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UAV-Assisted RIS for Future Wireless Communications: A Survey on Optimization and Performance Analysis

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ABSTRACT Reconfigurable intelligent surfaces (RIS), a device made of low-cost meta-surfaces that can reflect or refract the signals in the desired manner, have the immense ability to enhance the data transmission from the sender to the receiver. The concept of RIS is inspired by a smart radio environment or programmable radio environment. The introduction of this device in wireless communications aids in reducing the hardware requirements, energy consumption, and signal processing complexity. The integration of this device with various emerging technologies such as multiple-input multiple-output (MIMO) systems, non-orthogonal multiple access (NOMA) technique, physical layer security, etc., has increased its potentiality in terms of performance enhancement. One such integration could be studied, i.e. RIS-assisted unmanned aerial vehicles (UAVs). The UAVs exhibit aiding capability in various services to our society such as real-time data collection, traffic monitoring, military operations & surveillance, medical assistance, and goods delivery. Despite the positive appeal, the UAV has its limitations such as fuel efficacy, environment disturbances, limited network capability, etc. Considering these scenarios, the RIS can provide assistance to UAVs to enhance their performance when integrated. There is a limited number of articles and researches that consider UAV-assisted RIS systems. This article provides a detailed survey on RIS-assisted UAV systems considering multiple contexts such as optimization, communication techniques, deep reinforcement learning, secrecy performance, efficiency enhancement, and the internet of things. Finally, we draw attention to the open challenges and possible future directions of UAV-assisted RIS systems in phase shifting, channel modeling, energy efficacy, and federated learning.

INDEX TERMS Reconfigurable intelligent surface, UAV communications, NOMA, mmWave and THz communications, physical layer security (PLS), deep reinforcement learning (DRL), Internet of Things (IoT), efficiency enhancement.

I. INTRODUCTION

Reconfigurable intelligent surfaces (RIS) is a next-generation technology made of low-cost meta-surfaces that possesses the ability to manipulate the propagation of an electromagnetic signal by either reflecting or refracting the signal. The recent evolution of smart radio environments, which are supposed to control the radio signal or electromagnetic signal operations in its environment, has initiated a major discussion in the research about its involvements in the 5G and 6G wireless networks. The concept of RIS a.k.a. IRS stands closer to the working of SRE. To make it more clear, each meta-surface on the RIS device acts as a human-made reflective and refractive radio mirror for the impinging radio waves. A similar operation is also performed by relays but with different functionality. In relays, the radio signals are boosted with the extra power to make the signals transmit for a long distance. Whereas, RIS is a passive device that performs reflecting

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functionality instead of boosting the signal. The RIS proves to be the most promising technology to enhance the efficiency of data transmission. In the last two years, a lot of research has been done to introduce RIS technology as an aid to 5G and 6G wireless communication networks. The meta-surfaces have the ability to control the phase shift, frequency, amplitude of radio waves and suppress the signal power, which helps significantly in secure data transmission in presence of an eavesdropper [1], [2]. There are some real-world prototypes developed by the researchers at the Massachusetts Institute of Technology namely RFocus [3] and NTT Docomo meta-surface [4]. These meta-surfaces are thin transparent or semi-transparent materials that are easily deployable in any kind of environment, either indoor or outdoor. This helps the communication networks to eliminate the requirement of LOS between the sender and receiver, aids the signal to be transmitted in good quality, even in the presence of obstacles that diminish the quality of the signal.

RIS provides a full-duplex communication mode and does not encourage the creation or amplification of the noise signal [5]. In [6], the authors have proposed an active and passive beamforming approach at the access point and RIS, respectively, to enhance the spectral and energy performance of the proposed system, along with optimizing the transmit power. Similarly in [7], beamforming optimization basing phase-shift model is proposed. In this model, the transmit power at the access point is optimized by jointly designing access point transmit beamforming and RIS reflect beamforming. In [8], the authors have proposed integration of cognitive Radio networks with IRS to enhance the performance of the secondary network and to eliminate the interference caused to primary users in the network. Similarly in [9], the authors have proposed a NOMA-assisted RIS system to maximize the throughput by optimizing the power allocation and reflection coefficients. In [10], the authors have proposed an efficient algorithm developed basing AO, s-procedure, and SCA techniques to overcome the secrecy issue and data leakage to the eavesdropper present in the network. In [11], the authors have proposed usage of RIS with beyond 5G networks in IoT systems. Extensive simulations were performed to analyze the performance of the proposed framework and parameters impact. The authors have also proposed a low-complexity algorithm to reduce the total energy consumption.

