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Designing an Efficient Power Allocation method for OFDM system for 5G WiMaX System

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Abstract– **Over the past decade, Wi-Max (Worldwide Interoperability for Microwave Access) has emerged as a fast data transfer mechanism for 5G communications. A key element of 5G wireless transmission systems is optimal power distribution. The OFDM has recently grown in popularity due to the demand for high-speed transmission and increased data capacity. To optimize system performance while consuming less energy, it comprises distributing transmit power among several sub-carriers, users, including antennas in a clever manner. Therefore, finding the appropriate parameters for water-filling based on the best power allocation for the performance of the OFDM system is prime goal of the research. Paper has evaluated the impact of increasing sub-carriers and bandwidth over power allocation and capacity enhancement for OFDM W-AMX channels. It is concluded that using WFA may improve the system performance and minimize the N/C ratio. Also the energy slots are better utilized.**

Keywords-- **OFDM, MIMO, Wireless Communication, PAPR Reduction, AWGN, Selective Mapping, Amplitude Clipping**

I. INTRODUCTION

The robust and adaptable OFDM (Orthogonal Frequencies Division Multiplexing) technique greatly boosts the efficiency of wireless Wi-MAX networks. Because of its capacity to provide fast data speeds, boost bandwidth utilization, and sustain consistent connections in difficult settings, it is essential to modern communication technological advances, including 4G LTE, 5G, and more complex Wi-Fi protocols. Since the demand for more quickly, more dependable wireless connectivity grows, OFDM is becoming an increasingly significant part of the establishment of global communications networks.

A crucial component of 5G WiMAX systems, OFDM provides notable gains in spectral efficiency and data throughput. Optimizing power allocation is essential to achieving optimal performance of the system. The goal of the optimal power allocation algorithm for MIMO (Multi-I/O) systems employing the Water-Filling approach (WFA) [1] was to increase channel capacity for the purpose of enhancing spectral efficiency (SE).

By assigning power according to the signal-to-noise ratio (SNR) as well as channel state information (CSI), the optimal Water-Filling procedure attempted to optimize channel capacity and successfully improve spectral efficiency (SE) of MIMO systems. In order to maximize power allocation and minimize energy consumption, the Gravitational Search Algorithm (GSA) [2] simulates gravitational forces. This allows for effective subcarrier power distribution of the MIMO-OFDM systems.

Enhancing capacity requires addressing power allocation including peak average power reduction (PAPR). The Optimal allocation of power can boost the entire data capacity of an OFDM system. As a result, determining the best approach for power allocation is necessary. The main causes of research on optimal power allocation are as follows;

- The channel matrix is crucial because it shows the parameters of the propagation among the transmitter and reception antennas. Extreme fading or interfering channels require a higher power allotment.
- Reducing power usage is crucial to prolonging the battery life of portable electronics.
- Higher power allocation might be necessary for real-time applications like audio or video since they may demand more dependable transmission.
- Increasing the power allocated to users who require more data might enhance the overall throughput of the system.

There are many power allocation method the most common ones used for the MIMO-OFDM context are Water Filling [5], Successive Convex Approximation (SCA) [6, 7], Game Theory [8, 9] Reinforcement Learning]10\ and Deep Learning (DL) [11]. In coded MIMO systems, the deep learning approach performs better than traditional power allocation algorithms in terms of bit error rate (BER) performance.

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II. Application Of 5G Wi-Max-Communication

In recent times due to demand of high rate transmission and more data capacity the 5G Wi-Max-OFDM has gained huge popularity. The most popular wireless communication uses are illustrated in the Figure 1. Higher spectrum effectiveness as well as improved data throughput is made possible by MIMO-OFDM. Using OFDM and several antennas at each end of the radio spectrum 5G-LTE (long term evaluation) could provide faster data connections, streaming video, and phone over LTE (VoLTE) more frequently. DVB-T2 employs MIMO-OFDM, which enables transmitters to provide more channels and better quality images most notably HDTV—using the same frequency spectrums.

