# An Intelligent Deep Neural Based Peak-To-Average Power Ratio Mitigated System for Multi User OFDM Channel

**G. krishna Reddy** ( gkrishareddy@gmail.com )
G Narayanamma Institute of Technology and Science for Women https://orcid.org/0000-0001-7455-0564
**G.Merlin sheeba**
Sathyabama Institute of Science and Technology

**Research Article**

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# An Intelligent Deep Neural Based Peak-To-Average Power Ratio Mitigated System for Multi User OFDM Channel

***G.krishna Reddy · G.Merlin sheeba**

**Abstract**An Orthogonal Frequency Division Multiplexing (OFDM) signal having a large Peak-to-Average Power ratio (PAPR) can cause noise signals and power degradation. To remove the high PAPR in OFDM signals, the proposed Strawberry-based Recurrent Neural Framework (SbRNF) model is proposed. While transmitting the signals in the OFDM channel, the rate of PAPR was high due to more subcarriers. Basically, more subcarriers are needed to convey the OFDM channel's signals. Our proposed model made the reduction of PAPR in the OFDM channel easier. The result of the proposed model (SbRNF) was determined, and signal-to-noise ratio (SNR), Throughput, and Bit Error Rate (BER) were compared with other existing methodologies. Here, the presented model is executed in the MATLAB platform and shows that SbRNF has a low Bit Error Rate (BER), high throughput value, and Cumulative Distribution Function (CCDF) performance in the presence of high PAPR. While comparing the existing models with SbRNF provides better PAPR reduction in the signal transmission.

**Keywords** Signal Transmission, Peak to Average Power Ratio, Strawberry plant optimization, recurrent neural network, Bit error rate, signal to noise ratio.

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*G.krishna Reddy
Research scholar,
Sathyabama institute of science and Technology, Chennai, India
Associate professor,
Department of Electronics and Telematics Engineering,
G.Narayanamma institute of Technology and Science, Hyderabad, India
E-mail: gkr999gkr@gmail.com

G.Merlin sheeba
Research guide,
Department of Electrical and Electronics Engineering,
Sathyabama institute of science and Technology, Chennai, India
E-mail: merlinsheebu@gmail.com

## 1 Introduction

The digital communication industry is experiencing a period of upheaval [1]. Anything, Rather than the basic phone conversations in the past, people today choose the 3A's technologies, Anywhere, and Anything, Anytime [2]. As a result, wireless communications are becoming more advanced [3]. A cellular technology or simple wireless connectivity transfers data or electricity from one location to multiple points, which are not tightly linked by electromagnetic wires [4]. Moreover, the recent advancement of next-generation networks in the Massive-Multi-input Multi-Output (MIMO) system appears to be an effective choice for the significant hassle-free transmission that is becoming increasingly popular [5]. Massive MIMO is concerned with a higher number of less-power antennas that are highly predictive, like Orthogonal Frequency Division Multiplexing (OFDM) ideas [6]. Furthermore, the MIMO uses a large number of multiple antennas to broadcast various signals. In contrast, OFDM divides the multiple channels into micro-channels to ensure precise and speedy correlation [7]. The MIMO-OFDM is described in fig.1.

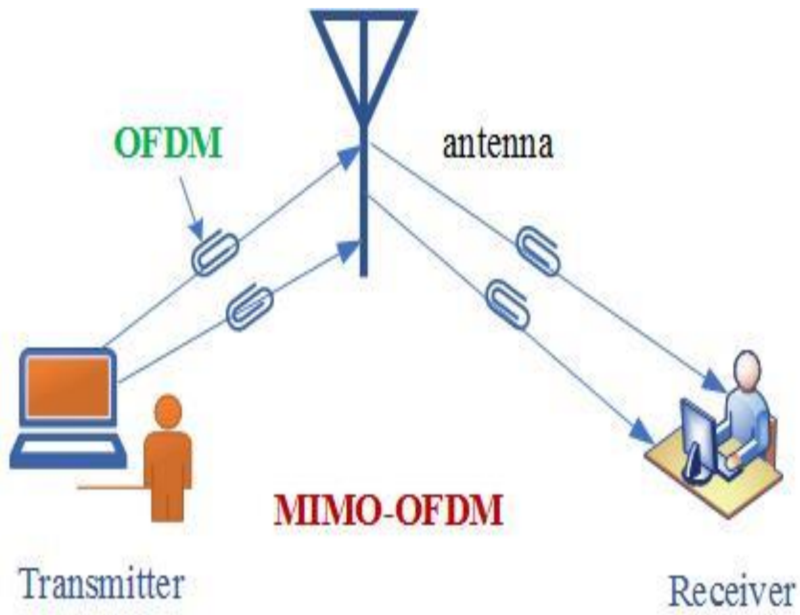


**Fig.1** MIMO_OFDM

Due to the high level of technological proficiency, the Wireless communication system has arranged versatile broadband communication [8], which is the purpose of its existence [9]. The transmitter-receivers system has been used to execute beam shaping and diversity operations on the signal [10]. A large frequency band is divided into several sub channels [11], securely separated for trustworthy correspondence to the OFDM system [12]. This line of action eliminates the most significant difficulty for the MIMO-OFDM system [13]. When the spectrum is restricted in the current environment, the demands for such resistance to high data have maximized the system's service quality [14, 15]. As a result, the OFDM method has been introduced to offer a solution to the issue of restricted spectrum availability [16]. Additionally, merging an OFDM-MIMO has the potential to improve the function of next-generation wireless applications [17]. Furthermore, the high Peak-to-average power ratio (PAPR) is a significant disadvantage of OFDM [18]. With the high peaks in signal power, the transistors are forced to operate in the saturation area, resulting in signal distortion [19]. Two different techniques embed the protected intermediate in the guard interval [20]. Moreover, the cyclic extensions and Zero padding are the dual types of padding in the OFDM system.

Considering these advantages, high PAPR is the chief problem that has degraded the signal probability. So, numerous methods were designed, such as Partial Transmit mode [21], Selective mapping [22], etc., were executed to reduce the ratio of PAPR in the OFDM channel. But the desired outcomes are not attained because of energy consumption, design complexity, and high duration. So, the current article has aimed to develop a novel PAPR mitigation strategy using optimization and deep features. Moreover, the robustness of the designed scheme has been measured by estimating the communication channel parameters.

