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# Enhancing OFDMA for Next-Generation Wireless Communications

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**Abstract:** Orthogonal Frequency-Division Multiple Access (OFDMA) is a cornerstone technology of modern wireless communication networks, known for its ability to increase spectral efficiency and network performance This review explores several techniques aimed at increasing OFDMA performance of resources among many important ones: reduce latency, optimize spectrum utilization, increase system flexibility, advance Analysis and support of various service needs in the evolving landscape of -generation wireless communications include advanced resource optimization techniques, focusing on efficient allocation of wireless resources to maximize data flow and ensure optimal access for all users Advanced modulation of products. Scheduled and real-time subcarrier allocation techniques are important in this regard, considering system-wide architectural integration to improve overall network efficiency and responsiveness in addition to enabling dynamic adaptation to different network environments and their user requirements. More emphasis is placed on the use of low-latency transmission protocols. Standards such as IEEE 802.11e for WiFi and 3GPP Release 16 for cellular networks are tested for faster packet delivery and reduced protocol overhead, thereby reducing latency in real-time applications and improving user experience Short complements to these protocols -The timeliness of data transmission is further enhanced by innovative techniques such as slot scheduling and pre-scheduling The study also investigates ways to streamline OFDMA processes, ensuring robust interruption and environmental conditions ahead applies to systems that can dynamically adjust transmission parameters to maintain optimal performance. Overall, this study provides a comprehensive overview of the potential developments in OFDMA technology, offering a strategy to enhance efficiency, reliability, and flexibility in wireless networks. By addressing the increasing demand for high-performance, low-density networks, the findings of this study will significantly contribute to the development of OFDMA systems, enabling them to support the diverse requirements of modern low-density networks.

**Keywords:** Enhance OFDMA; Next-Generation; Spectral efficiency; Latency; Robustness

## 1. INTRODUCTION

The continuing need for faster data rates, reduced delays, and increased reliability have determined the evolution of radio technology. OFDMA has become one of the main technologies that explain the success of modern wireless networks in addressing growing demand [1]. Because of OFDMA's unique ability to effectively utilize the spectral resources by allocating available bandwidth into numerous vertical sub-hubs, this system turned out to be a basis in 4th Generation LTE, as well as Wi-Fi and other wireless standards [2]. As they increase, the demand for more OFDM improvements brings the completion of mobile devices, the introduction of IOT applications, and the utilization of new usage such as motor vehicles and smart cities. The challenges that radio systems must encounter as we move towards the fifth generation and beyond become even more severe [3]. As the existing basic access technique, one must be inventive to help prevent delays, increase the rate of data, and support different types of applications alongside the essential increase in reliability [4].

The main objective of this study is to investigate options for enhancing OFDMA to meet the evolving needs of next-generation radio communication Our study aims to drive system flexibility increase, reduce latency, improve spectrum utilization, and provide a wider spectrum of services within the OFDMA framework By conducting this research, incorporating various methods, We aim to develop a strategy for advanced telecommunications systems exhibiting high performance, flexibility, and flexibility. These systems are designed to better meet the multifaceted requirements of future applications. A key feature of our approach is a new development that promises to enhance the technical capabilities and reliability of OFDMA, ensuring that it is ready to support the increasingly complex and diverse needs of modern networks.

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The remainder of the paper is arranged as follows; in section 2, the methods used to enhance spectrum efficiency in the OFDMA systems, including complex conversion algorithms and flexible sub-tank distribution procedures, are addressed. In section 3, emphasis is placed on reducing delays through the use of techniques such as reliable and highly delayed communication (URLLC) and grant-free access. In section 4, strategies to improve resilience, such as hybrid access plans and approaches to reduce overlap, are discussed. In section 5, the methods used to accommodate different services, such as multi-service support and resource allocation that take into account quality of service, are discussed (QoS). Finally, Section 6 presents the end of the article by emphasizing the importance of increasing the OFDMA trend in wireless communication.

In general, expanding the capabilities of radio systems to suit the diverse and changing demands of society is a more important objective of the improvement project OFDMA than simply making small and gradual gains. By adopting innovation and expanding the capacity of OFDMA, we may open up new horizons and set the stage for a period when smooth, reliable, and high-speed communication is expected.

