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Optimizing Energy Efficiency of Mimo-Ofdm Systems in Wireless Sensor Networks

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Abstract

MIMO-OFDM systems in Wireless Sensor Networks (WSNs) are optimized for energy efficiency in this paper. Research enhances Orthogonal Frequency Division Multiplexing (OFDM) systems to improve unwavering quality and lessen inter-carrier interference (ICI) notwithstanding channel noise and frequency balances. BPSK, QPSK, 8-PSK, and 16-PSK regulation plans with varied sub-carrier counts are utilized to evaluate Bit Error Rate (BER) under Rayleigh and Ricean blurring channels. Simulations show that more sub-carriers increase BER owing to noise and fading. The work also applies ICI cancellation and Extended Kalman Filtering (EKF) to frequency offset estimation, improving system robustness and BER. These findings show that improved modulation and signal processing approaches optimize OFDM systems in wireless communication situations. Energy-efficient communication techniques for MIMO-OFDM systems in resource-constrained WSNs are advanced by this study.

Keywords: Optimizing,Energy,MIMO-OFDM,Wireless Sensor,Communication

1. INTRODUCTION

Wireless Sensor Networks (WSNs) are essential for many different applications, including healthcare, industrial automation, and environmental monitoring. Since many sensor nodes in these networks are usually equipped with limited energy resources, energy efficiency is a crucial consideration. The capability of Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) to support otherworldly proficiency and increment unwavering quality in wireless communications has made it a helpful innovation for WSNs. However, because MIMO-OFDM demands more computational and transmission resources than conventional systems, its application in WSNs presents major energy consumption difficulties.

WSN-wide MIMO-OFDM system energy efficiency optimisation requires creative approaches and methods to solve these problems. The objective is to minimise energy usage and maintain or improve communication performance in order to extend the lifespan of sensor networks. This requires a comprehensive system that considers various factors, including effective asset portion, adaptive balance procedures, power control, and radio wire determination. It is feasible to obtain notable increases in energy efficiency without sacrificing the overall performance of the system by optimising these parameters. This research investigates new developments and approaches targeted at improving MIMO-OFDM systems' energy efficiency in wireless sensor networks (WSNs). It examines the body of research to pinpoint the main issues and their resolutions in this field, emphasising the relative merits of various optimisation techniques. These approaches are shown to be beneficial in extending the operational lifetime of WSNs through thorough research and simulation tests. In the end, the results aid in the creation of more resilient and sustainable communication protocols designed especially for contexts with limited energy, such as wireless sensor networks.

2. REVIEW OF LITREATURE

AbdelhamidRiadi, Boulouird, and Hassani (2019) Examine how well a Massive-MIMO OFDM (Orthogonal Frequency-Division Multiplexing) system performs by using Least Squares (LS) channel estimation and M-QAM (Quadrature Amplitude Modulation). This research aims to assess how well LS channel estimation performs in precisely estimating the channel state information in a massive-MIMO system—a device that makes use of numerous antennas to greatly increase data throughput and dependability. In their performance analysis of the system, the authors show how LS channel estimation in conjunction with M-QAM modulation methods can maximize error performance and data throughput in OFDM systems. By demonstrating the potential of massive-MIMO and sophisticated modulation techniques to raise the effectiveness and performance of contemporary wireless communication systems, this study contributes to the area.

Agwah and Aririguzo (2020)give a thorough analysis of the key problem in wireless communication: minimizing the Peak to Average Power Ratio (PAPR) in MIMO-OFDM systems. Because high PAPR causes power amplifier inefficiency and raises the possibility of signal distortion, PAPR is a serious problem. The writers go over a number of PAPR reduction strategies, such as coding, probabilistic methods, and clipping and filtering. Additionally, they highlight current developments and suggest future lines of inquiry for addressing open issues with PAPR reduction. This survey is useful because it provides a thorough overview of the approaches used to address PAPR in MIMO-OFDM systems, which are essential for enhancing the effectiveness and performance of contemporary wireless networks.

