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An Enhanced Approach of MIMO-OFDM Data Transfer by Varying User Location Optimized by Machine and AI Learning

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Abstract

Objectives: Orthogonal Frequency Division Multiplexing (OFDM) was designed in order to increase the data transfer rate in a channel. Furthermore to cope up with the demand of the user, Multiple Inputs Multiple Output (MIMO) concepts were introduced to it. **Methods/Statistical Analysis**: This work has taken the existing architecture to the next level. It presents a solution to a problem in which the user changes its location rapidly and then attempts to transfer the data from one end to another. Users have been divided into regions, MIMO OFDM architecture has been used to transfer the data. The data to send have been optimized with a combination of natural and swarm intelligence technique and then finally classified with Artificial Intelligence algorithm to make the transfer smoother. The process is judged by mean square error and bit error rate. **Findings:** This research has optimized data transfer process and uses the channel well. **Application/Improvements:** The result has shown that the proposed algorithm has put an important impact in lessening both MSE and BER.

Keywords: Artificial Intelligence, Optimization, OFDM, MIMO

1. Introduction

In the modern era, high transmission rate with reliability and security have become the unrest necessity of any network. Commercial use of data transfer cannot be ignored and hence high pro-efficiency is required in order to avoid transmission loss. Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM)[1] has gained a lot of respect in the area for secure and high speed transmission. To avoid the error in the bit sequence transferred by the architecture, pilot bits are added in the bit sequence. Figure 1 represents the general architecture of MIMO-OFDM architecture[2].

The architecture involves data multiplexing block[3]. In this block, data from multiple users are combined for the transfer. To make the data feasible for the transfer of data[4], modulation technique is applied[5-6]. There are lots of modulation techniques like BPSK[7-8], QPSK[9-10], QAM (16,32,64)[11-12] is available for this purpose. Digital data cannot be transferred directly to any medium; hence, it has to be changed to analog. For this purpose, IFFT block[13-14] is required and hence serial to parallel converter is there in the architecture followed by the encoder block changes the encoded data to an architecture which can be transferred. There are various channels like AWGN[15-16], Rayleigh fading channel[17-18], Racian fading channel[19-20] etc. which can be utilized for the transfer.

2. Problem Statement

MIMO OFDM has gained a lot of attention in fast transmission requirement. If there are users are varying their position on a rapid manner. It becomes difficult to trace them and to provide them facilities to transfer the data. The first problem of this research work is to divide the users as per their region and to monitor the GPS system of users in order to facilitate them with the transfer mechanism of different channels available in that region.

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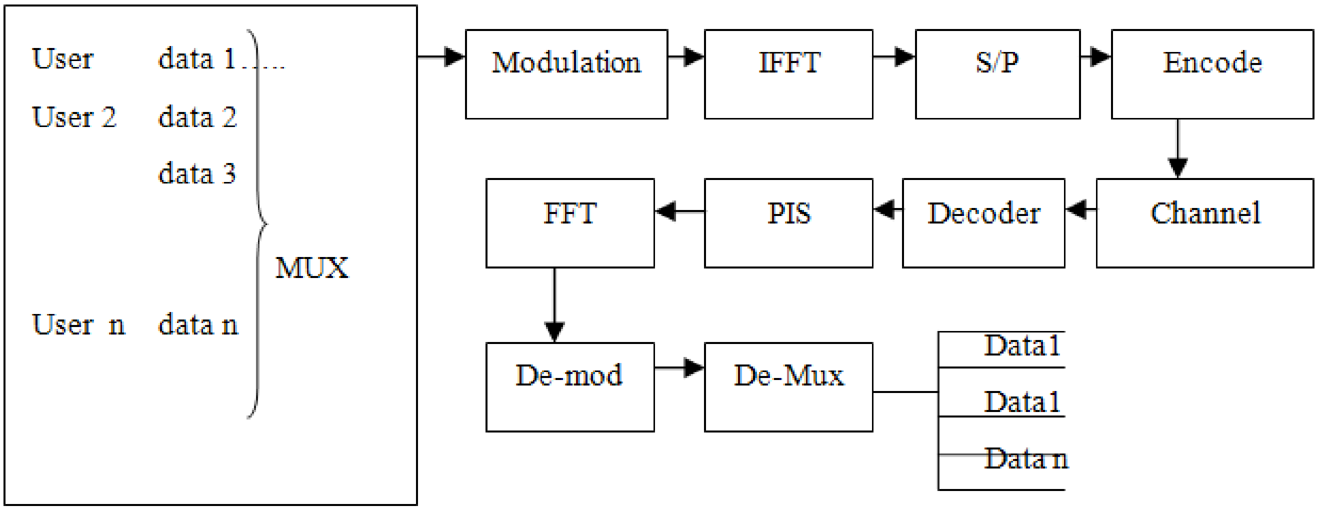