## 2. IMPROVING SPECTRAL EFFICIENCY

Spectral efficiency, characterized by the amount of data conveyed per unit bandwidth, is an essential measure to be considered for improving OFDMA systems. Increasing spectral efficiency increases the data rate transmitted from the source system, and fully utilizes the available spectrum resources. In this respect, this section examines some of the measures that could be undertaken to improve the spectral efficiency of OFDMA systems, such as novel modulation designs and intelligent subcarrier deployment methodologies [5].

### *A. Advanced Modulation Schemes*

The first and most fundamental method to increase spectral efficiency is to utilize higher-order modulation schemes, such as Quadrature Amplitude Modulation (QAM). High-order QAM encodes more than one bit per symbol, allowing the data rate per subcarrier to be increased [6]. However, the use of higher modulation makes the receiver more vulnerable. Sensitivity to noise and cochannel interference. therefore, Turbo code and other complex debugging techniques and Low-Density Parity-Check (LDPC) codes must be used to protect against these effects and remain reliable of communication [7].

### *B. Adaptive Subcarrier Allocation*

Dynamic subcarrier allocation based on the channel conditions is a key method for optimizing spectral efficiency. Since the number of assigned subcarriers can directly influence the user throughput, adaptive subcarrier allocation allocates more subcarriers to users with better channel conditions. Algorithms such as the water-filling algorithm and proportional fairness scheduling help to ensure an adequate allocation of subcarriers and fair resource distribution [2], [8]. Such algorithms can be adjusted based on the channel feedback, which makes resource allocation more efficient and enhances spectral efficiency. Thus, advanced modulation schemes and adaptation of resource allocation present a multi-level approach to increasing spectral efficiency in OFDMA systems.

## 3. REDUCING LATENCY

Latency is defined as the time difference, it takes for the sent signal to be received by the receiver in most wireless communication systems [9]. Applications requiring continual interaction, such as internet games, video calling, and motor cars, ought to have the shortest latency possible. The following are some of the methodologies to minimize the latency level in OFDMA systems: Efficient resource allocation. In OFDMA systems, efficient resource allocation is critical to reducing latency. Using dynamic sub-carrier and transmission power allocation depending on the user's needs and channel conditions may help reduce waiting for downtime and enhance the system's overall performance. Adaptive algorithms, such as dynamic subcarrier allocation and power control, can be employed to effectively allocate resources in real-time[10].

### *A. Reduced Guard Intervals*

One solution to enhance spectral efficiency and reduce latency are shorter guard in OFDMA systems. A guard interval (also known as a guard band or guard time) is the length of time in which the receivers disable their RF (radio frequency) sections to avoid possible short-time interference at the start or the middle of packet. Multipath propagation: causes because signals transmitted propagate along multiple paths from transmitter to receiver, where signal components not only experience different arrival time delay but also different intensity. First is this concept of a guard interval [11], [12], the idea that we buffer these symbols not to let the Delays interfere with new symbols.But the use of too many guard intervals can lead to longer transmission times at the expense of an overall delay in the system. Latency, the delay between the issuing of a command and when the data transfer actually begins, is an essential metric in network systems, especially in real-time apps (such as video conferencing, online gaming, and vehicle-to-everything communication) where high delays can detrimentally affect performance and user experience.

The study [13] discusses a few strategies that have been suggested to tackle this problem to minimise latency without sacrificing the reliability of the communication link. It includes one strategy referred to as adaptive defensive language systems. These schemes change the size of the guard intervals based on the real-time channel conditions. In some embodiments, the system adjusts the guard interval length by evaluating the present multipath environment and interference levels, lowering the guard interval length when channel circumstances are good and solely raising the guard interval length when required to retain signal integrity.

Such channel-aware techniques are an alternative means to decrease the guard interval duration. These methods, utilize the knowledge of channel state information (CSI) for making decisions regarding selecting the perfect guard interval length. Failures: When using the channel state we can decrease the duration of the guards and, therefore, minimize unnecessary delays. contributing to an overall increase of spectral efficiency. But the downside is that it involves some complex signal processing and requires the ability to monitor the channel in real time. Nevertheless, the reduced latency and increased spectral efficiency gain advantages accrue only from the former two and so are relevant even for the design of modern OFDMA systems. This type of innovation is important for the development of wireless communication technologies and to support the growing need for high-speed, reliable data transmission in many applications [14].

