Optimal resource allocation in 5G system using modified lion algorithm

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Abstract
This research work intends to examine the resource allocation issues within the hybrid multi-carrier non-orthogonal multiple access (MC-NOMA) systems, which includes the NOMA and orthogonal multiple access (OMA) modes. This is exploited to attain the energy efficiency (EE) and spectral efficiency (SE) tradeoff with the minimum rate requirements of users. The entire degree of freedom that is incorporated within the resource allocation comprised user clustering, power allocation, choice of multiple access (MA) modes, and subcarrier assignment as well. This work mainly focuses on the resource allocation issue having every minimum rate requirement of users for the SE-EE tradeoff in hybrid MC-NOMA systems. Moreover, this work aims to make this possible with the incorporation of the optimisation aspect since it is the most significant way of solving multi-objective problems. Here, the resource allocation along with power allocation seems to be the crucial fact that is modelled or designed as the single-objective problem. Thereby, the subcarriers, and powers are optimally allocated by means of a new algorithm named Lion algorithm with Probabilistic Mating, which is the modification of the Lion algorithm. Finally, the performance of the proposed work is compared over other state-of-the-art methods in terms of cost analysis.

1 | INTRODUCTION

The emerging fifth generation (5G) [1, 2] heterogeneous networks devastate the tremendous growth in mobile data traffic. In order to deal with the volatile traffic demand, more rigorous needs on latency, network security and so on have been made. The features of a few advanced 5G [3–8] are assigned as the core of media services: dependable and reliable network having zero downtimes; faster access with low latency and greater user experience data rate; and network agility that reduce the functioning time cycles to minutes from hours to cope with dynamics from mobility speed and density of connection. There is tremendous growth in the computation tasks because of the advancement in mobile devices and the IoT emergence, though they have limitations over the transmission and computation resources at users and MEC servers. Utmost, based on the transmission and computation delay, the task offloading delay happens. The identification is needed on how much computation task bit have been offloads to MEC servers, as well as how many radio resources have been allotted to disseminate every computation task in downlink and uplink. This is made in the case of partial offloading, to effectively exploit the communication and computation resources at end-users and MEC servers. Further, User Association and Resource Allocation (UARA) [9–11] must be a needed one and can be identified mutually for optimal leverage heterogeneity problems. The network throughput and quality of service (QoS) can be improved considerably using intelligent joint UARA [12–15] strategies. The network intelligence with the basic aspect is given as the self-adaption to the context of networks and users.

In the 5G [16, 17] system, numerous challenging techniques have been evolved like mobile edge computing, massive multiple-input and multiple-output (MIMO), and millimetre-Wave (mmW). Moreover, the performance improvement over cellular communication in 5G has been effectively made by non-orthogonal multiple access (NOMA), which can be identified as the most challenging candidate in multiple access (MA) schemes. Here, the instantaneous multiple users’ transmission
on every subcarrier is enabled by NOMA that uses the superposition coding within the receiver side, and also the preferred signal by means of successive interference cancellation (SIC) within the receiver side. The researchers change their concern over the non-orthogonality instead of orthogonality, as because of the complications in NOMA receiver is larger rather than OMA receiver. From this, it has been concluded that there is potentially massive support on connectivity for NOMA [18], and as well as enhances the spectral efficiency. However, the models limit maximum spectral efficiency, as well as restricts in the range of scenarios, and so on.

This research work has made an effort to introduce a new resource allocation strategy for solving multi-objective problems. For the effective resource allocation, the subcarrier allocation along with power allocation is considered jointly as a single-objective problem. This optimisation problem is solved effectively by introducing a new optimisation concept, called LA-PM, which is the modified LA algorithm. Finally, the proposed model is distinguished over other conventional optimisation algorithms regarding the cost analysis.

The paper is arranged in the following format: Section 2 defines the literature survey on resource allocation in NOMA. Section 3 explains the objective model, and Section 4 depicts the designing of a system model: hybrid multi-carrier non-orthogonal multiple access (MC-NOMA). Section 5 explains the proposed concept of optimal resource allocation with optimal power. Section 6 delineates the improved lion for optimisation problem: subcarrier allocation with optimal power. Section 7 exemplifies the results along with the discussions. Section 8 concludes the paper.

2 | LITERATURE SURVEY

2.1 | Related works

In 2018, Li et al. [19] have proposed a joint multiple-RAT user association along with the approach of resource allocation with the triple decision and the user’s context awareness as well. They have also designed a dynamic Game-Based Ant Colony Algorithm (GACA) for simultaneous system utility maximisation and resource allocation. Finally, the outcomes have reviewed that it was more sensible for making the association decision of multi-RAT. When comparing to other conventional works, the proposed model has alleviated the network congestion and has also effectively optimised the resource allocation strategy.

In 2018, Song et al. [18] have investigated the problem of resource allocation to attain spectral efficiency and energy efficiency tradeoff along with the needs of the minimum rate of user in hybrid MC-NOMA systems that have incorporated NOMA as well as orthogonal multiple access (OMA) modes in a single unified model. The freedom degrees included in resource allocation has the choice of MA modes, subcarrier assignment, user clustering, and power allocation was concerned combined. They have initially formulated the SE-EE tradeoff as the multi-objective optimisation (MOO) issue having the constraint of reduced rate requirement. Subsequently, the MOO issue was transferred into the issue of single-objective optimisation (SOO) with the utilisation of the weighted Tchebycheff model. Further, the SOO issue was solved by applying sequential convex programming and Lagrangian dual decomposition. Finally, the proposed work has proved its efficiency over other models.

In 2018, Martin et al. [20] have provided a new network resource allocator system that has enabled the independent network management aware of quality of experience (QoE). The respective system has predicted the demand to forecast the network resources count to be fixed and the needed topology for coping with the demand for traffic. Furthermore, the system dynamically provisions the network topology in a proactive way, while keeping the network operation within QoS ranges. To this end, the system processes the signal from multiple network nodes and end-to-end QoS and QoE metrics. This work has evaluated the system for live and on-demand dynamic adaptive streaming over hypertext transfer protocol (HTTP) and high-efficiency video coding services. From the experiment results, it was concluded that the system was able to scale the network topology and to address the level of resource efficiency, required by media streaming services.

In 2017, Femenías et al. [21] have stated the current position of next-generation wireless communication namely 5G networks. The main basic technique among other technical decisions was proposed namely, physical layer modulation waveform or format. The more fascinating two candidates were (i) orthogonal frequency division multiple (OFDM), which was the traditional proposal, construct on the large 4G network’s legacy; and (ii) filterbank multinary-carrier/offset quadrature amplitude Modulation (FBMC/OQAM), which was an advanced approach that gives up the subcarrier orthogonality of frequency selective channels regarding the maximised spectral efficacy. In this paper, a comprehensive scrutinise of both formats on modulation has been introduced regarding the practical network indicators like fairness, delay and service coverage. Finally, this paper further has introduced the unifying cross-layer approach, where the resource allocation procedures and downlink scheduling has encompassed. This was further constructed on the queuing process model in the data-link control layer and also the physical layer abstraction, which has been selected for constructing either of the above methods. The result has thus revealed the efficiency of the proposed work with better advantages.

In 2018, Alqerm and Shihada [22] propose an improved resource allocation approach on the basis of online learning, in which interference was mitigated and energy efficiency was maximised, on sustaining QoS needs for the entire users. RBs and power were included in the resource allocation process. The implementation of this adopted structure has been made using two techniques: centralised and decentralised, wherein centralised, the processing of resource allocation in the controller was incorporated along with the baseband processing unit. In a decentralised system, the optimal resource allocation constraint has been attained by macro BSs cooperation. In this, the priority of user in compact state representation learning and resource block (RB) allocation method has been considered, in
order to enhance the convergence speed and for the curse of dimensionality at the time of learning procedure. The simulation experiment that investigated thus concluded the betterment of the proposed model.