Figure 1. General architecture of MIMO OFDM.

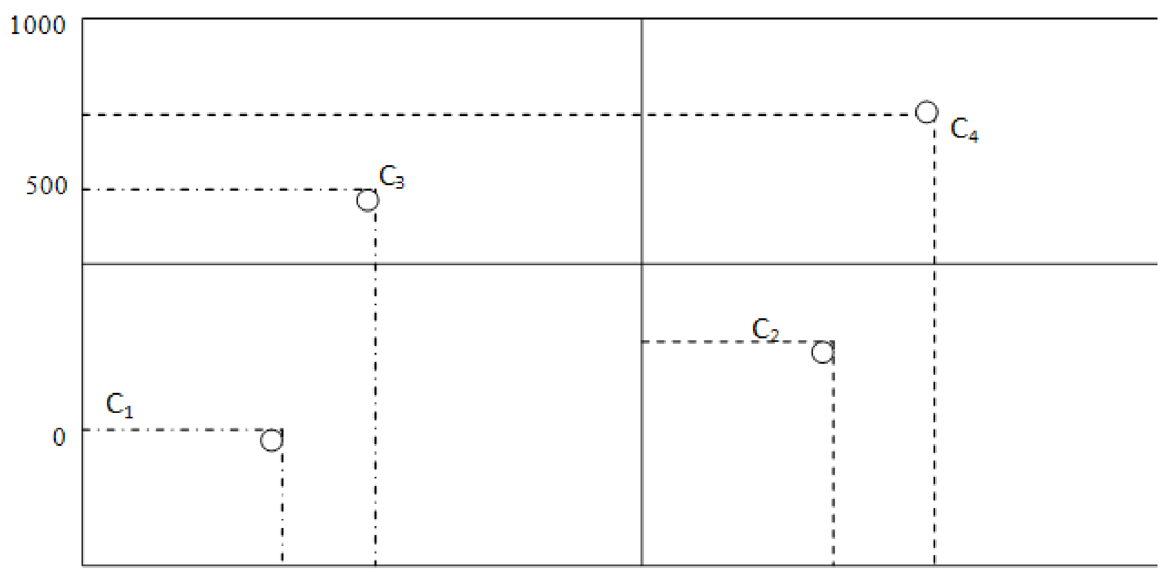


Figure 2. Clustered network.

When a user attempts to transfer the data, there could be a lot of invalid bits which may affects the transfer process and may decrease the signal quality of the data. The second problem of this research work is to optimize the data quality which has to transfer. The evaluation has to be done on the basis of the bit error rate and mean square error.

This research paper is organized in five sections. The first section is the introduction part which briefs the MIMO-OFDM architecture. The second phase is the problem statement which describes the formation of the problem. The third section is the proposed methodology which describes the computation parameters and the comparison graphs and tables. This section also illustrates the significance of the proposed algorithm. The last part is the conclusion part which includes the description of the entire work process and the description of the improvements.

3. Proposed Methodology

The proposed methodology is divided into following sections:

3.1 Basic Construction of Network

a) Construction of the network;

b) Division of area;
c) Employment of MIMO; and
d) Route discovery process.

3.2 Optimization and Classification

a) Data initialization and transfer channel after optimization;
b) Comparison of classification algorithm; and
c) Application of the classification algorithm.

