ADAPTIVE PSO- BASED POWER SCHEDULING ALGORITHM IN WIRELESS MESH NETWORK

Varalakshmi K R[*1], Dr. Vijayakumar C N[2] & Suresh Kumar H S[3]
[*1]Research Scholar, East West Institute of Technology, Bengaluru, India Assistant Professor, Presidency University, Bengaluru, India
[2]Professor, East West Institute of Technology, Bengaluru, India
[3]Assistant Professor, SJC Institute of Technology, Chickballapur, Karnataka, India

Abstract:
We introduce an adaptive PSO-based scheduling algorithm to maximize network throughput in wireless mesh networks through adaptive power and rate control. By configuring the modulation/coding scheme of wireless communication at the highest feasible power and rate levels, the algorithm allows transmitters of unscheduled links to calculate the maximum potential Signal-to-Interference and Noise Ratio level at which their links could operate if scheduled next. This process is repeated until the power margins of scheduled links cannot accommodate more additions to the scheduled time slot. Our proposed work focuses on an Adaptive PSO-based power scheduling algorithm for maintaining power margins in different wireless channels in OFDM and CDMA channels.

Keywords: PSO, OFDM, CDMA, Signal-to-Interference, Noise Ratio.
DOI: 10.24297/j.cims.2023.6.8

1. Introduction

The wireless mesh network technology holds immense potential to provide low-cost Internet broadband access, wireless local area network coverage, and network connectivity for both network operators and customers. Its rapid growth and development of wireless technologies have captured the attention of Internet Service Providers (ISPs). This promising technology can provide high bandwidth network coverage, keeping users connected to the internet at all times and in any location through wireless mesh routers. Moreover, mesh routers have bridge functionality, allowing them to connect with various existing wireless networks, such as cellular, wireless sensor, wireless-fidelity (Wi-Fi), worldwide interoperability for microwave access (WiMAX), and WiMedia networks. By utilizing multiple smaller routers, a mesh network can expand the coverage area within a home. The central node connects to the internet provider's modem, and other devices can link up to it. In a mesh network, each device is managed by a mobile application.

Wireless Mesh Networks have shown immense potential as a wireless technology with diverse applications, including broadband home networking, community and enterprise networking, public Internet access, and more.

Their stable structure and easy deployment make them a competitive candidate for delivering low-cost and high-performance solutions for last-mile broadband Internet access and disaster recovery in regions where deploying wire line networks is either too expensive or impossible.

1.1 Overview:

In satellite telecommunication, the term "downlink" pertains to the transmission link from a satellite to one or more ground stations or receivers, while "uplink" refers to the transmission link from a ground station to a satellite shown in Fig. 1.

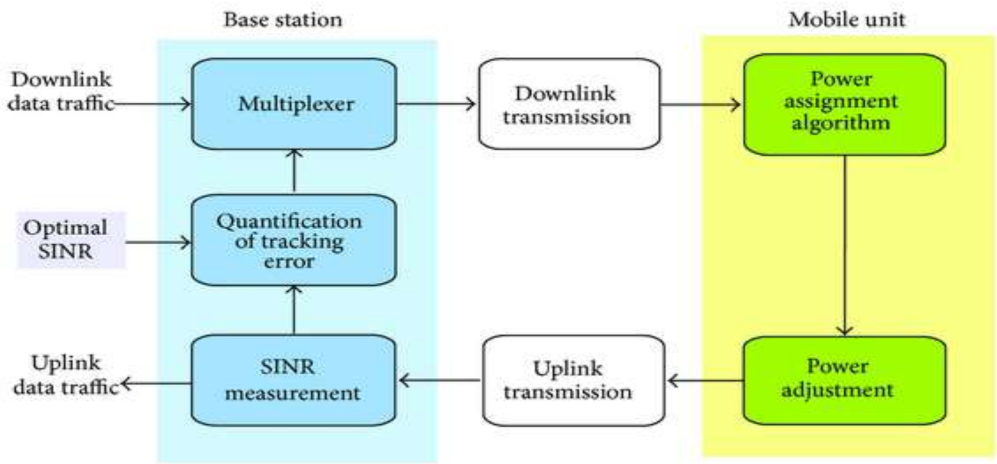


Fig. 1. Overview of Base Station and Mobile Unit

In the context of wireless communication, the term "uplink" denotes the transmission path used to send data from a device to the network side, whether from a mobile or fixed terminal. The uplink frequency is the frequency employed for all transmissions from the Mobile Subscriber Unit (MS) to the Base Station (BS), such as Node-B or eNB.

The uplink direction refers to the data transmission direction from the MS to the BS. Conversely, the term "downlink" signifies the transmission path used to send data from the Base Station to the Mobile Subscriber Unit (MS), and the downlink frequency refers to the frequency used for all transmissions from the BS to the MS. The downlink direction represents the direction of data transmission from the BS to the MS depicted in Fig. 2 and Fig. 3. To optimize bandwidth usage in wireless systems, TDD (Time Division Duplex) and FDD (Frequency Division Duplex) are employed in combination with FDMA (Frequency Division Multiple Access) and TDMA (Time Division Multiple Access).

