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DESIGNING ADVANCED SIGNAL PROCESSING ALGORITHMS FOR ENHANCING ENERGY EFFICIENCY IN UAV-ASSISTED WIRELESS COMMUNICATION NETWORKS

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ABSTRACT

Unmanned Aerial Vehicles (UAVs) have emerged as promising platforms for enhancing wireless communication networks, offering advantages such as mobility, flexibility, and coverage extension. However, the integration of UAVs into wireless communication systems presents various challenges related to energy efficiency, resource optimization, and performance enhancement. This paper conducts a systematic literature review to explore advancements, challenges, and solutions in UAV-assisted wireless networks. By analyzing recent research articles, we identify key research gaps and propose methodologies for addressing them. Advanced signal processing algorithms, including optimization techniques, machine learning approaches, and simulation methods, are proposed to improve energy efficiency, resource allocation, and trajectory optimization in UAV-based communication systems. Through collaborative efforts between academia, industry, and government agencies, significant progress can be achieved in overcoming the challenges faced by UAV networks. This paper provides valuable insights and guidance for researchers, practitioners, and policymakers working in the field of UAV-assisted wireless communication networks.

Keywords: Unmanned Aerial Vehicles, Wireless Communication Networks, Energy Efficiency, Advanced Signal Processing, Machine Learning.

I. INTRODUCTION

Unmanned Aerial Vehicles (UAVs) have rapidly emerged as versatile platforms with transformative potential across various industries, including telecommunications. These aerial vehicles, commonly known as drones, offer unique capabilities such as mobility, flexibility, and adaptability, making them well-suited for a wide range of applications, including surveillance, monitoring, disaster management, and telecommunications support. In recent years, there has been a growing interest in leveraging UAVs to enhance wireless communication networks, particularly in scenarios where traditional ground-based infrastructure may be insufficient or inaccessible.

The integration of UAVs into wireless communication systems holds significant promise for extending network coverage, improving connectivity, and enabling new services and applications. By deploying UAVs as aerial base stations or relays, operators can rapidly deploy temporary communication infrastructure in remote or disaster-affected areas, provide connectivity in urban environments with high user density, and support various emerging applications such as precision agriculture, environmental monitoring, and public safety.

Despite their potential benefits, the deployment of UAV-assisted wireless communication networks poses several technical and operational challenges that must be addressed to realize their full potential. One of the primary challenges is optimizing the energy efficiency of UAVs, as these vehicles typically operate on limited battery power and require efficient energy management strategies to prolong their flight duration and support continuous communication operations.

Furthermore, resource optimization is critical for maximizing the performance of UAV-assisted communication networks while efficiently utilizing available spectrum, power, and computational resources. Efficient resource allocation algorithms are needed to dynamically allocate resources among UAVs and ground nodes, considering factors such as user demand, network congestion, interference mitigation, and quality of service requirements.

Another key challenge is trajectory optimization, which involves designing optimal flight paths for UAVs to achieve specific communication objectives, such as maximizing coverage, minimizing interference, or optimizing energy consumption. Trajectory planning algorithms must take into account various factors, including terrain conditions, environmental obstacles, airspace regulations, and mission constraints, to ensure safe and efficient UAV operations.

In addition to energy efficiency, resource optimization, and trajectory planning, UAV-assisted communication networks also face security and privacy challenges that must be addressed to protect sensitive data and ensure the integrity and reliability of communication services. As UAVs become increasingly integrated into critical infrastructure and sensitive applications, cybersecurity measures, encryption techniques, and authentication mechanisms will play a crucial role in safeguarding against potential threats and vulnerabilities.

To address these challenges and unlock the full potential of UAV-assisted communication networks, significant research efforts are underway to develop advanced signal processing algorithms, optimization techniques, and machine learning approaches tailored to the unique characteristics and requirements of UAV-based communication systems. These efforts aim to enhance the energy efficiency, scalability, reliability, and security of UAV-assisted networks while enabling innovative applications and services across various domains.

Figure 1: A land-based communication system using unmanned aerial vehicles (UAVs).

In this paper, we present a comprehensive review of recent advancements, challenges, and solutions in UAV-assisted wireless communication networks. We analyze a diverse range of research articles, surveys, and technical papers to identify key research gaps and propose methodologies for addressing them. By synthesizing insights from the literature, we aim to provide valuable guidance and recommendations for researchers, practitioners, and policymakers working in the field of UAV-assisted communication networks.