The presented research was ordered as follows: Section 2 describes the related work, section 3 establishes the system model, Section 4 explains the proposed model, and Section 5 describes the result of the proposed model, and the conclusion of this research work was presented in Section 6.

## 2 Related Work

Some of the recent literatures related to Peak-to-Average Power Ratio (PAPR) reduction are described as follows*:*

In the MIMO-OFDM systems, the PAPR is the main problem. A novel Partial Transmit model with Tone Reservation-based Gaussian pulse was presented by Vijayalakshmi and Ramalinga Reddy [21] to mitigate PAPR. The TR methods basic plan to compute the additive time-domain based signal. The results demonstrated that the PAPR gets reduced by choosing the phase sequence's finest combination. However, the PAPR effects and subcarrier levels of OFDM are not investigated.

Singal and Kedia [22] have analyzed the various methods like the Selective Mapping-U2 method, conventional selective mapping model, etc. PAPR reduction and computational complexity performances. The result demonstrated that selective mapping-Additive Mapping-U2 has the best performance in PAPR reduction and has the least computational complexity. Moreover, the computational time is high.

Zayani et al. [23] have investigated the PAPR mitigation issues in MIMO-OFDM and created a downlink transmission-based method. In addition, a novel PAPR-based Gradient Descent model with multi-users to mitigate the transmitted signals PAPR. The results demonstrated that the presented model had attained significant PAPR performance and less computational complexity. However, the processing and transmission time is high.

Prasad and Jayabalan [24] have introduced selective mapping to minimize the PAPR ratio. Here, the variation of the PAPR ratio during the communication process has been measured by changing the phase sequence based on the communication range. Finally, it has gained the finest PAPR reduction outcome than the conventional schemes. However, more resources and computation time have required to execute the process.

Several PAPR reduction systems have been introduced with several control schemes. In that, some methods have resulted in a high design complexity ratio. So, Xing et al. [25] have introduced the design parameters regularization strategy using an optimization model. Here, the signal samples were collected in the initial phase. Then, the MIMO-OFDM channel parameters have regularized based on the signal amplitude. But, it has consumed more power to execute the process. The key contributions of the present research work are defined as follows,

- Initially, the MIMO-OFDM channel was designed with the desired number of users and antennas.
- Consequently, a novel SbRNF has been designed with an optimal PAPR ratio.
- During the communication process, if the PAPR is high, then strawberry fitness has tuned it to the optimal level.
- Finally, the chief metrics are validated and compared with other existing schemes in terms of BER, throughput, communication delay, PAPR ratio, and energy consumption.

## 3 System Model and Problem Statement

The MIMO-OFDM has well elaborated in the wireless communication application in all sectors for transferring and receiving the information without much delay. Moreover, this system is suitable for multi-user environments. However, high PAPR has reduced the signaling capacity by degrading the signal. So, the communication delay and energy consumption have increased. Hence, the present research has focused on an optimized deep neural strategy for mitigating the high PAPR in the MIMO-OFDM channel.

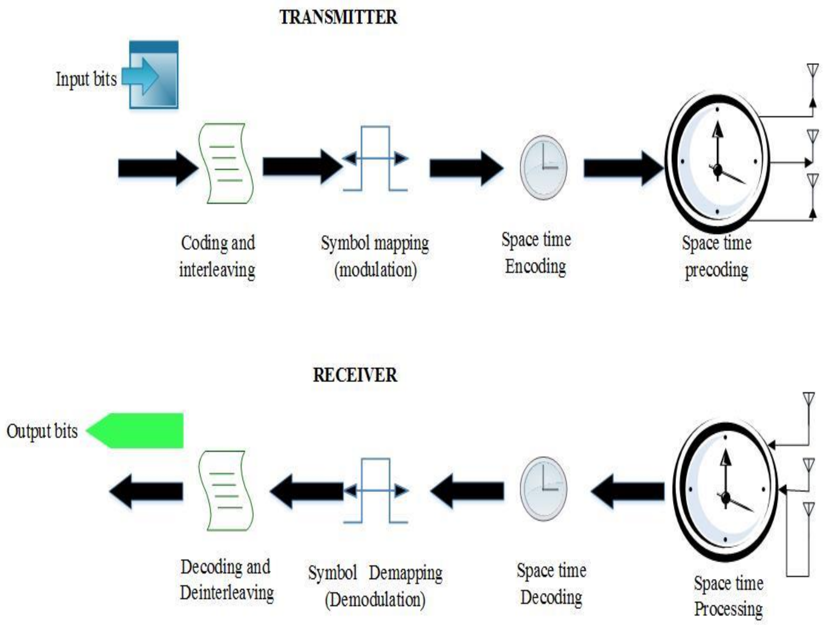


**Fig. 2** MIMO-OFDM System model

MIMO technology uses many antennas at both the transmitter and receiver to get high band communication. Using MIMO with OFDM is an influential grouping since MIMO avoids the mitigate multipath propagation while OFDM avoids the necessary for equalization of the signal. This combination (MIMO-OFDM) acquires high spectral efficiency when the transmitter does not Have Channel State Information (CSI). System model of MIMO-OFDM was represented in fig.2. The major demerits of using the MIMO system are that more antennas needs extra high-cost RF modules and these RF modules increase the cost. Common disadvantages found in OFDM are that OFDM is more sensitive to frequency synchronization and carrier offset. Due to cyclic prefix, loss of efficiency occurred in OFD.

## 4 Proposed Method (Strawberry Based Recurrent Neural Framework)

In the OFDM wireless system, PAPR reduction is key to enriching the OFDM communication performance. Hence, the proposed article has aided in designing a novel PAPR reduction strategy named Strawberry-based Recurrent Neural Framework (SbRNF). Initially, the MIMO_OFDM was created with 4 antennas and multiple users. Consequently, a novel SbRNF has been introduced to minimize the PAPR rate in the OFDM channel. Finally, the communication channel parameters were calculated and compared with other models. The proposed architecture is described in fig.3.

Here, for Occurring the best estimation of channel parameters, we use the Strawberry-based Recurrent Neural Framework. The antennas are connected to receivers and transmitters through the antenna set of signals transmitted. The antenna is a device used to radiate or deliver radio waves. The parameters based on communication were estimated through this SbRNF. Those communication parameters are maybe in high or low bandwidth.