In 2019, Pouria et al. [23] have introduced an effective method for reducing the entire user’s execution delay within a single-cell power-domain non-orthogonal multiple access (PDNOMA) on the basis of Mobile edge computing MEC system having single MEC server and multiple users. Therefore the partition of the computation task of every user has been made as two estranged parts, one for local computing and other for network edge offloading. On taking the partial offloading structure, both the transmit power allocation and subcarrier policies were mutually gained on the downlink and uplink transmission having computation resource allocation and task scheduling on both MEC servers and users. The analysis thus alleviated that the performance on the network has been enhanced over 30% while comparing over the other task allocation and joint computation method when the computation and communication resources have been mutually optimised within the task allocation methods. Here, the fixed assumption on the values of both downlink and uplink data rates were made.

In 2016, Condoluci et al. [24] have implanted the virtual code resource allocation (VCRA) technique, in which the code-expanded strategy has been extended for supporting the large count of devices that concurrently access the system. Additionally, in order to make sure of the energy priority in the access procedure, a virtual resource allocation structure has been developed. The notion of this process was about the various access levels’ definition which develops access codewords with disjoint sets. The experimental outcome has explained the efficiency of the adopted scheme regarding the (i) reduction in machine’s collision probability with a restricted capacity of the battery as well in very huge cell load scenario and (ii) efficiency has been enhanced regarding the legacy code-expanded tactic.

In 2018, Hasabelnaby et al. [25] have proposed two joint and resource allocation and transceiver placement methods for redrected cooperative hybrid free-space optics (FSO)/mmW fronthaul networks. The major objective of this structure was to optimally attain the FSO/mmW transceiver placement, which has optimised the average bit error rate (BER), reliability, a number of disrupted links and average transmitted power of redrected cooperative hybrid FSO/mmW front haul networks on diverse weather situations. In order to gain the optimal solution, the formulation of the problem has been made as multi-objective and bilevel integer linear programming issues and was resolved on the basis of an exhaustive search model. The mathematical analysis has thus discussed the developments over the average BER, network reliability and average transmitted power, and by introducing the placement optimally, specifically on large rainfall rate and lesser visibility situations.

### 2.2 | Review

Features and challenges of some of the conventional works in resource allocation of 5G networking are summarised in Table 1. GACA [19] does improve the performance rate and also it achieves a better convergence rate. Additional algorithms are in need to enhance the performance rate. MC-NOMA [18] is the model that solves both the MOO and SOO problems. However, the model is complex in solving the error. K-mean clustering [20] is computationally faster, and it is complex to predict the k-value. Moreover, the clusters having different size and density cannot be handled more efficiently. FBMC/OQAM [21] does mine the related measures like service convergence and average delay. However, more future works are needed to enhance the performance rate. The online learning resource allocation model [22] does attain high energy efficiency, spectral efficiency and so on, but the computational complexity can be solved by making innovative ideas in the existing work. VCRA [24] reduces the collision complexity and also improves the performance rate with respect to the legacy code expansion model. However, the effect of phantom codes should be reduced by implementing future works. C-RAN [25] has the ability to tally all the weather conditions and in order to attain better results, more enhancements are needed in the optimisation concept.

### 3 | OBJECTIVE MODEL

This work mainly focused on the resource allocation issue having every minimum rate requirement of users for the SE-EE tradeoff in hybrid MC-NOMA systems, in this the normalised system throughput over bandwidth is depicted as SE and the delivered bits per unit energy is delineated as EE, that is, \( SE = \frac{J}{P} \) and \( EE = \frac{J}{P} \). In this, the joint consideration of entire degrees of freedom in resource allocation is made, which involves the choosing of MA nodes, subcarrier assignment, power allocation, and user clustering. Owing to [26], the tradeoff among SE and EE can really be equal to reducing the total power consumption and increasing the SE concurrently. Therefore, this has originated as MOO problem and is stated in the following.

\[
\begin{align*}
\min_{z, p} & \quad J(z, p) \\
\text{s.t.} & \quad C1 : P_i \leq P_T \\
& \quad C2 : \rho_{k, h_1}^z(b_1) \geq 0, \rho_{k, h_2}^z(b_2) \geq 0, \ldots, \rho_{k, h_N}^z(b_N) \geq 0 \quad \forall k \\
& \quad C3 : \sum_{h_1=1}^{H} \sum_{h_2=1}^{H} \ldots \sum_{h_N=1}^{H} \rho_{k, h}^z \leq 1 \quad \forall k \\
& \quad C4 : z_{k, h}^z \in \{0, 1\}, \quad \forall k \\
& \quad C5 : f_{k} \geq f_{\min}, \quad \forall h
\end{align*}
\]

In Equation (14), \( p = \{\rho_{k, h_1}^z(b_1), \rho_{k, h_2}^z(b_2), \ldots, \rho_{k, h_N}^z(b_N)\} \) and \( z = \{z_{k, h}^z\} \) having \( h_1, h_2, ..., h_N \in \{1, 2, ..., H\} \) and
### TABLE 1 Features and challenges of resource allocation strategies of conventional algorithms

| Author [citation] | Methodology | Features | Challenges |
|-------------------|-------------|----------|------------|
| Li et al. [19]    | GACA        | • Attains better convergence rate  
• Enhances the performance rate | • Enhancement is needed for further improvement  
• The involvement of additional algorithms is in need |
| Song et al. [18]  | MC-NOMA     | • Solves the MOO and SOO problem  
• Enhances the tradeoff among fairness and system effectiveness | • Additional complexity is there in reducing the error  
• Mode selection is quite complex |
| Martin et al. [20]| K-mean clustering | • Computationally faster | • Difficult to predict the k-value  
• Clusters with varied sizes and density cannot be worked out effectively |
| Femenias et al. [21]| FBMC/OQAM | • Extracts the user-relevant measures such as average delay, service coverage  
• High throughput | • An additional enhancement is needed to improve the performance rate |
| Alqerm and Shihada [22]| Online learning resource allocation model | • Assigns the task of resource allocation  
• Spectral efficiency  
• High energy efficiency | • The further enhancement makes the system model stronger |
| Pouria et al. [23]| PD-NOMA     | • Attains high-performance gain | • High computational complexity  
• Future work must be in consideration of communication resources |
| Condoluci et al. [24]| VCRA       | • Minimises the collision probability.  
• Improves efficiency in terms of the legacy code expansion strategy | • The impact of phantom codes must be minimised in the future |
| Hasabelnaby et al. [25]| C-RAN      | • Reliable.  
• Can tally all kinds of weather conditions | • Advancement is needed in the optimisation concept |

$k \in \{1, 2, ..., K\}$. The C3 and C4 constraints denote every subcarrier $k$ that adapted to the minimum one user cluster $(h_1, h_2, ..., h_N)$, whereas one user that occupies the maximum count of subcarriers is not constrained. The minimum rate requirement that serves as the QoS guarantee for every user is termed as C5.

For the summarised MOO problem in [27], the EE maximisation matches up to the precise option of the weighting parameter, after converting it as a scalar problem. The SE is maximised when the highest weighting parameter is being forced on the single objective (1a). Even though the SE is maximised and total power consumption is minimised by the MOO problem (1), despite directly increasing the SE and EE, it further can accomplish the SE-EE tradeoff for a precise weighting parameter range [26]. In this work, the multi-objective or multi-constraints are determined to form a single-objective definition, which is given in Equation (2).

$$
\text{Fit} = (w_1 \times J_h) + ((1 - w_1) \times P), \quad (2)
$$

$$
\text{obj} = \min(\text{Fit}). \quad (3)
$$

### 4 SYSTEM MODEL

Figure 1 illustrates a single-cell downlink MC-NOMA system, which applies hybrid MA transmission protocols of OMA (for instance: OFDMA) and NOMA to communicate one BS with $H$ simultaneously via $K$. The entire subcarriers are considered to go through quasi-static Rayleigh fading, which has the constant channel coefficients for every transmission block, still unique among diverse blocks.