UAV systems have gained significant attention over the last decade because of their ability to hover across the area, easy deployment, and being affordable [12]. UAV's are mostly being used for real-time data collection, traffic monitoring, surveillance, goods delivery, precision agriculture, and rescue operations. UAVs, also called drones, can travel to areas that lack infrastructure and are impossible to travel for a human. In the initial deployment, the UAV worked alone without any integration of communication techniques or IoT technology. As the requirements of humans began to rise, the UAV has been developed for various purposes as mentioned above. With all these implementations, the UAV has been integrated with various technologies for data transmission using wireless networks. To enhance the data transmission significantly from the UAV in outdoor scenarios, various communication technologies and techniques were applied such as NOMA, mmWave, THz communications. Whereas for indoor purposes, Bluetooth, P2P communications, mesh network, and wireless sensor network have been efficient options. The selection of either centralized or decentralized networks for data transmission and communication would play a major role as mentioned in [13]. It is suggested that a hybrid of two types will help increase operational efficiency and drones learn from each other. It is the case that, the speed of travel and altitude of the UAV will affect the data transmission with an increased Doppler effect. In [14], it is suggested that the selection of appropriate communication technology would be helpful to reduce its effect. The applications of UAVs with various wireless networks and IoT are mentioned in [15]–[17]. Meanwhile, identifying the ease in deploying the UAVs, the cellular network operators have proposed its utilization in the field to enhance the network connectivity and area coverage during the time of peak loads. As mentioned, the UAV has the potential to adjust its location to enhance the communication links between a wide number of IoT devices. Understanding the functionality of UAVs, may not be helpful in assisting a few particular locations like urban areas where LOS communication is not possible.

As discussed above UAV provides immense advantages because of coverage area, data collection, connectivity among devices, easy deployment, and precision monitoring. Whereas, RIS being a different technology provides major addition to any network or device it associates with like increasing the signal capacity and channel gain, low-cost, and easily deployable on any kind of surface. Most importantly, RIS enables massive device connectivity. In a Multiple user RIS-assisted MISO system, the phase shift at RIS and power allocation at the transmitter are efficiently optimized to achieve sum-rate and EE [18]–[20]. In a similar system in presence of eavesdroppers, at [21], the secrecy rate of the transmission has been enhanced. A DRL-based algorithm was proposed in [22] for RIS-assisted multiple user MISO systems to enhance the beamforming and phase shift at BS and RIS, respectively. A RIS-assisted cooperative NOMA system was suggested in [23], to enhance the performance of weak users by optimizing the various parameters such as beamforming and power allocation. In [24], the authors have focused on analyzing and enhancing the performance of RIS-assisted NOMA system in presence of hardware impairments and efficiently optimized the power allocation, transmit SNR and number of meta-surfaces at RIS, whereas for a similar system, authors in [25] and [26] have considered imperfect CSI. Energy-efficient UAV communications with ground users were studied in [27], whereas in [28], analysis of efficient coverage probability for a UAV to the ground user was studied. As discussed above, UAV provides immense flexibility in deployment, coverage area, throughput, and energy efficacy, the effective utilization of UAV-enabled

TABLE 1. List of abbreviations.

Abbreviation	Meaning
3GPP	3rd Generation Partnership Project
5G	5th Generation
6G	6th Generation
AF	Amplify and Forward
AO	Alternating Optimization
AOI	Age of Information
BCD	Block Coordinate Descent
BER	Bit Error Rate
BS	Base Station
CARLO	Capacity increase through trajectory and placement optimizations
CLT	Central Limit Theorem
CSI	Channel State Information
DBS	Drone base station
DQN	Deep Q-Network
D-DQN	Decaying Deep Q-Network
DRL	Deep Reinforcement Learning
EE	Energy Efficiency
EC	Ergodic Capacity
FDMA	Frequency Division Multiple Access
FSO	Free-Space Optical
HetNets	Heterogenous Networks
IoT	Internet-of-Things
IRS	Intelligent Reflecting Surfaces
LOS	Line of Sight
MISO	Multiple Input Single Output
MIMO	Multiple Input Multiple Output
mmWave	Millimeter-Wave
MEC	Mobile Edge Computing
NOMA	Non-Orthogonal Multiple Access
NLOS	No-Line-of-Sight
OMA	Orthogonal Multiple Access
OP	Outage Probability
OFDMA	Orthogonal Frequency Division Multiple Access
P2P	Point-to-Point
PLS	Physical Layer Security
QoS	Quality-of-Service
RIS	Reconfigurable Intelligent Surfaces
SCA	Successive Convex Approximation
SDR	Semidefinite Relaxation
SE	Spectral Efficiency
SER	Symbol Error Rate
SNR	Singal to Noise Ratio
SRE	Smart Radio Environment
THz	Tera-Hertz
TDMA	Time Division Multiple Access
TDDRL	Twin-Deep Deterministic Policy Gradient Deep Reinforcement Learning
UAV	Unmanned Aerial Vehicles
URLLC	Ultra Reliable and Low Latency
VLC	Visible Light Communication