3.3 Estimation of the Error Rate and Mean Square Error of Transferred Data

a) Construction of network

A network has to be constructed in order to transfer the data from one end to another. The following aspect as shown in Table 1 has been utilized to construct the network and is shown in Figure 2.

Table 1. Simulation environment

Width of the network	1000
Height of the network	1000
Total number of nodes in the network	[50,100,150]
Number of clusters	4

b) Algorithm used to divide the nodes in the clusters

Algorithm 1: Divide nodes into clusters

function clusters=divide_nodes_clusters (nodes,X,Y)

// x and y are the x and y co-ordinates of the nodes

// the network clust1=[ ]; clust2= [ ];clust3= [ ]; clust4=[ ];

clust1count=0;clust2count=0;clustcount=0;clust4count=0;

fpr i=1:nodes.count
initialize current_x=0;
initialize current_y=0;
current_x=x[i];
current_y=y[i];
if current_x<500&&currenr_y<500
clust1[clust1count]=i;
clust1count=clust1count+1;
elseif current_x>500&&current_y<500
clust2 [clust2count]=i;
clust2count=clust2count+1;
elseif currenr_x<500&&currenr_y>500
clust3[clust3count]=i;
clust3count=clust2count+1;
else
clust4[clust4count]=i;
clust4count=clust4count+1;
end if
end for
end fnction

As the nodes locations are random, any node can lie to any region.

c) Route discovery processes

The route discovery process involves three steps:
i) Random collection of sources form clusters
ii) Random collection of destinations from clusters
iii) Route discovery from source to destination

The node movement is not fix nodes may changes their position and accordingly the cluster region may also change as shown in Figure 3. In order to monitor the cluster change process, the following algorithm is utilized.

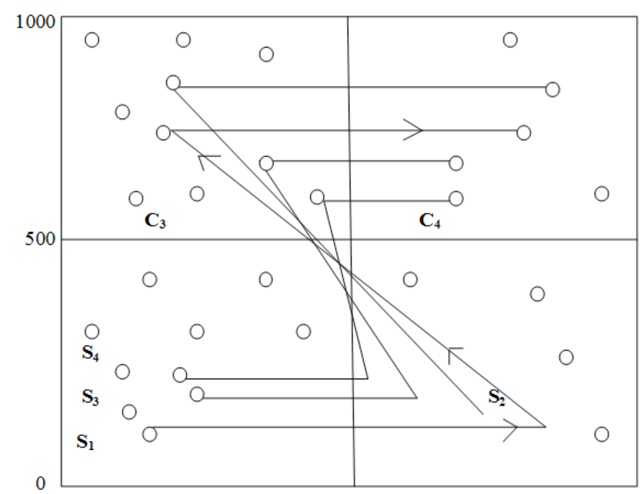


Figure 3. Source list to destination list route discovery process.

Algorithm 2: To identify the change in region of nodes

function region_change=identify_new region (nodes,xo,yo,xn,yn)

for i=1:nodes.count
if x o [i] !=xn[i]
regionchanges=true; //here the updation is required in the cluster information
//Hence again region calculator is required
divide_nodes_clusters(nodes (i),xn,yn);
end if
end for
end function

As the initial step phase is complete, the data has to be prepared for the channel. A total of 96 bit pattern data is randomly generated.

Data=rand i [1, 96];

a) Data initialization and transfer after optimization

The first step according to Figure 1 is the modulation of data. The modulation process changes the data into a format which can be transferred by any channel. There are different types of modulation techniques which can be applied to data as shown in Figure 4. The modulation is a typed carrier signal that varies in accordance with message signals.