Initially, the main concern is on the $k$th subcarrier with no loss of generality and $H_k$ users are supposed to cluster and assign for transmission on this subcarrier. In this, the count of $H_k$ having to gratify the following criteria $1 \leq H_k \leq N$, where the maximum count of users permitted to transmit on $k$th subcarrier is depicted as $N$. If the condition $H_k = 1$, the single
user transmits on subcarrier $k$ under OMA manner, whereas when $H_k > 1$ the transmission of $R_k$ users on $k$th subcarrier is made simultaneously by NOMA protocol. Like such a transmission case, the inference may receive by the user $b \in \{1, \ldots, H_k\}$ from other users multiplexed on a similar subcarrier. Further, $\Psi_k$ on subcarrier $k$ and that indicates $H_k = |\Psi_k|$. Subsequent to this, the received signal for the user $b$ on the $k$ is stated in Equation (4).

$$r_{\Psi_k}^k (b) = f_k^b \sum_{i \in \Psi_k} \sqrt{p_{\Psi_k}^k (i)} \phi^k_{\Psi_k} (i) + p_b^k. \quad (4)$$

In this, the $\phi^k_{\Psi_k} (i)$ from BS on subcarrier $k$ to user $i$, the additive white Gaussian noise (AWGN) having $\sigma^2$ at user $b$ on subcarrier $k$, $f_k^b$ among the BS and user $b$ at subcarrier $k$ and $p_{\Psi_k}^k$ that is assigned to user $b$ at subcarrier $k$.

On behalf of every subcarrier which invokes the NOMA scheme, the normalised channel gains of $H_k$ users are assumed to be at subcarrier $k$ that trails the order of $0 < \hat{b}_1^k \leq \hat{b}_2^k \leq \ldots \leq \hat{b}_{b_k}^k$ in this $\hat{b}_j^k = \int f_j^k/\sigma^2$, $b \in \{1, \ldots, H_k\}$. SIC is performed as a result of this on the powerful channels. When assuming $1 \leq j \leq b < i$, the message of $j$th user can be decoded by $b$th user and treat the $i$th user message as interference. Especially, the message can be decoded by $b$ users, and after that successively the message gets subtracted for gaining their own instruction. Followed by this aforesaid procedure, the received signal to interference plus noise ratio (SINR) on subcarrier $k$ for $b^{th}$ user is portrayed in Equation (5). Now, Equation (6) explains the normalised achievable data rate at a unit bandwidth on subcarrier $k$ for user $b$.

$$\gamma_{\Psi_k}^k (b) = \frac{b_k^k p_{\Psi_k}^k (b)}{\hat{b}_j^k \sum_{i \in \Psi_k} \hat{b}_j^k \geq b_k^k, i \neq b_k^k} f_{\Psi_k}^k (b) + 1, \quad (5)$$

$$d_{\Psi_k}^k (b) = \log_2 \left( 1 + \gamma_{\Psi_k}^k (b) \right). \quad (6)$$

**Remark 1.** On the basis of the NOMA principle, the SINR expression in Equation (5) is extracted. When $H_k = 1$ then only one single user can access the subcarrier $k$ orthogonally. For such a case, Equation (6) yet clings to the denominator’s first term and is disappeared, therefore no inter-user interference on subcarrier $k$ is there that is just pretending to be the OMA case. That is why Equation (5) is relevant for NORMA and OMA. The implemented model is really incorporation of OMA and NORMA within a unified structure by using the generic SINR expression, that is, hybrid MC-NOMA model. Such a structure has the benefit of performing the resource allocation and optimisation algorithm design for OMA and NORMA by deploying the unified technique rather than performing distinctly.

**5 | PROPOSED MODEL OF OPTIMAL RESOURCE ALLOCATION WITH OPTIMAL POWER**

**5.1 | Achievable data rate**

Consider, $N \geq 2$ users are permitted to multiplex and cluster on the similar subcarrier by applying NOMA mode. For subcarrier $k$, the user cluster is considered as $\Psi_k = \{b_1, b_2, \ldots, b_N\}$, in this $b_1, b_2, \ldots, b_N \in \{1, 2, \ldots, H\}$. Owing to Equation (6), when $b_1^k \geq b_2^k \geq \ldots \geq b_{b_N}^k$, Equation (7) defines the normalised achievable data rate of user $b_1$. Equation (8) explains the normalised achievable data rate of user $b_2$.

$$\frac{d_{\Psi_k}^k (b_1)}{b_k^k} = \log_2 \left( 1 + \frac{b_k^k p_{\Psi_k}^k (b_1) \hat{b}_1^k}{b_k^k} \right), \quad (7)$$

$$\frac{d_{\Psi_k}^k (b_2)}{b_k^k} = \log_2 \left( 1 + \frac{b_k^k p_{\Psi_k}^k (b_2) \hat{b}_2^k}{b_k^k} \right). \quad (8)$$

Likewise, based on Equation (3), the normalised achievable data rate of the other users in $\Psi_k$, that is, $d_{\Psi_k}^k (b_2), \ldots, d_{\Psi_k}^k (b_N)$ which has been eliminated in this for the sake of simplicity. Consequently, the subcarrier $k$’s total normalised data rate is depicted as per Equation (9).

$$f_{\Psi_k}^k = \frac{d_{\Psi_k}^k (b_1) + d_{\Psi_k}^k (b_2) + \cdots + d_{\Psi_k}^k (b_N)}{b_k^k}. \quad (9)$$

Equations (7)–(9) still holds for the special case of $b_{h_1}^k = b_{h_2}^k = \cdots = b_{h_N}^k$. Actually, for a particular subcarrier, the channel gains of diverse users are not similar because of their mutually independent arbitrary nature. Certainly, the event of two links with similar channel gain has been verified as Lebesgue-measure zero having the fading process as a continuous cumulative distribution function. Because of the significance, the occurrence of a special case of $b_{h_1}^k = b_{h_2}^k = \cdots = b_{h_N}^k$ is made, only if $b_1 = b_2 = \cdots = b_N$. While $b_1 = b_2 = \cdots = b_N$ on a subcarrier, a single user $b_1$ is adopted with the transmission, that is, orthogonally, the user $b_1$ has access over the subcarrier $k$. This again expresses that the proposed system model is a hybrid MA model that integrates the OMA and NOMA. For the exceptional case $b_{h_1}^k = b_{h_2}^k = \cdots = b_{h_N}^k$ for expressing the OMA and NOMA in a unified work, the user $b_1, b_2, \ldots, b_N$ is viewed as diverse users in the arithmetical perception. Then $b_{h_1}^k = b_{h_2}^k = \cdots = b_{h_N}^k$, do not need to consider the decoding order is and how the power is allotted for each subcarrier $k$ among $b_{h_1}^k p_{\Psi_k}^k (b_1), b_{h_2}^k p_{\Psi_k}^k (b_2), \ldots$ and $p_{\Psi_k}^k (b_N)$, but $f_{\Psi_k}^k$, which is the total normalised data rate of subcarrier $k$ keeps as the same, as one user is really represented by $b_1, b_2, \ldots, b_N$.