II. LITERATURE REVIEW

Dai et al. (2022) , The rapid advancement in communication and computing technologies has empowered unmanned aerial vehicles (UAVs) to offer robust and cost-effective wireless communication and computing services from aerial platforms. Unlike traditional fixed infrastructures, UAVs boast significant benefits, including enhanced flexibility, operability, and the capacity to establish on-demand line-of-sight connections. As such, UAV-assisted wireless networks are increasingly recognized as a vital framework to extend coverage and connectivity in future wireless communications. Key to the efficacy of these networks are high energy efficiency, advanced sensing, robust communication and computing capabilities, and stringent security and privacy measures. Over recent years, various frameworks and mechanisms have been designed to refine the performance of UAV-assisted wireless networks. This article delivers a detailed survey of these advancements, providing an architectural overview across four domains—framework-related, technology-related, challenge-related, and solution-related—and examining four critical aspects: sensing, communication, computing, and applications. It further explores the integration of sensing, communication, and computing in UAV networks, discusses challenges, state-of-the-art solutions, and details the implementation and applications of these networks. Finally, the article explores advanced technologies for UAV-assisted networks and identifies potential future research directions [1] .

Basharat et al. (2022), Unmanned aerial vehicles (UAVs) are increasingly essential in meeting the burgeoning demands of future wireless networks. Recent studies have explored various issues within UAV-assisted networks, including UAV placement, resource management, and spectrum sharing, across a range of applications such as disaster management, ground sensor network data collection, surveillance, and logistic support. This article provides an exhaustive review of the recent advancements in UAV-assisted networks, focusing primarily on the optimization of UAV-assisted wireless networks. It discusses different objectives such as coverage area, throughput, energy efficiency, quality of service, delay, and outage probability, offering an in-depth analysis for each objective along with their constraints, optimization problems, solution approaches, and performance metrics. It also examines the interrelations between different objectives and parameters documented in existing literature. The article concludes by outlining open research challenges and suggesting directions for future research to enhance the optimization of UAV-assisted wireless networks [2] .

Chen et al. (2022) , Edge devices (EDs) possess limited energy resources, and the advent of 6th generation (6G) mobile networks is set to increase their energy demands. UAV-assisted wireless communication networks offer a novel solution by providing signal-free communication links to EDs. However, issues such as time-lag in the system prevent dynamic adjustment of emission energy by EDs, due to inaccuracies in acquiring dynamic UAV coordinates. Moreover, static emission energy settings result in poor endurance of EDs. Addressing this challenge, this paper introduces a deep learning-based energy optimization algorithm (DEO) designed to dynamically adjust the emission energy of EDs to match the energy received by mobile relay UAVs as closely as possible to the sensitivity of the receiver. Utilizing a deep learning framework, the edge server predicts the position of relay UAVs in dynamic environments, allowing for appropriate adjustments in ED emission energy. This enables reliable minimum-energy communication between EDs and mobile relay UAVs. Experimental results demonstrate the effectiveness of this approach, with the Weighted Mean Absolute Percentage Error (WMAPE) of the algorithm reported at 0.54%, 0.80%, and 1.15% under communication delays of 0.4 s, 0.6 s, and 0.8 s, respectively [3] .

AlJubayrin et al. (2022), The integration of ambient backscatter communication (ABC) with non-orthogonal multiple access (NOMA) technologies shows significant promise for enabling large-scale Internet of Things (IoT) connectivity within UAV networks. ABC technology allows for battery-free transmissions by harvesting energy from existing RF signals from sources like WiFi, TV towers, and cellular base stations/UAVs, while NOMA facilitates simultaneous communication across multiple IoT devices on the same frequency. This study presents an energy-efficient transmission design for an ABC-aided UAV network using NOMA. The research aims to optimize UAV system power consumption while ensuring minimal data rates for IoT devices. Challenges such as co-channel interference among UAVs, imperfect channel state information (CSI), and NOMA interference are addressed by formulating a non-convex joint optimization problem, subsequently simplified and solved using a sub-gradient method. The study also compares this approach with a conventional NOMA UAV framework, showcasing the advantages of incorporating ABC into NOMA UAV networks [4] .

Park et al. (2022), The emerging technologies of unmanned aerial vehicles (UAVs) and intelligent reflecting surfaces (IRSs) are gaining significant attention as enablers of future wireless networks. IRS-assisted UAV communication, which integrates IRSs within UAV communications, is designed to overcome the inherent limitations of UAV communications and enhance overall system performance. This article provides an extensive survey of IRS-assisted UAV communications, presenting six representative scenarios that combine IRSs and UAVs based on the installation points of IRSs and the roles of UAVs. It also reviews the technical features of the latest works on IRS-assisted UAV communication systems from various performance criteria perspectives, such as spectral efficiency, energy efficiency, and security. Additionally, the article discusses the application of machine learning algorithms in previous studies and highlights key technical issues and research challenges that must be addressed to advance IRS-assisted UAV communication systems [5] .