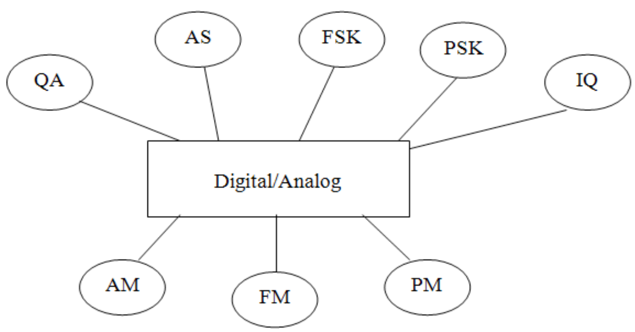
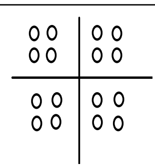
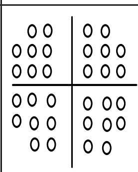
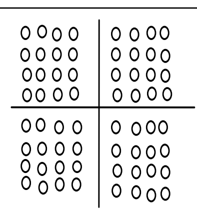


Figure 4. Different types of digital and analog modulation.

Here, three types of modulation techniques have been applied. They are listed as shown in Table 2.

Table 2. Modulation techniques

Modulation Type	Architecture
16 QAM	
32 QAM	
64 QAM	

The benefit of using QAM is it can carry higher bit transfer rate.

4. Inverse Fast Fourier Transformation (IFFT)

IFFT is used for division. If Y is a data vector, IFFT tests the conjugate symmetry in Y.

$$\mathbf{Y}\,(\mathbf{K}) = \sum_{P=1}^{nb} \mathbf{X}(\mathbf{j})\mathbf{Wn}(\mathbf{j}-\mathbf{1})(\mathbf{k}-\mathbf{1}) \tag{1}$$

$$\mathbf{X}(\mathbf{K}) = \frac{\mathbf{1}}{\mathbf{nb}} \sum_{K=1}^{nb} \mathbf{Y}(\mathbf{K})\mathbf{W_n}^{(\mathbf{j}-\mathbf{1})(\mathbf{k}-\mathbf{1})} \tag{2}$$

where, X is the sampled data and W is the wave bit series

5. Serial to Parallel (S/P)

S/P stands for serial to parallel converter and it converts the data from serial to parallel format.

After the process, the data becomes almost ready to transfer. Addition of any parity bit may also be an option. Encoders are used to prevent the data from any kind of theft.

The third part of the proposed algorithm is the optimization and classification part in order to utilize the channel more and more.

The proposed algorithm utilizes two optimization algorithms fro, different types of behavior:

i) Genetic Algorithm (Belongs to natural computing)
ii) Artificial Bee Colony Algorithm (Belongs to swarm Intelligence)

The proposed algorithm optimizes the data with both the algorithms and computes the Signal to Noise Ratio (SNR) after optimization. Higher SNR leads to the selection of the optimization algorithm. The structure of genetic algorithm is shown in Table 3.

Table 3. Structure of the genetic algorithm

Population Size	**Total number of bits to be optimized**
Mutation	.05
Crossover	Linear
Fitness Function	$f = 1 \quad if \sum_{i=1}^{n} bit(i) x rand(0,1) < \sum_{i=1}^{n}\sum_{j=i+1}^{n} \frac{bits}{n^2}$ 0 otherwise

Genetic Algorithm put 0 to that bit which is not satisfied by the fitness function.

Table 4. Bit error rate analysis

BER	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5
Ethical	.12	.24	.15	.76	.55
Proposed	.09	.11	.075	.34	.13

The same fitness function is utilized for artificial bee colony algorithm. The structure for ABC is shown in Table 4.

Table 4. Structure of the ABC

Total Bees	Bit Count
Employed Bee	Per Bit
Onlooker Bee	Fitness Function of genetic algorithm

After the optimization, SNR is computed for energy bit sequence

$$\text{SNR}=\frac{abs\ \left[\sum_{i=1}^{n}\sum_{j=1}^{k} bit(i,j)-\sum_{i=1}^{n}\sum_{j=1}^{n} bit_{n}(i,j)\right]}{n*k} \tag{3}$$

The optimized bit sequence has to be tested whether they have been optimized well or not. For such a case, artificial Intelligence has been used. 70 % of the bit sequences have been used as the classification part.

6. Artificial Neural Network

Artificial Neural Network is a layered architecture and it has drawn attention from several fields for the last couple of years. There are three layers in a neural network.

i) Input layer: The data which has to be trained is provided on this layer.
ii) Hidden layer: Hidden layer converts the input data to a processable format.
iii) Output layer: The classified results are viewed at this layer.