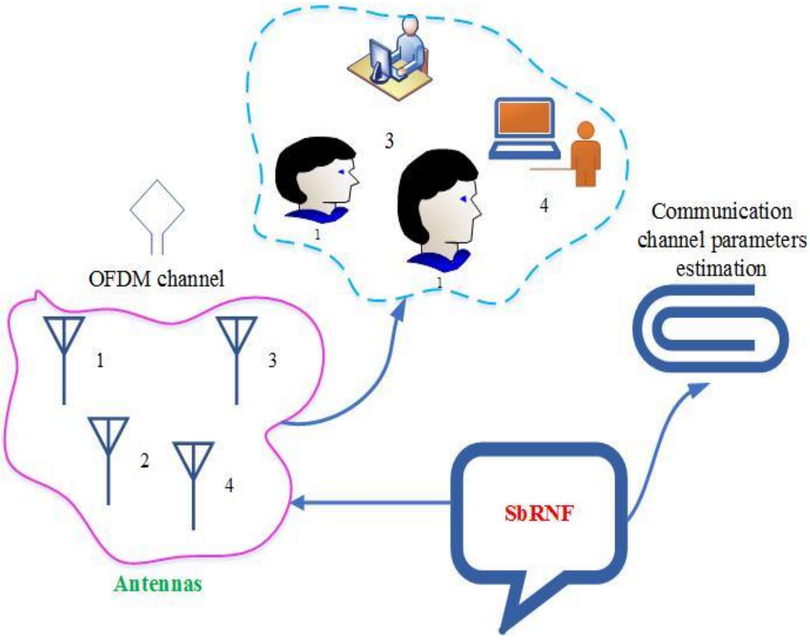


**Fig. 3** Proposed Architecture

4.1 Proposed design for SbRNF

The novel SbRNF has been designed based on recurrent neural networks and Strawberry functions. Here, the recurrent neural networks are tuned by the strawberry fitness. The OFDM channel is intended for data transmission in the initial stage. Then the novel-based SbRNF was developed to separate the high power data signal and the average power data signals in the data transmission. Moreover, the proposed model has four layers which was illustrated in fig.4.

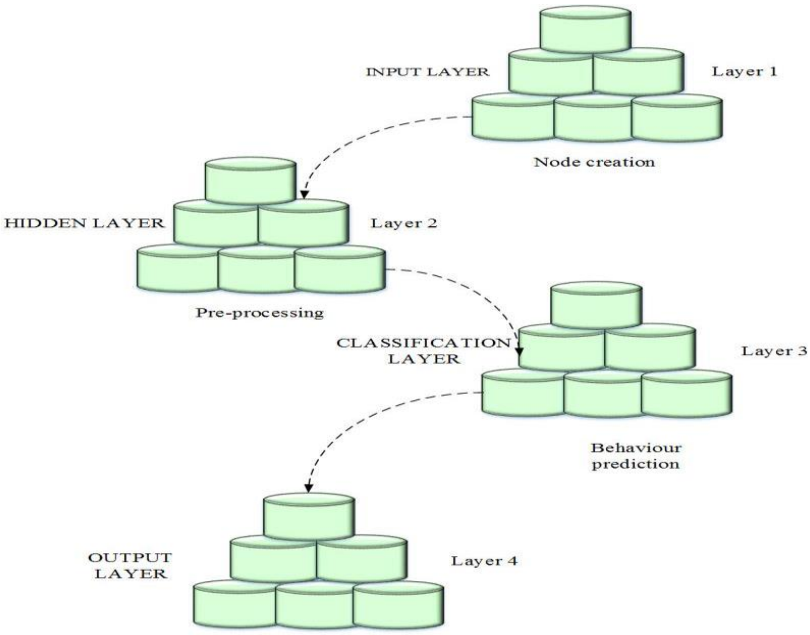


**Fig. 4** Layers of SbRNF

The layers of the designed SbRNF are presented in fig 4. There are four different layers in the proposed model, and every layer has specific functions. The first layer is the input layer, and the function of this input layer is which creates more nodes for the power ratio prediction. The second layer is hidden. This layer performs non-linear operations. And the third layer of SbRNF is the classification layer. This layer classifies the nodes according to the range of power to predict behaviour. Classification is based on the high and average power of the nodes. The last layer is the output layer, and this layer provides the output.

#### *4.1.1 Pre-processing*

The process of reducing high power into an average power while transmitting the OFDM signal is called PAPR reduction. Moreover, Pre-processing in signal transmission helps remove the noisy data, giving a clean data set for transmission. The signal used in transmission was declared in Eqn. (1).

$$x_n = \frac{1}{\sqrt{N}} \sum_{u=0}^{K-1} X_k e^{j\frac{2\Pi}{N}kn}; 0 \le n \le K-1 \tag{1}$$

Where $x_n$ denotes the number of signals were transmitted, $X_k$ the baseband modulated symbol, $K$ signifies the length of the frames and k denotes the channel coefficient, $n$ denotes number of samples, $\sqrt{N}$ signifies the number of frames used for transmission, $e^j$ is the exponential function as well as N refers the total number of signals are transmitted in an OFDM signal. The PAPR is the relation between the maximum powers to the average power of the transmitted OFDM signal was given in Eqn. (2).

$$PAPR = \frac{max\{[y_n]^2\}}{C\{[y_n]^2\}} \tag{2}$$

Consequently, Cumulative Distribution Function (CCDF) is considered as the most common technique which determines the performances of PAPR method. Where $max\{[y_n]^2\}$ denotes the maximum power and $C\{[y_n]^2\}$ denotes the average power of the transmitted signals.

Through this CCDF method, the threshold level of the PAPR were increasing and the exceed peak to average power reduction was termed as $PAPR_0$ was defined in Eqn. (3).

$$CCDF = P(PAPR > PAPR_0) = 1\text{-}1(e^{-PAPR_0})^{NL} \tag{3}$$

Where $P$ denotes the power of the transmitted signal , $PAPR$ denotes the Peak-to average ratio of the signal transmitted,- $PAPR_0$ refers the low threshold level, $L$ defines over sampling factor and $PAPR_0$ refers the exceed threshold level.