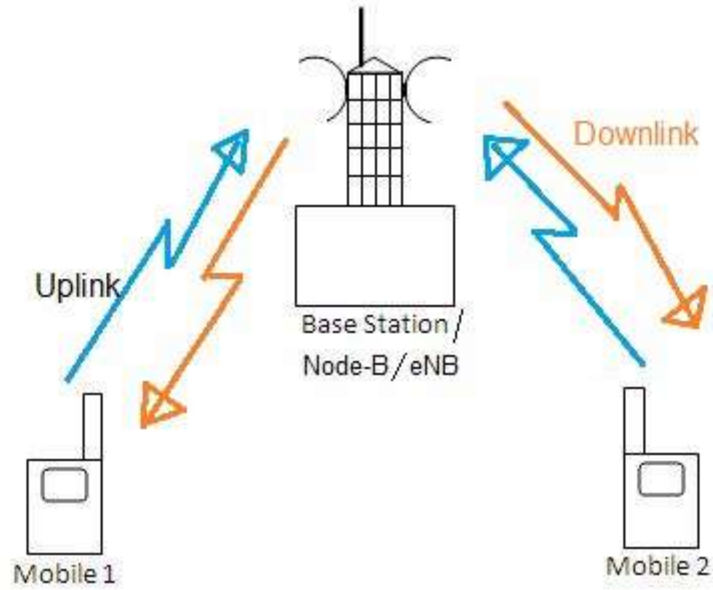


Fig. 2. Representation of Uplink and Downlink

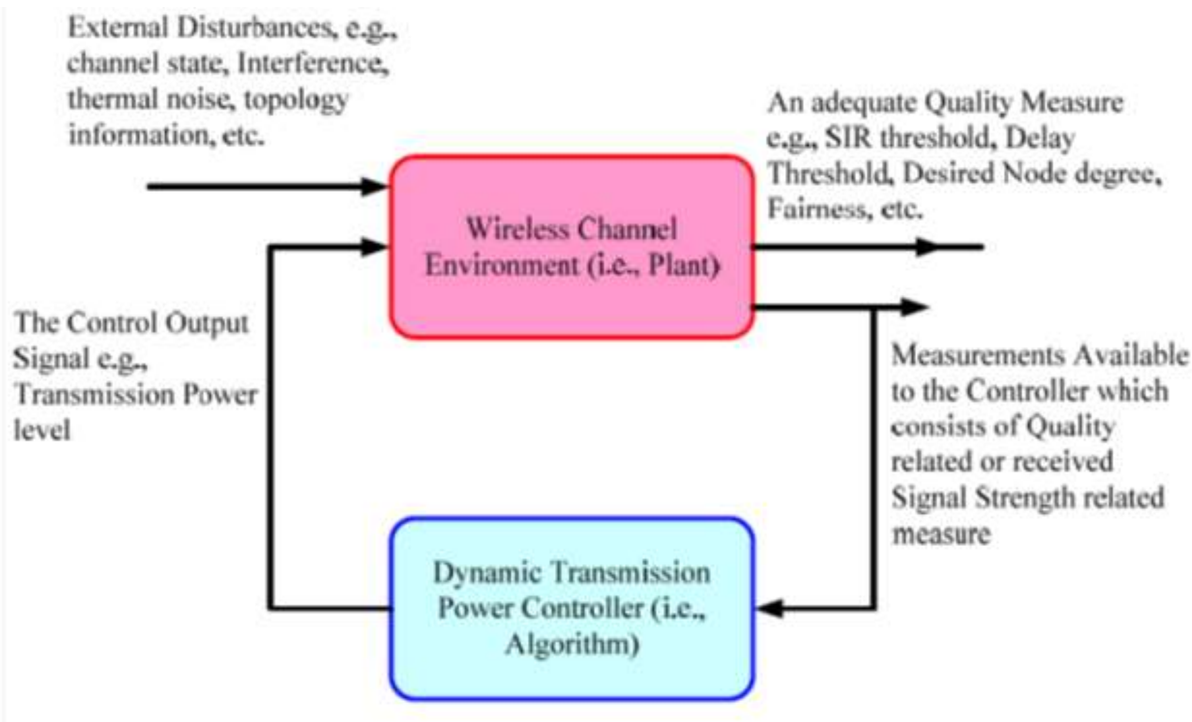


Fig. 3 Wireless Channel Environment

1.2 Adaptive Algorithm:

An initial response is generated by an adaptive filter, which is then compared to the desired signal, producing an error that is utilized as feedback for the filter are shown in Fig. 4.

The filter can improve its performance over time by adjusting the filter weight and system response based on this feedback. Ideally, the filter response should closely approximate the originally desired signal.