The idea is to test the significance of 30 % data to the 70 % of the bit pattern. Neural Network will return the accuracy of the significance. If the accuracy is greater than 80 % then it can be termed that the optimization has made significant changes to the data pattern.

The following training Model as shown in Figure 5 has been observed after the training of neural network.

A total of 30 hidden neurons have been provided at the input layer in order to change the input pattern to a pattern which is understandable by the Neural Network. A total of 100 Iterations is allowed (It can be changed through the construction of the program). It is not necessary that the network run all the 100 iterations. If any of the stopping criteria (Epochs, Time, Performance, Gradient, Mutation and Validation Checks) is met then the training of the Feed Forward Network is complete. The work of Neural Network does not end here. When the feed forward network completes its task, it is cross validated by Back propagation Neural Network. The architecture is shown in Figure 6.

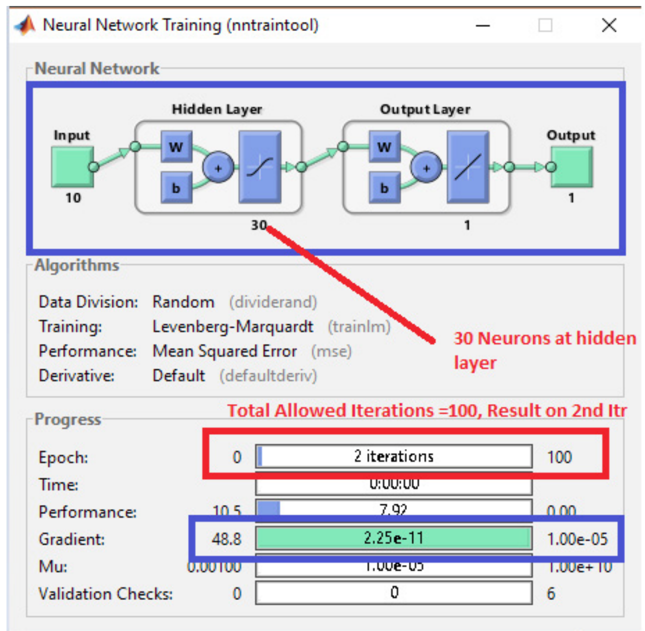


Figure 5. Architecture of neural network after training.

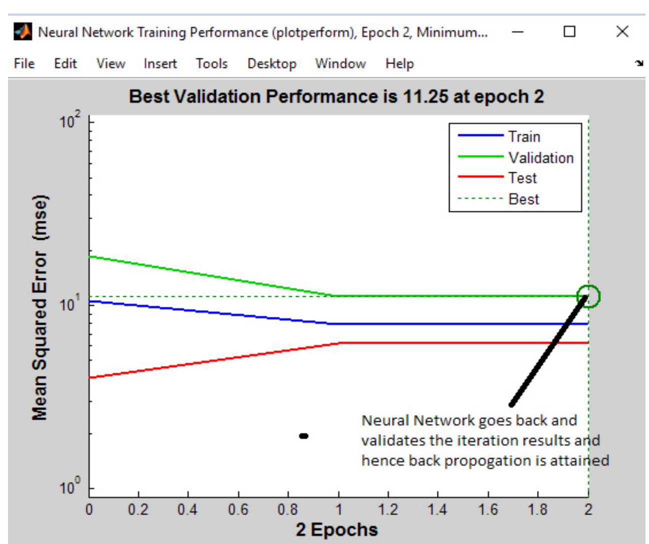


Figure 6. Back propagation selection.

The figure shows that a cross validation step has been performed and the least MSE has been identified at epoch number 2.

7. Results and Analysis

The following parameters have been evaluated and analyzed.

a) Bit Error Rate (BER)

It is the total error in the bits to the total bits transferred. The mathematical formulation is as follows.

$$\mathbf{BER} = \sum_{i=1}^{n} \frac{\mathbf{error}}{\mathbf{n}} \tag{4}$$

The following Table 4 has been observed.