Khan and Das (2021)offered a cutting-edge method for multiuser detection in MIMO-OFDM systems created especially for circumstances involving underwater communication. Their work, which was published in the Journal of Bionic Engineering, presents a hybrid bionic binary spotted hyena optimizer that combines optimization methods with biologically inspired algorithms. The goal of this method is to improve signal recognition from numerous users when there are underwater acoustic channel impairments such as Doppler effects and multipath propagation. Through the use of MIMO-OFDM's advantages, which provide robustness against interference and channel fading, the suggested approach helps to increase communication throughput and reliability in difficult underwater conditions. The research findings answer important needs in marine exploration, environmental monitoring, and underwater sensor networks, and they significantly advance the effectiveness of MIMO-OFDM systems in underwater applications.

Li et al. (2021)examined how Intelligent Reflecting Surfaces (IRS) might be integrated into wideband MIMO-OFDM communications, with an emphasis on useful modeling and reflection optimization methods. Their study, which was published in IEEE Transactions on Communications, looks into how IRS might improve the MIMO-OFDM systems' performance by adjusting the reflection coefficients of passive reflecting parts. In wireless communication contexts, IRS technology allows for effective beamforming and interference management by allowing for dynamic control of electromagnetic wave propagation. The goal of the research is to optimize the phase shifts of reflecting surfaces according to channel conditions and system requirements in order to maximize spectral efficiency and improve signal quality. The study's findings are crucial for improving IRS's practical implementation in upcoming wireless networks, especially 5G and beyond

3. MATHMATICAL MODEL OF OFDM PERFORMANCE

With an image pace of s f at the sub-carriers, let us consider an input information grouping (,,......) X0 X1 XN, where N is the quantity of sub-carriers. By padding zeros, the transmitter takes into account a cyclic prefix with an adequate guard interval. Phase shift keying is the transmission modulation technique, whereas multipath fading and Gaussian noise make up the channel noise.

X and K are examined over sets of {±1} because M-ary PSK is utilised to modulate every sub-carrier. One source for the frequency-domain demodulated signal is the time-variant multipath fading channel. A bit error will happen at the system's output in light of the fact that the sent message will prompt stage and extent surrenders in the received signal because of channel noise. While working out the channel's BER under Rayleigh and Ricean blurring, the underlying extent error is thought of. Following this, the BER of the channel is registered by factoring in the random stage error and the steady extent error.

The received signal "y" in the blurring divert in a level blurring environment has the accompanying structure:

$$y = hx + n$$

3.1 BIT ERROR RATE

For each value of spot energy to clamor ratio N0 Eb, the tail of the Gaussian probability density capability is integrated to calculate the likelihood of error for transmission of either +1 or - 1, which is known as the BER computation in AWGN. The rate of spot errors is Nonetheless, the effective piece energy to racket proportion is 0 2 N h Eb when channel "h" is available. For a given value of "h," the piece error likelihood is thusly,

$$P_{b/h} = \frac{1}{2} erfc\left(\sqrt{\frac{|h|^2 E_b}{N_0}}\right) = \frac{1}{2} erfc\left(\sqrt{\kappa}\right)$$

in which 0 2 N h Eb κ =. Look at the contingent likelihood thickness capacity Pb h over the likelihood thickness ability of κ to get the error likelihood of over all random values of 2 h. is the likelihood thickness ability of κ using chi-square random variable.

$$P(\kappa) = \frac{1}{(E_b/N_0)} e^{\frac{-\kappa}{(E_b/N_0)}}, \ \kappa \geq 0$$

Thus, the likelihood of an error is

$$p_b = \int_0^{\infty} \frac{1}{2} erfc\left(\sqrt{\kappa}\right) p(\kappa)\, d\kappa$$

3.2 BER VERSES CHANNEL NOISE

The transmitted data is in phase with the message's fixed magnitude phasor, and the message's amplitude is one. The din can be thought of as an extra random vector to the signal being sent. The received vector will be equal to the vector amount of the communicated message and the disturbance.

Let's say the signal that was transmitted is

where "L" is the noise vector's length with phase angle φ.

Thus, y = Lsinϕ is the received signal.