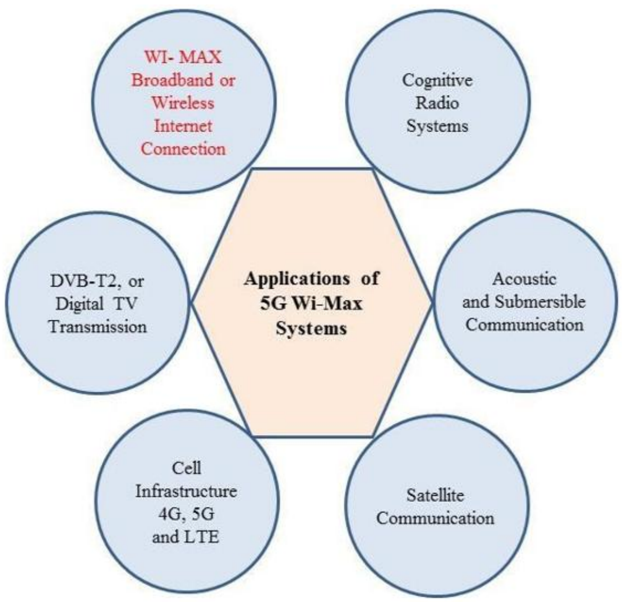

Figure 1 vast range of 5G Wi-MAX-OFDM applications

Although LTE has completely replaced WiMAX for communication, but WiMAX uses MIMO-OFDM to provide internet connection, particularly in rural or impoverished areas. Using MIMO-OFDM technology, WiMAX can deliver consistent, fast internet over long distances—even in situations where a straight line of sight (LOS) is not possible. The satellite network's capacity and reach are increased through the utilization of MIMO-OFDM in satellite broadcasting. It improves utilization of the easily available spectrum and helps mitigate multiple path effects that are common in satellite communications, especially in urban areas.

2.1 Important MIMO-OFDM Features in 5G:

The 5G MIMO-OFDM system offers certain advantages for enhanced system performance.

With the introduction of scalable astrology in 5G, the sub-carrier frequencies may be changed according to the spectrum and usage scenario. Technology, especially in high-voltage bands, increases spectral efficacy and facilitates more targeted exchange, improving coverage and data throughput. The major features of the 5G MIMO-OFDM systems are illustrated in Figure 2.

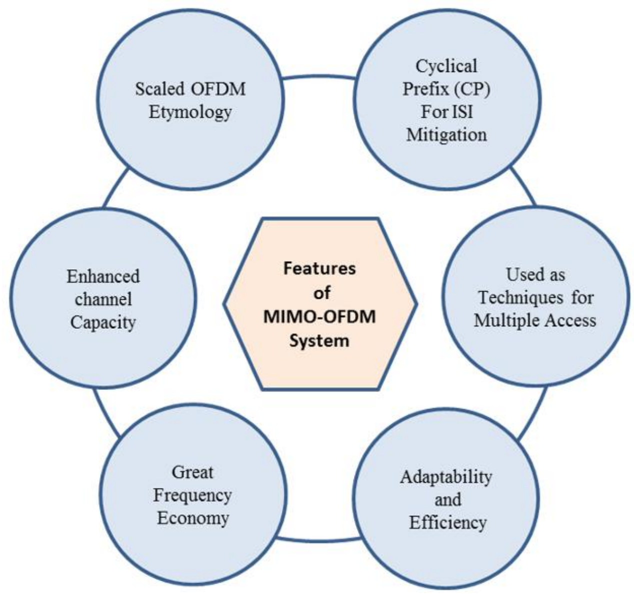

Figure 2 Features of MIMO-OFDM system

To deal with interruptions from multi-paths WiMAX, 5G employs an OFDM cyclic prefix (CP) insertion. However, 5G has the ability to change the periodic prefix's length. Additionally the MIMO-OFDM version of 5G is more adaptable then WiMAX's, with extensible arithmetic that allows for a wider range of possibilities as well as better use of the bandwidth.

