



## An Efficient Resource Allocation Scheme for Non Orthogonal Multiple Accerss in a Millimeter Wave Channel for 5g

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### ABSTRACT

*Due to the ever-increasing demand for telecommunications services, the network suffers low speed and high latency. This seriously affects the performance of the networks due to the high burden placed on the existing wireless technologies to deliver high speed data rates with low latency. The exponential increase in demand for high speed and low latency data communications by mobile users define features of future networks. To ease the burden on the existing multiple access techniques, by offering high data rates, Non-Orthogonal Multiple Access (NOMA) and millimeter wave (mmwave) were proposed in 5G systems and beyond. NOMA as a multiple access scheme allows the multiplexing of several users over the same channel at same frequency and time resources. While mmwave allows the use of higher frequencies (that is 30-300GHz) for mobile communication purposes. However, the high-speed user and system sum capacity of data in this kind of multiple access system is another problem because it depends on efficient resource allocation techniques used to avoid high rate of interference and decoding errors. These important conditions are difficult to meet because techniques are not perfect. The techniques used by previous researchers to resolve low speed and high latency introduced some problems such as high interference and decoding errors, hence the need to improve these techniques. In this research work therefore, a resource allocation scheme that puts these problems in to cognizance and efficient energy utilization was developed. A single cell, multi user downlink mmwave NOMA system with N sub-channels and 110 users that are evenly spread in a cell of 150 meters diameter was considered. The performance of the developed scheme was compared with the existing works for validation.*

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### INTRODUCTION

The emergence of numerous technologies such as; Internet of Things (IOT), Artificial Intelligence (AI), Intelligent Transport Systems (ITS), Ultra High Definition Transmission Videos, etc., in our societies have led to the exponential increase in the demand for mobile data services in wireless Networks [1]. As wireless network service providers

attempt to provides high quality and low latency services to these applications and technologies, they are restricted to a carrier frequency spectrum of 700MHz to 2.6GHz, in which allocated spectrum for cellular technologies is just 780MHz. A spectrum of 200MHz is allocated to major wireless providers for their entire cellular activities [2]. Mobile data traffic is expected to keep increasing

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exponentially, due to continuous increase in high data demand applications and technologies. This demand necessitates the need to enhance the current mobile network capacity and capabilities [3]. Fifth Generation mobile network (5G) was proposed to solve this exponential increase in demand for mobile data. The four key technologies and techniques are identified as major players for boosting capacity in 5G. They include: the use of millimeter wave (mmwave) frequencies and small cells [4]. Deployment of Massive Multiple Input and Multiple Output (M-MIMO) antenna systems and the use of Non-Orthogonal Multiple Access (NOMA) techniques [5]. The mmwave provides a spectrum ranging from 30GHz to 300GHz for mobile communication purposes overcoming spectrum scarcity problem in microwave frequencies used in mobiles communications today [6]. More spectrum gives room for higher channel bandwidth which in turn leads to higher channel capacity. Even though the frequencies to be used in 5G are yet to be specified, the 60GHz and E-band (71-76GHz and 81-86GHz) are considered as the most promising of all [7].

Apart from the use of mmwave, effective utilization of the multi-user operations in the mobile network has the potentials of improving overall system capacity significantly. NOMA as a multiple access technique can enhance the capacity of the network, by allowing multiple users utilize the available resource (time and frequency) concurrently without special separation. This is achieved by the used of super position techniques [8]. It was estimated that about 5% of the total energy generated in the world is used up by Information and Communication Technology (ICT) equipment's which a great concern is both socially and economically worldwide. With the desire for greener future, efficient energy utilization by communication systems and processes is one of the great concerns in

the future networks (that is 5G and beyond). This makes Energy Efficiency (EE) one of the primary targets of 5G [9]. To exploit the potentials of the future networks, efficient resource allocation procedure is of paramount importance [10]. Hence, the development of a resource allocation scheme for 5G mmwave NOMA system is proposed.