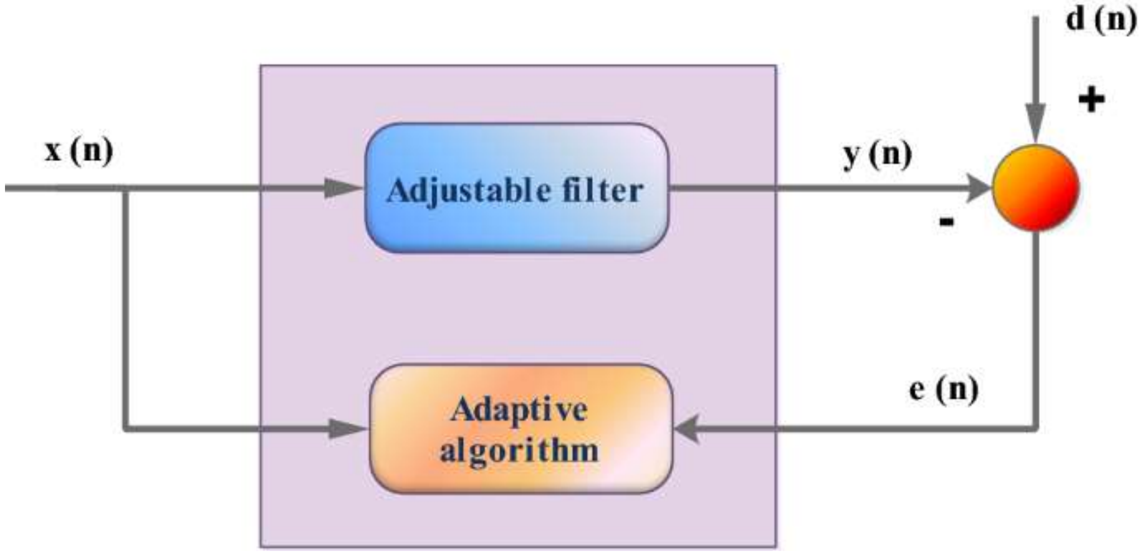


Fig. 4. Representation of Adaptive Algorithm

There are several approaches available for determining the optimal active noise cancellation algorithm for a given application, each with its own set of advantages and disadvantages depending on the context. As a result, different algorithms may produce different responses depending on the situation. An adaptive algorithm typically follows the process outlined below:
The active noise cancellation process usually consists of two stages:
Firstly, a filtering process computes a transversal filter output based on the tap inputs, and then compares this output to a desired response, generating an error estimate.
Secondly, an adaptive process automatically adjusts the tap weights based on the estimated error, allowing for improved noise cancellation.

1.3 Scheduling Algorithm:

DPRL algorithm:

If there is no scheduled link during a particular time slot, the transmitter of an unscheduled link will transmit a test signal at Pmax and calculate the maximum potential SINR value at its receiver. This process will continue until the SINR value of the unscheduled link is greater than or equal to $r1$.

i. After calculating its potential SINR value, an unscheduled node broadcasts it to its neighbors, and the node with the highest SINR value in the neighborhood is selected as the winner.
ii. The winner computes the maximum feasible transmit power and rate level, as well as the resulting power margin at its receiver.

iii. A control message is transmitted by the winner at the computed transmit power, announcing the power margin.

Artificial Bee Colony Algorithm:

The ABC algorithm mimics the foraging behavior of honey bees to solve optimization problems using swarm-based techniques. It consists of three groups of artificial bees, including employed bees, onlookers, and scouts. The employed bees represent the first half of the colony and are assigned to specific food sources that correspond to the solutions in the population. Meanwhile, the onlookers observe the behavior of the employed bees to choose a food source, and the scouts search randomly for new food sources. In this context, the position of a food source corresponds to the position of a solution, and the quality of nectar represents the fitness (quality) of the solution.

The ABC algorithm follows three distinct rules in each search cycle:

1. The employed bees assess the quality of nectar at their assigned food sources.
2. The onlooker bees choose a food source based on the information acquired from the employed bees and the quality of nectar.
3. The scout bees are deployed to explore new potential food sources.

Initially, the positions and nectar qualities of the food sources are selected randomly. Subsequently, the employed bees share information about the nectar sources with the other bees in the dance area of the hive. Using visual information, the employed bees return to their previously visited food source and select another food source in their neighborhood. In the final stage, the onlookers use the information shared by the employed bees to choose a food source, with the probability of selection is proportional to the nectar quality of the source. The employed bee with information on the source with the highest quality then recruits onlookers to that source and chooses another food source in the neighborhood based on visual information. In the event that a food source is abandoned by the onlookers, a scout bee generates a new random food source to replace it.

Particle swarm optimization (PSO) Algorithm:

Particle swarm optimization (PSO) is an optimization technique [5-9] that was developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by the social behavior of bird flocking or fish schooling. PSO is a stochastic population-based method that shares similarities with other evolutionary computation techniques such as Genetic Algorithms (GA), but it does not use evolution operators such as crossover and mutation. The method consists of a population of particles that move in a D-dimensional space, each particle representing a potential solution. Each particle keeps track of its position and the best solution it has found so far (pbest). The swarm also keeps track of the best solution found by any particle in the swarm (gbest). Additionally, each particle adjusts its position according to the best solution found by particles in its neighborhood (lbest). The particles in the swarm change their positions based on three principles: (1) maintaining their inertia, (2) moving towards their personal best position, and (3) moving towards the swarm's best position. The neighborhood size can be adjusted, leading to two types of PSO: whole PSO, where the entire swarm is considered as the neighborhood, and partial PSO, where only a subset of the swarm is considered. The positions and velocities of particles are updated at each iteration until the stopping criterion is met.