Therefore

$$\theta = \tan^{-1}\left(\frac{L\sin\varphi}{1 + L\cos\varphi}\right)$$

$$L = \frac{1}{SNR}$$

The signals' amplitudes, which are the basis for the SNR, must be accurately scaled when converted to decibels (dB). Equation 5.9 is then substituted for equation 5.8.

$$\theta = \tan^{-1}\left[\frac{\left(\frac{1}{SNR}\right)\sin\varphi}{1 + \left(\frac{1}{SNR}\right)\cos\varphi}\right]$$

Any phase angle can be available in the commotion signal. Finding the average phase error, or RMS phase error, is therefore necessary (assuming the commotion phase angle is always sure). To find the average phase angle, integrate ϕ over a half circle, where ϕ ranges from 0 to π.

$$\theta_{Average} = \frac{1}{\pi}\int_0^{\pi} \tan^{-1}\left(\left(\frac{1}{SNR}\right)\frac{\sin\varphi}{1+\left(\frac{1}{SNR}\right)\cos\varphi}\right)d\varphi$$

$$\theta_{Average} = \frac{1}{\pi}\int_0^{\pi} \tan^{-1}\left(\frac{\sin\varphi}{SNR+\cos\varphi}\right)d\varphi$$

To compute the average stage error for various Channel SNRs, use Condition 2.13. It is feasible to process the RMS stage error as:

$$\theta_{RMS} = \frac{\sqrt{2}}{\pi}\int_0^{\pi} \tan^{-1}\left(\frac{\sin\varphi}{SNR+\cos\varphi}\right)d\varphi$$

3.3 SIMULATION RESULTS

According to the state of the study, OFDM seems like a good modulation technology for high-performance wireless telephony. The simulation's settings are displayed in Table 1.

Table 1: Simulation Parameters

Parameter	Specification
System	OFDM
Modulations	BPSK, QPSK, 8-PSK, 16-PSK
Size of FFT/IFFT	64
Sub-carriers (N)	32, 64, 256, 512, 1024
Carrier frequency	2.15 GHz
Sampling Time (Ts)	72 µs
Frequency spacing (δf)	15 KHz
Bandwidth	5 MHz
SNRs	0 dB to 50 dB
Flat Fading	Rayleigh, Ricean

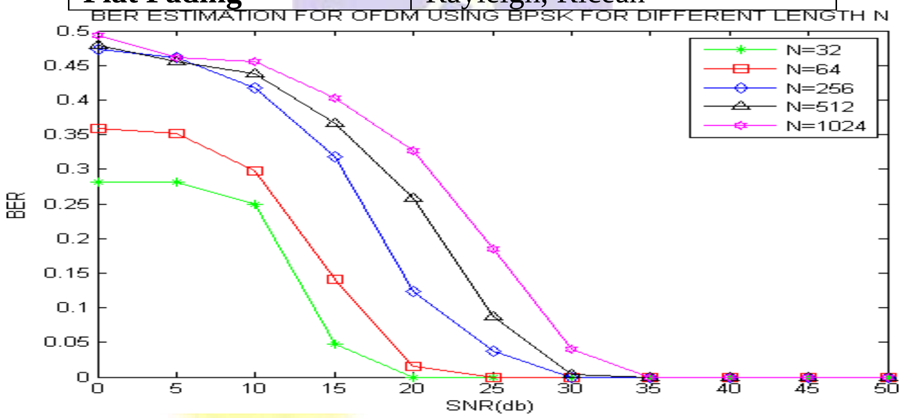

Figure 1: Bit Error Rate of OFDM using BPSK modulation for sub-carriers 'N'

Figure1 illustrates how the number of subcarriers, or "N," in an OFDM system with BPSK modulation and white Gaussian channel noise is taken from 32 to 1024. Greater values of N result in a higher Bit Error Rate. Figure 2 illustrates how the number of subcarriers, or "N," in an OFDM system with QPSK modulation and white Gaussian channel noise is taken from 32 to 1024. Greater values of N result in a higher Bit Error Rate.

4. ICI CANCELING MODULATION

A fundamental thought is to develop a get-together of sub-carriers with fixed coefficients and then regulate the input information symbol onto them so the ICI signals created inside that social event counteract one another. Bit rate rising in computerized compact radio communication systems causes channel profound blurring and inter-symbol interference

(ISI), two significant issues in customary single carrier systems. Orthogonal Frequency Division Multiplexing (OFDM) in a radio compact situation has been the subject of an assessment. Utilizing guard intervals can assist with bringing down the ISI, and utilizing a wide symbol interval gives the system tremendous resistance to channel deep fading.

