a single Base Station (BS) with 32 users uniformly distributed in a cell range of 300 meters at random locations were considered. The minimum distance between a user and the BS was 30 meters, the bandwidth and the carrier frequency of the system were 5MHz and 512Hz, respectively. To reduce demodulation and decoding complexity of the SIC receiver, each sub-channel was allocated with one matched pair (that is two users) in this NOMA system.

OFDMA scheme as a comparator could only be allocated by one user in a sub-channel. Also, for the power allocation, the developed scheme was compared with HPPA scheme of [12] and the optimal power allocation scheme for validation. The results obtained from simulation are presented in graphical form so as to evaluate the performance of the developed scheme.

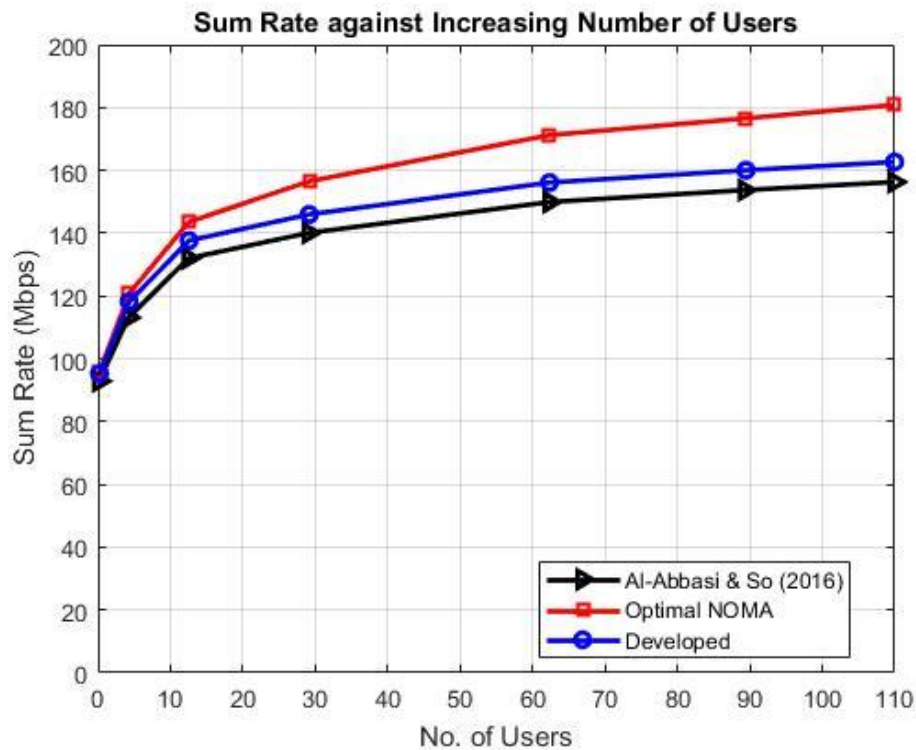


Figure 3. Sum Rate of the System versus Different Number of Users.

In figure 3, the performance of the total system sum rate is plotted against the number of users  $U$  (where  $U$  varies from 0 to 110). A tolerance,  $k_i$  of 0.2 and the maximum bandwidth limit of 5MHz were set. It is observed that the sum rate increases as the number of users grows as a result of multi users' diversity gain. As the number of users grows higher, the sum rate keeps on increasing, but the rate of the

growth becomes slower as expected from Shannon's formula for calculating sum rate. It is also observed that the performance of the developed scheme is better than the HPPA scheme of [12]. This is because the inter user and multi user interference in the system are mitigated. Also the schemes exhibit similar behavior as the optimal one plotted alongside them in Figure 3.

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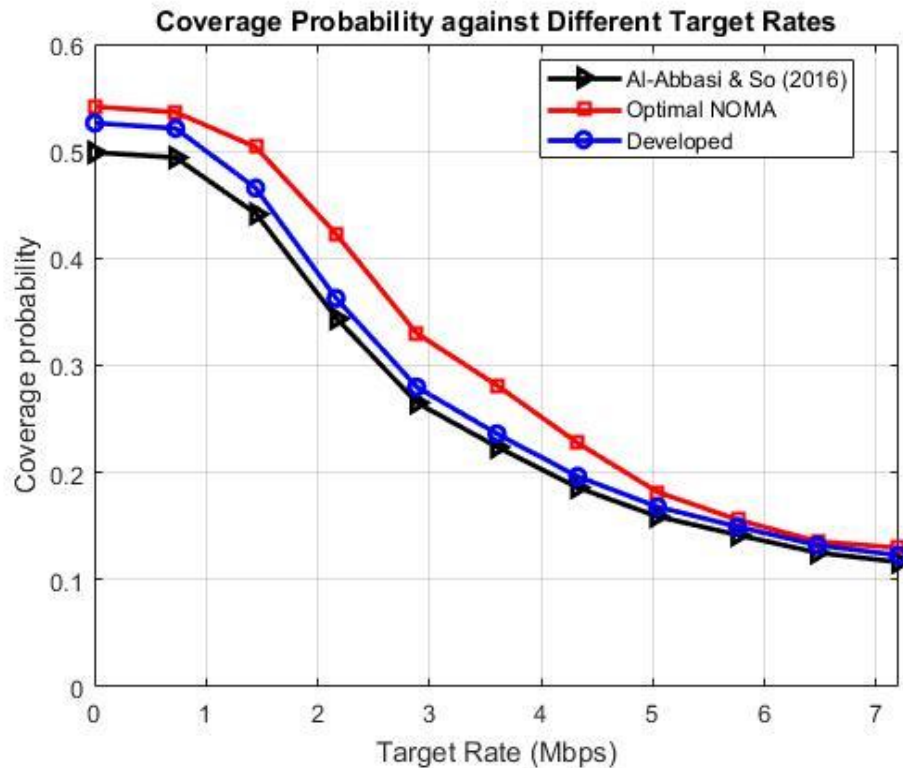


Figure 4. Coverage Probability versus Different Target Rate Values.

In Figure 4, coverage probability of 32 users is plotted against different target rates so as to examine the robustness of the developed scheme as compare to the optimal and HPPA scheme of [12]. The figure shows the sustainability of the developed scheme against different target rate and how close the scheme was to the optimal one which provide the effectiveness of the scheme's pairing process used in the NOMA system with a large number of users. It is also observed that the performance of the developed scheme is better than the HPPA scheme with recorded similar behavior as the optimal scheme.

## CONCLUSION

From the above results, it can be concluded that the developed scheme performed better than existing multi user resource allocation schemes in terms of sum rate and coverage probability. This was attributed to the fact that, unlike the existing schemes which paired similar users or random users and allocated power, this scheme paired dissimilar user, allocated them to a sub-channel then evaluate the power requirement of the sub-channel before its allocation. This reduced multi user interference, inter

user interference, and power wastage in the system, which made it possible for the sum rate and coverage probability of the system to improve.

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