### B. Efficient Handover Mechanisms

As users move between different cell boundaries, it is important to have efficient handover mechanisms for mobile communication networks in order to provide seamless connectivity and reduce latency. =¿=¿=¿ Handover or handoff is a process which is used to transfer the active call or data session from one base station (BS) or cell to another. Handover can be divided as hard handover (break-before-make) and soft handover (make-before-break) Lazy approach (hard handover being simpler but likely causing connectivity drop even if it only takes a few dozen milliseconds) compared to active approach (support by CDMA allowing multiple base stations to be connected during change over such as with soft handover, but the disadvantage of needing to communicate with multiple base stations at once) [15].

There are several factors that need to be taken into consideration in order to achieve efficient handover. For real-time applications like voice over IP and video conferencing, the one key requirement is minimizing latency. By predictively changing, the target cell even before the user decides to make the handover, the network minimizes latency. An important part of these decisions is made by handover decision algorithms that decide at which time, to which cell the handover should be performed considering some metrics such as signal strength, quality of service (QoS), user speed, and traffic situation. Machine learning is also used in many advanced algorithms to improve decision accuracy [16].

Load balancing is another key factor, which ensures that users are evenly distributed throughout the network to maintain QoS and avoid overloading any one base station. A dynamic resource allocation strategy is also needed to ensure that the target cell has sufficient resources (e.g., bandwidth, capacity) before delivery begins to prevent service disruption.

High-speed movements, such as in cars or trains, pose major challenges to handover methods. Solutions such as expedited vehicle delivery systems and efficient delivery systems effectively address these challenges. In addition, interference management is important in densely populated urban areas, where techniques such as coordinated multipoint and interference cancellation are used to reduce interference from neighboring cells.

In heterogeneous networks, which contain a mixture of macrocells, microcells, and small cells, the handover is complex. Advanced techniques developed for heterogeneous networks ensure smooth transitions between cell types and network layers. These advanced techniques are essential for seamless communication and reducing latency, thereby improving the user experience on today's mobile networks [17].

### C. Prioritized Traffic Management

Priority traffic management is essential in real-time networking to ensure the timely transmission of critical information, such as voice and video streaming. By prioritizing such vehicles, networks can significantly reduce downtime, improving user experience. The Quality of Service (QoS) policy is central to this approach, as it provides mechanisms for allocating, managing, and prioritizing traffic based on their needs, such as voice and video, and getting the required bandwidth and low-latency path, which prevents delays and interruptions This is important in applications such as VoIP calls, video conferencing, and live streaming, where even a slight delay can degrade communication quality and user satisfaction [18]. In [19] study refers to implementing prioritized traffic control, networks use various QoS mechanisms, such as traffic size, which control data flows to ensure that priority traffic is assigned first Traffic policing mechanisms are also implemented to monitor and enforce bandwidth limits and ensure that critical vehicles allocate subordinate resources to essential applications. In addition to disinterest, advanced scheduling algorithms, such as Weighted Fair Queuing ( WFQ) and Priority Queuing (PQ) are used to control packet transmission orders based on their priority level.

Another key feature of prioritized traffic management is the use of discrete and integrated service models. Discrete services mark packets to indicate their priority level so that router switches can be controlled accordingly. This model provides flexibility and scalability, making it suitable for large networks. Through the reservation of essential resources along the data stream, integrated services ensure that individual sessions receive a defined quality of service and that vital applications operate consistently [20]. One significant issue that may hinder real-time communication is network congestion. By implementing QoS policies, the network can minimize the effects of accidents, ensuring that high-priority traffic maintains its performance even during peak usage devices such as Random Early Detection (RED) and Explicit Congestion Notification (ECN) and accident avoidance and management contribute to network stability and performance [21]. In addition, modern networks often use multi-protocol label switching (MPLS) to improve traffic management. MPLS allows pre-defined vehicle routes and ensures that high-priority data travels the most efficiently, further reducing latency and increasing reliability [22].