#### *4.1.2 Reduction of High PAPR*

To reduce the high range of power in signal transmission, Selective Mapping (SM) was used. Using this SM technology range of power was reduced while transmitting the signals, and error was reduced by increasing the performance. Through SLM there is no data loss occurs. Then on transmitting, Selective mapping examined the range of power, be high in range or average. The optimal power for transmitting the signal was examined in Eqn. (4).

$$P(PAPR > X) = F(X)^N = (1-(1-e^{-z})^{xK})^U \tag{4}$$

Where, $U$ is termed as number of sequences used for transmission, and z is considered as the threshold value. Moreover, Partial transmit sequence (PTS) was also use to reduce the high PAPR.

#### *4.1.3 Classification module*

The rate of power used for signal transmission has been determined by using the rate of power used for transmitting the signal. Here, the first power signal transmitted, the power range is greater than 13 db.

And the second power signal transmitted the power, which was lower than 13 db. The maximum power used in transmitting the signal was 10-13 db. If the power exceeds more than 13 dB, it is considered as excess power and is denoted as $PAPR_0$.The classification of power and neglecting power process were developed in Eqns. (5) & (6).

$$P_1 = P_{(transmitted)} \geq 13; PAPR_0 \neq PAPR \tag{5}$$

$$P_2 = P_{(transmitted)} \leq 13; PAPR_0 = PAPR \tag{6}$$

In the present research work, $PAPR$ and $PAPR_0$ are taken as for considering the fitness process. Here, $PAPR_0$ is considered as the excessive power and if the transmitted power was exceeds 13dB $PAPR_0 \neq PAPR$ else it becomes equal. If the power was not equal to $PAPR$ and it was considered as excessive power hence the signal were neglected from the OFDM channel.

**Algorithm 1: SbRNF**

***start***
*{*
*OFDM Channel* *//design of OFDM communication channel*
*Int by using eqn (1)*
*//initializing the number of signals*
***Pre-processing()***
***{***
*int min, max power;*
*//Initialization of pre-processing signals*
$PAPR = \frac{Maximumpower}{Averagepower}$
*//neglecting the noise signals from the imported signals*
*}*
***Reduction of High PAPR***
*//predicting high power and average power*
*{*
//int using eqn (4)
*//high power initialization*
$(PAPR_0) \rightarrow extract$
*// Average power was predicted*
*}*
***Identification of power()***
*{*
$if(PAPR_0 = 0)$
*{*
***High power***
***}***
***Else (Average power)***
*//hence the high power were predicted*
***Neglect(high power)***
***}***
***}***
***stop***

The above-mentioned mathematical equations for the strawberry-based recurrent neural framework are designed in the pseudo-code format shown in the algorithm 1. Also, the program code and the flowchart of this algorithm were developed and executed. Flowchart of the SbRNF was illustrated in fig.5.

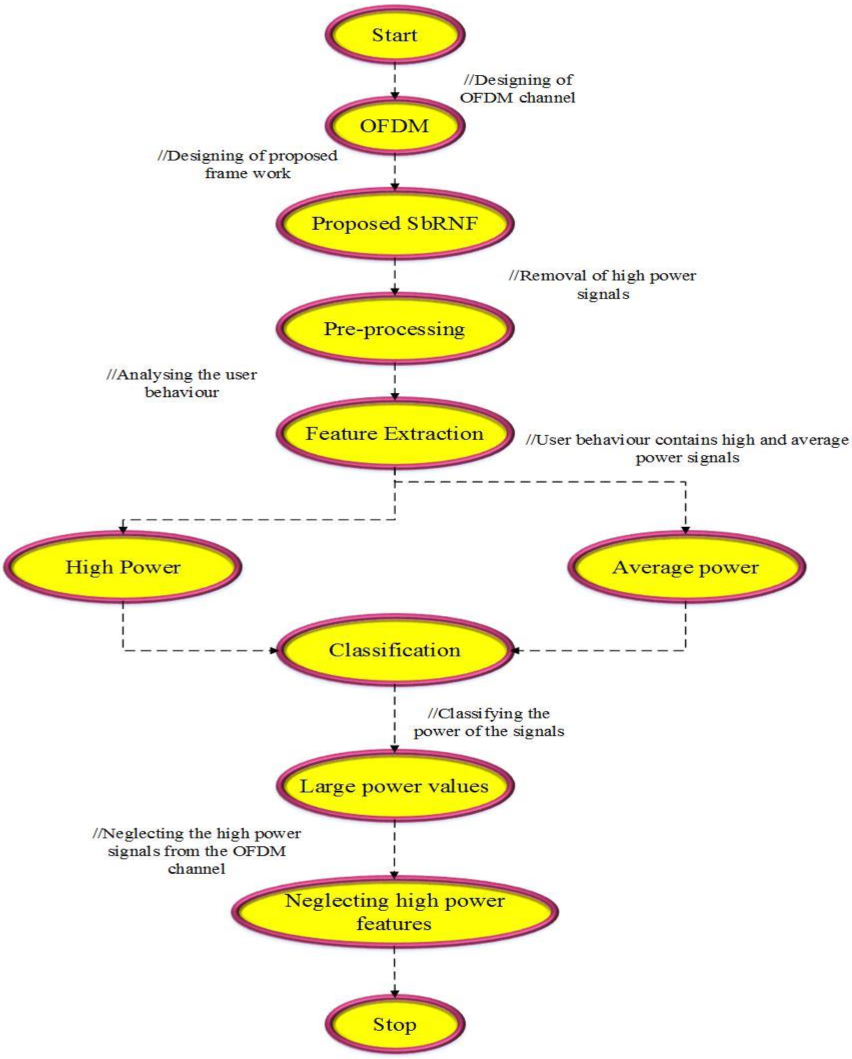


**Fig. 5** Flow of SbRNF

Once the user behaviour does not fall under 13dB, those signals are neglected from the OFDM channel. After that, the transmission process was behind, and the designed model (SbRNF) was enabled until the end of the transmission. These SbRNF possess a continuous monitoring process. So, the sudden involvement of high power signals was also blocked.

## 5 Results and Discussion

In this research work, the planned novel SbRNF reduces the peak power to average when the signal transmission. The planned design has been designed in a MATLAB environment and running on the Windows 10 platform. Initially, OFDM was designed with numerous features and more uses. However, a novel-based SbRNF was intended to validate the different transmission powers as high and average transmitting powers under the desired conditions.