2.2 Pros and Cons of Water-Filling based Power Allocation

The water-filling algorithm (WFA) is a popular and efficient method for power allocation in MIMO-OFDM systems. It offers several key advantages; main benefits of the WFA for MIMO-OFDM Power Allocation are as follows;

- *Simplicity:* The algorithm is simple to implement, thus making it ideal for practical applications.
- *Optimality:* The WFA can obtain the ideal power allocation in certain situations. These conditions includes, under Gaussian noise channel, considering no sub-carriers interferences, and independent sub-carriers fading.
- *Efficiency:* Because of its computational efficiency, real-time applications can benefit from it.

- *Adaptability:* The WFA guarantees optimal performance under a variety of circumstances by readily adapting to changes in channel conditions.
- *Intuitive Understanding:* The power allocation procedure is easily and intuitively understood by using the WFA.

2.3 Limitations of Water-Filling:

The water-filling algorithm has many drawbacks despite its widespread effectiveness:

Suboptimal in Some Scenarios: Where the channel matrix fails to meet diagonal or there are non-convex constraints, it might not be the best option.

Sensitivity towards Noise Floor: Variations in the noise floor may have an impact on how well the algorithm performs.

In summary, the water-filling method provides simplicity, efficiency, and frequently excellent performance, making it a useful tool for power allocation for 5G Wi-Max-OFDM systems.

III. Review Of Work

This section has presented the various related research considered for the designing. Leones, Sherwin et al [1] have studied capacity of Fast speeds Train (HST) network for communication was computed under the assumption that fluctuations in attenuate and network losses have no effect on the SNR. The Water-Filling approach is developed for MIMO systems with knowing CSI at both ends of the system. In order to attain spectral effectiveness (SE), the provided technique may be effectively tuned for enhancing channel bandwidth. Md. Helal Miah et al [2] suggested technique which is dependent on the laws of motion and gravity, this study uses the gravitational search technique (GSA) to determine the greatest power. For all masses in GSA, there are four requirements: inertial, location, active, and inactive mass. The inertia and magnetic masses are estimated using the fit function, and the precise location for the mass in question is determined as the answer to the issue. The agent is regarded as an object, and the performance is expressed in masses. One can attain excellent results from a substance that has ample mass by guiding it towards the optimal position. Nihad, Abdelhameed et al. [3] studied OFDM waveform is used by the MIMO-IRCS, and this study offers a power allocation plan for the two networks. The convex planning issue is formulated and solved analytically using standard Karush-Kuhn-Tuckers (KKT) optimal outcomes conditions.

The proposed approach decreases the total transmitted power and satisfying both of the system requirements: SNR (Signal-to-Noise Ratio) to ensure effectiveness and SCNR (Signal-to-Clutter-plus-Noise Ratio) as finding targets. The outcomes of the simulation demonstrate that the suggested strategy is successful in lowering the total energy use of the MIMO-IRCS system.

Mingjun Ying et al. [4] have presented a SE-optimal self-optimizing water-filling (SOWF) distribution technique that determines the voltage allotment scheme for all of each user's OFDMA, or sub-channels while taking into account the channel signal-to-interference-plus-noise ratio (SINR). Then, in order to reduce processing difficulty, a near-optimal proactive water-filling (FLWF) approach was developed. Dr.

A. N. Jadhav et al. [5] addressed optimal allocation of electricity method and water-filling have been studied in an interactive setting in this article. They demonstrate that, in comparison to water-filling, or traditional, power distribution algorithms, the optimal power assignment method can achieve better transfer. Ruina Mao et al. [6] have investigated a SISO network's sum rate the achievement challenge subject to a power maximum constraint at each broadcaster. They suggest an approach based on sequential convex approximating (SCA) to solve this power control challenge. X. Tang et al. [7] have examined energy-efficient broadcasts that raise security issues when an active full-duplex in (FD) eavesdropper is present.

H. Fawaz et al [8] present an article used a game mathematical method for energy allotment in several-access nets with full-duplex transverse frequencies division. Naeem M et al. [9] have addressed increasing popularity of RL and DL, new and potent methods that reduce problems in MIMO communications are introduced. This paper presents a thorough overview of the connection among the two domains, with a particular focus on RL & DL approaches for systems with MIMO. Salama, W.M et al. [10] have used linear processing algorithms such as Minimum Proportion Transmission/Maximum Ratio Mixing (MRT/MRC), Zero-Forcing (ZF), and Minimum mean square error (MMSE). Our suggested CNN - LSTM is trained using these algorithms. The model beat previous algorithms by 10%, 10.44%, and 12.05% when use MRT, ZF (ineffective CSI), and MMSE, as for the EE function. It is noticed that the results are enhanced by 12.8% using ZF (perfect CSI).