Genetic Algorithm:
Genetic algorithms utilize a heuristic search approach in artificial intelligence and computing to solve search problems by finding optimal solutions. The algorithm draws inspiration from natural selection and evolutionary biology, making it ideal for exploring large and complex datasets, and offering practical solutions for both constrained and unconstrained optimization problems.

Machine learning Algorithm:
Machine learning algorithms are a crucial component of artificial intelligence that use optimized and probabilistic techniques to enable computers to learn from historical data and recognize patterns that are difficult to discern from large, noisy, or complex datasets. These algorithms play a central role in converting a dataset into a model. Unlike traditional nonlinear regression that is restricted to fitting a specific mathematical function like a polynomial, machine learning algorithms can address more intricate problems.

Machine learning is commonly used to solve two types of problems: regression, which pertains to numeric data, and classification, which deals with non-numeric data.

2. Related Work

Ho*et al.*[1] this paper present evidence that incorporating power control into a network has multiple benefits, including reducing unfair bandwidth distribution and improving overall network capacity as compared to the minimum-transmit-power method. This is achieved by decreasing mutual interferences among links and avoiding hidden nodes using two adaptive power control algorithms that operate in a distributed manner. In practice, these power control algorithms can more than double the capacity of conventional non-power-controlled 802.11 networks while also eliminating hidden nodes.

Agarwal*et al.*[2] the aim of this paper is to suggest and assess a power control loop for ad-hoc wireless networks, which resembles the ones utilized in cellular CDMA networks, using a simulation infrastructure incorporating group mobility, group communication, and terrain blockage models. As ad-hoc wireless devices have limited energy scavenging capabilities and small batteries, reducing energy consumption is a significant area of research. Our findings indicate that the proposed power control loop reduces energy consumption per transmitted byte by 10-20% while increasing overall throughput by 15%.

Fowler *et al.* [3] the authors proposed a method that utilizes two factors, namely measuring the standard deviation of the noise-to-signal ratio and detecting packet loss due to congestion, to detect intrinsic channel conditions. The method was found to be effective in improving the packet-sending rate in a WMN. The effectiveness of the approach was demonstrated through packet-level simulations on a simulated wireless network testbed.

Saluja*et al.* [4] commodity 802.11 radios have facilitated the deployment and growth of Wireless Mesh Networks (WMNs) with their multi-hop architecture and cost-effectiveness for last-mile broadband Internet access. This paper proposes a mechanism called Aggregate Rate Control (ARC), which achieves fair rate allocation without requiring changes to individual mesh routers or incurring control traffic overhead. ARC limits the network capacity to the sum of fair rates for a set of flows, achieving approximately max-min fair rate allocation and weighted flow rate fairness. The comparative analysis indicates that ARC improves fairness indices compared to networks without rate limiting and performs similarly to distributed source rate limiting mechanisms that require software modifications on all mesh routers.

Kang*et al.* [5] heuristic algorithm prioritizes speed over optimality, accuracy, precision, or completeness in order to solve a problem more efficiently than traditional methods. These algorithms are frequently employed to address NP-complete problems, which are decision problems that do not have an established efficient approach for rapidly and accurately discovering a solution, even though solutions can be verified when provided. Heuristics can create a solution on their own or serve as a useful starting point, and they can be augmented with optimization algorithms.

Lorincz*et al.* [6] this paper examine energy-saving opportunities for wireless local area networks (WLANs) by utilizing integer linear programming (ILP) models. We assess the efficiency of these ILP models on WLANs of varying sizes. Because some ILP models demand a significant amount of computational time, we recommend a range of heuristic algorithms that utilize greedy methods and local search. While these heuristics may result in marginally higher energy consumption than their corresponding ILP models, they can minimize network energy consumption within a practical time frame. This highlights the significance of network management algorithms in creating energy-efficient network management systems in the future.

Shariff*et al.* [7] this paper proposes a new approach to address the issue of capacity limitations in wireless networks by considering the cognitive capacity of nodes. Specifically, we leverage directional antennas to propose a two-step multicast routing scheme for establishing multicast trees in wireless multi-hop networks. We suggest that nodes can make use of advanced energy-efficient transmission/reception techniques, such as maximal ratio combining of redundant codes, or data aggregation with rateless codes.

Khan*et al.* [8] the paper explores various localization algorithms in wireless sensor networks (WSNs), which can be classified as either range-based or range-free. Range-based algorithms necessitate expensive hardware to measure physical quantities for precise localization, while range-free algorithms use coarse-grained quantities like connectivity for limited precision. A hybrid range-based technique can be employed to utilize existing received signal strength indicator (RSSI) readings from sensor nodes to enhance coarse-grained localization methods. Furthermore, distributed localization algorithms are preferred in WSNs owing to their computational feasibility.

To address these considerations, we present a distributed localization algorithm called Range Lookup-MDS that falls under the hybrid range-based category. The algorithm generates sub-regions using only connectivity information before leveraging RSSI readings to improve localization accuracy.

Asgeirsson*et al.* [9] this paper investigates the problem of link scheduling in wireless networks with stochastic packet arrivals and presents a fully distributed algorithm that guarantees stability under the physical interference model known as SINR. The proposed algorithm achieves high efficiency, which is defined as the maximum traffic that can be handled without queue overflow, and it does not depend on the network size. Furthermore, the algorithm requires no knowledge of the network topology from individual nodes, making it fully distributed.