4.1 ICI Canceling Demodulation

Each pair of sub-carriers really transmits a single data signal thanks to the ICI cancelling modulation. The receiver side of the system can perform better thanks to the signal redundancy. Here, the so-called ICI cancelling demodulation approach is examined in light of a potential future decrease in ICI. It is recommended that the demodulation work by increasing each signal at the ( ) th k +1 sub-carrier (where k connotes an even number) by "-1" and then adding it to the signal at the k-th sub-carrier. The judgment on the symbol is then made utilizing the subsequent information succession. It is portrayed as:

$$Y''(k) = Y'(k) - Y'(k+1)$$

Were $$Y''(k) = \sum_{\substack{l=0 \\ l=even}}^{N-2} X(l)\,[-S(l-k-1) + 2S(l-k) - S(l-k+1)] + n_k - n_{k+1}$$

After then, the matching ICI coefficients become

$$S'(l-k) = -S(l-k-1) + 2S(l-k) - S(l-k+1)$$

Three different kinds of ICI coefficients have been found thus far:

1) s(l − k) for the OFDM system being utilized 2) s (' l − k) for tweak of ICI retraction and 3) s (" l − k) for regulation and demodulation of joined ICI undoing. The examination of the previously mentioned three extents for N=16 and ε=0.2 and 0.6 is shown in Figure 3.4.

For the most part l k − values, S l k '(-) is considerably more modest than S l k (-), and S l k "(-) is much more modest than S l k (-). A more modest ICI signal is the outcome of applying ICI dropping regulation. Notwithstanding, ICI dropping demodulation can additionally diminish the excess ICI in the received signals. What we call this crossover way to deal with ICI abrogation, regulation, and demodulation is the ICI self-wiping out system. The advised ICI dropping demodulation further develops the system's signal-to-upheaval proportion, which ought not be dismissed. We may hypothetically decide the ICI self-retraction plan's CIR as

$$CIR = \frac{|-S(-1) + 2S(0) - S(1)|^2}{\sum_{l=2,4,6}^{N-1} |-S(l-1) + 2s(l) - s(l+1)|^2}$$

In the scope of 0 < ε < 5.0, an ICI retraction strategy for this thoughtful deals with the CIR by more than 15 dB.

For little to medium frequency balances in the scope of 0 < ε < 2.0, the CIR improvement can be essentially as high as 17 dB. The ICI self-abrogation system's bandwidth productivity is cut down the center by the emphasis coding. It is sensible to use a bigger signal letter set size to achieve the fundamental bandwidth effectiveness. In contrast with conventional OFDM systems, which have a bandwidth effectiveness of 1 bit/Hz/s, the ICI self-undoing approach with 4-PSK regulation can achieve a similar result. Right when the channel frequency offset is minor, using a more noteworthy signal letters in order size rather than a more modest one could build the system bit-error rate (BER). Whatever the case might be, the proposed technique extensively upgrades BER for medium to high channel frequency balances (ε > 05.0).

4.2 EXTENDED KALMAN FILTERING TO OFDM SYSTEM

The discrete Kalman filter's state-space model is described as

$$z(n) = a(n)d(n) + w(n)$$

The ideal value, d(n), and the observation, z(n), in this worldview, are corresponded linearly. In view of the observation of z(n), d(n) can be iteratively assessed utilizing the discrete Kalman channel, and the refreshed assessment in every recursion is ideal in the impression of the negligible mean square.

$$y(n) = x(n)\, e^{j\frac{2\pi n'\varepsilon(n)}{N}} + w(n)$$

It is evident that there exists a nonlinear connection between the planned value ε (n) and the observation y(n).

$$y(n) = f(\varepsilon(n)) + w(n)$$

$$\text{where} \quad f(\varepsilon(n)) = x(n)\, e^{j\frac{2\pi n'\varepsilon(n)}{N}}$$

Utilizing the first-request Taylor's development, a surmised linear association is built to assess ε (n) productively in calculation.

$$y(n) \approx f(\hat{\varepsilon}(n-1)) + f'(\hat{\varepsilon}(n-1))[\varepsilon(n) - \hat{\varepsilon}(n-1)] + w(n)$$

5. CONCLUSION

This research reveals how to optimize OFDM performance in wireless communication. The research examines the trade-offs between spectral efficiency and channel impairment robustness using BPSK, QPSK, 8-PSK, and 16-PSK modulation schemes and sub-carrier configurations in Rayleigh and Ricean fading channels. The simulation findings show that more sub-carriers increase Bit Error Rates (BER), emphasizing the influence of channel noise and fading on system performance. ICI cancellation and Extended Kalman Filtering (EKF) for frequency offset estimation reduce interference and improve system reliability. In actual wireless communication applications, optimizing modulation schemes and using modern signal processing technologies improve OFDM system performance. Future study could refine these strategies to minimises BER and increase spectral efficiency, improving wireless communication network dependability and throughput.