### 5.1 Case Study

The presence of more QAM symbols, which are under linear combination, causes PAPR in the OFDM channel. The transmitted power is taken at high and average levels for case study validation. The maximum power values are 10-11dB and 12-13 dB for the earlier two cases. Through partial sequence transmitting, clipping, and other techniques are used to improve the OFDM channel and reduce power in the transmitted signal. When the range of the force exceeded the maximum range, the output was noisier. The range and size of the outcome depend on optimization. The optimization process maintains the signal without getting traffic while on transmission. Subcarriers are used to transmit more information in a single transmission. Initially, the OFDM channel was created with the help of four antennas. Antennas play a vital role in signal transmission. Each antenna was designed to transmit or receive signals with a particular frequency range. If the frequency range exceeds the average level, then the transmitting power was also increased. OFDM has many subcarriers to carry the signals for transmission. When the transmitted signal is entered into the OFDM channel, the channel is divided into independent channels, then modulation of the signal is done. After signal modulation, the split channel is united, and then it forms the OFDM signal. The high power is generated by creating a more independent channel to make the OFDM signal. It needs more subcarriers, increasing power, and the data rate also increased. Instead of using the subcarriers, the proposed model and the transmitted signal provide reduced power in transmitting the signals.

5.2 Analysis PAPR by Complementary Cumulative Distribution Function (CCDF)

Cumulative distribution functions are used to determine the performance of PAPR. Through this CCDF method, the threshold level of the PAPR was increasing, and the exceeding peak to average power reduction was termed as. Here the PAPR level was more in before optimization, and it got reduced after optimization. The state of performance of PAPR was given in Eqn. (7).

$$PAPR_0 = 1\text{-}1(e^{-PAPR_0})^{NL} \quad (7)$$

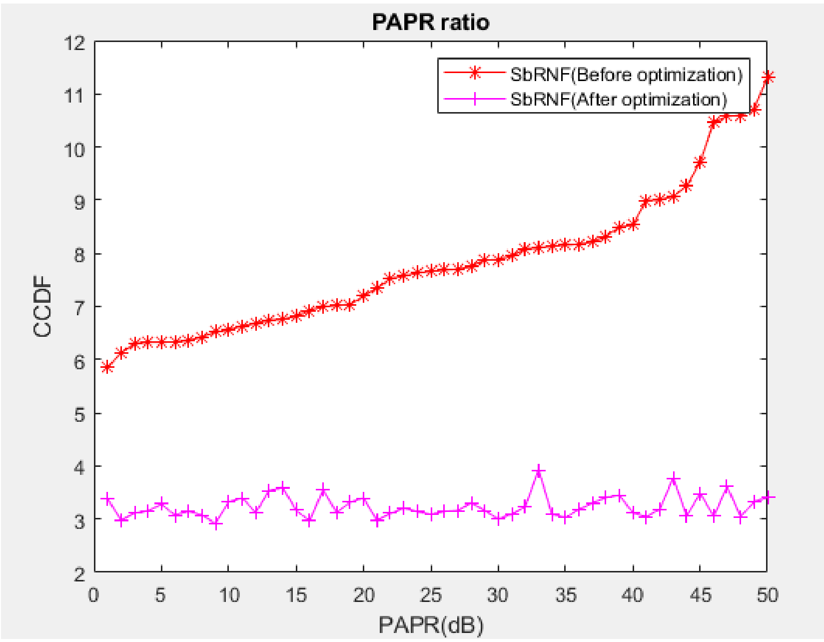


**Fig. 6**Cumulative Distribution Function Analysis for the proposed model

Before applying the proposed model to the OFDM, the cumulative distribution function increases, which causes reduced presentation of PAPR; Performance of PAPR in the presence of CCDF before and after optimization was shown in fig.6. After applying the proposed model, the range of CCDF gets lower while the PAPR performance was increased.

## 5.3 Performance Analysis

The proposed model (SbRNF) gives better performance than the other existing methodologies. It provides a very low bit error rate with high throughput as well as the performance of PAPR was better in the presence of CCDF.

### *5.3.1 Throughput*

Throughput refers to the number of signals or data received in a number of bits per second. The throughput can be calculated using Eqn. (8).

$$Throughput = \frac{Received \quad Data}{Time \quad taken} \tag{8}$$

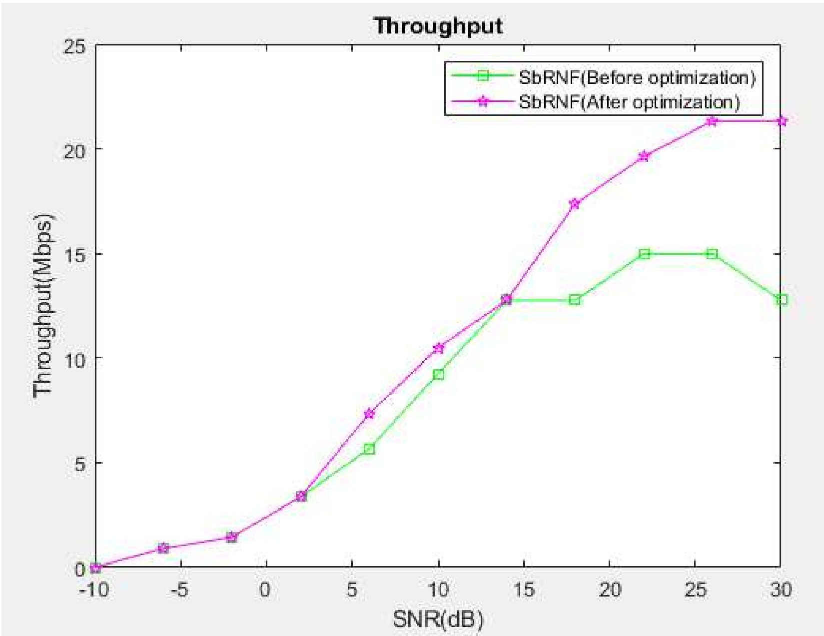


**Fig. 7** Analysis of Throughput

The throughput was calculated before and after the optimization of SbRNF. fig. 7 displays the throughput analysis after and before the optimization process. From the figure, it is clear that the throughput value was better after optimization. Before applying our proposed model, the signal-to-noise ratio was low. At the same time, it increases after using the SbRNF. Throughput was increased by reducing the processing time.

### *5.3.2 Bit Error Rate*

BER is defined as a number of error bits received among the total number of bits in a transmission. The bit error rate is expressed as shown in Eqn. (9).

$$\text{BER} = \frac{N_{be}}{N} \tag{9}$$

Where, $N_{be}$ refers to the quantity of error bits and N denotes the total amount of transmitted bits.