A binary variable $z_{\Psi_k}^k \in \{0, 1\}$ and parameter $b_{\Psi_k}^k \in \{0, 1\}$ are presented to portray the system throughput and power consumption. The user clustering indicator and subcarrier assignment are given by $z_{\Psi_k}^k$. When the user cluster $\Psi_k$ is
assigned with subcarrier $\Psi^k$ is assigned with one; or else, $\Psi^k$ is given as zero. Here, the parameter is $\Psi^k$ defined as per Equation (10).

$$
\Psi^k = \begin{cases} 
1, & \text{if } \psi^k \geq \psi^k \geq \cdots \geq \psi^k, \forall k, \\
0, & \text{otherwise}
\end{cases} \tag{10}
$$

It is to be noted that, based on the channel conditions of the entire users in the cluster $\Psi_{\Psi^k}$, $\Psi^k$ is assigned as a constant parameter, other than the optimisation variable. By using $\Psi_{\Psi^k}$ and $\Psi_{\Psi^k}$, the throughput of the hybrid MC-NOMA system is computed as the sum of data rates produced by the entire subcarriers, and that is stated in Equation (11).

$$
J = \sum_{h_1=1}^{H} \sum_{b_1=1}^{H} \cdots \sum_{h_N=1}^{K} \sum_{k=1}^{K} \Psi^k \Psi^k (b_1) + \Psi^k (b_2) + \cdots + \Psi^k (b_N) \tag{11}
$$

The data rate of any user $b$ is extracted next. The data rate of any user $b \in \{1, 2, \ldots, H\}$ involves multiple parts. The produced data rate is given as per the Equation (12), when a user $b$ is one among the largest channel gain within $\Psi_{\Psi^k}$. In cases like the user $b$ has the second-largest channel gain within the $\Psi_{\Psi^k}$, Equation (13) explains the produced data rate.

$$
J_{b,1} = \sum_{h_1=1}^{H} \sum_{b_1=1}^{H} \cdots \sum_{h_N=1}^{K} \sum_{k=1}^{K} \Psi^k \Psi^k (b_1) + \Psi^k (b_2) + \cdots + \Psi^k (b_N) \tag{12}
$$

$$
J_{b,2} = \sum_{h_1=1}^{H} \sum_{b_1=1}^{H} \cdots \sum_{h_N=1}^{K} \sum_{k=1}^{K} \Psi^k \Psi^k (b_1) + \Psi^k (b_2) + \cdots + \Psi^k (b_N) \tag{13}
$$

Similarly, the other data rate expressions can be extracted that is $J_{b,3}, J_{b,4}, \ldots, J_{b,N}$, while the user $b$ channel gain is within other user cluster order $\Psi_{\Psi^k}$ that defines the structure the same as (12) and (13). Hence, the sum of data rates that produced from above entire cases is termed as the total data rate of the user $b$ and that is denoted as per Equation (14).

$$
J = \sum_{h_1=1}^{H} \sum_{b_1=1}^{H} \cdots \sum_{h_N=1}^{K} \sum_{k=1}^{K} \Psi^k \Psi^k (b_1) + \Psi^k (b_2) + \cdots + \Psi^k (b_N) + \Psi^k (b_1) + \cdots + \Psi^k (b_N) \tag{14}
$$

### 5.2 Power consumption model

The BS's transmit power is given in Equation (15), with the help of $\Psi^k$ and $\Psi_{\Psi^k}$. Now, BS's total power consumption is stated as the sum of the dynamic amplifier's power and static circuit power, and this is expressed in Equation (16).

$$
P_f = \sum_{h_1=1}^{H} \sum_{b_1=1}^{H} \cdots \sum_{h_N=1}^{K} \sum_{k=1}^{K} \Psi^k \Psi^k (b_1) + \Psi^k (b_2) + \cdots + \Psi^k (b_N), \tag{15}
$$

$$
P_f = P_f + \varepsilon P_f. \tag{16}
$$

### 6 IMPROVED LION FOR SOLVING OPTIMISATION PROBLEM: SUBCARRIER ALLOCATION WITH OPTIMAL POWER

#### 6.1 Solution encoding

The solution encoding of the proposed algorithm is expressed using an example. Consider the number of subcarriers as $k = 5$ and a maximum number of users per subcarrier as $l = 3$ and $\nu$ is the user. Then the allocated subcarriers for users are given in Figure 2. The respective power allocation to users for each subcarrier is given in the figure, then the solution encoding is explained using Figure 3. The exemplary solution encoding of the proposed work is illustrated in Figure 4.

#### 6.2 Conventional lion algorithm

LA [28] is a huge-scale and standard bilinear systems that solve the single-object and multi-object optimisation problems. Actually, Lions survive as clusters and have a head, which is male
named as pride. The male cubs usually stay with pride that gave birth to it, till the cubs achieve the adult phase. After that stage, they leave the birth pride and acts as a nomadic lion that wanders alone. If this nomadic lion meets up with other pride, the challenge has been made in terms of supremacy. After the victory of a nomadic lion over the pride, it will become the new pride. The LA incorporates four processes such as the generation of pride, territorial defense, mating, and territorial takeover.

6.2.1 Problem formulation

Assume the objective function of this algorithm as per the Equation (17). The solution space is of size \( \mathbb{R}^n \) and is expressed as \( f(\bullet) \) that denotes the continuous unimodal or multimodal function in Equation (1). \( x_i : i = 1, 2, \ldots, n \) is delineated as a solution variable in \( n \) position and \( n \) on \( n \)th position. Equation (18) explains the solution space size and the optimal solution size that is termed as \( X^{opt} \), and that is stated as per the Equation (19).

\[
X^{opt} = \arg\min_{x \in \mathbb{R}_{\min}^{\mathbb{R}_{\max}}} f(x_1, x_2, \ldots, x_n); \quad n \geq 1, \quad (17)
\]

\[
\mathbb{R}^{-} = \prod_{n=1}^{n} (x_{\min}^{n} - x_{\max}^{n}), \quad (18)
\]

\[
X^{opt} = X : f(X) = f(X') [X' \neq X; x'_m] \in (x_{\min}^{m}, x_{\max}^{m})), \quad (19)
\]

Here, \( X \) is evaluated by \( X = [x_1, x_2, \ldots, x_n] \).

6.2.2 Pride generation

The pride is initiated by the following solutions: \( X^{\text{nomad}}, X^{\text{male}}, \) and \( X^{\text{female}} \). The nomadic lion is involved in this process of pride generation despite not having any membership. The lion formulation is quite equivalent to the solution vector. The vector element of \( X^{\text{nomad}}, X^{\text{male}} \) and \( X^{\text{female}} \) is symbolised as \( x_{\text{nomad}}^{q}, x_{\text{male}}^{q} \) and \( x_{\text{female}}^{q} \). The female fertility is making sure by \( f_{\text{female}} \).

\[
\text{Solution encoding}
\]

\[
\text{FIGURE 3: Exemplary representation of respective power allocation to users for each subcarrier.}
\]

\[
\text{FIGURE 4: Solution encoding.}
\]

\[
6.2.3 Fertility evaluation
\]

The laggards achieve the global and local optima, while \( X^{\text{male}} \) and \( X^{\text{female}} \) get saturated over to skip from local optimal solutions. Afterwards, \( X^{\text{male}} \) is assumed to be laggard and the laggardness rate \( d_r^{\text{b}} \) is elevated by 1 when \( f(X^{\text{male}}) \) is larger than \( f^{\text{new}} \). At the time of \( d_r^{\text{b}} \) exceeds by \( d_r^{\text{h}} \), and then the territorial defense is urged. Once after the completion of crossover, \( X^{\text{female}} \) fertility is making sure by \( \delta t_r \), and is moreover elevated by one. Equation (24) represents the update for \( X^{f}\), if \( \delta t_r \) surpasses the \( \delta t_r^{\text{max}} \). On the basis of advancement, the mating function is exploited over a stipulation of updated female \( X^{\text{female}^+} \) and is considered as \( X^{\text{female}} \).

\[
x_{\text{female}}^{+} = \begin{cases} x_{\text{female}^+}^{q} & \text{if } k = q \\ x_{\text{female}}^{q} & \text{otherwise} \end{cases}, \quad (24)
\]

\[
x_{\text{female}}^{+} = \min|x_{\text{female}}^{max}, \max(x_{\text{female}}^{min}, \nabla_q)|, \quad (25)
\]

\[
\nabla_q = \left[ x_{\text{female}}^{q} + (0.1 \times n_{\text{ran}2} - 0.05) \left( x_{\text{male}}^{q} - n_{\text{ran}1} x_{\text{female}}^{q} \right) \right]. \quad (26)
\]
Here, \( x_k^{\text{female+}} \) and \( x_q^{\text{female}} \) are assumed as \( k \)th and \( q \)th vector element of \( X^{\text{female+}} \), correspondingly, \( k \) within the intervals \([1, k]\), \( \mathbb{V} \) as well as \( ran_1 \) and \( ran_2 \), and falls over the range \([0, 1]\).