Ke, Ma et al [11] have used the BER as the tool for performance evaluation of MIMO system using deep learning based power allocation techniques. Minki, Ahn et al [12] have suggested a novel approach to stream distribution of power for BICM MIMO-OFDM networks single-user beam shaping.

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The approximate functional of the MMIB is used to generate the best power distribution using the diagonal matrix. Mohammed R et al. [13] in the MIMO-downlink structure comparative analysis is carried out of the exhaustive algorithms-based water filling engine (EWFA), the CQOA, and the water filled binary search algorithms (WFA-BSA). Yu, David et al. [14] proposes an effective repetitive water-filling technique to handle the power allocation issue. They stated that in binary coding (BC) has solution to the problem.

Prabhu, Raghavendra et al [15] studied effects of transmitting energy and continuous circuit energy use are modeled. Both the maximal rate (MR) & maxim margin (MM) challenges are included in the general formulation of the energy reducing problem as special cases. Consequently, the energy conservation point of view offers a practical and cohesive view regarding the several water-filling options. Md. Noor-A-Rahim et al [16] to enhance the communication systems' achievement, OFDM and MIMO are combined in this work. At the receiving and sending ends, several antennas are used. An OFDM system's effectiveness is evaluated taking into account distortion, multipath delay propagate, network noise, and Chromatic ageing. In this work, modulator methods including QPSK, 8PSK, & QAM are used to create bits and subsequently map them. Subsequently, the map data is split up into chunks of 120 modulating data, with a training arrangement of information appended to both the block's.

J. A. C. Bingham et al [17] proposed a multicarrier modulating (MCM), a broad method of simultaneous communication on many transport companies, is described. We cover the achievable efficiency on an unaffected channel as well as the algorithms to reach that performance. Techniques for addressing channel limitations and enhancing efficiency via coding are discussed, along with approaches for application. Song Wei et al [18] have presented a water-filling algorithm-based efficiency method for channels distribution of resources. Based on the initial water-filling algorithm, certain enhancements have been implemented. By adjusting the transmission interfering heat limit (Sk) with the help of the sgn operation, the transmission network's capability is efficiently improved and channel screenings becomes more flexible because the screening outcome is not only subject to the Sk.

Deng, X et al [19] presents article, to put forward a two-dimension water-filling (2D-WF) allocation of power approach to effectively increase the rate attained by MIMO-OFDM systems that operate on low-pass VLC circuits. The technique works in both frequency & space dimensions.

Using the suggested 2D-WF power allocation method and five standard power distribution strategies—uniform (UF), pre-emphasis (PE), beam-forming (BF), or two types of limited water-filling (1D-WF) power allocation—the feasible prices or optimal bandwidth of a MIMO-OFDM VLC structure are calculated logically. Overall many researches have tried to improve the performance of WFA widely being used in OFDM environment. But still needs to address the capacity and power allocation issue.

IV. Optimal Power Allocation Using WFA

Consider a tank of water with an uneven bottom. A portion of the tank corresponds to each subcarrier. The power allotted to each subcarrier is represented by the water level. Up to the water level approaches the noise floor, the algorithm filled the tank. More power will be delivered to subcarriers with deeper portions (higher channel gains) and less power to those with shallower sections (lower gains).

The iterative water-filling technique offers a closed- form approach for optimal power as well as subcarrier distribution in both MC-NOMA downlink along with uplink scenarios. It adjusts for interference between stronger users including Gaussian noise, resulting in different water levels among weaker users.

Among various sub-carriers, users, and antennas, transmit power must be intelligently allocated to improve system performance while using less energy. Therefore, the main objective of research is to determine the best power allocation during the operation of the OFDM system in order to determine the optimal parameters for water-filling. The block diagram is shown in Figure 3. The impacts of sub carries no and Band width (BW0 are evaluated. The WFA is used for the optimal power allocation in the Wi-MAX based OFDM physical system.