Mohsan et al. (2022), Intelligent Reflecting Surfaces (IRS) are transforming wireless communication by smartly configuring wavefronts, including amplitude, frequency, phase, and polarization, through passive reflections without the need for radio frequency (RF) chains. This innovation is set to revolutionize wireless communication by significantly enhancing spectrum and energy efficiencies at a reduced cost and energy consumption. Concurrently, Unmanned Aerial Vehicle (UAV) communication has garnered significant attention due to its high mobility, flexible deployment, and seamless integration with other technologies. However, challenges such as obstructions and potential eavesdropping in real-time scenarios persist. The combination of IRS and UAV technologies promises substantial improvements in challenging environments by proactively modifying wireless propagation through maneuver control and intelligent signal reflections in three-dimensional spaces. This study reviews the current literature on IRS-assisted UAV communications, covering both ground and airborne scenarios, highlights emerging technologies and applications, and further explores research opportunities aimed at designing and optimizing wireless systems with minimal energy footprints and costs. It also discusses the ongoing challenges and future directions in IRS-assisted UAV communication [6].

Ma et al. (2022), UAVs, known for their high mobility, are pivotal in re-establishing wireless connections in areas impacted by various disruptions. Traditionally, studies have often overlooked the impact of limited airborne energy on the reliability of UAV data transmission. Addressing this gap, this article introduces a UAV-assisted wireless powered system designed for reliable data collection in Internet of Things (IoT) networks. In this system, a UAV employs energy beamforming to transmit energy to ground users (GUs) during a downlink subtimeslot, while GUs send data back to the UAV using the harvested energy in an uplink subtimeslot. The study presents a joint optimization problem involving subtimeslot allocation and UAV route planning to maximize system energy efficiency while considering UAV dynamics, time slot duration, and GUs' rate requirements. To solve the nonconvex problem, a low-complexity alternating iterative algorithm is introduced, which optimizes subtimeslot allocation and UAV route in two distinct subproblems. Simulation results demonstrate the effectiveness of this approach, optimizing both UAV routing and achieving a balance between system throughput and UAV propulsion energy consumption [7].

Zhou et al. (2022), As an aerial base station, UAVs are emerging as a promising technology for future wireless communications, offering flexibility, rapid deployment, and cost-effectiveness, where resource allocation is crucial for energy efficiency. This paper tackles a complex optimization challenge involving user association, UAV trajectory design, and power control to maximize channel capacity for all ground users at a constrained power level during downlink transmissions. A novel clustering-aided reinforcement learning strategy is proposed, encompassing three stages: a modified expectation-maximization algorithm for clustering ground users, the Kuhn-Munkres algorithm for user association, and a multi-agent twin delayed deep deterministic (MATD3) policy gradient for fine-tuning UAV trajectories and power settings. By incorporating a low-bias value estimation, the MATD3 algorithm enhances rewards and achieves faster convergence compared to existing reinforcement algorithms, demonstrating lower computational complexity and improved performance metrics in simulations [8].

Pogaku et al. (2022), Reconfigurable Intelligent Surfaces (RIS), constructed from low-cost meta-surfaces, are poised to significantly enhance wireless communication by reflecting or refracting signals as needed. Inspired by the concept of a smart radio environment, RIS reduces hardware requirements, energy consumption, and signal processing complexity. Integrating RIS with technologies like multiple-input multiple-output (MIMO) systems, non-orthogonal multiple access (NOMA), and physical layer security significantly boosts performance. Particularly in UAV-assisted applications, RIS can mitigate limitations related to fuel efficiency, environmental disturbances, and network capacity, enhancing UAV services in data collection, surveillance, and logistics. Despite the potential, research on UAV-assisted RIS systems remains limited. This article surveys the current landscape, focusing on optimization, communication techniques, deep reinforcement learning, and internet of things applications, and outlines the open challenges and future research directions in phase shifting, channel modeling, and energy efficiency [9].

Zhang et al. (2021), This paper proposes an energy-efficient trajectory optimization scheme for UAV-assisted Internet of Things (IoT) networks, where a single UAV, powered by both solar energy and charging stations (CSs), ensures sustainable communication services. The optimization considers average data rate, total energy consumption, and coverage fairness for IoT terminals operating in discontinuous reception (DRX) mode. A combination of module-free, action-confined on-policy and off-policy reinforcement learning (RL) approaches is applied to address the optimization problem, demonstrating superior performance over traditional dynamic algorithms in simulations. The results highlight the adaptability of the proposed trajectory scheme in responding to the temporal and dynamic conditions of communication networks, significantly enhancing data transmission, energy efficiency, and battery management [10].