6.2.4 Mating

Two processes are there in the mating process, mutation, and crossover. In accordance with this, the new set of generations has been evolved, which contains \( X^{\text{male}} \) and \( X^{\text{female}} \) cubs. In this, the crossover process creates four cubs and the mutation creates the other four cubs.

6.2.5 Lion operators

Here, the territorial defense has been performed by assisting the prevention of local optimum point to the algorithm and wide search solution space and also determines the equivalent fitness diverse solution. The territorial defense has been sequenced in this as producing nomad coalition, survival fight and then, the update of nomad and pride coalition. \( X^{\text{e−nomad}} \) selection will be performed, only if the Equations (27)–(29) gets fulfilled.

\[
\begin{align*}
    f(X^{\text{e−nomad}}) &< f(X^{\text{mal}}), \\
    f(X^{\text{e−nomad}}) &< f(X^{\text{mal_cub}}), \\
    f(X^{\text{e−nomad}}) &< f(X^{\text{fem_cub}}).
\end{align*}
\]

Once the \( X^{\text{male}} \) gets defeated, the update of new pride is made. Similarly, after the defeat of \( X^{\text{nomad}} \), the update of the nomad coalition happens.

6.2.6 Termination

The stopping criteria are obtained only if the processes satisfy the following condition on Equation (30) and (31).

\[
C_{\text{gen}} > C_{\text{gen max}}, \quad (30)
\]

\[
f(X^{\text{male}}) - f(X^{\text{opt}}) \leq ER^{\text{th}}, \quad (31)
\]

Here, \( C_{\text{gen}} \) is assigned as zero and then gradually increased in correspondence to the happening of the territorial takeover. Algorithm 1 depicts the pseudo-code of the conventional LA algorithm.

### Algorithm 1: Pseudo-code of conventional LA

| Step | Description |
|------|-------------|
| 1    | Initiate \( X^{\text{ma}} \), \( X^{\text{fe}} \) and \( X^{\text{nd}} \) |
| 2    | Evaluate \( f(X^{\text{ma}}) \), \( f(X^{\text{fe}}) \) and \( f(X^{\text{nd}}) \) |
| 3    | Assign \( f^{\text{th}} = f(X^{\text{ma}}) \) and \( C_{\text{gen}} = 0 \) |
| 4    | Store \( X^{\text{ma}} \) and \( f(X^{\text{ma}}) \) |
| 5    | Carry out fertility evaluation |
| 6    | Carry out mating and gain cubpool |
| 7    | Carry out gender clustering and gain \( X^{\text{ma_cub}} \) and \( X^{\text{fe_cub}} \) |
| 8    | Initiate \( \hat{A}_{\text{max}} \) as zero |
| 9    | Implement the cub growth function |
| 10   | Execute territorial defense; if the result of a defense is 0 move to step 4 |
| 11   | If \( \hat{A}_{\text{cub}} < \hat{A}_{\text{max}} \), move to step 9 |
| 12   | Carry out territorial takeover and gain updated \( X^{\text{ma}} \) and \( X^{\text{fe}} \) |
| 13   | Increment \( C_{\text{gen}} \) by one |
| 14   | If the stopping criteria did not meet, move to step 4 |
| 15   | Else |
| 16   | Terminate the process |

### Algorithm 2: Pseudo-code of proposed LA-PM Algorithm

| Step | Description |
|------|-------------|
| 1    | Initiate \( X^{\text{ma}} \), \( X^{\text{fe}} \) and \( X^{\text{nd}} \) |
| 2    | Evaluate \( f(X^{\text{ma}}) \), \( f(X^{\text{fe}}) \) and \( f(X^{\text{nd}}) \) |
| 3    | Assign \( f^{\text{th}} = f(X^{\text{ma}}) \) and \( C_{\text{gen}} = 0 \) |
| 4    | Store \( X^{\text{ma}} \) and \( f(X^{\text{ma}}) \) |
| 5    | Carry out fertility evaluation |
| 6    | Carry out mating by assign two variables \( ra \) and \( pb \) |
| 7    | If \( ra < pb \) |
|      | { Crossover process } else |
|      | Mutation process |
|      | Gain cubpool |
| 8    | Carry out gender clustering and gain \( X^{\text{ma_cub}} \) and \( X^{\text{fe_cub}} \) |
| 9    | Initiate \( \hat{A}_{\text{max}} \) as zero |
| 10   | Implement the cub growth function |
| 11   | Execute territorial defense; if the result of a defense is 0 move to step 4 |
| 12   | If \( \hat{A}_{\text{cub}} < \hat{A}_{\text{max}} \), move to step 9 |
| 13   | Carry out territorial takeover and gain updated \( X^{\text{ma}} \) and \( X^{\text{fe}} \) |
| 14   | Increment \( C_{\text{gen}} \) by one |
| 15   | Else |
| 16   | Terminate the process |
6.3 | Proposed LA-PM algorithm

LA is the new renowned nature-inspired metaheuristic optimisation concept that developed based on Lion’s social behaviour [33]. This lion algorithm is certainly insisted on four stages pride generation, mating, territorial takeover, and territorial defense, they are well known on solving the single-objective and MOO issues. Moreover, LA has few interesting features over the other nature-inspired algorithms such as pre-defined algorithm parameters and defined initial population size ($=3$). The algorithm has also been reported as competing in wide search problems [34, 35]. Inspired from these features, this paper uses LA to solve the resource allocation problems, in view of the fact that LA is more suitable for high dimension problems and scalable in its nature. Nevertheless, the general procedures of LA are not suited for handling the resource allocation problem. For that reason, the resource allocation problem is solved efficiently by developing a new optimisation model, known LA-PM, which is the modified LA algorithm.

Here, the modification is exploited within the mating phase. In the conventional LA algorithm, both the crossover and mutation process is formulated within the mating phase. In this proposed work, a random number $ra$ is assigned which ranges between the interval $(0, 1)$ and the probability $pb$ is assigned as per the Equation (32). Then it checks on the condition if the random number $ra$ is less than probability $pb$. If the condition is attained to be true, then only the crossover process is taken place within the mating phase, or else the mutation process is performed. The representation of the pseudo-code for the proposed LA-PM Algorithm is given in Algorithm 2. The flowchart of the proposed LA-PM Algorithm is symbolised in Figure 5. In Equation (32), male fit defines the male lion’s fitness and female fit concludes the female lion’s fitness.

$$pb = \frac{\text{male fit} + \text{female fit}}{\max(\text{male fit}, \text{female fit})}. \quad (32)$$

7 | RESULTS AND DISCUSSIONS

7.1 | Simulation setup

The implementation of this proposed resource allocation model is simulated using MATLAB 2018a. In this, the analysis is performed by varying the number of subcarrier ($k$) as 1, 5, 8 and 10 along with varying the maximum number of users per subcarrier ($l$) as 3, 6, 8 and 10, as well as weight as 0, 0.5 and 1. Further, the cost analysis and statistical analysis is carried out in this paper. The statistical analysis is made over the other conventional models like GA [29], PSO [30], DA, GWO and FF [31], WOA [32], LA [28] in terms of best, worst, mean, median and standard deviation measures. The used parameters for the experimentation purpose are given in Table 2.