Consequently, the Bit Error Rate was determined in accordance with the Signal Noise Ratio (SNR). Increasing the SNR causes BER reduction. The rate of bit error before and after optimization was illustrated in Fig.8. Bit error was calculated to know the percentage of error bits from the overall amount of transmitted bits. After optimization, the range of bit error rate is 0.0001465 dB

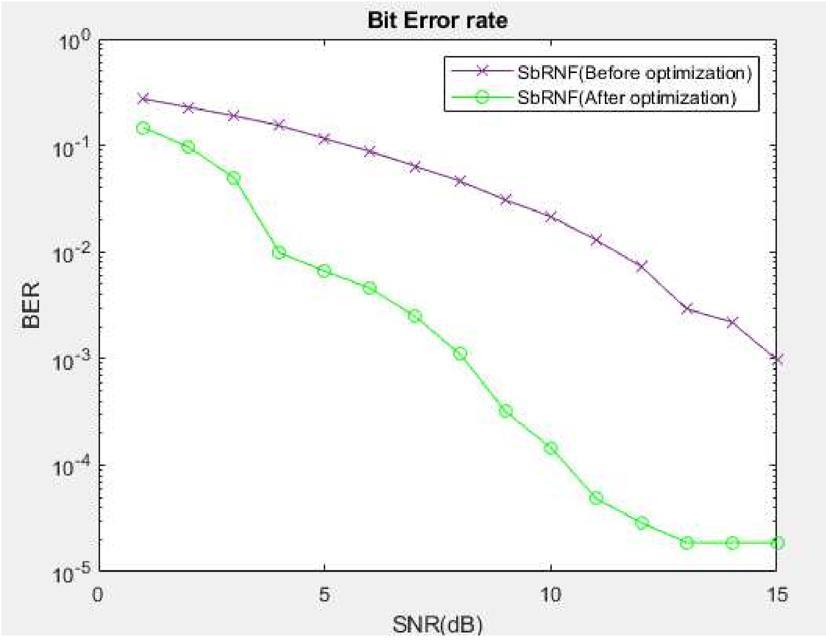


**Fig. 8** Bit Error Rate (BER) before and after optimization

### *5.3.3 Energy Consumption*

Energy needs to perform some process is termed Energy consumption. Fig 9 shows the energy need to perform Signal to noise ratio process. Here, the SNR process needs more energy before optimization, and after applying the proposed model, the energy consumption was low. Energy consumption was expressed in Eqn. (10).

$$E = P^{*}\left(\frac{t}{1000}\right) \tag{10}$$

Where, $E$ = energy measured in Joules or kilowatt-hours (kWh), $p$ = power units in watts, and $t$ = time over which the power or energy was consumed.

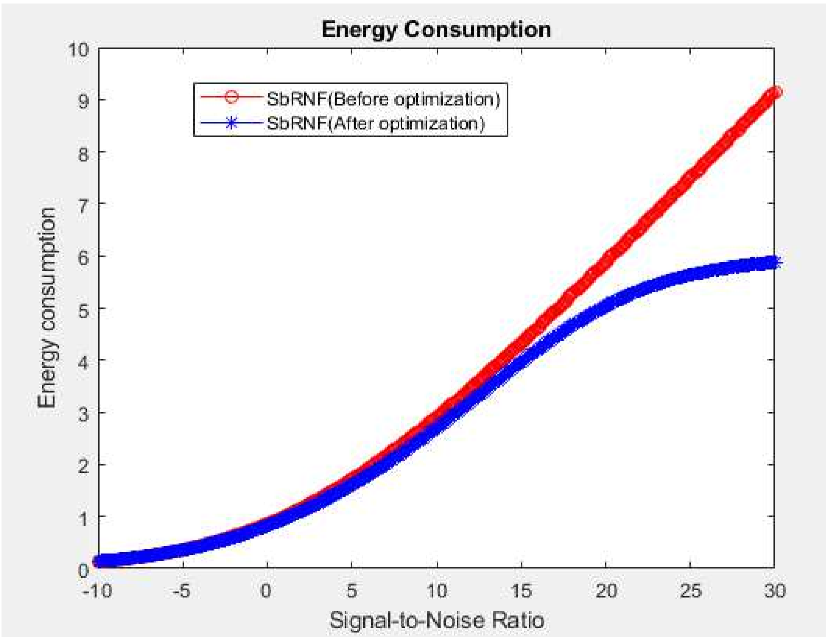


**Fig. 9** Energy consumption to perform SNR

While comparing the energy level before and after optimization, a huge difference occurs in energy consumption. Form fig. 9, it is clear that for performing the SNR operation, the need for energy was more in before optimization and when applying the proposed model, energy consumption gets reduced.

### *5.3.4 PAPR (Peak-to-average Ratio)*

PAPR is nothing, but it is the ratio of the highest power to the normal power of a signal, and those signals are conveyed in decibels (dB). It was measured for a communicated signal in an OFDM system. A minor PAPR remains preferred for the effective presentation of a system, PAPR were determined by using Eqn. (11).

$$PAPR = \frac{maximum \quad power \quad required \quad for signal \quad transmission}{average \quad power} \tag{11}$$