Jiang*et al.* [10] The task of designing distributed scheduling algorithms that attain maximal throughput in multi-hop wireless networks is complicated by interference constraints. Although traditional maximal-weight scheduling (MWS) is throughput-optimal, it is difficult to implement in distributed networks. Conversely, a distributed greedy protocol comparable to IEEE 802.11 does not guarantee maximal throughput. This paper proposes an adaptive carrier sense multiple access (CSMA) scheduling algorithm that can achieve maximal throughput in a distributed manner to address these challenges. The algorithm is suitable for a wide range of interference models and is both simple and distributed. Moreover, it operates asynchronously and is paired with congestion control to achieve optimal utility and fairness for competing flows. The algorithm's effectiveness is demonstrated through simulations, and it can be integrated with a variety of protocols in the transport and network layers. Finally, the paper examines implementation issues in the context of 802.11 networks.

Rubin*et al.* [11]his paper introduces a new distributed heuristic algorithm that maximizes network throughput in adaptive power and rate spatial-TDMA networks. The algorithm selects the link with the highest current receive-SINR in its 2-hop neighborhood at each step and schedules it for the underlying time slot, configuring its Modulation/Coding Scheme for transmission at the highest feasible power and rate. The winning link announces its power margin to its neighbors, and receivers of unscheduled links calculate the maximum potential

SINR for their link if scheduled next. The process is repeated until the transmitting links' power margin cannot support further schedule additions for the underlying time slot.

The proposed algorithm's simulation results demonstrate that it achieves performance equivalent to our recently developed centralized algorithms, with only 5-10% of the computational complexity.

Hedayati*et al.* [12] In this paper, we propose a distributed heuristic algorithm to maximize network throughput in adaptive power and rate spatial-TDMA wireless mesh networks. Our algorithm selects the link with the highest Signal-to-Interference and Noise Ratio in its neighborhood at each step and schedules it for the underlying time slot. The Modulation/Coding Scheme of the winning link is configured to transmit at the highest feasible power and rate levels. The winning link transmits the current receive power margin of its link's receiver to its neighbors, and unscheduled links calculate the maximum potential Signal-to-Interference and Noise Ratio level at which their links could operate if scheduled next. The process is repeated until the announced power margins of scheduled links do not allow further additions to the schedule at the underlying time slot. Our distributed algorithm achieves performance comparable to our recently developed centralized algorithm while inducing much lower computational complexity. We also demonstrate the robustness and energy efficiency of our algorithm by using it to schedule a new set of links on top of an existing schedule. The incremental scheduling scheme achieves a throughput rate within 15% of the throughput rate achieved when complete scheduling of all the links is carried out. Furthermore, our algorithm reduces the control traffic overhead rate and achieves more energy-efficient operation.

Lianget al. [13] this paper explores the potential of deep learning for wireless resource allocation in vehicular networks, discussing both its key motivations and roadblocks. Recent studies that apply the deep learning approach to wireless resource allocation are analyzed, including deep learning-assisted optimization. Additionally, the paper investigates the use of deep reinforcement learning to address resource allocation problems that are challenging to solve within traditional optimization frameworks. Finally, the paper identifies several research directions that require further investigation.

Ismail*et al.* [14] in this paper, we propose an approach that combines Orthogonal Frequency Division Multiplexing (OFDM) and Code Division Multiple Access (CDMA) to improve the throughput and reduce packet loss in noisy networks. The proposed approach, called Orthogonal CDMA, aims to overcome the limitations of traditional CDMA in noisy environments. By using the orthogonal approach, we demonstrate how the noise ratio can be reduced and the resulting throughput increased. Our results show the efficacy of this approach and its potential for improving wireless network performance in challenging environments.

3. Methodology

Adaptive power scheduling algorithms offer multiple methods to adjust power or service use, making them useful for managing limited resources in different conditions. Power amplifiers, on the other hand, are electronic amplifiers that increase the power of an input signal to a level sufficient for driving output devices such as speakers, headphones, and RF transmitters. Unlike voltage/current amplifiers, power amplifiers are designed to drive loads directly and are typically used as the final block in an amplifier chain are shown in Fig. 5 and Fig.6.