*D. Low-Latency Transmission Protocols*

The researcher [23] indicates that Low-latency transmission protocols play an important role in OFDMA systems by increasing packet delivery time and reducing protocol overhead The IEEE 802.11e standard in WiFi networks provides quality of service (QoS). Development aimed at supporting applications with stringent latency requirements. This standard provides mechanisms such as Enhanced Distributed Channel Access (EDCA) and Hybrid Synchronization Function Controlled Channel Access (HCCA), which prioritize traffic based on their QoS requirements, ensuring that high-priority traffic, e.g., voice and video, will share less. In cellular networks, 3GPP Release 16 brings many improvements optimized for seamless communication. This release focuses on ultra-reliable low-latency communication (URLLC), which is important for applications such as autonomous driving, remote surgery, industrial automation, etc. Shorter slot scheduling in URLLC, earlier scheduling, and faster cost mechanisms, such as for retransmission protocols. Scheduling shorter timeouts allows data to be transmitted in shorter periods, greatly reducing the waiting time for transmission. Pre-programmed scheduling allows high-priority traffic to interrupt high-priority data flows, ensuring that critical data packets are processed immediately [24].

Moreover, the latency of an OFDMA system can be further optimized by varying the transmission parameters. Parameters such as Transmission Time Interval (TTI) and frame structure can be adjusted to balance the trade-off between throughput and latency. For example, shorter TTIs reduce the time the data spends in the queue before being sent, thereby reducing latency. However, this must be handled with caution to avoid overload that can negate the benefits of low latency [25].

Protocol overhead can be reduced by efficient header compression techniques and simplified handoff scheduling. Protocols such as Robust Header Compression (RoHC) reduce the size of IP, UDP, and RTP headers, thus reducing the amount of data that needs to be processed and transmitted A simple handshake ensures that needs little modification to create and maintain connections, and reduces the time spent on protocol connections[26]. By using these low-latency transmission protocols and modifying the relevant parameters, the latency of the OFDMA system can be significantly reduced, thus meeting the stringent requirements of modern real-time in the application of the solution[27].

To reduce latency in OFDMA structures, a complete strategy is required, including green resource allocation, rapid channel estimation, efficient handover mechanisms, priority visitor management, and low-latency communication protocols. OFDMA systems may meet high latency requirements for real-time applications while maintaining fast wireless communication.

## 4. ENHANCING ROBUSTNESS

Improving the resilience of OFDMA systems is critical for maintaining reliable communication under challenging channel circumstances. Robustness refers to the machine's capacity to sustain efficient verbal communication in the face of various limitations such as frequency-selective fading, co-channel interference, and noise. In [28], obtaining resilience necessitates a complete approach that includes advanced signal processing methods, channel coding systems, interference mitigation algorithms, diversity tactics, and error-tolerant transmission protocols. Advanced signal processing algorithms play an important role in increasing resilience by overcoming the issues given by multipath propagation and frequency-selective fading. Techniques such as 0-forcing equalization and Minimum Mean Squared Error (MMSE) equalization aid in equalizing distorted signals, while diversity tactics such as area and frequency range employ the greatest number of transmission routes or antennas to prevent fading consequences [29]. Channel coding systems with additional Forward Error Correction (FEC) rules and Hybrid Automatic Repeat Request (HARQ) mechanisms, provide additional protection against errors caused by channel degradation. FEC codes improve communication connection dependability by adding redundant information to sent facts, allowing the receiver to detect and correct mistakes [30].

Interference mitigation algorithms are crucial for reducing the impact of co-channel interference and enhancing the device's capacity to differentiate between desired warnings and undesirable interference. Techniques such as interference cancelation and interference alignment reduce interference consequences, but cognitive radio solutions such as spectrum sensing and dynamic spectrum admission enable adaptive spectrum usage, hence lowering interference. Diversity approaches, which include geographical and frequency ranges, increase robustness by utilizing several transmission channels or frequencies to improve signal dependability. Spatial range, achieved through the use of several antennas, provides for the mitigation of fading effects, and frequency diversity, achieved by sending data over more than one subcarrier, adds robustness against frequency-selective fading. Furthermore, error-resilient transmission protocols enhance verbal exchange protocols for green retransmission of lost or broken facts packets, therefore boosting device dependability in noisy or crowded settings. By employing those processes in OFDMA structures, operators might also ensure dependable communique and premiere ordinary overall performance even under hard-working situations, thereby enhancing the machine's average resilience.