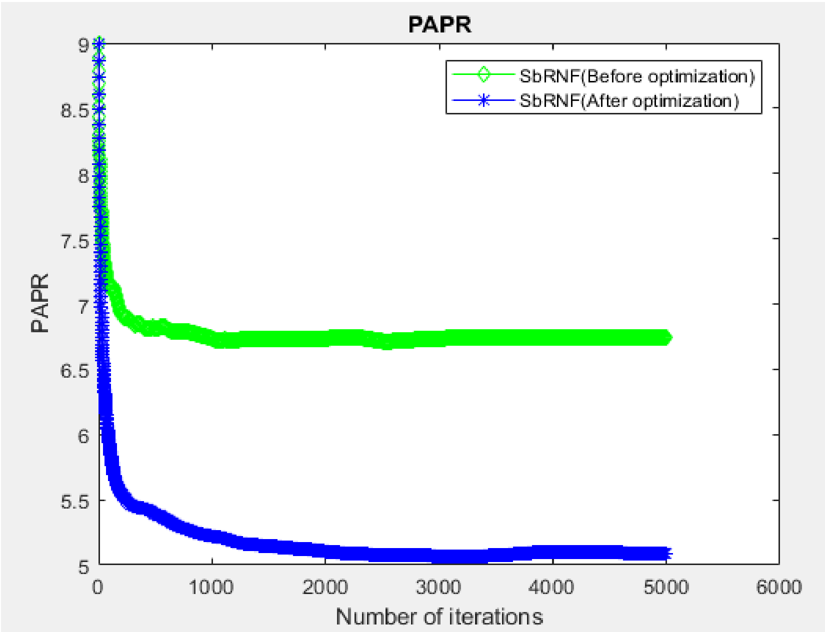


**Fig. 10** PAPR rate based on number of iterations

Here the power rate was high before optimization, that is, before applying the proposed model, and power was reduced after optimization. Our proposed model is used through the OFDM channel and the signal instead of the subcarriers. From fig. 10, it is clear that PAPR will be excess when more number signals. Subcarriers need more power for other processes, but using SbRNF for subcarriers reduces the power rate from high to average. From fig. 10, it is clear that after optimization, the power range was reduced up to 2dB. Before; the optimization power range was between 9dB to 7dB. Consequently, after optimization, the power rate was reduced to 5dB.

## 5.4 Comparative Analysis

Evaluating consequence of the planned technique, the parameters of the designed model remain compared with some recent techniques associated with this work. The fresh methods used for assessment are Piecewise Linear Companding (PLC), Iterative Filtering (IF), and Neural Network based Active Constellation Extension (NN-ACE). These techniques validate that the proposed technique has low BER and high throughput, and high performance in the presence of CCDF.

### *5.4.1 Bit Error Rate (BER)*

Through Bit Error Rate, the rate of error bits transmitted was noticed. And Error bit rate was reduced in the proposed model compared to other existing methodologies. Comparing the below methods to the proposed model, the proposed model (SbRNF) provides a less bit error rate. Among the existing models interleaving method consumes more error bits.

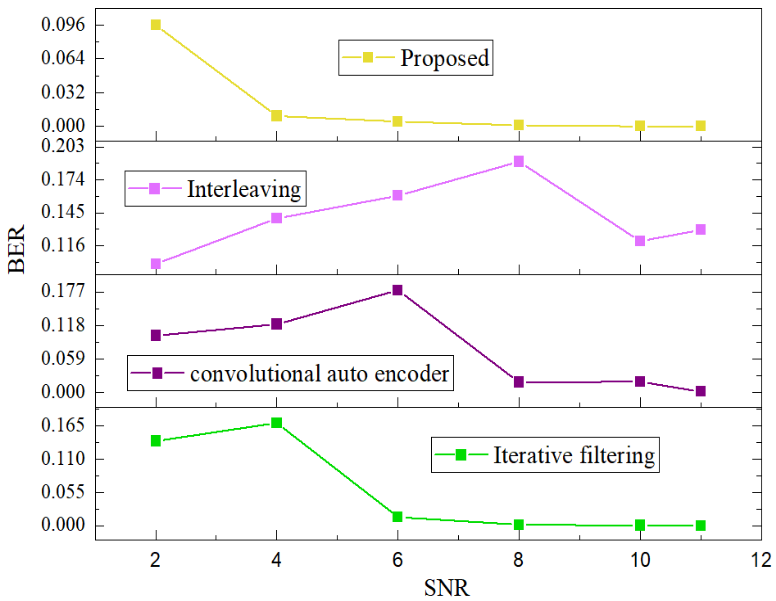


**Fig. 11** Comparison of BER with Interleaving, Iterative filtering and Convolution auto encoder

The bit error rate (BER) of the planned model remains linked with the other techniques such as Iterative filtering, Convolutional auto encoder, and Interleaving. The comparison of BER of proposed with Interleaving and SbRNF was displayed in fig.11. It is observed that the BER of the proposed design is which is smaller than other techniques. Generally, the BER decreases if the SNR increases. The BER in SbRNF and SbRNF also decrease with the increase of SNR. But, its BER is high when compared with the proposed model. The BER of SbRNF is about 0.0001465.

### *5.4.2 PAPR using CCDF (Complementary Cumulative Distribution Function)*

When comparing the performance of PAPR in the presence of CCDF, the performance was much better after the optimization process after applying our proposed model. Transmitting the signals in the presence of CCDF, PAPR having low bit errors and performance was increased as well as the resultant signal is noiseless.

From the figure, it is clear that by increasing the CCDF rate, PAPR reduces automatically. So the output signal was noiseless. Comparison of peak to average reduction ratio with other proposed techniques such as Neural Network-based Active constellation Extension (NN-ACE), OFDM-based VLC system, and Piecewise Linear Companding (PLC) was shown in fig.12. Compared with the other proposed techniques, SbRNF provides better performance in CCDF and has high data rates in reducing PAPR.

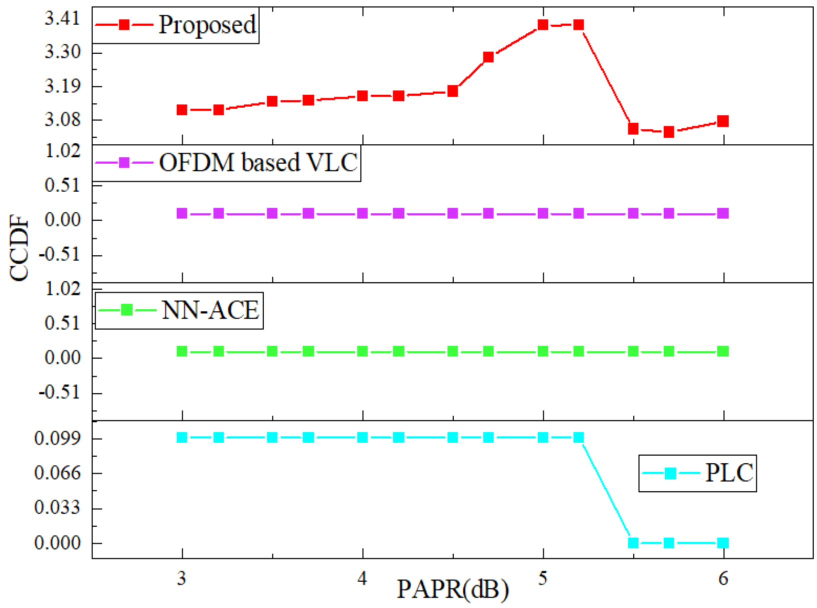


**Fig. 12** Comparison of PAPR with other proposed techniques

### *5.4.3 Throughput*

Comparing the throughput rate of the other three proposed models with our proposed model, our proposed model (SbRNF) provides more throughputs. Only Strawberry-based Recurrent Neural Framework has more successful signals that are less error bits are received over the OFDM channel.