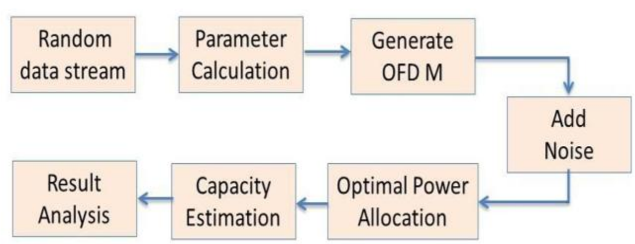

Figure 3 Proposed block diagram of OFDM-WIMAX System using WFA

V. Proposed Methodology

In the proposed work water filling algorithm (WFA) is employed to increase a frequency selective channel's capacity.

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The entire bandwidth is divided into N sub-channels using OFDM modulation. Adding the appropriate cyclic prefix to the last portion of each OFDM symbol prevents an excessive number of sub-channels from causing each sub-channel to encounter a flat fading channel. The water-filling method gives sub-channels with good conditions more power, and it can give sub-channels with poor conditions no power at all.

The water-filling approach (WFA) is a basic way of spreading power across numerous channels or sub-carriers during communication systems, such as OFDM. The major goal is to optimize the total data transfer rate while staying under a total power constraint. Generating the N number of OFDM sub carrier using IFFT mathematically given as;

$$s(t) = \frac{1}{N}\sum_{k=0}^{N-1} x_k \emptyset_k(t) \ , \quad where \ \ 0 < t < NT \qquad (1)$$

Symbol x_k is the k^{th} data symbol of M-PSK or QAM modulation, and NT is the length of OFDM symbol. The subcarriers frequency f_k is separated by fixed amount. Let N_{SC} $is\ number\ of\ sub\ carriesrs$ then

$$Noise_{SC} = n_{density} * BW/N_{SC} \qquad (2)$$

The carrier to noise ratio is determined as;

$$\frac{c}{n} = CSI^2/Noise_{SC} \qquad (3)$$

The proposed Flow chart is illustrated in the Figure 4.

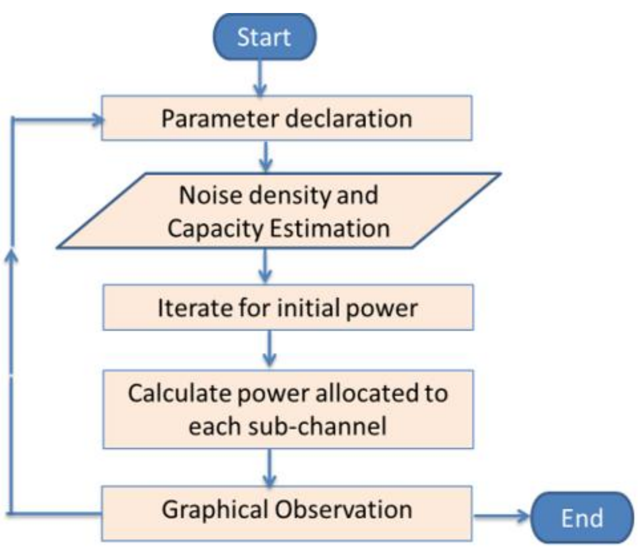

Figure 4 Flow chart of the proposed analysis

VI. Results And Simulations

To increase system performance while consuming less energy, transmit power must be intelligently distributed among different sub-carriers, users, and antennas. In order to ascertain the ideal parameters for water-filling, the primary goal of research is to ascertain the best power allocation throughout the operation of the OFDM system. This paper implements the parametric simulation. Table 2 displays the fundamental simulation settings used in the paper. The waterfilling algorithm is used to increase a frequency selective channel's capacity. The entire bandwidth is divided into N sub-channels by OFDM modulation. Adding the appropriate cyclic prefix to the end of each OFDM symbol prevents a large number of sub-channels from causing each sub-channel to experience a flat fading channel. The waterfilling method gives sub-channels with good conditions more power, and it can give sub-channels with poor conditions no power at all.