The Figure 7 shows that the BER of the proposed mechanism is quite low as compared to the Ethical BER. A maximum BER of .76 has been recorded for the ethical MIMO –OFDM where as if put in the same situation, a maximum of .34 BER has been observed for the proposed algorithm. This is due to the rejection of the redundant bits of the data before it is transmitted to the channel. ABC has reduced the error rate to a significant point. Verification through Neural Network has assured that the error rate is reduced.

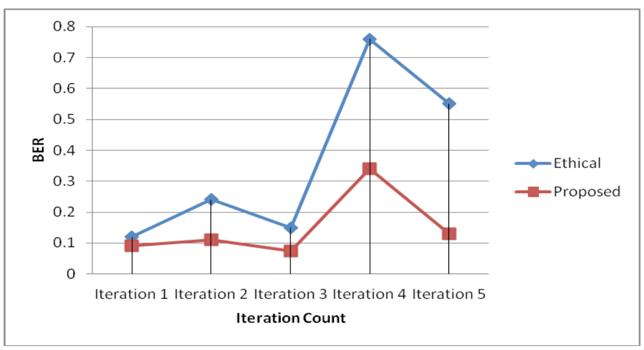


Figure 7. Comparison of bit error rate.

b) Mean Square Error (MSE)

MSE is one of the most relevant parameters in the evaluation of the strength of the transferred data. MSE is exactly reciprocal to the signal strength. The mathematical formula is as follows

$$MSE = \frac{(\sum_{I=}^{n} TotalBitsofReceivedData - \sum_{i=1}^{n} [TotalBitsofTransferredData)]}{n} \tag{5}$$

The Table 5 has been observed. A significant decrease in the Mean Square Error has been recorded as compared to the ethical process in MIMO OFDM as shown in Figure 8. The reason is same as that of BER The maximum MSE is .055 for ethical process and for the proposed architecture is .0074.

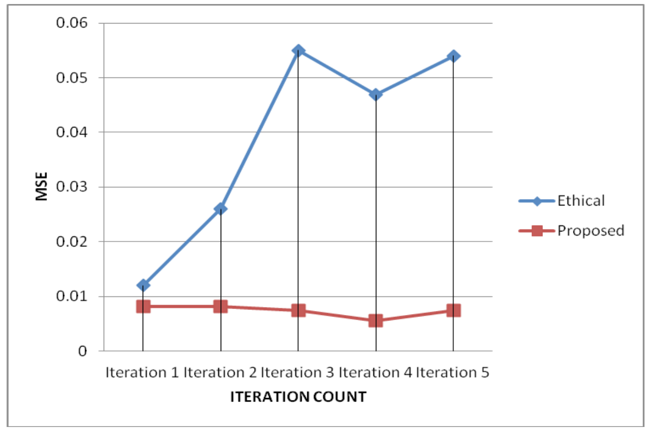


Figure 8. Comparison of mean square error.

8. Conclusion

MIMO OFDM is a fast and efficient method of transmission of the data which suits the modern world demand. The entire process of data transfer involves a lot of small steps like IFFT, S/P and encoding. A user is not always aware that what he should send and what he should not send. The MIMO OFDM does not analyze the data architecture and puts it into transfer process. The proposed algorithm optimizes the process of data transfer and utilizes the channel well. The proposed algorithm has been tested with three types of modulation techniques and two types of optimization techniques. The proposed algorithm has also used AI to finally evaluate the optimized data through GA and ABC. The results section compares the bit error rate and mean square error under two situations, with and without proposed algorithm.

The analysis of the results shows that the proposed algorithm has put a significant impact in decreasing both MSE and BER

Table 5. Mean square error analysis

MSE	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5
Ethical	.012	.026	.055	.0469	.054
Proposed	.0082	.0081	.0074	.0055	.0073

The proposed research work has opened a lot of gates for the future research workers. The upcoming researchers may try their hand in other optimization algorithms like PSO and Cuckoo Search. It would also be interesting to see how hybridization of optimization algorithm works in the presented scenario.

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