Liu et al. (2022), In the realm of the Internet of Things (IoT), unmanned aerial vehicles (UAVs) maintain network connectivity even when ground infrastructures are compromised. However, the performance of UAV-enabled IoT networks is often limited by the UAVs' constrained energy resources. This paper proposes a multi-UAV-enabled IoT system where UAVs function as base stations, transmitting data to ground IoT nodes during their flight. To address energy concerns, the paper explores a fair energy-efficient resource optimization scheme aimed at equalizing energy consumption among multiple UAVs. The optimization process, which aims to maximize the minimum energy efficiency of each UAV, involves joint optimization of communication scheduling, power allocations, and UAV trajectories. By decomposing the non-convex optimization problem into three manageable subproblems, solutions are derived using the Dinkelbach method and successive convex approximation (SCA). A joint optimization algorithm is then implemented, iteratively solving the subproblems to achieve globally optimal solutions. Simulation results indicate significant performance improvements in the multi-UAV-enabled IoT system, with notable gains in energy efficiency and fairness [11].

Hashesh et al. (2022), UAV communications have recently emerged as a promising technology for future wireless networks, drawing significant attention for their potential and versatility. This article reviews the integration of artificial intelligence (AI) techniques in UAV networks, particularly for enhancing capabilities beyond fifth-generation (B5G) and sixth-generation (6G) services. A comprehensive summary of various machine learning (ML) approaches is provided, highlighting their applications and significant contributions to UAV network implementations. Advanced ML techniques such as bandits, federated learning (FL), and meta-learning are discussed in detail. Additionally, the paper outlines future research directions and challenges in UAV communication, emphasizing the role of AI in advancing these systems [12].

Qi et al. (2022) , Vehicular networks are poised to play a crucial role in data transmission, especially in the context of autonomous driving. Given the high data traffic load, UAVs are increasingly seen as a solution to assist vehicular networks by alleviating terrestrial network burdens. This paper explores a dense UAV-assisted vehicular network where UAVs facilitate data transmission to vehicular users while allowing vehicle-to-vehicle (V2V) links to reuse the spectrum for critical message exchanges. A joint optimization framework is developed to enhance UAV energy efficiency and ensure user quality of service (QoS) by optimizing content placement, spectrum allocation, co-channel link pairing, and power control. The optimization challenge is tackled using a combination of the Hungarian method and deep Q-network (DDQN), with performance evaluations demonstrating improved decision-making timeliness, enhanced energy efficiency, and maintained user QoS [13].

Gu et al. (2021) , UAVs, often deployed for services like mapping and monitoring, face challenges due to their moderate computational capabilities and limited energy, which can restrict local data processing. This paper investigates a UAV-multiaccess edge computing (MEC) system, enhanced by wireless power transfer (WPT) to mitigate these challenges. The proposed system allows UAVs to offload computationally demanding tasks to MEC servers while maintaining confidentiality against potential eavesdroppers. A full-duplex protocol enables simultaneous data reception and control instruction broadcasting, with control signals also creating interference to confuse eavesdroppers. An optimization framework is developed to minimize energy consumption while considering offloading time, data size, and transmit power, enhancing both the security and efficiency of UAV operations. Numerical results illustrate the efficacy of various offloading strategies, comparing them to existing approaches and demonstrating improvements in offloading capacity and energy efficiency [14].

Fu et al. (2022), This paper addresses the challenge of wireless data aggregation (WDA) in multi-cluster networks through the use of UAVs and over-the-air computation (AirComp), eliminating the need for terrestrial base stations. The focus is on optimizing UAV trajectory, transceiver design, cluster scheduling, and association to maximize the performance of WDA tasks in each cluster while managing interference across the network. A complex non-convex mixed-integer nonlinear programming problem is formulated, and an efficient iterative algorithm is developed using bisection and block coordinate descent methods to find optimal transceiver solutions. Dual methods and successive convex approximation are employed to obtain binary variables and suboptimal trajectories. Simulation results validate the superiority of the proposed design over benchmarks, demonstrating significant enhancements in task performance and access delay reduction through the strategic deployment of multiple UAVs [15].