Experiment 1:

The first experiment is performed by varying the number of sub carries in the order of 2. The impact on the power allocation and capacity are evaluated. Results of the waterfilling based optimal power allocation For 16 sub-carriers shown in the Figure 5. And respective results for 32 sub carries are represented in the Figure 6. The diagram shows how electricity flows into the container like water due to noise vs carrier ratios (N/C) or information about the channel state (CSI).

Table 2 Design MIMO-OFDM system parameters

Parameters	Range	Data Description
SNR_dBV	3:1:15	SNR range
N-mc	100	Number of Monte Carlo simulations
K	128	OFDM sub-carriers opted
Nt	[2, 4, 8, 16]	Number of transmit antennas
Nr	[3, and 4]	Number of receive antennas
cnt3	By 1	Loop Counter
Nb	100	Number of Blocks
G	1;4	Guard interval (CP length)
Mod	4, 16	Order of PSK
L	6	Number of taps/ antennas
LSE	-	Channel Estimation (CE)

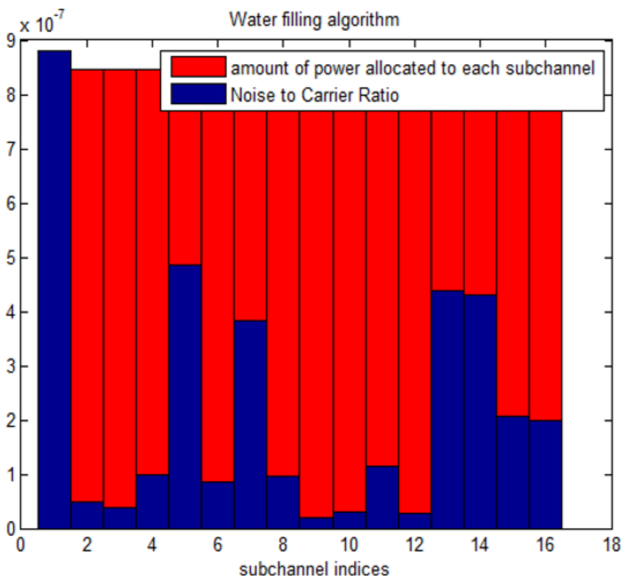

Figure 5 results of the waterfillling based optimal power allocation For 16 sub-carriers

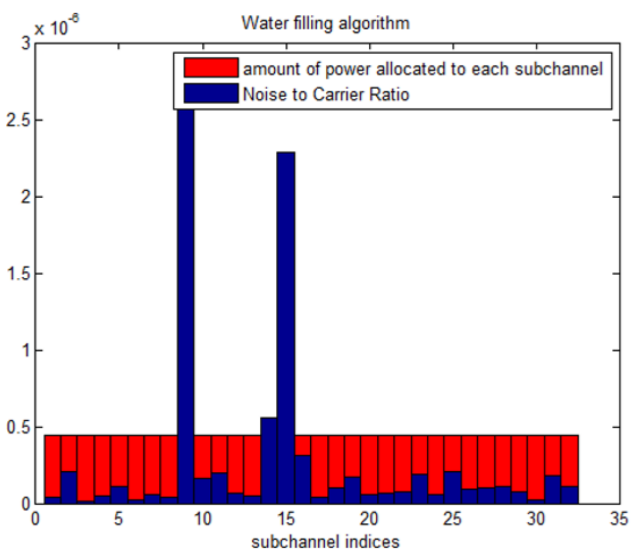

Figure 6 results of the water-filling based optimal power allocation for 32 sub carries

It can be clearly concluded that increasing the sub carries may offers less noise impact. The power allocation is increased from order of 10^{-7} to 10^{-6} by just doubling the sub carries.

The results of the power distribution amongst the each sub carrier for the increasing Nsc numbers are presented in the Figure 7. It can be observed that as the number of carriers is increased the power density per Carrier is reduced. Thus it is difficult to allocate the power.