## 5. OFDM MODLE

An effective OFDMA to achieve a high data rate and robust performance depends on accurate data rate and SINR estimation. By optimizing subcarrier allocation, modulation schemes, and interference management strategies, OFDMA systems can meet the increasing demands of modern wireless communications such as video streaming, online gaming, and real-time multimedia communications Such capabilities shape the future of wireless networks toward increased performance and reliability emphasize the important role OFDMA plays.

In OFDMA, the calculation of data rate and signal-to-interference-plus-noise ratio (SINR) plays an important role in determining the system performance and capacity, we can show that [5]:

*A. Data Rate Calculation*

The data rate achieved by user $m$ on subcarrier $n$ can be calculated using the Shannon capacity formula [31]:

$$R_{mn} = \log_2\left(1 + \frac{P_{mn}|h_{mn}|^2}{N_0 + \sum_{k\neq m} P_{kn}|h_{kn}|^2}\right) \quad (1)$$

where:

$R_{mn}$ refers to data rate achieved by user $m$ on subcarrier $n$ (bits per second), $P_{mn}$ refers to power allocated to user $m$ on subcarrier $n$ (Watts), also, $|h_{mn}|^2$ indicates channel gain between user $m$ and subcarrier $n$, $N_0$ indicates noise power spectral density (Watts per Hertz), and $\sum_{k\neq m} P_{kn}|h_{kn}|^2$ refers to interference from other users and noise on the subcarrier.

This formula assumes a signal-to-noise ratio (SNR) on a subcarrier, which determines the effect of power distribution, channel conditions, and bandwidth on the achievable data rate. Power and sub-carriers are efficiently allocated based on channel circumstances and depending on the user needs can increase all data significantly rate in OFDMA systems. These criteria are usually implemented by the higher ecological adaptation, which is the most desirable and the most useful of the network to enhance and can this approach not only optimizes the available bandwidth but also improves the quality of service (QoS) experienced by users, making it an integral part of modern OFDMA-based networks.

*B. SINR Calculation*

The Signal-to-Interference-plus-Noise Ratio (SINR) is important for determining the available data rate and the overall performance of the network since higher SINR values indicate better signal quality and possible higher data rates With computing and quality, the network operator's spectral efficiency to improve quality, improve quality of service (QoS), and ensure strong and reliable connections for users This strategy is especially important in complex networks with interference is a great challenge. The management of SINR is facilitated by advanced technologies, including beamforming, interference synchronization, and dynamic spectrum access, all of which enhance the overall efficacy and efficiency of OFDMA systems.

The SINR for user $m$ on subcarrier $n$ can be calculated as [32]:

$$\mathrm{SINR}_{mn} = \frac{P_{mn}|h_{mn}|^2}{N_0 + \sum_{k\neq m} P_{kn}|h_{kn}|^2} \quad (2)$$

where:

$\mathrm{SINR}_{mn}$ indicates signal to interference plus Noise Ratio for user $m$ on subcarrier $n$, and $P_{mn}$ refers to power allocated to user $m$ on subcarrier $n$, and $|h_{mn}|^2$ is channel gain between user $m$ and subcarrier $n$, and $\sum_{k\neq m} P_{kn}|h_{kn}|^2$ refers to interference from other users and noise on the subcarrier.

## 6. PRACTICAL SPECTRAL EFFICIENCY CALCULATION

In the available spectrum employed for data transmission, an OFDMA system's spectral efficiency (SE) is a crucial measure of the system's overall efficiency. Bits per Hertz per second (bps/Hz) is a common unit of measurement for spectral efficiency, which is the throughput of all data acquired per unit bandwidth [33], [34]. This includes how well the system can transmit data in a given bandwidth, factoring in modulation schemes, coding methods, and inherent characteristics of the wireless channel. High spectral efficiency means the system can transmit adequate amounts of data with limited frequency resources. Techniques such as adaptive modulation and coding, multi-user variation and interference mitigation strategies are often used to enhance SE to achieve higher spectral efficiency, including power allocation, subcarrier assignment, and advanced signal processing techniques for the estimation have problems such as interference, noise, and optimal non-channel conditions. Additionally, system-wide architectural integration and real-time power management of resources play an important role in maintaining high spectral efficiency. The interconnectedness of the networks provides the need to improve the community and relief to the neighbors to stay connected to keep the struggling system was necessary for.