Wang et al. (2022), Utilizing unmanned aerial vehicles (UAVs) in wireless sensor networks (WSNs) offers controllable mobility and flexible deployment but faces challenges related to energy limitations and data security. To address these challenges, this paper formulates a complex optimization problem focused on maximizing secrecy energy efficiency (EE), subject to constraints on secrecy rate, maximum power, and UAV trajectory. An iterative algorithm is developed, employing alternating optimization, successive convex approximation, and fractional programming to jointly optimize the UAV's trajectory and velocity, alongside the sensors' power settings. This energy-efficient and secure solution effectively enhances the secrecy EE of UAV-enabled data collection in WSNs, improving both performance and data security as demonstrated by simulation results [16].

Liu et al. (2022), Integrated Sensing and Communications (ISAC) technology merges radio sensing and communication functionalities, enabling 6G networks to interact with the physical world. This technology significantly enhances vehicular-to-everything (V2X) networks by facilitating high-precision traffic environment perception. The paper discusses how UAVs, when deployed flexibly, can extend the sensing range beyond what vehicle-mounted sensors can achieve, thus ensuring safer driving conditions. It introduces an energy-efficient computation offloading strategy for data fusion in UAV-aided V2X networks, which includes a cooperative perception architecture and a computation offloading strategy that accounts for dynamic computing resource allocation. Employing a successive convex approximation (SCA) algorithm, the paper converts a non-convex problem into a tractable convex approximation, leading to reduced UAV energy consumption and shorter data fusion processing delays, as evidenced by simulation outcomes [17].

Khan et al. (2022), The integration of fifth-generation (5G) and UAV technologies offers a promising avenue for seamless communication in critical applications such as disaster management. This paper addresses the challenges of dynamic control and external factors like weather in UAV communications through dynamic positioning and energy-efficient path planning. Using a lightweight gated recurrent unit (LGRU) for weather prediction and a density-based optics clustering (DBOC) algorithm for reliable communication, the approach optimizes UAV deployment and path planning using dynamic positioning-based soft actor–critic (DPSAC) algorithms. Simulations validate the effectiveness of this method in improving quality of service (QoS), reliability, and energy efficiency in 5G-assisted multi-UAV environments, demonstrating superior performance metrics across various parameters [18].

Chen and Tang (2022), This work addresses challenges in a heterogeneous Wireless Sensor Network (WSN) where sensor nodes vary in residual energy (RE). It explores dynamic working modes for sensors based on their RE and an introduced energy threshold, employing a UAV for data collection. The study aims to minimize the weighted sum of energy consumption from both the WSN and UAV, optimizing cluster head selection, energy threshold, and working modes through an efficient search method and a penalty-based successive convex approximation algorithm. The iterative approach effectively reduces energy consumption for low-RE sensor nodes and overall network energy use, as supported by numerical results [19].

Mu and Sun (2022) , Investigating a UAV-assisted wireless power transfer (WPT) system, this paper explores how UAV-mounted mobile energy transmitters (ETs) can maximize energy transfer to a ground-based energy receiver (ER) within a finite flight period, considering UAV speed and collision avoidance constraints. The study deeply analyzes scenarios with one to two UAVs, employing the Lagrange multiplier method for optimization, and extends the findings to configurations involving up to seven UAVs. The derived trajectories suggest that UAVs should hover at fixed locations to optimize energy transfer, supported by numerical results that validate the effectiveness of the proposed trajectory design for a multi-UAV-enabled WPT system [20].

Shi et al. (2021), This article proposes a decoupled access scheme with enhanced energy efficiency (EE) for cellular networks that serve both ground and aerial users. The scheme addresses the interference caused by UAVs with omnidirectional antennas by separating control and data links into different frequency bands for uplink and downlink transmissions. An optimal power allocation algorithm, based on fractional programming and successive convex approximation, optimizes EE and minimizes interference. Numerical results demonstrate substantial improvements in sum-rates for uplink and downlink transmissions and a significant enhancement in ground user equipment (GUE) sum-rate and EE, highlighting the efficiency of the proposed decoupled access and power allocation strategies [21].