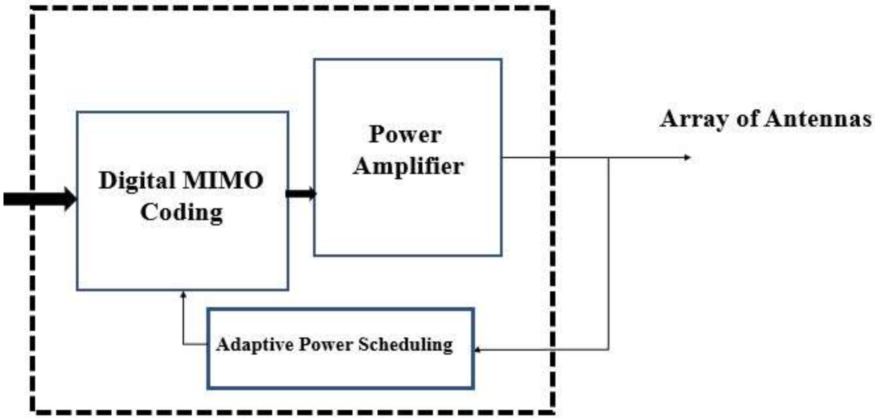


Fig. 5 Adaptive Power Scheduling Algorithm

OFDM is a Multicarrier Modulation Technique that divides the frequency-selective channel into multiple narrowband flat fading channels using overlapping signals. Instead of transmitting data sequentially on a single carrier at a high symbol rate, the block of symbols is encoded using FFT. To make the sub-channels orthogonal, the subcarriers are spaced at the increase of symbol time. Multipath fading can be eliminated by making the symbol period of the sub-channel longer than the multipath delay spread. Additionally, signals with high noise and interference are deactivated, reducing the effects of fading and interference.

OFDM modulation technique utilizes complex signal processing approaches such as Fast Fourier Transforms (FFTs) and inverse FFTs in the transmitter and receiver sections of the radio shown in Fig. 7.

One advantage of OFDM is its ability to combat the adverse effects of multipath propagation, thereby minimizing inter-symbol interference in a channel. Furthermore, OFDM is spectrally efficient due to the overlap and contiguity of the channels.

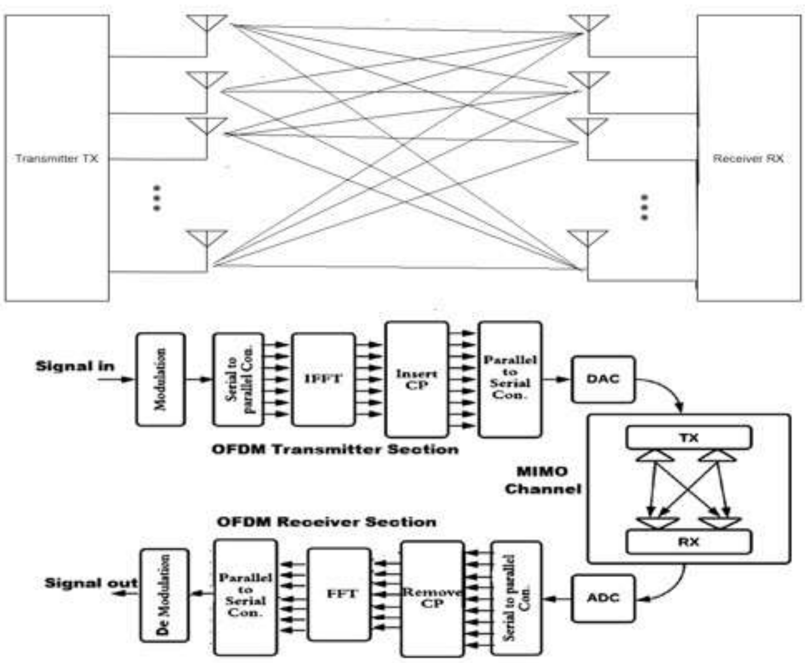


Fig. 6 MIMO Communication

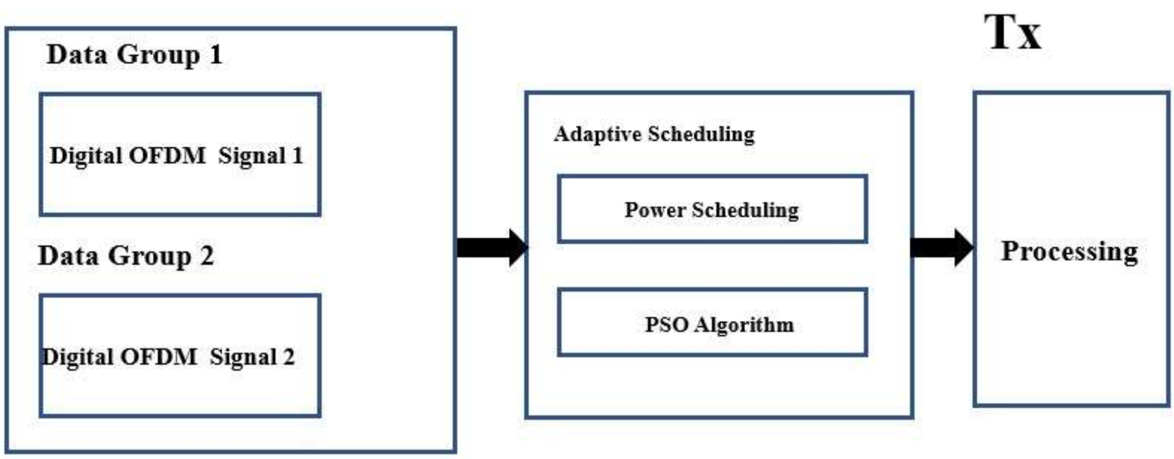


Fig. 7 - OFDM Input Signal to Adaptive PSO-Based Scheduling Algorithm

Code Division Multiplexing (CDM) is a networking technique that combines multiple data signals for simultaneous transmission over a shared frequency band. When this technology is used to enable multiple users to share a single communication channel, it is called Code Division Multiple Access (CDMA) are in Fig. 8.