## MATERIALS AND METHOD

### Model of the System

In this model, a single-tier 5G mmwave NOMA system in downlink scenario with K users is considered. The users were clustered into  $S^{\text{th}}$  pairs according to their channel gains.  $|h_{H,S}|^2$  denotes the channel gains of users with strong channel conditions while that with weak condition is denoted as  $|h_{L,S}|^2$ . A Base Station (BS) transmitting  $X_{i,S}$  signal to the  $K^{\text{th}}$  users (were:  $K = \{1, 2, \dots, k\}$ ) with a transmit power  $P_{i,S}^k$ , (were:  $i = \{H, L\}$ ) the signal received by the user K in pair S is,  $Y_{i,S}^k$  which is given by Equation (1).

$$Y_{i,S}^k = \sum_{k=1}^K \sqrt{(P_{i,S}^k |h_{i,S}^k X_{i,S}^k + N_{i,S}^k)} \quad (1)$$

where:

$|h_{i,S}^k$  denotes channel gain of the user

$N_{i,S}^k$  denotes additive white Gaussian noise.

The channel conditions of users are used as a yardstick for pairing them in this model. The paired users are then allocated to sub channels to mitigate the effects of interference that occurs due to multiplexing of high number of users in a single channel. These will lead to reduction in the receiver design complexity. Unrelated channel gain users, (that is weak and strong user) are paired and assign to a sub channel, which mitigates inter user interference that occurs due to pairing of users with related channel state condition. To ensured conformity with the constraint for 5G green communications and beyond, energy efficiency evaluation techniques is also incorporated in the designed model.

The developed modified model Equations are given as:

$$R_{sym} = \sum_{n=1}^N R_{subc n} \quad (2)$$

where:

$R_{sym}$  symbolize system total sum rate.

$R_{subc n}$  represent sum rate of the sub channel  $n$ .

$N$  symbolizes number of available sub channels in

the system (given as  $N: 1, 2, 3, 4, \dots, n$ )

$R_{subc n}$  is expressed as:

$$R_{subc n} = \beta \log_2((1 + \lambda_{L,S}) + (1 + \lambda_{H,S})) \quad (3)$$

where:

$\beta$  denotes bandwidth of a sub-channel  $n$ , which is expressed as:

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

where:

$W_T$  represent system's total bandwidth.

$\lambda_{L,S}$  and  $\lambda_{H,S}$  are SINR of the weak and strong user in the  $S^{th}$  pair, which are determined using the Equation (5).

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

where:

$N_0$  symbolizes noise spectral power density.

$P_{L,S}$  and  $P_{H,S}$  are the power allocated to the weak and strong users. They are obtained using Equation (6) and (7):

$$P_{H,S} = \frac{-\left(\beta N_0(|h_{H,S}|^2 + |h_{L,S}|^2)\right) + \sqrt{4|h_{H,S}|^2 |h_{L,S}|^2 \beta N_0(|h_{H,S}|^2 P_s) + ((N_0 \beta)^2) (|h_{H,S}|^2 + |h_{L,S}|^2)^2}}{2|h_{H,S}|^2 |h_{L,S}|^2} \quad (6)$$

$$P_{L,S} = \frac{\beta N_0(|h_{H,S}|^2 + |h_{L,S}|^2) + 2P_s |h_{H,S}|^2 |h_{L,S}|^2 - \sqrt{4|h_{H,S}|^2 |h_{L,S}|^2 \beta N_0(|h_{H,S}|^2 P_s) + ((N_0 \beta)^2) (|h_{H,S}|^2 + |h_{L,S}|^2)^2}}{2|h_{H,S}|^2 |h_{L,S}|^2} \quad (7)$$

$|h_{H,S}|^2$  and  $|h_{L,S}|^2$  are the channel gains which are estimated using Equation (8).

$$|h_{L,S}|^2 = |h_{H,S}|^2 = \xi |h_{K,S}|^2 d^{-\nu} \quad (8)$$

where:

$|h_{K,S}|^2$  denotes the Rayleigh fading factor.

$\xi$  symbolizes the log-normal shadowing factor.

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

$\nu$  denotes the path loss exponent of the path.

The expression used for power allocation given in Equation (9) is:

$$P_n = \frac{G_{g,n} P_{tal}}{\sum_{n=1}^N G_{g,n}} \quad (9)$$

where:

$G_{g,n}$  stands for channel gains sum of users in sub channel  $n$ .

$P_{tal}$  represent total power of the system.