communication networks were efficiently enhanced by optimizing various parameters, such as trajectory [27], [29]–[31], placement optimization [32], [33], bandwidth and power allocation [34]. In [35],the authors have developed an algorithm named CARLO, to decrease the energy consumption while the drones are in working placement. The considered drones are goods delivering drones that are enabled to optimize their placement and trajectory, thereby reducing the energy consumption and also beating the deadline for the delivery. Whereas in [36], the authors have considered DBSs that are randomly hovering in the network. The main objective of this model is the immediate teleportation of DBSs over the head of users. Considering LOS and NLOS scenarios, the coverage probability and area spectral efficiency are derived for different altitudes.

A. RELATED WORKS

The integration between RIS and UAV creates an innovative space for enhancing the 5G networks and beyond to provide enormous services to the users [37], [38]. From the aforementioned advances of two techniques, UAVs rely on their high mobility to provide LoS dominant transmission links with the ground users, while RISs smartly adjust their reflecting elements can achieve passive beamforming. For instance, UAV can be implemented as a mobile base station to communicate with the ground devices with the help of a RIS or multiple RISs. Moreover, the issues like LOS and energy consumption at UAV can be mitigated along with improving the quality of wireless channels by integrating RIS during the communication. Research on the respective integration has shown the numerical results that are convincing, for real-world implementation, in various applications such as energy optimization and PLS. In particular, a UAV equipped with a RIS was leveraged to achieve secure communications. In the scenario of the deep learning-based algorithm, one can design RIS's passive beamforming and the UAV's trajectory to obtain the optimal values of data rate and weighted fairness. Single antenna UAV devices were studied based on resource allocation and trajectory of the system in [39] and [40]. The performance of a device can be significantly enhanced by installing multiple antennas [41], but increasing the number of antennas in UAVs gives birth to new constraints such as an increase in weight, size, and power consumption. In contrast, the RIS has the potential to mimic the MIMO ability of multiple antennas with its inexpensive meta-surfaces [42], [43]. Therefore, the RIS has the ability to achieve higher gain by adjusting the phase shift of the meta-surfaces, eliminating the requirement of deploying multiple antennas into UAVs. The integration of RIS into the UAV system also helps to minimize the trajectory of the UAV as the user nearer to RIS can attain the signal from RIS than the UAV traveling from one point to another. The RIS, with help of the UAV, will be able to reflect the signals by beamforming to enhance the signal transmission to the far users who can receive it with an acceptable data rate.

B. STRUCTURE OF PAPER

This survey paper is organized as shown in Fig 1. Section 2 provides the motivation for this survey paper and an explanation of related survey papers, which are briefly summarized in Table 2. Section 3 contains various subsections of important applications in the UAV-assisted RIS system. The subsections are optimization for UAV-RIS, efficiency enhancement, UAV-RIS with secrecy performance, UAV-RIS with emerging communications, deep reinforcement learning in UAV-RIS, and UAV-RIS based internet-of-things. Each subsection begins with an introduction to each application or technique, moving to state-of-the-art technologies and concluding with summarizing the studies and providing the insights obtained. Section 4 provides a brief summary of overall studies from all the articles that are studied in the previous sections. Section 5 provides a detailed explanation of open challenges and future research directions which are energy consumption, federated learning, channel modeling and estimation, and phase shift controller at UAV and RIS. Finally, in section 6, we conclude the survey paper based on the learning and insights obtained from the study.