![Flow chart presentation of the proposed LA-PM algorithm](image-url)

| TABLE 2 | Parameters for simulation |
|----------|--------------------------|
| Parameters | Default value |
| $P_t$ | 30 dBm |
| $P_i$ | 1W |
| $\varepsilon$ | 2.6316 |
| Path loss exponent | 3.8 |
FIGURE 6 Performance of proposed resource allocation model over conventional methods under different constraints $l_v$, $k$ and $w$: set $l_v = 3$ with varying $k$ as 1, 5, 8 and 10 (a) power (b) data rate (c) Total cost

7.2 Overall performance analysis

Figures 6–9 illustrate the overall performance analysis of the proposed resource allocation model over other conventional models under different constraints $k$, $l_v$ and $w$. Figure 6(a–c) exemplifies the graph plotting of power, data rate, and total cost by fixing $l_v$ as 3 and varies the $k$ by 1, 5, 8 and 10. Figure 7(a–c) symbolises the graph of power, data rate and total cost with $k$ fixed as 10 and varying the $l_v$ as 3, 6, 8 and 10. Figure 8(a–c) expresses the power, data rate and total cost graph with minimum $k$ and $l_v$ as 1 and 3, and by varying in accordance to weight. Figure 9(a–c) plots the graph for power, data rate and total cost with maximum $k$ and $l_v$ as 10 and 10, and with varied weight.

7.3 Cost analysis

In order to attain efficient resource allocation, the following factors are needed to be considered, that is, the power consumption has to be minimised along with the minimised data rate, thereby the total cost (total fitness) should be minimised, which is already mentioned in Equation (15). In this proposed work, on comparing with the other conventional models, the power consumption and total cost are achieved to be low. Hence, based on these factors, the models are ranked for both the conventional and proposed algorithms and are given in Table 3.

In this, a new ranking strategy is made, for comparing the performance of proposed over the conventional models that are
explained as follows: For the number of subcarrier $k = 1$ with $v = 3$, the proposed model has attained the power as 8.90 with rank 1, data rate as 7.72 with rank 4 and total cost as 0.0074 with rank 1. Then the final rank is calculated as follows: Average rank $= \frac{1 + 4 + 1}{3}$, that is, 2. Same for the conventional 1 (GA), the power obtained is 33.62 with rank 3, data rate as 18.57 with rank 3, total cost as 0.0941 with rank 3, then the average rank is $\frac{3 + 3 + 3}{3}$, which is 3. For the conventional algorithm 2 (PSO), the gained power is 32.58 with rank 2, data rate as 18.90 with rank 2 and total cost as 0.0855 with rank 2, then the average rank is 2. Similarly, for other conventional FF, WOA, and LA, the average rank that obtained is 3, 2 and 2. From this, the final rank is estimated as follows:

| Algorithm | Average rank | Final rank |
|-----------|--------------|------------|
| GA        | 3            | 2          |
| PSO       | 2            | 1          |
| FF        | 3            | 2          |
| WOA       | 2            | 1          |
| LA        | 2            | 1          |
| LA-PM     | 2            | 1          |
TABLE 3  Ranking of the proposed algorithm over other conventional methods in terms of total cost

| Algorithm | Power | Data rate | Total cost | Final rank | Power | Data rate | Total cost | Final rank | Power | Data rate | Total cost | Final rank | Power | Data rate | Total cost | Final rank |
|-----------|-------|-----------|------------|------------|-------|-----------|------------|------------|-------|-----------|------------|------------|-------|-----------|------------|------------|
| No. of subcarrier $k = 1$ |
| GA [28] | 33.62(3) | 18.57(3) | 0.0941(3) | 2 | 61.74(5) | 47.97(2) | 0.0861(6) | 6 | 79.95(3) | 86.52(4) | $-0.0411(5)$ | 5 | 60.04(4) | 27.30(3) | $0.2048(5)$ | 4 |
| PSO [29] | 32.58(2) | 18.90(2) | 0.0855(2) | 1 | 47.64(4) | 42.83(3) | 0.0263(4) | 4 | 55.66(1) | 66.67(5) | $-0.0689(4)$ | 4 | 27.32(1) | 3.60(5) | $0.1483(1)$ | 1 |
| FF [30] | 37.8424(4) | 19.30(1) | 0.1160(4) | 2 | 79.95(6) | 71.81(1) | 0.0509(5) | 5 | 79.95(2) | 107.38(2) | $-0.1716(2)$ | 2 | 56.53(2) | 25.21(4) | $0.1959(2)$ | 2 |
| WOA [31] | 8.90(1) | 7.72(4) | 0.0074(1) | 1 | 28.13(1) | 24.19(6) | 0.0247(3) | 3 | 79.95(3) | 107.96(1) | $-0.1752(1)$ | 1 | 79.95(5) | 47.71(1) | $0.2016(4)$ | 3 |
| LA [28] | 8.89(1) | 7.72(4) | 0.0074(1) | 1 | 31.05(2) | 27.17(5) | 0.0242(2) | 2 | 55.66(1) | 66.67(5) | $-0.0689(4)$ | 4 | 59.70(3) | 28.04(2) | $0.1981(3)$ | 2 |
| DA | 35.16(4) | 19.22(2) | 0.099(4) | 3 | 50.9(5) | 44.1(4) | 0.042(5) | 5 | 61.8(2) | 68.89(6) | $-0.04(5)$ | 4 | 30.67(2) | 4.53(6) | $0.16(2)$ | 2 |
| WOA | 35.61(5) | 18.79(4) | 0.10(5) | 6 | 66.0(7) | 47.7(3) | 0.114(8) | 7 | 79.9(4) | 84.90(5) | $-0.03(7)$ | 6 | 66.4(6) | 30.10(2) | $0.227(7)$ | 5 |
| LA-PM | 8.89(1) | 7.72(4) | 0.0074(1) | 1 | 34.95(3) | 31.15(4) | 0.0238(1) | 1 | 79.95(3) | 106.75(3) | $-0.1677(3)$ | 3 | 27.32(1) | 3.60(5) | $0.1483(1)$ | 1 |

| No. of subcarrier $k = 5$ |
| GA [28] | 63.62(4) | 41.75(1) | 0.1367(3) | 2 | 79.95(2) | 50.11(4) | 0.1866(4) | 4 | 79.95(2) | 46.26(2) | 0.2107(2) | 2 | 79.95(4) | 11.2(3) | 0.43(5) | 4 |
| PSO [29] | 40.47(1) | 34.95(3) | 0.0346(1) | 1 | 79.95(2) | 45.28(6) | 0.0346(1) | 1 | 79.95(2) | 45.28(6) | 0.0346(1) | 1 | 79.95(2) | 45.28(6) | 0.0346(1) | 1 |
| FF [30] | 79.95(5) | 41.19(2) | 0.2423(5) | 3 | 79.95(2) | 49.07(5) | 0.1931(5) | 5 | 79.95(2) | 46.16(3) | 0.2113(3) | 3 | 79.95(5) | 6.37(6) | $0.4602(6)$ | 5 |
| WOA [31] | 54.90(3) | 29.13(5) | 0.1612(4) | 3 | 79.95(1) | 55.13(2) | 0.1552(2) | 2 | 79.95(1) | 38.92(5) | 0.2566(5) | 5 | 79.95(3) | 11.69(2) | $0.4269(4)$ | 3 |
| LA | 48.37(2) | 32.69(4) | 0.0980(2) | 2 | 79.95(2) | 53.08(3) | 0.1680(3) | 3 | 79.95(2) | 40.13(4) | 0.2490(4) | 4 | 74.28(2) | 8.03(5) | $0.4144(2)$ | 3 |
| DA | 58.05(4) | 41.22(3) | 0.10(3) | 2 | 79.9(2) | 45.0(8) | 0.21(8) | 8 | 79.9(3) | 32.4(8) | 0.29(8) | 8 | 79.9(7) | 12.3(2) | 0.42(4) | 79.9(7) | 3 |
| WOA | 71.93(6) | 44.17(1) | 0.17(6) | 4 | 79.9(2) | 50.2(4) | 0.18(4) | 4 | 79.9(1) | 48.85(4) | 0.21(4) | 4 | 79.9(6) | 11.3(4) | 0.428(6) | 79.9(6) | 4 |
| LA-PM | 40.47(1) | 34.95(3) | 0.0346(1) | 1 | 79.95(2) | 55.31(1) | 0.1540(1) | 1 | 79.95(3) | 48.13(1) | 0.1990(1) | 1 | 67.07(1) | 8.09(4) | $0.3688(1)$ | 1 |
### TABLE 3 (Continued)