$P_n$  is the power allocated to a subchannel  $n$ .

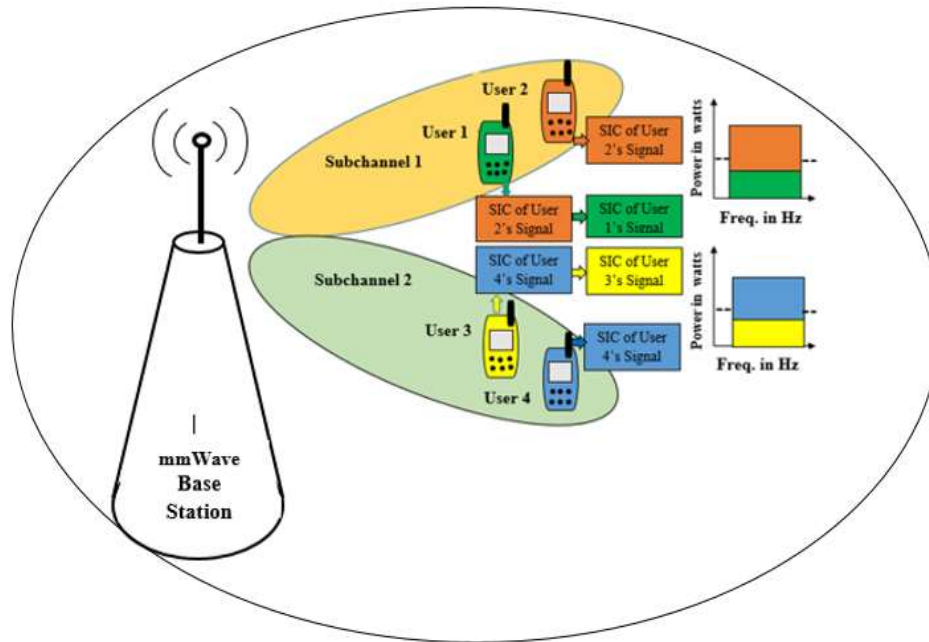
Energy Efficiency (EE) of sub channel  $n$  can be determine using Equation (10) as:

$$EE_n = \frac{R_{subc n}}{P_n} \quad (10)$$

where,  $R_{subc n}$  is the sub channel  $n$  total sum rate.

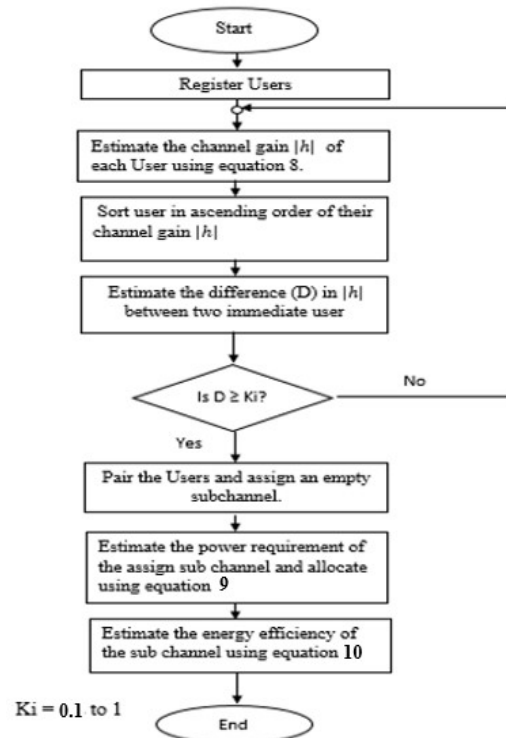
### The Developed Resource Allocation Scheme

The scheme employed sub channeling to mitigate the effect of interferences from multiple user's sources. This in turn reduces complexity of receiver design. It pairs users with unrelated channel state conditions (that is, weak and strong) to reduce inter-user interference. The energy usage of the scheme was minimized by allocating the exact required power by users and sub channel, so as to guarantee compliance with the requisite for green communication in 5G networks and beyond. To illustrate the operational procedure of the scheme, four users where considered, the pairing, sub-channeling, and power allocation procedure is shown in Figure 1.