II. MOTIVATION

The recent studies from [44]–[47] have provided a detailed survey on the implementation of RIS technology with various emerging technologies and applications such as PLS, and deep learning [44], [45]. In [46] and [47], the authors focused on analyzing the parameters such as reliability, secure transmission, channel estimation, and power optimization importantly, providing a detailed survey on the performance of the system with various optimization techniques. In [48], the authors have provided a brief summary of the UAV-assisted RIS system in a single subsection discussing its efficient results in the field. Whereas in [49], a detailed survey of the performance of a UAV with various communication and networking technologies is provided. In [50], the implementation of UAV with IoT technologies with various categorizations such as MEC, communications data transmission services are explained. In [12], the authors have surveyed the requirements of UAVs such as connectivity, adaptability, privacy, security, and safety. In [51], the author has surveyed the implementation of UAVs with relaying networks. As we know, energy consumption plays a major role in either enhancing or diminishing the performance of a UAV. In [52] the authors have provided a detailed survey on the realistic assumption of deploying UAV and explained various energy-consuming models. Authors in [53] have provided a detailed explanation of integrating the RIS and UAV with its applications and challenges. However, to the best of our knowledge, there is no dedicated paper that provides a detailed survey on the UAV integrated RIS systems. But the studies prove that combining these two technologies will pave the way for enhanced communications in the future. This paper is motivated to explore the benefits and key challenges to be addressed on integrating UAV with RIS in various scenarios, shown in Fig. 2, Fig. 3, Fig. 4. These promising applications can develop optimization to improve system performance of current systems which is more advanced compared to the numerous recent studies. Compared to other survey and application papers, which only deal with the application of stand-alone systems such as either RIS or UAV, our survey paper provided a detailed report specifically focused on UAV-assisted RIS. Because, the study on this field indicates the importance of integrating the RIS device with UAV, which acts as a tool to enhance various functions of the whole system, bringing better performance for the stand-alone devices. The findings of related papers just will be discussed later in the following sections. Table 2 provides a brief summary of the relative survey papers we have discussed above.

In the following sections, the paper is aimed to provide a survey on UAV-assisted RIS communications in high potential areas such as secrecy performance, deep reinforcement networks, communication techniques, parameter optimization, internet of things, and efficiency enhancement. As demonstrated in Figure. 1, we focus on the different scenarios such as UAV-mounted RIS, UAV as the base station, and RIS installed on walls in indoor and outdoor environments. Our survey will provide a technical view to the readers about various optimizations, algorithms, and techniques that are used to enhance the performance of proposed systems. To ease the understanding of the paper, we have briefly summarized our studies in the form of tables. Table 1 provides the entire list of abbreviations used in the paper. Meanwhile, table 2 explains the contributions of other survey and applications papers in the respective and relative fields. Table 3-8 provides a brief summary of the survey papers discussed in the respective subsections. After surveying the papers in detail, we came to a conclusion that in almost every paper, the authors have focussed on finding a solution for one particular problem by optimizing various parameters such as UAV velocity, altitude, mobility, RIS phase shift, user allocations, beamforming, etc., and using an optimal technique to achieve the solution. Therefore, the tables in each section will briefly provide the above-mentioned details to ease the understanding for the readers. Whereas, Table 9 provides a brief summary to understand the overall discussion of this survey article and papers referred to that particular context under different performance metrics such as energy efficiency, performance rate, and reduced latency. This is the first paper dedicated to writing a survey on UAV-assisted RIS systems and we have primarily focused on all the articles that provide a major contribution to the field.

III. UAV-ASSISTED RIS SYSTEM WITH EMERGING TECHNOLOGIES

A. OPTIMIZATION FOR UAV-RIS

There are many articles that discuss the optimization of UAV parameters which help the device to elevate the performance. The overall performance of the UAV depends on weight, power consumption, and trajectory. Therefore, optimizing these parameters provides a significant gain in the performance of the system. Similarly, the phase shift at RIS plays an important role in enhancing the communication between the source and destination. So it is important for us to identify the particular parameter that helps to increase the performance of the system and optimize it. Therefore, in this subsection, we review different optimized parameters and techniques at UAV and RIS that help in improvising the performance of the system. Table 3 provides a brief summary of the discussions below.