Table 1: Systematic Literature Review

Reference	Year	Method	Advantage	Future Scope
Dai et al. (2022)	2022	Review and analysis	Provides insights into advancements and challenges	Explore new solutions to overcome identified challenges
Basharat et al. (2022)	2022	Literature review and analysis	Offers a comprehensive overview of resource optimization techniques	Investigate emerging optimization methods and their applicability
Chen et al. (2022)	2022	Deep learning-based optimization	Utilizes advanced machine learning techniques for energy optimization	Investigate the scalability and adaptability of deep learning models
AlJubayrin et al. (2022)	2022	Design optimization with NOMA and backscatter	Improves energy efficiency in UAV networks with imperfect channel state information	Explore methods to mitigate the impact of imperfect CSI
Park et al. (2022)	2022	Survey and analysis	Provides insights into the potential of intelligent reflecting surfaces in UAV communications	Investigate practical implementations of intelligent reflecting surfaces
Mohsan et al. (2022)	2022	Review and analysis	Explores current trends and challenges in utilizing intelligent reflecting surfaces for UAV communications	Investigate novel applications and deployment scenarios
Ma et al. (2022)	2022	Optimization algorithm development	Develops energy efficiency optimization algorithms for UAV-assisted wireless powered systems	Investigate real-world implementation and performance of optimization algorithms
Zhou et al. (2022)	2022	Clustering-aided reinforcement learning	Introduces a novel approach for resource allocation in UAV-assisted networks	Evaluate the performance and scalability of reinforcement learning in

				practical scenarios
Pogaku et al. (2022)	2022	Survey and optimization analysis	Investigates optimization techniques for UAV-assisted reconfigurable intelligent surface (RIS) systems	Explore practical deployment scenarios and performance evaluation of RIS-assisted UAV systems
Zhang et al. (2021)	2021	Trajectory optimization	Focuses on energy-efficient trajectory design for UAV-assisted IoT networks	Investigate the impact of dynamic environmental factors on trajectory optimization
Liu et al. (2022)	2022	Optimization algorithm development	Develops a fair energy-efficient resource optimization scheme for multi-UAV enabled IoT	Investigate methods for achieving fairness in resource allocation
Hashesh et al. (2022)	2022	Analysis and discussion	Explores challenges and future directions of AI-enabled UAV communications	Investigate practical applications of AI in UAV communications
Qi et al. (2022)	2022	Resource allocation optimization	Focuses on energy-efficient resource allocation for UAV-assisted vehicular networks	Investigate dynamic resource allocation strategies
Gu et al. (2021)	2021	Security offloading optimization	Addresses security concerns in UAV-aided edge computing networks	Explore advanced security mechanisms and their impact on system performance
Fu et al. (2022)	2022	Over-the-air computation optimization	Investigates UAV-assisted multi-cluster over-the-air computation	Explore scalability and efficiency of over-the-air computation
Wang et al. (2022)	2022	Power allocation and trajectory optimization	Develops energy-efficient and secure power allocation and trajectory optimization for UAV-enabled data collection	Investigate the impact of security constraints on optimization algorithms
Liu et al. (2022)	2022	Computation offloading strategy development	Proposes an energy-efficient computation offloading strategy in UAV-aided V2X network with integrated sensing and communication	Investigate dynamic offloading strategies for varying network conditions
Khan et al. (2022)	2022	Dynamic positioning and path planning optimization	Develops dynamic positioning and energy-efficient path planning strategies for disaster scenarios in 5G-assisted multi-UAV environments	Investigate the robustness of proposed strategies in real-world disaster scenarios
Chen and Tang (2022)	2022	Optimization algorithm development	Investigates UAV-assisted data collection for wireless sensor networks with dynamic working modes	Explore adaptive optimization strategies for dynamic network conditions
Mu and Sun (2022)	2022	Trajectory design optimization	Proposes trajectory design for multi-UAV-aided wireless power transfer	Investigate the scalability and efficiency of trajectory design in large-scale systems
Shi et al.	2021	Access scheme	Develops an energy-efficient	Investigate the practical

(2021)		optimization	decoupled access scheme for cellular-enabled UAV communication systems	deployment and performance of decoupled access schemes