This represents the total throughput achieved per Unit bandwidth is usually expressed in bits per hertz (bps/Hz) per second. The realistic spectral efficiency can be calculated as follows:

$$SE = \frac{\text{Total throughput}}{\text{Total bandwidth}} \quad (3)$$

Where:

Total throughput is the sum of data rates achieved by all users over all subcarriers, and Total bandwidth is the total bandwidth available in the system.

To calculate the total throughput, we collect the data rates achieved by all users ($R_m$) over all subcarriers ($N$)[35]:

$$\text{Total throughput} = \sum_{m=1}^{M} \sum_{n=1}^{N} R_{mn} \quad (4)$$

Similarly, to calculate the total bandwidth, we collect the bandwidth of all subcarriers ($B_n$) [36]:

$$\text{Total bandwidth} = \sum_{n=1}^{N} B_n \quad (5)$$

Useful spectral efficiency provides valuable insight into the efficiency with which OFDMA systems use available spectral resources. Particularly useful in bandwidth-limited scenarios or congested internal environments Spectral efficiency provides valuable insight into the performance of the OFDMA systems using spectrum resources. Various influencing factors, such as the number of applications, subcarrier allocation strategies, modulation and coding schemes, channel conditions, interference levels, and spectral efficiency and optimization, enhance the overall capability and performance of OFDMA systems, especially in bandwidth-limited scenarios or cramped indoor environments.

Figure 1 illustrates graphically the relationship between the spectral efficiency and the total bandwidth of the network. Spectral efficiency refers to the amount of information transmitted over a given bandwidth or frequency range, while total bandwidth refers to all frequencies available for communication In this case statistics can show how spectral efficiency varies with different total bandwidth allocations As the available frequency spectrum is more efficient it is used to transmit data. The graph can display spectral efficiency as a function of total bandwidth increase or decrease, allowing managers to monitor how changes in bandwidth allocation affect data transmission efficiency If we relate spectral efficiency to total bandwidth, then these issues provide trade-offs between computed bandwidth allocation and data transmission efficiency and optimize value system production and delivery to achieve the intended harmony between output and performance.

Figure 2 presents a graphical representation of the spectral efficiency of a communication system before any enhancements are applied to OFDMA technique. Spectral efficiency is a crucial performance metric in communication systems, indicating how efficiently the available frequency spectrum is utilized to transmit data. In this context, "Before Enhancing OFDMA" suggests that the depicted spectral efficiency values represent the system's performance prior to any improvements or optimizations made to the OFDMA technology. The figure may depict spectral efficiency as a function of various parameters, such as signal-to-noise ratio, modulation scheme, or channel conditions. By visualizing spectral efficiency before enhancement, the figure provides valuable insights into the baseline performance of the communication system and highlights areas where