REFERENCES

1. AbdelhamidRiadi, Mohamed Boulouird, MohaM' RabetHassani, 2019, 'Performance of Massive-MIMO OFDM system with M-QAM Modulation based on LS Channel Estimation', International Conference on Advanced Systems and Emergent Technologies (IC_ASET).
2. Agwah, B. C., & Aririguzo, M. I. (2020). MIMO-OFDM system in wireless communication: a survey of peak to average power ratio minimization and research direction. International Journal of Computer Science Engineering, 9(4), 2020.
3. Daniel costa araújo, andré l. F. De almeida, joão p. C. L. Da costa, and rafael t. De sousa, 2019, 'Tensor-Based Channel Estimation for Massive MIMO-OFDM Systems', 2019 IEEE. Translations, Vol 7, 2019, 42133-42147
4. Gopadi, H. K., & Rao, P. T. (2022). Emergence of energy optimization in MIMO-OFDM communication system with hybrid teamwork-grasshopper optimization. Journal of Optical Communications, (0).
5. Jose Ribeiro, Joao Gomes, Rui Dinis, 2019, 'An Interference Cancellation Approach for MIMO Orthogonal Signal-Division Multiplexing in Time-Varying Channels', OCEANS 2019 – Marseille.

6. Jothi, S., & Chandrasekar, A. (2022). An efficient modified dragonfly optimization based mimo-ofdm for enhancing qos in wireless multimedia communication. Wireless Personal Communications, 122(2), 1043-1065.
7. Kansal, L., Berra, S., Mounir, M., Miglani, R., Dinis, R., & Rabie, K. (2022). Performance analysis of massive MIMO-OFDM system incorporated with various transforms for image communication in 5G systems. Electronics, 11(4), 621.
8. Kant, S. (2022). Optimization and Learning for Large-Scale MIMO-OFDM Wireless Systems: Theory, Algorithms, and Applications (Doctoral dissertation, KTH Royal Institute of Technology).
9. Khan, M. R., & Das, B. (2021). Multiuser detection for MIMO-OFDM system in underwater communication using a hybrid bionic binary spotted hyena optimizer. Journal of Bionic Engineering, 18(2), 462-472.
10. Lavish Kansal, Salah Berra, Mohamed Mounir, Rajan Miglani, Rui Dinis and Khaled Rabie, 2022, 'Performance Analysis of Massive MIMO-OFDM System Incorporated with Various Transforms for Image Communication in 5G Systems', electronics MDPI.
11. Li, H., Cai, W., Liu, Y., Li, M., Liu, Q., & Wu, Q. (2021). Intelligent reflecting surface enhanced wideband MIMO-OFDM communications: From practical model to reflection optimization. IEEE Transactions on Communications, 69(7), 4807-4820
12. Muoghalu, C. N., Achebe, P. N., &Aigbodioh, F. A. (2022). MIMO-OFDM techniques for wireless communication system: performance evaluation review. International journal of advanced networking and applications, 14(4), 5572-5581.
13. Sindhwani, N., Anand, R., Nageswara Rao, G., Chauhan, S., Chaudhary, A., Gupta, A., & Pandey, D. (2022). Comparative Analysis of Optimization Algorithms for Antenna Selection in MIMO Systems. In Advances in Signal Processing, Embedded Systems and IoT: Proceedings of Seventh ICMEET-2022 (pp. 607-617). Singapore: Springer Nature Singapore.
14. Yue, M., Liu, L., & Yuan, X. (2022). RIS-aided multiuser MIMO-OFDM with linear precoding and iterative detection: Analysis and optimization. IEEE Transactions on Wireless Communications.
15. Zhong, C., Lou, M., Gu, C., Tang, L., & Bai, Y. (2022). Performance optimization and parameters estimation for MIMO-OFDM dual-functional communication-radar systems. Digital Communications and Networks.