In [54], the authors have investigated a RIS system assisted by multiple UAVs in the presence of NOMA communications

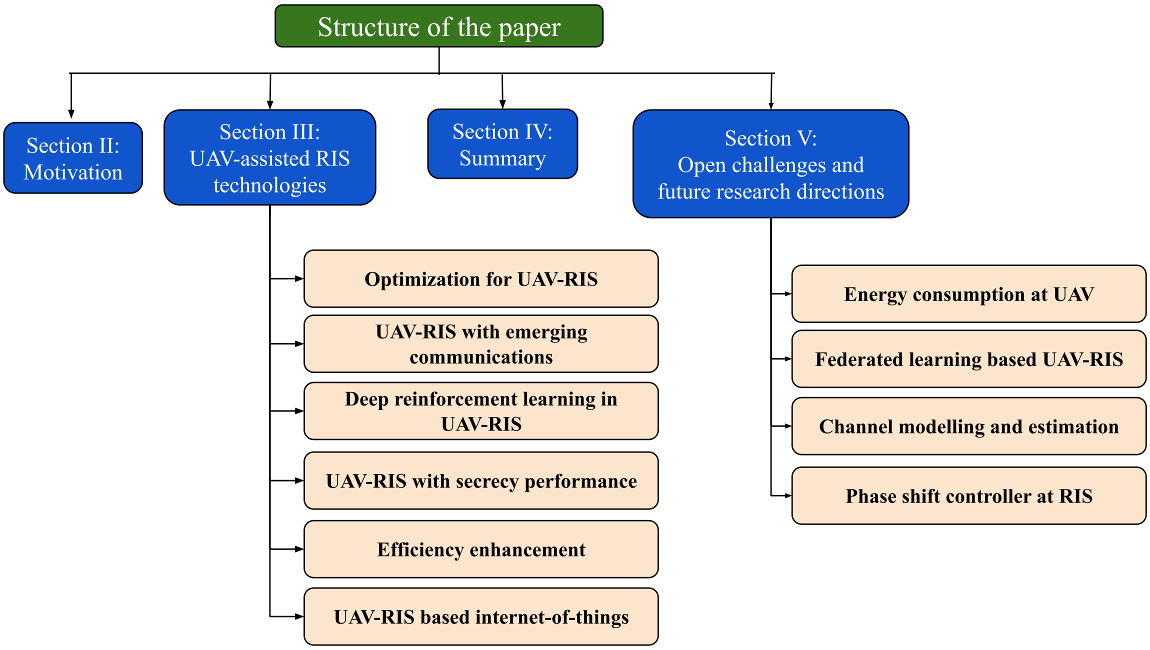

FIGURE 1. Organization of this article.

TABLE 2. Contributions of recent survey articles on UAV and RIS.

Reference	Contribution
[44]	Explores the performance of RIS in PLS under different performance metrics and antenna classification
[45]	Implementation of deep learning techniques with RIS assisted Wireless networks
[46]	Discusses RIS performance in implementation with wireless networks with various optimization techniques at RIS and in the network
[47]	RIS-assisted THz communications and studies on implementing it with 6G networks
[48]	Survey on state-of-the-art technologies of RIS and its performance analysis
[49]	Insights and challenges on the performance of UAV assisted communication networks
[50]	Integration of UAV with IoT presented in various domains
[12]	UAV networks for enhancing the adaptability, privacy, secrecy, and scalability
[51]	Survey on UAV-assisted relaying networks with state-of-the-art technologies
Our paper	Survey on implementing the UAV-assisted RIS system in various optimization techniques and emerging technologies

networks with multiple user clusters. Their approach has been interesting since they have mounted the base station to the UAV, which enables it to be a mobile base station that transmits data where physical installation of the base station is not possible. The authors have proposed a BCD algorithm to maximize the sum rate of the transmission network. The primary problem was divided into three sub-problems including UAV placement, NOMA decoding order and IRS reflection matrix design. The authors have proposed joint optimization of these problems utilizing the SCA technique. The simulations were performed based on the BCD algorithm convergence and the optimal placement of the UAV. As the simulations demonstrated, the proposed BCD algorithm required a higher number of iterations for the increased number of meta-surfaces. The performance of the proposed model was also analyzed in comparison to traditional benchmark schemes such as OMA and IF. The simulations clearly demonstrate that the height of the UAV and the distance between the two UAVs can reduce the interference significantly. The system has achieved higher sum rates than the benchmark schemes in existence. The integration of RIS with UAV has increased the performance gain by enhancing the channel link qualities and eliminating the interference between the two UAVs. In [55], the authors have studied a UAV-assisted RIS radio system where the UAV aids the RIS to reflect its signals to the base station during the uplink transmission. The authors have considered minimizing the BER by proposing a relaxation-based algorithm in which joint optimization of UAV trajectory, RIS phase shift, and scheduling. This is algorithm 1. Similarly, to minimize the maximum BER to achieve BER fairness among the users, the authors have proposed a penalty-based algorithm with joint