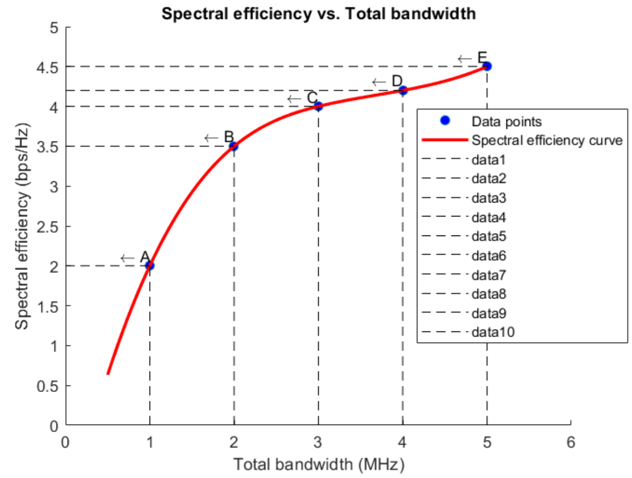


Figure 1. Spectral efficiency vs. total bandwidth

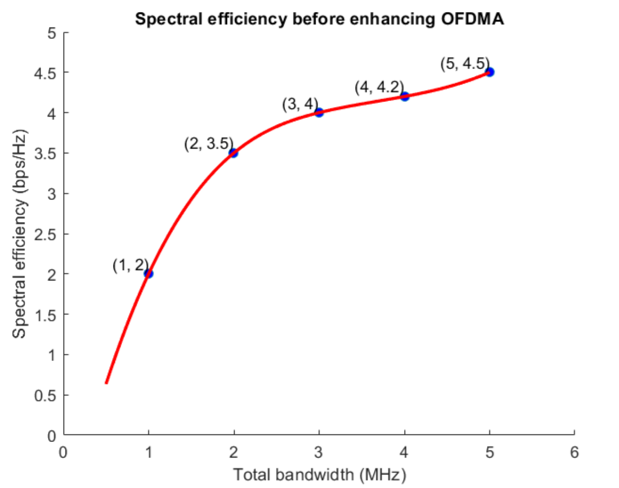


Figure 2. Spectral efficiency before enhancing OFDMA

OFDMA improvements could potentially enhance spectral efficiency. This information is essential for evaluating the effectiveness of OFDMA enhancements in optimizing the system's spectral efficiency and overall performance.

Figure 3 presents an image or data showing the spectral efficiency of the communication system by improving the OFDMA technology. Spectral efficiency refers to how well information is transmitted over a given bandwidth or frequency range. In this case, OFDMA improvements indicate that the spectral efficiency values plotted represent system performance following improvements or optimizations used primarily in OFDMA technology The figure shows an increase in spectral efficiency compared to baseline or before the enhanced OFDMA scenario. These improvements indicate that the enhanced OFDMA technology has significantly improved the efficiency of data transmission in the system. The figure shows the spectral efficiency as a function of various parameters, such as signal-to-noise ratio,

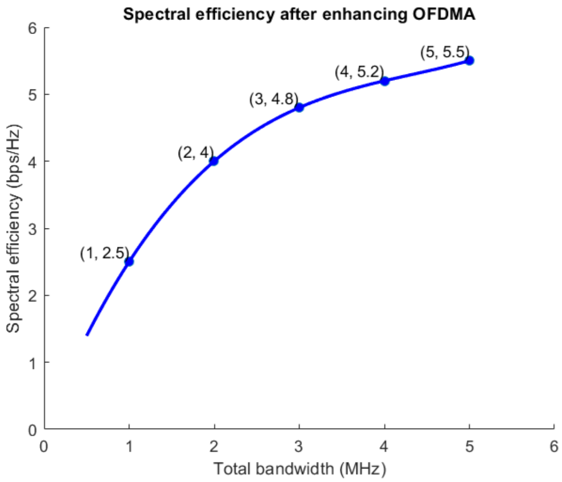


Figure 3. Spectral efficiency after enhancing OFDMA

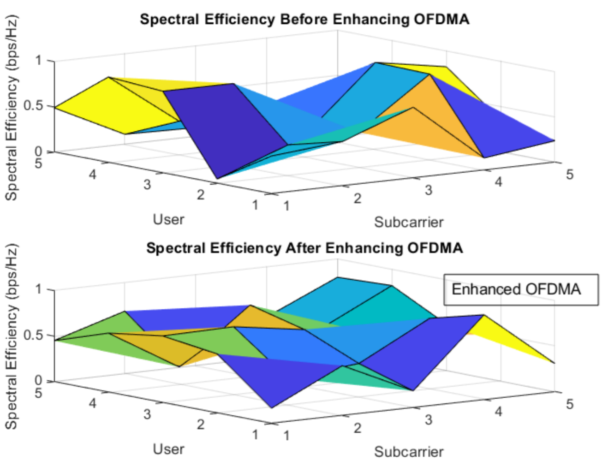


Figure 4. Spectral efficiency before and after enhancing OFDMA

modulation scheme, or channel conditions, as also shown in Figure 4. Overall, the data provide evidence that OFDMA enhancement is effective and determines the profitability of investment in OFDMA enhancement.