| No. of subcarrier $k$ | GA [28] | PSO [29] | FF [30] | WOA [31] | LA [28] | DA | WOA | LA-PM |
|-----------------------|---------|----------|---------|-----------|---------|----|------|-------|
| $k = 8$               |         |          |         |           |         |    |      |       |
| GA                    | 72.17(2) | 50.27(2) | 79.95(4) | 63.25(2) | 79.94(5) | 59.86(5) | 62.89(1) | 79.95(3) |
| No. of subcarrier $k$ | 1       | 4        | 5       | 2         | 1       | 5  | 4    | 1     |
| GA                    | 46.58(4) | 0.1856(4) | 49.09(3) | 51.32(2) | 79.94(6) | 54.98(1) | 54.98(1) | 79.95(3) |
| PSO                   | 79.95(5) | 79.95(1) | 79.95(1) | 79.95(3) | 59.86(5) | 79.95(3) | 54.98(1) | 79.95(3) |
| FF                    | 79.95(5) | 79.95(5) | 79.95(5) | 79.95(3) | 79.94(5) | 79.95(3) | 79.95(3) | 79.95(3) |
| WOA                   | 64.16(1) | 45.45(5) | 49.09(3) | 51.32(2) | 63.25(2) | 54.98(1) | 54.98(1) | 79.95(3) |
| LA                    | 79.95(4) | 79.95(4) | 79.95(4) | 79.95(3) | 79.94(5) | 79.94(5) | 79.94(5) | 79.95(3) |
| DA                    | 79.94(6) | 51.32(2) | 79.95(4) | 79.94(6) | 79.95(2) | 79.95(3) | 79.95(3) | 79.95(3) |
| WOA                   | 79.94(4) | 50.84(3) | 79.95(5) | 51.32(2) | 63.25(2) | 54.98(1) | 54.98(1) | 79.95(3) |
| LA-PM                 | 79.95(3) | 54.98(1) | 79.95(3) | 54.98(1) | 79.94(5) | 79.94(5) | 79.94(5) | 79.95(3) |

| No. of subcarrier $k = 10$ | GA [28] | PSO [29] | FF [30] | WOA [31] | LA [28] | DA | WOA | LA-PM |
|-----------------------------|---------|----------|---------|-----------|---------|----|------|-------|
| GA                          | 79.95(4) | 79.95(5) | 79.95(5) | 79.95(3) | 79.94(5) | 79.94(5) | 79.94(5) | 79.95(3) |
| No. of subcarrier $k$       | 1       | 4        | 5       | 2         | 1       | 5  | 4    | 1     |
| GA                          | 82.84(1) | 79.17(3) | 74.14(4) | 82.36(2) | 63.25(2) | 59.86(5) | 59.86(5) | 79.95(3) |
| PSO                         | 79.95(5) | 79.95(1) | 79.95(1) | 79.95(3) | 79.94(5) | 79.94(5) | 79.94(5) | 79.95(3) |
| FF                          | 79.95(5) | 79.95(5) | 79.95(5) | 79.95(3) | 79.94(5) | 79.94(5) | 79.94(5) | 79.95(3) |
| WOA                         | 64.16(1) | 51.32(2) | 79.95(5) | 63.25(2) | 63.25(2) | 54.98(1) | 54.98(1) | 79.95(3) |
| LA                          | 79.95(4) | 79.95(4) | 79.95(4) | 79.95(3) | 79.94(5) | 79.94(5) | 79.94(5) | 79.95(3) |
| DA                          | 79.94(6) | 51.32(2) | 79.95(4) | 79.94(6) | 79.95(2) | 79.95(3) | 79.95(3) | 79.95(3) |
| WOA                         | 79.94(4) | 50.84(3) | 79.95(5) | 51.32(2) | 63.25(2) | 54.98(1) | 54.98(1) | 79.95(3) |
| LA-PM                       | 79.95(3) | 54.98(1) | 79.95(3) | 54.98(1) | 79.94(5) | 79.94(5) | 79.94(5) | 79.95(3) |
| Model  | Mean | Std-dev |
|--------|------|---------|
| GA [29] | 0.22221 | 0.044679 |
| PSO [230] | 0.087325 | 0.039732 |
| FF [31] | 0.01625 | 0.000353 |
| WOA [32] | 0.016957 | 0.001581 |
| LA [28] | 0.01674 | 0.001096 |
| WOA-PM | 0.01625 | 0.000353 |

**Overall statistical analysis of the proposed model over other conventional models**

| Model  | $L_r = 3$ | $L_r = 6$ | $L_r = 8$ | $L_r = 10$ |
|--------|-----------|-----------|-----------|-----------|
| Mean   | 0.22221   | 0.14622   | 0.033564  | 0.23576   |
| Std-dev| 0.044679  | 0.010951  | 0.021245  | 0.033045  |

**Table 4**
From this example, the final rank is given as one for the minimum average rank, that is, average rank 2 is given the final rank as 1 (least total cost); the next maximum is given as rank 2, that is, the average rank 3 is provided with final rank as 2, and goes on. Similarly, the rest of the final ranks are calculated for other subcarriers and plotted in Table 3.

Further, for a number of subcarrier \( k = 1 \) with \( l_v = 3 \), the proposed model has achieved the final rank as 1. Similarly, for \( k = 8 \) with \( l_v = 6 \) has also gained 1 as the final rank. Thus from the overall performance, it is exemplified that the proposed model has achieved the maximum count of first ranking when compared to other conventional ones.

7.4 Overall statistical analysis

The overall statistical analysis of the proposed work over the conventional models is stated in Table 4. Owing to this, the analysis is handled in terms of mean, and std-dev measures.

The main scenario that concentrated in this proposed work is the mean measure, where it attains the better mean value that any other conventional models. For \( k = 1 \) and \( l_v = 6 \), the implemented model in terms of performance has gained an enhanced value and that is 66.18%, 34.2%, 6.77%, 7.84% and 24.57% than GA, PSO, FF, WOA, and LA, respectively. Subsequently, when \( k = 5 \) and \( l_v = 8 \), the performance of the proposed work is 7.55%, 4.3%, 1.57%, 3.16% and 0.51% superior to conventional methods like GA, PSO, FF, WOA, and LA, respectively. On taking \( k = 8 \) and \( l_v = 10 \) into consideration, the implemented method has regained betterment than GA, PSO, FF, WOA, and LA by 23.72%, 23.95%, 16.05%, 13.63% and 6.8% than GA, PSO, FF, WOA, and LA, respectively.

In the view of std-dev, when \( k = 1 \) and \( l_v = 8 \), the implemented model is 95.8%, 97.61%, 95.13%, 46.97% and 4.69% superior to GA, PSO, FF, WOA, and LA by 9.84%, 9.84%, 8.03%, 6.18%, and 2.69%, respectively. while fixing \( k = 10 \) and \( l_v = 6 \), the proposed work is better and that is 23.75%, 23.98%, 16.05%, 13.63% and 6.8% than GA, PSO, FF, WOA, and LA, respectively.