III. RESEARCH GAP

The systematic literature review reveals several research gaps in the current body of literature on unmanned aerial vehicle (UAV)-assisted wireless networks. Firstly, while there is a comprehensive overview of advancements, challenges, and solutions in UAV-assisted wireless networks, there is a notable gap in the exploration of novel solutions to overcome identified challenges, such as energy limitation and data security. Secondly, although resource optimization techniques in UAV-assisted networks have been extensively surveyed, there is a lack of investigation into emerging optimization methods and their applicability in real-world scenarios. Thirdly, while deep learning-based energy optimization methods show promise for improving energy efficiency in UAV-aided communications, there is a need to explore the scalability and adaptability of these models to dynamic network conditions. Additionally, the impact of imperfect channel state information (CSI) on energy-efficient transmission design in UAV networks remains underexplored, highlighting a gap in research on mitigating the effects of imperfect CSI. Furthermore, while there is growing interest in intelligent reflecting surface (IRS)-assisted UAV communications, practical implementations and performance evaluations of IRS-assisted systems are lacking, indicating a gap in translating theoretical concepts into real-world applications. Moreover, research on energy efficiency optimization for UAV-assisted wireless powered systems lacks investigation into the real-world implementation and performance of optimization algorithms. Additionally, while reinforcement learning-based resource allocation methods have been proposed for UAV-assisted networks, their performance and scalability in practical scenarios require further evaluation. Furthermore, optimization techniques for UAV-assisted reconfigurable intelligent surface (RIS) systems have been surveyed, but there is a need to explore practical deployment scenarios and performance evaluation of RIS-assisted UAV systems. Moreover, the impact of dynamic environmental factors on trajectory optimization for UAV-assisted IoT networks is underexplored, highlighting a gap in research on adapting trajectory optimization to dynamic conditions. Lastly, while there is ongoing research on energy-efficient resource allocation for UAV-assisted vehicular networks, further investigation into dynamic resource allocation strategies is needed to address varying network conditions effectively.

IV. METHODOLOGY FOR SOLVING ISSUES

1. **Advanced Optimization Techniques**: Utilize advanced optimization algorithms, such as convex optimization, mixed-integer nonlinear programming (MINLP), and fractional programming, to develop efficient resource allocation and trajectory optimization solutions. These methods can address challenges related to energy efficiency, spectrum allocation, and trajectory planning in UAV networks.

2. **Machine Learning and Deep Learning**: Explore the potential of machine learning (ML) and deep learning (DL) techniques to develop adaptive and scalable solutions for energy optimization, resource allocation, and channel estimation in UAV-assisted networks. ML models can learn from historical data to make intelligent decisions and adapt to changing network conditions.

3. **Simulation and Performance Evaluation**: Conduct extensive simulations and performance evaluations using realistic network models and scenarios to assess the effectiveness and scalability of proposed solutions. This involves using network simulators like ns-3 or MATLAB to validate the performance of optimization algorithms and communication protocols under various conditions.

4. **Experimental Prototyping**: Implement real-world prototypes and testbeds to validate the feasibility and practicality of proposed solutions in UAV-assisted wireless networks. Experimental validation can provide valuable insights into the performance of algorithms and protocols in real-world environments, considering factors like hardware limitations and environmental conditions.

5. **Integration of Emerging Technologies**: Explore the integration of emerging technologies, such as reconfigurable intelligent surfaces (RIS), intelligent reflecting surfaces (IRS), and edge computing, to enhance the efficiency and reliability of UAV-assisted networks. These technologies can optimize signal propagation, mitigate interference, and improve network capacity and coverage.

6. **Collaborative Research and Field Trials**: Foster collaboration between academia, industry, and government agencies to conduct field trials and pilot deployments of UAV-assisted network solutions. Collaborative research efforts can facilitate technology transfer, standardization, and regulatory compliance, paving the way for the practical implementation of UAV-based communication systems.

V. CONCLUSION

This research paper presents a comprehensive overview and analysis of the advancements, challenges, and solutions in UAV-assisted wireless networks. Through a systematic literature review, we have identified key research gaps and formulated methodologies for addressing them. By leveraging advanced optimization techniques, machine learning algorithms, simulation and performance evaluation, experimental prototyping, integration of emerging technologies, and collaborative research efforts, significant progress can be made in overcoming the challenges faced by UAV networks. These methodologies offer promising avenues for improving energy efficiency, resource allocation, trajectory optimization, and overall performance of UAV-assisted communication systems. By embracing interdisciplinary approaches and fostering collaboration between academia, industry, and government agencies, we can drive innovation and accelerate the deployment of UAV-based network solutions. Overall, this research provides valuable insights and guidance for researchers, practitioners, and policymakers working in the field of UAV-assisted wireless networks.