**Figure 1:** Pairing, Sub channeling, and Power Allocation Concept of the Developed Scheme using Four Users.

The sequence flow of the scheme developed is shown in Figure 2. The scheme is consisting of two focal stages which are: the pairing and sub channel allocation of users, and power allocation and energy efficiency estimation stages. In pairing and sub channel allocation users' stage, user's channel gains are evaluated. Unrelated channel gains users are paired and allocate to sub channel, to mitigate the effect of interferences from user to user (that is inter-user) and from multiple-user sources. Whereas in the power allocation and energy efficiency estimation stage, the amount of power needed by the sub channel base on its users' pair is assessed and then assigned, to limit power consumption. The energy efficiency of the sub channel is also estimated in this phase to guarantee conformity with the constraint for 5G green communications.



**Figure 2:** A Flowchart of the Developed Scheme Operations.

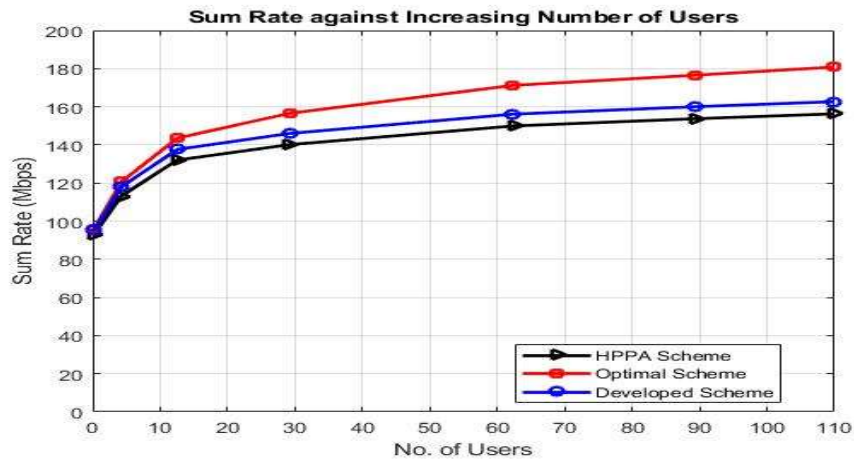
## RESULTS AND DISCUSSION

The results obtained from simulations are presented in this section to estimate the performance of the developed scheme. A Base Station (BS) with 32 users which are homogeneously spread in a cell range of 150 meters at unsystematic locations was considered in the simulation. A minimal distance of 30 meters between a user and the BS was set. The bandwidth and the carrier frequency used are 500MHz and 60GHz. The parameters used in the simulation

are presented in Table 1. To mitigate the decoding and demodulating toil in the SIC receiver, sub channels are assigned with one matched pair in this scheme. OFDM scheme as a comparator allocates one user. The performance of the developed scheme in terms of power allocation and energy efficiency estimation was compared with the Hierarchical Pairing and Power Allocation (HPPA) and optimal power allocation schemes for validation purposes.

**Table 1:** Simulation parameters used:

Parameters	Values
Number of users (U)	32
Total Transmit Power ( $P_T$ )	30 dBm
Total Bandwidth ( $W_T$ )	500 MHz
Carrier Frequency (CF)	60 GHz
Number of subscribers ( $N_S$ )	512
mmWave Losses (I.e. Penetration, atmospheric and Implementation loss)	8 dB
Noise Power Density ( $N_0$ )	-174 dBm/Hz
Cell Diameter (D)	300m
Link space ( $k_i$ )	0.1 to 1
Path Loss Exponents ( $\nu$ )	3
Minimum rate requirement ( $\Phi_{u,m}$ )	$0.6 \times 10^5$ bps