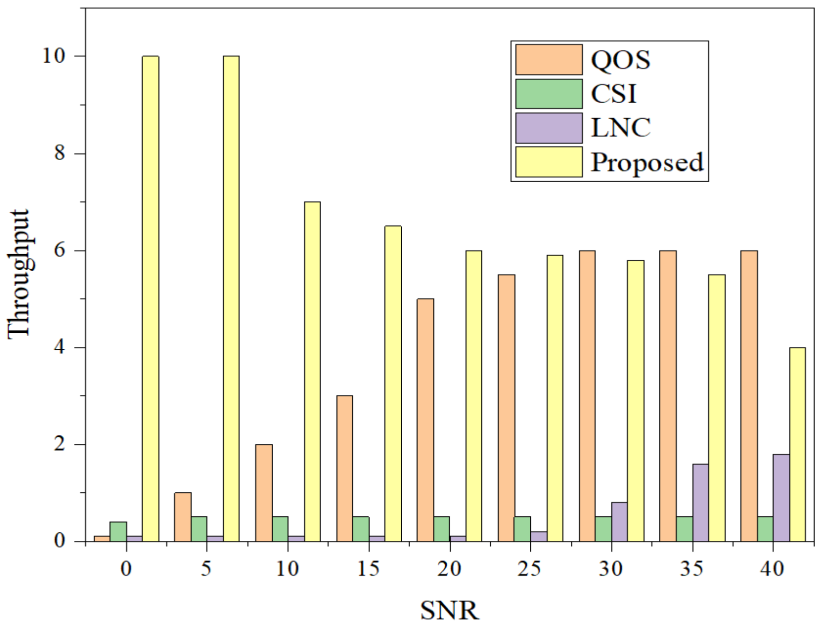


**Fig. 13** Comparison of Throughput with other proposed models

Throughput is nothing but a number of received signals correctly at a particular bit signal. Our proposed model has more throughput values while comparing our proposed throughput values to other proposed techniques like Quality of Service (QoS), Channel State Information (CSI), and LNC algorithm. The clear diagrammatic representation of the greater throughput tare of our proposed model was shown in fig 13. Our proposed model (SbRNF) receives more bits than other models. The throughput of our proposed model is about 21.33 bits/ sec.

### 5.5 Discussion

The main objective of the presented model is to determine and reduce the power rate while on the signal transmission. Here, the power range is estimated using a strawberry-based algorithm, and then the estimated parameters are then reduced by using the SbRNF optimization process. By analyzing the above methods with our proposed model bit error rate was low, and the high achieving rate of PAPR in the presence of CCDF as well as it reaches the high throughput and attains a low Bit Error Rate (BER). SbRNF having a throughput of 21.33 bits/sec and has less bit error rate is about 0.0001465, and the performance range of PAPR in the presence of CCDF is about3.4050.

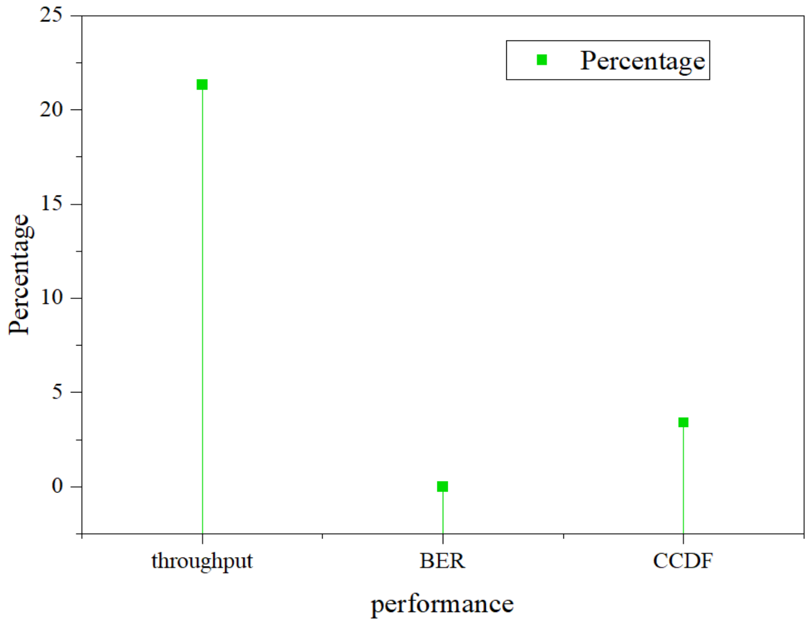


**Fig. 14** Overall performances

On comparing the parameters like throughput, BER, and performance of PAPR in the presence of CCDF with another existing model, our proposed model gives better results, as shown in fig. 14.

## 6 Conclusion

Here, the altered possessions of the OFDM system exist examined. The BER was marked against the SNR to recognize the performance of the OFDM system. Therefore, an efficient data transmission technique is important for uninterrupted signal transmission. The proposed SbRNF technique identifies high power and reduces the high PAPR by increasing the throughput in this present work. Finally, the outcome of the presented technique is compared with the other techniques. Our proposed method provides a high throughput rate of receiving 21.33 bits/sec. It increases 6% the throughput range from the existing techniques and has a low bit error rate of 0.0001465. It reduces 4% BER compared to the existing methodologies and provides an error-less bit in the range of 3.4050 bits/sec. That is, it improves 5% performance in the presence of CCDF. Thus, the executed model estimates the transmission and makes the signal without high power. Through clipping, selected mapping and partial transmit Sequence methodologies help to transmit the signals without signal loss.

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None

**Compliance with Ethical Standards**

1. Disclosure of Potential Conflict of Interest:

   The authors declare that they have no potential conflict of interest.

2. Statement of Human and Animal Rights

   i. *Ethical Approval*

   All applicable institutional and/or national guidelines for the care and use of animals were followed.

   ii. *Informed Consent*

   For this type of study formal consent is not required.

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