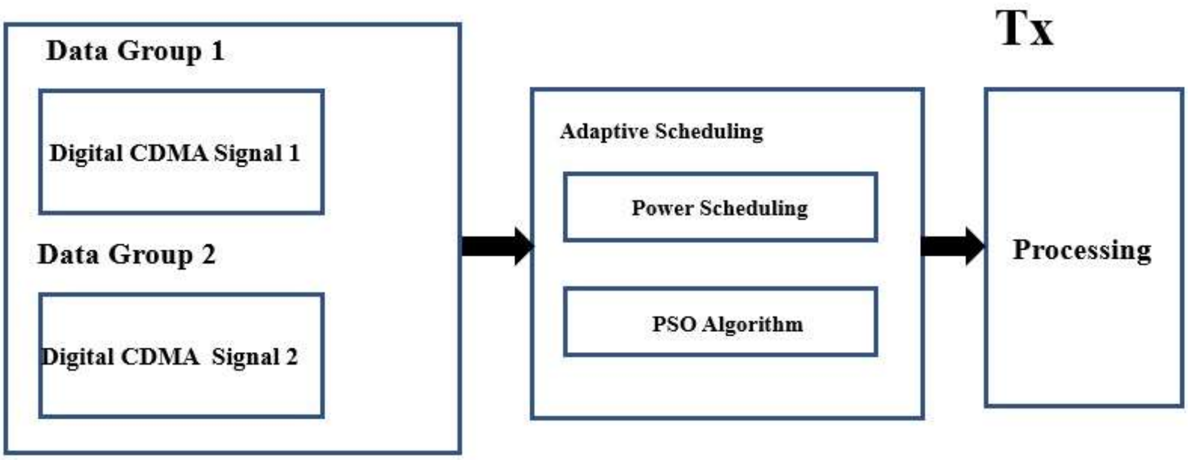
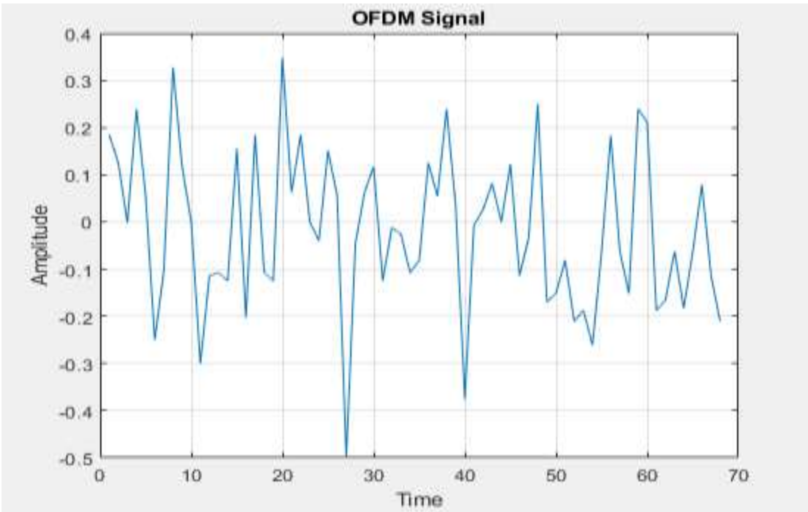
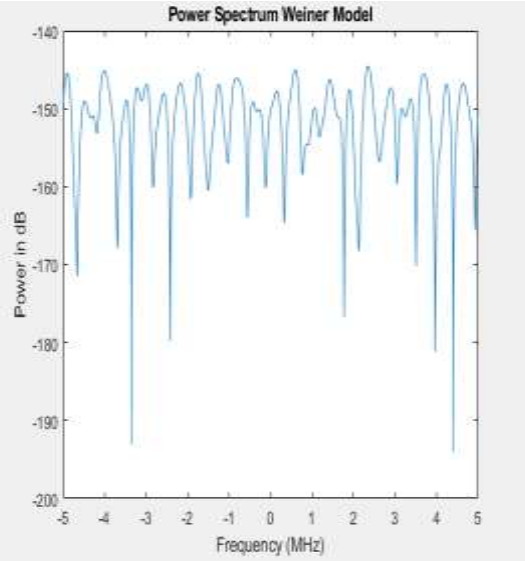


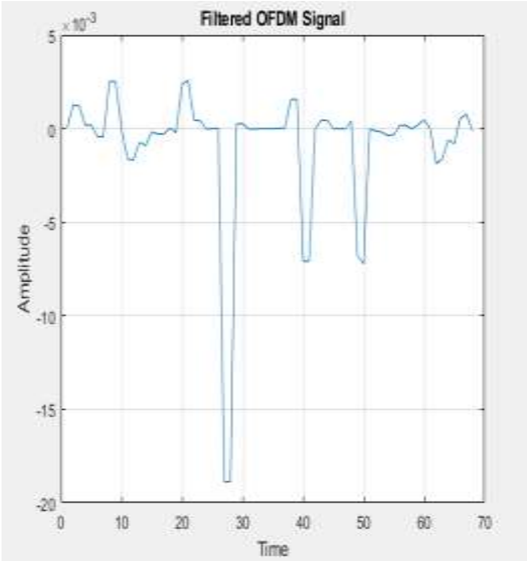
Fig. 8 CDMA Input Signal to Adaptive PSO-Based Scheduling Algorithm