Table I provides a detailed comparison of key performance metrics Before and after OFDMA development. Before the upgrade, the wireless network showed a throughput of 100 Mbps, a latency of 20 milliseconds, a signal-to-noise ratio of 25 dB, an interference level of -80 dBm, and a coverage area of 50 square kilometers Improvements were observed in various metrics after OFDMA improvements, with throughput up to 150 Mbps increased, delay reduced by 15 milliseconds, improved signal-to-noise ratio by 30 dB, interference levels reduced to - 100, 85 dBm, and an area covered expansion to 60 square kilometers. Additionally, the number of supported users increased from 50 to 75, channel utilization improved from 60% to 80%, packet loss rate decreased from 2% to 1%, jitter reduced from 5 milliseconds to 3 milliseconds, and spectral efficiency enhanced from 2 bits per second per Hertz (bps/Hz) to 3 bps/Hz. These enhancements signify a significant optimization in network performance, reliability, and capacity following the implementation of OFDMA improvements.

## 7. ACCOMMODATING DIVERSE SERVICES

In the continuous improvement of OFDMA technology, the system must be capable of communication, information transfer, video content, and live applications. Integration of these functions is essential to ensuring quality of service (QoS) and improving the user experience. To improve OFDMA implementation through a dynamically open delivery frequency spectrum based on network conditions and service requirements. MLD methods can be used to determine the number of variables required for unique jobs and flexibly allocate resources in response. In addition, other sophisticated coding techniques and multiple waveforms can be used to improve the spectrum used and the ability of the system to accommodate changes relating to services. Intelligent management and responsive spectrum allocation applying advanced techniques such as artificial intelligence and autonomous learning are required for OFDMA systems to successfully integrate services. The use of these tools and methodologies can improve spectrum efficiency and ensure the provision of various services in OFDMA system configurations in an accurate and high-quality manner.

## 8. CONCLUSION

OFDMA technology is essential for wireless communication because to its great spectrum efficiency, flexibility in resource allocation, and resilience to channel damage. This paper has investigated several options and strategies aimed at making OFDMA even more suitable for addressing various tasks. We studied methods of increasing spectral efficiency, from improved modulation situations to adaptive allocation of subcarriers. As a result, OFDMA shaping is available for the process of increasing multiplication and optimization of the allocation of resources, increasing the overall performance of the entire network. We also considered the ability to minimize delays, one of the key characteristics of any processing in real-time. Due to increased efficiency mechanisms for allocating resources, reducing the size of guard intervals in the frame, and accelerated computation of the restoration of the resolution, OFDMA systems can reduce latency and ensure a viable link for services. Furthermore, we investigated the attributes that one can exploit in the physical layer to enhance overall robustness. The elements that were examined are advanced signals. processing, channel coding, interference mitigation, and diversity methods. They bolster the OFDMA output against multiple categories of loss, and, as demonstrated, they ensure stable performance in real-world operating circumstances. They also factor in large-scale trends across sectors by focusing on the need for dynamic distribution, the need for user groups, and the need for flexible modulation coding techniques. That enables us to serve many “envelope” consumers in

TABLE I. Comparison of results before and after enhancing OFDMA

| Metric | Before Enhancement | After Enhancement |
|---|---|---|
| Throughput (Mbps) | 100 | 150 |
| Latency (ms) | 20 | 15 |
| Signal-to-Noise Ratio (dB) | 25 | 30 |
| Interference Level (dBm) | -80 | -85 |
| Coverage Area (sq. km) | 50 | 60 |
| Number of Users | 50 | 75 |
| Channel Utilization (%) | 60 | 80 |
| Packet Loss Rate (%) | 2 | 1 |
| Jitter (ms) | 5 | 3 |
| Spectral Efficiency (bps/Hz) | 2 | 3 |

a suitable manner while preserving the assumed aspirations of fairness and performance. Emphasize the importance of Looking ahead, future directions in OFDMA systems were identified, emphasizing areas such as integration with 5G and beyond, advanced modulation and coding techniques, dynamic spectrum access, interference management, ultra-reliable low-latency communication, an emphasis on energy efficiency, and security privacy. Then, we delved into minimizing latency, an important feature of real-time processing. By using more efficient resource allocation mechanisms, reduced guard intervals, and faster resolution computation methods, OFDMA systems can reduce latency and ensure a viable link for services.

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