REFERENCE

1. Dai, M., Huang, N., Wu, Y., Gao, J. and Su, Z., 2022. Unmanned-aerial-vehicle-assisted wireless networks: Advancements,challenges,andsolutions.*IEEEInternetofThingsJournal*,*10*(5),pp.4117-4147.
2. Basharat, M., Naeem, M., Qadir, Z. and Anpalagan, A., 2022. Resource optimization in UAV-assisted wireless networks—A comprehensive survey. *Transactions on Emerging Telecommunications Technologies*, *33*(7), p.e4464.
3. Chen, C., Xiang, J., Ye, Z., Yan, W., Wang, S., Wang, Z., Chen, P. and Xiao, M., 2022. Deep learning-based energy optimization for edge device in UAV-aided communications. Drones, 6(6), p.139.
4. AlJubayrin, S., Al-Wesabi, F.N., Alsolai, H., Duhayyim, M.A., Nour, M.K., Khan, W.U., Mahmood, A., Rabie, K. and Shongwe, T., 2022. Energy efficient transmission design for NOMA backscatter-aided UAV networks with imperfect CSI. *Drones*, *6*(8), p.190.
5. Park, K.W., Kim, H.M. and Shin, O.S., 2022. A survey on intelligent-reflecting-surface-assisted UAV communications. *Energies*, *15*(14), p.5143.
6. Mohsan, S.A.H., Khan, M.A., Alsharif, M.H., Uthansakul, P. and Solyman, A.A., 2022. Intelligent reflecting surfaces assisted UAV communications for massive networks: current trends, challenges, and research directions. *Sensors*, *22*(14), p.5278.
7. Ma, X., Na, Z., Lin, B. and Liu, L., 2022. Energy efficiency optimization of uav-assisted wireless powered systems for dependable data collections in internet of things. *IEEE Transactions on Reliability*.
8. Zhou, S., Cheng, Y., Lei, X., Peng, Q., Wang, J. and Li, S., 2022. Resource allocation in UAV-assisted networks: A clustering-aided reinforcement learning approach. *IEEE Transactions on Vehicular Technology*, *71*(11), pp.12088-12103.
9. Pogaku, A.C., Do, D.T., Lee, B.M. and Nguyen, N.D., 2022. UAV-assisted RIS for future wireless communications: A survey on optimization and performance analysis. IEEE Access, 10, pp.16320-16336.

10. Zhang, L., Celik, A., Dang, S. and Shihada, B., 2021. Energy-efficient trajectory optimization for UAV-assisted IoT networks. *IEEE Transactions on Mobile Computing*, *21*(12), pp.4323-4337.

11. Liu, X., Liu, Z., Lai, B., Peng, B. and Durrani, T.S., 2022. Fair energy-efficient resource optimization for multi-UAV enabled Internet of Things. *IEEE Transactions on Vehicular Technology*, *72*(3), pp.3962-3972.

12. Hashesh, A.O., Hashima, S., Zaki, R.M., Fouda, M.M., Hatano, K. and Eldien, A.S.T., 2022. AI-enabled UAV communications: Challenges and future directions. *IEEE Access*, *10*, pp.92048-92066.

13. Qi, W., Song, Q., Guo, L. and Jamalipour, A., 2022. Energy-efficient resource allocation for UAV-assisted vehicular networks with spectrum sharing. *IEEE Transactions on Vehicular Technology*, *71*(7), pp.7691-7702.

14. Gu, X., Zhang, G., Wang, M., Duan, W., Wen, M. and Ho, P.H., 2021. UAV-aided energy-efficient edge computing networks: Security offloading optimization. *IEEE Internet of Things Journal*, *9*(6), pp.4245-4258.

15. Fu, M., Zhou, Y., Shi, Y., Jiang, C. and Zhang, W., 2022. UAV-assisted multi-cluster over-the-air computation. *IEEE Transactions on Wireless Communications*.

16. Wang, D., Yang, Y., Li, X., Wang, C., Liu, F. and Hu, Y., 2022. Energy-Efficient and Secure Power Allocation and Trajectory Optimization for UAV-Enabled Data Collection in Wireless Sensor Networks. *Journal of Communications and Information Networks*, *7*(3), pp.333-348.

17. Liu, Q., Liang, H., Luo, R. and Liu, Q., 2022. Energy-efficiency computation offloading strategy in UAV aided V2X network with integrated sensing and communication. *IEEE Open Journal of the Communications Society*, *3*, pp.1337-1346.

18. Khan, A., Zhang, J., Ahmad, S., Memon, S., Qureshi, H.A. and Ishfaq, M., 2022. Dynamic positioning and energy-efficient path planning for disaster scenarios in 5G-assisted multi-UAV environments. *Electronics*, *11*(14), p. 2184-2197.

19. Chen, J. and Tang, J., 2022. UAV-assisted data collection for wireless sensor networks with dynamic working modes. *Digital Communications and Networks*.

20. Mu, J. and Sun, Z., 2022. Trajectory design for multi-UAV-aided wireless power transfer toward future wireless systems. *Sensors*, *22*(18), p.6859.

21. Shi, Y., Alsusa, E. and Baidas, M.W., 2021. Energy-efficient decoupled access scheme for cellular-enabled UAV communication systems. *IEEE Systems Journal*, *16*(1), pp.701-712.