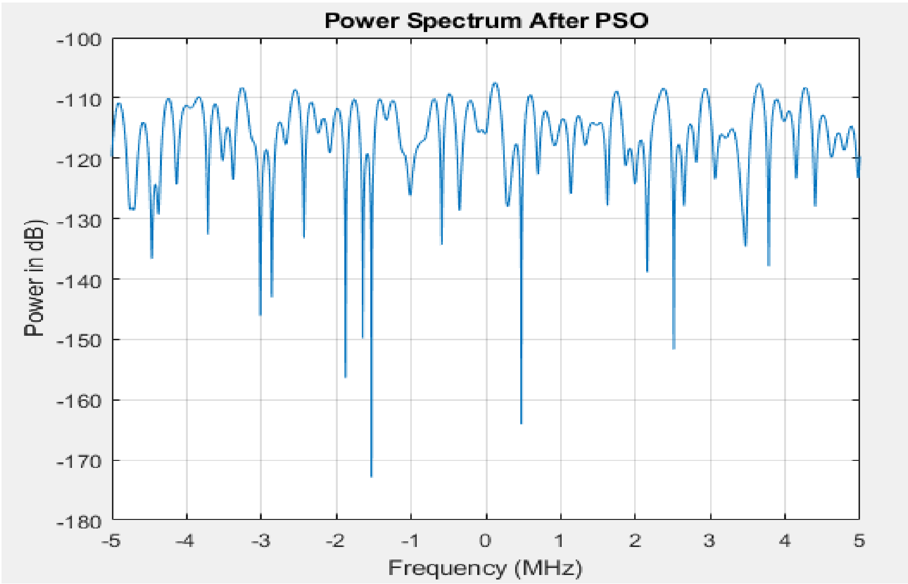
4. Results

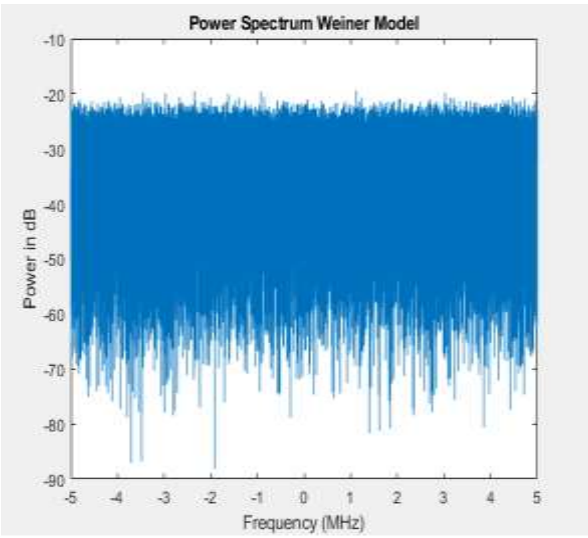
To achieve optimal performance of the adaptive power scheduling algorithm, inputs from both OFM and CDMA channels were utilized. The adaptive algorithm approach involved filtering the signals and managing power levels using a scheduling algorithm based on Particle Swarm Optimization (PSO). The results of this approach are displayed in the figures below.

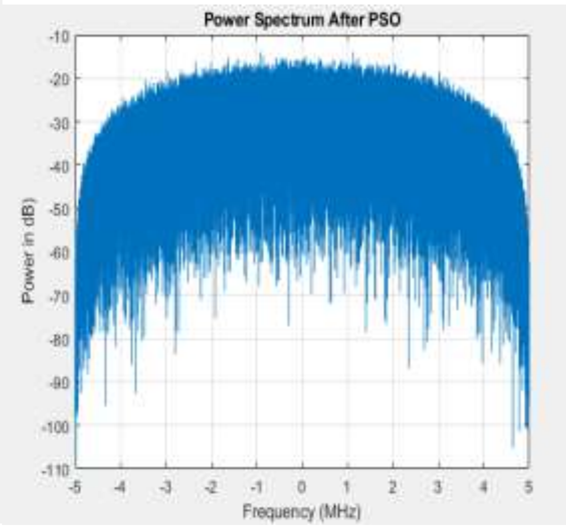



Power Spectrum Weiner Model
Power in dB
Frequency (MHz)


Filtered OFDM Signal
Amplitude
Time


Power Spectrum After PSO
Power in dB)
Frequency (MHz)


Power Spectrum Weiner Model
Power in dB
Frequency (MHz)


Power Spectrum After PSO
Power in dB)
Frequency (MHz)

5. Conclusion

OFDM is a Multicarrier Modulation Technique that can be utilized in MIMO channels to enable transmission over multiple narrowband flat fading channels. Instead of sending data sequentially on a single carrier at a high symbol rate, the block of symbols is encoded using FFT. Additionally, code division multiplexing can be used to allow multiple users to share a single communication channel, which is known as code division multiple access (CDMA).The adaptive algorithm approach involves filtering the signals and managing power levels using a scheduling algorithm based on Particle Swarm Optimization (PSO). Through simulations, it has been observed that the power spectrum is effectively maintained by the adaptive scheduling algorithm.

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