8 | CONCLUSION

Because of the characteristic of transmitting multiplexed signals in superposed mode over the similar spectrum, NOMA technology was supposed as a promising manner to enhance spectral efficiency in fifth generation (5G) networks. In this paper, the resource allocation problems among the hybrid MC-NOMA systems were examined, which was the incorporation of NOMA and OMA modes, for achieving the EE and SE trade-off with minimum user’s rate requirement. This resource allocation was composed of user clustering, power allocation, choice of MA modes, and subcarrier assignment. The main intention of this paper was to ensure this possibility using the integration of the optimisation aspect. In this, resource allocation along with power allocation was the core factor that was designed as a single-objective problem. Thereby, the subcarriers, and powers were optimally tuned using a new algorithm called, LA-PM. To the end, the implemented work in terms of the performance was compared with other standard classical models and thus proves the effectiveness of the proposed model. For the best-case scenario, by fixing \( k \) as 1 and by varying the \( l_v \) as 6, the performance of the implemented work has attained the betterment as 61.94%, 3.06%, 0.09%, 5.23% and 3.84% than GA, PSO, FF, WOA, and LA, respectively. For the same count of subcarrier by varying \( l_v = 10 \), the proposed model was 23.75%, 25.76%, 18.92%, and 23.37% better from GA, FF, WOA, and LA, respectively.

NOMENCLATURE

Abbreviations

| Symbol | Description |
|--------|-------------|
| \( H \) | Users |
| \( w_i \) | Weight |
| \( \text{Fit} \) | Total fitness |
| \( \Psi \) | Subcarriers |
| \( K \) | Set of users |
| \( k \) | Subcarrier |
| \( \hat{s}_{k}(i) \) | Transmit signal |
| \( q_{k} \) | Additive white Gaussian noise (AWGN) |
| \( \sigma^2 \) | Variance |
| \( p_{k} \) | Transmission power |

TABLE 5 Computation time of the proposed algorithm over conventional algorithms

| Algorithm | Computation time |
|-----------|------------------|
| GA        | 0.70228          |
| PSO       | 0.55073          |
| FF        | 1.1225           |
| WOA       | 0.47227          |
| LA        | 0.77003          |
| GWO       | 0.92704          |
| DA        | 0.68956          |
REFERENCES

1. Condluci, M., et al.: Virtual code resource allocation for energy-aware MTC access over 5G systems. Ad Hoc Netw. 43, 3–15 (2016)
2. Chaochen, X., et al.: Research of resource allocation technology based on MIMO ultra density heterogeneous network for 5G. Procedia Comput. Sci. 131, 1039–1047 (2018)
3. Mishra, P.K., et al.: Device-centric resource allocation scheme for 5G networks. Phys. Commun. 26, 175–184 (2018)
4. Li, W., et al.: Energy efficiency maximization oriented resource allocation in 5G ultra-dense network: Centralized and distributed algorithms. Comput. Commun. 130, 10–19 (2018)
5. Huang, X., et al.: Utility-optimized bandwidth and power allocation for non-orthogonal multiple access in software defined 5G networks. J. Netw. Comput. Appl. 113, 75–86 (2018)
6. Gao, W., et al.: Joint optimization of component carrier selection and resource allocation in 5G carrier aggregation system. Phys. Commun. 25, 293–297 (2017)
7. Tseng, C., Shih, J.: Two-stage coalition formation and radio resource allocation with Nash bargaining solution for inband underlaid D2D communications in 5G networks. J. Netw. Comput. Appl. 111, 64–76 (2018)
8. Na, Z., et al.: Subcarrier allocation based simultaneous wireless information and power transfer algorithm in 5G cooperative OFDM communication systems. Phys. Commun. 29, 164–170 (2018)
9. Zappone, A., Jorswieck, E.A.: Energy-efficient resource allocation in future wireless networks by sequential fractional programming. Digit. Signal Process. 60, 324–337 (2017)
10. Liu, J.: Joint downlink resource allocation in LTE-advanced heterogeneous networks. Comput. Netw. 146, 85–103 (2018)
11. Lin, Z., et al.: P2P-based resource allocation with coalition game for D2D networks. Pervasive Mob. Comput. 42, 487–497 (2017)
12. Tang, H., et al.: Dynamic resource allocation strategy for latency-critical and computation-intensive applications in cloud–edge environment. Comput. Commun. 134, 70–82 (2019)
13. Wang, Y., et al.: Resource allocation of wireless backhaul in heterogeneous network based on the large-scale MIMO. Future Gener. Comput. Syst. 88, 117–126 (2018)
14. Begishev, V., et al.: Resource allocation and sharing for heterogeneous data collection over conventional 3GPP LTE and emerging NB-IoT technologies. Comput. Commun. 120, 93–101 (2018)
15. Lucas-Estañ, M.C., Guozalez, J.: Distributed radio resource allocation for device-to-device communications underlaying cellular networks. J. Netw. Comput. Appl. 99, 120–130 (2017)
16. Shrivastava, R., et al.: Towards service-oriented soft spectrum slicing for 5G TDD networks. J. Netw. Comput. Appl. 137, 78–90 (2019)
17. Sofi, I.B., Gupta, A.: A survey on energy efficient 5G green network with a planned multi-tier architecture. J. Netw. Comput. Appl. 118, 1–28 (2018)
18. Song, Z., et al.: Spectrum and energy efficient resource allocation with QoS requirements for hybrid MC-NOMA 5G systems. IEEE Access 6, 37055–37069 (2018)
19. Li, J., et al.: Context-oriented multi-RAT user association and resource allocation with triple decision in 5G heterogeneous networks. China Commun. 15(4), 72–85 (2018)
20. Martin, A., et al.: Network resource allocation system for QoE-aware delivery of media services in 5G networks. IEEE Trans. Broadcast. 64(2), 561–574 (2018)
21. Fuentes, G., et al.: Downlink scheduling and resource allocation for 5G MIMO-multicarrier: OFDM vs FBMC/OQAM. IEEE Access 5, 13770–13786 (2017)
22. Alqerm, I., Shihada, B.: Sophisticated online learning scheme for green resource allocation in 5G heterogeneous cloud radio access networks. IEEE Trans. Moh. Comput. 17(10), 2423–2437 (2018)
23. Paymard, P., et al.: Joint task scheduling and uplink/downlink radio resource allocation in PD-NOMA based mobile edge computing networks. Phys. Commun. 32, 160–171 (2019)
24. Condoluci, M., et al.: Virtual code resource allocation for energy-aware MTC access over 5G systems. Ad Hoc Netw. 43, 3–15 (2016)
25. Hasabelnaby, M.A., et al.: Joint optimal transceiver placement and resource allocation schemes for redirected cooperative hybrid FSO/mmW 5G fronthaul networks. IEEE/OSA J. Opt. Commun. Netw. 10(12), 975–990 (2018)
26. Amin, O., et al.: Energy efficiency spectral efficiency tradeoff: A multiobjective optimization approach. IEEE Trans. Veh. Technol. 65(4), 1975–1981 (2016)
27. Zappone, A., Jorswieck, E.: Energy efficiency in wireless networks via fractional programming theory. Found. Trends Commun. Inf. Theory 11(4), 185396 (2015)
28. Boothalingam, R.: Optimization using lion algorithm: A biological inspiration from lion's social behavior. Evol. Intell. 11(1-2), 31–52 (2018)
29. McCall, J.: Genetic algorithms for modelling and optimisation. J. Comput. Appl. Math. 184(1), 205–222 (2005)
30. Pedersen, M.E.H., Chipperfield, A.J.: Simplifying particle swarm optimization. Appl. Soft Comput. 10(2), 618–628 (2010)
31. Gandomi, A.H., et al.: Firefly algorithm with chaos. Commun. Nonlinear Sci. Numer. Simul. 18, 89–98 (2013)
32. Mirjalili, S., Lewis, A.: The whale optimization algorithm. Adv. Eng. Softw. 95, 51–67 (2016)
33. Rajakumar, B.R.: Lion algorithm for standard and large scale bilinear systems. Procedia Technol. 6, 126–135 (2012). https://doi.org/10.1016/j.protcy.2012.06.90561
34. Rajakumar, B.R.: The Lion’s algorithm: A new nature inspired search algorithm. Procedia Comput. Sci. 185, 99–106 (2015)
35. Rajakumar, B.R., Lion algorithm and its applications. In: Frontier Applications of Nature Inspired Computation, Sanjay Kumar Jena, Banshidhar Majhi (eds.), pp. 100–118. Springer, Singapore (2020)