Experiment 2

Another experiment is performed to compare the impact on channel capacity. The channel capacity of the system is calculated using the following eq().

$$C = BW/N_{SC} * \sum \log_2(1 + P_s) * C/N) \qquad (4)$$

Number of sub carriers N_{SC} is varied from 16, 32 and 64 and channel capacity is plotted for same bandwidth. It has adverse effect for same bandwidth of 1MHz as shown in Figure 7.

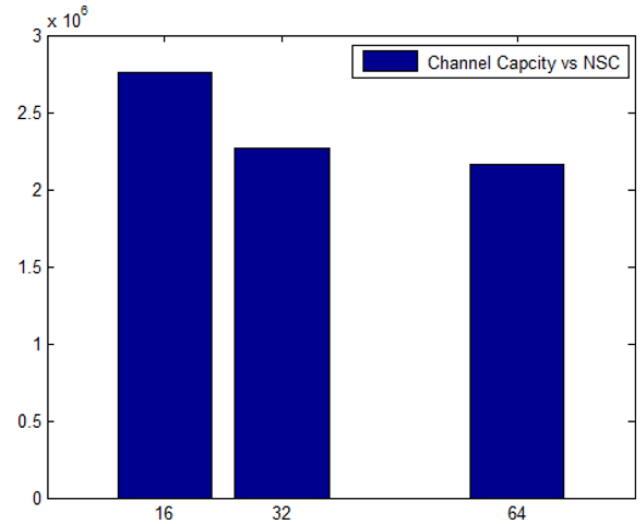

Figure 7 Results of the channel capacity performance evaluated for three different N_{SC}

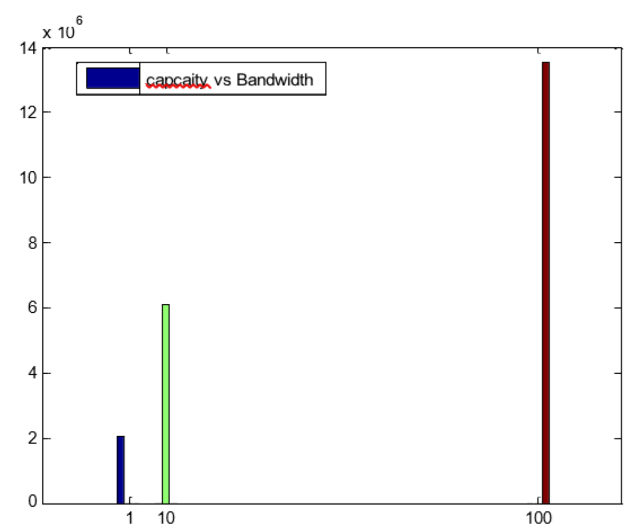

Figure 8 Evaluation of results for the capacity vs. channel Bandwidth

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As an another experiment the bandwidth of the channel is increased to 1MHz, 10 MHz and 100 MHz the capacity performance is evaluated and illustrated in the Figure 8. The bandwidth (BW) in MHz is take on x axis and plotted capacity on y axis respectively in Figure 8.

It is observed that the significant improvement in the capacity is observed with the increase in the bandwidth. Thus Wi- MAX with nearly having BW of 90 MHz has significant capacity of communication.

VII. Conclusions And Future Scopes

An essential component of 5G wireless transmission schemes is an ideal power allocation. The need for higher data capacity and high-speed transmission has led to a recent surge in the adoption of OFDM. It involves intelligently allocating transmit power among several sub-carriers, users, and antennas in order to maximize system performance while using less energy.

Therefore, the main objective of the research is to determine the proper water-filling parameters based on the optimal power allocation for the OFDM system's performance. The effects of increasing bandwidth and subcarriers affecting power allocation as well as capacity improvement for OFDM W-AMX channels have been assessed in this paper. The utilization of WFA is suggested to enhance system efficiency and reduce the N/C ratio. The energy slots are also used more effectively.

It is concluded that there might be reduced noise influence if the sub carries are increased. By just doubling the amount of sub-carries, the power allocation is enhanced from order of 10-7 to 10-6.t is also concluded that capacity is also increase with the increasing bandwidth.

In future the performance can be assessed for the coded OFDM system used for Wi-Max. Also other power allocation methods can be used for comparison.

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