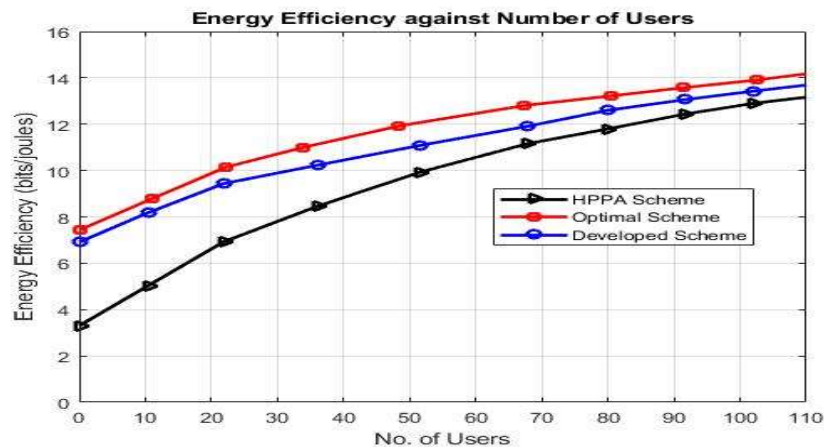
**Figure 3:** Variation of System's Sum Rate with Increase in Number of Users.

In Figure 3, variation of the overall system sum rate is presented with an increase in number of users U (where:

U varies from 0 to 110). A maximum bandwidth of 500Hz and a tolerance factor,  $k_i$  of 0.1 are set.

From the Figure, it is observed that the system's total sum rate increases with increased in number of users. This is due to users' multi diversity gain. As the number of users keep on increasing, the systems sum rate also keeps on growing further, but the rates of the growths become smaller as the number of users kept increasing up to its highest value. This was established by Shannon's theorem of sum rate estimation. The

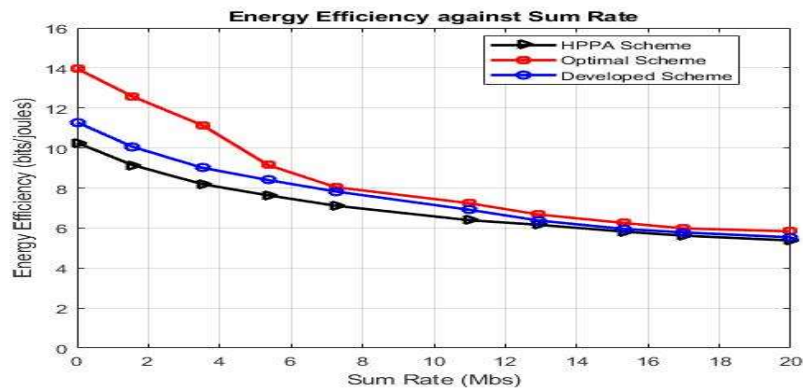
developed scheme was compared with HPPA and optimal NOMA schemes. The scheme shows improvement over HPPA with similar behavior as the optimal one. At a point where the number of users is 62, the sum rate of the developed scheme is 6.8% more than that of the HPPA scheme. This is due to mitigation of inter user and multi user interferences by the developed scheme.



**Figure 4:** Variation of System's Energy Efficiency with Increase in Number of Users.

The variation of the system's energy efficiency with increase in number of users is shown in Figure 4, with similar constraints as Figure 3. The system's energy efficiency also increases with increase in number of users. The trend of the growth curve is similar to that of sum rate curve, this is due to the high dependency of the system's energy

efficiency on sum rate which was established in Equation 11. From the Figure, it can also be observed that the developed scheme shows improvements in terms of performance as compared to the HPPA scheme with similar behavior as the optimal NOMA scheme. At a point where the number of users is 36, the developed scheme is 25% more energy efficient than the HPPA scheme.



**Figure 5:** Variation of System's Energy Efficiency with increase in Sum Rate.



The variation of the system's energy efficiency with increase in sum rate was shown in Figure 5, while considering the same deliverables as in Figure 3. It can be observed that the system's energy efficiency decreases as the sum rate increases. This direct effect continues until a saturation point is reached where the increased in sum rate has no effect on the energy efficiency, which is due to the direct dependency of system sum rate on SINR which is also dependent on transmit power, which was established in Equation (3) and (5).

### CONCLUSION

From the obtained results, it can be resolved that the developed scheme presented better performance in terms of system's sum rate capacity and energy efficiency than the existing schemes. This is accredited to the fact that, the scheme developed, pair's dissimilar user, allocate them to a sub channel, and evaluate the power requirement of the sub channel before it allocate the power. Unlike the existing schemes which pair similar users or random users and allocate power. This in turn mitigates the interference and reduce systems energy wastage. These made it feasible for the systems sum rate capacity to improved and also reduced energy usage of the system which in turn improved the energy efficiency.

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