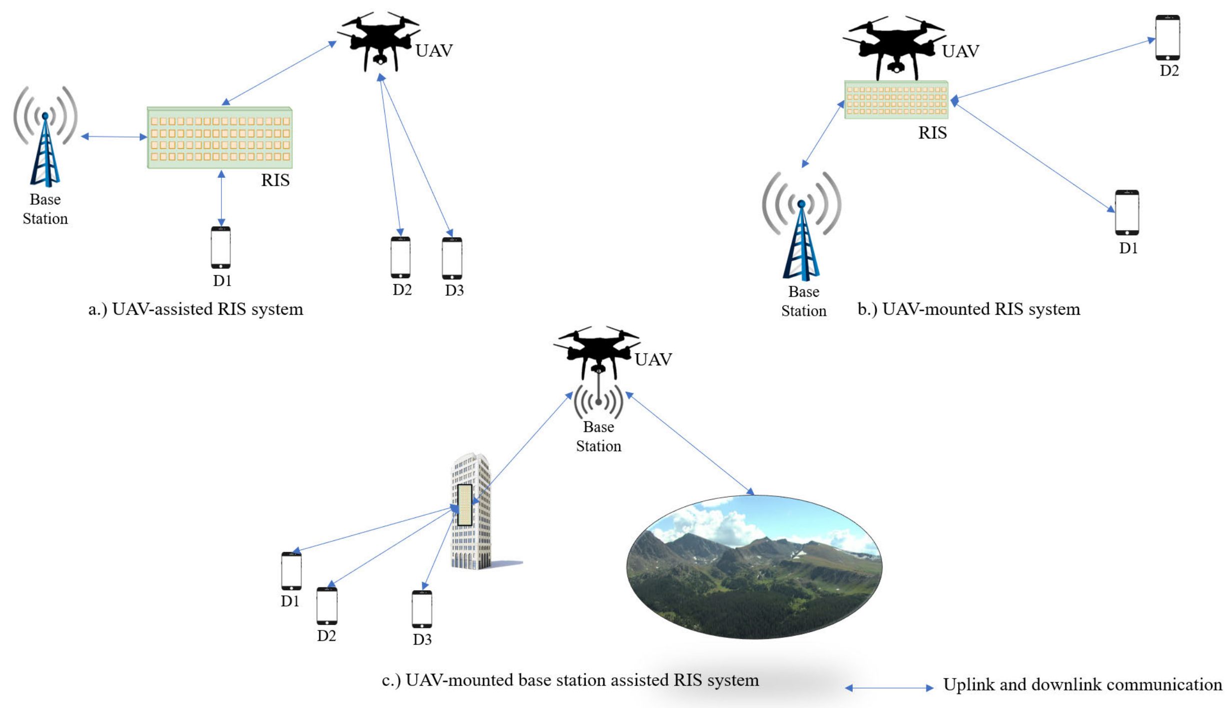

FIGURE 2. **Various models of UAV-assisting RIS for efficient communications.**

optimization of UAV trajectory, IRS phase shift, and scheduling, which is algorithm 2. The simulations were performed for both the algorithm to analyze the system performance in various parameters such as convergence behavior, optimal UAV trajectory, and speed, RIS scheduling an average weighted sum of BER. The simulations have demonstrated that optimizing UAV trajectory and RIS phase shift can significantly enhance the performance of the system.

In [56], the authors have considered a simple UAV-RIS aided NOMA system to perform the downlink communication to the two users on the ground. The authors' primary goal was to maximize the rates for the near user while maintaining a good target rate for the far user to provide quality signal strength. The authors have proposed optimization of horizontal UAV position, beamforming vectors at the base station and phase shifting at the RIS to achieve better target rates for users. The authors proposed two algorithms to perform optimal phase shift at RIS. In particular, SDR based iterative algorithm that can achieve elevated data rates but with higher complexity and an SCA technique that has lower complexity. The simulations provide that the proposed SDR algorithm and the presence of RIS have improved the data rate performance significantly. The simulations also provide the proposed model performance with OFDMA The obtained results show that implementation of RIS with OFDMA can only enhance the performance of the strong users significantly, whereas, in NOMA, superior performance was demonstrated for both the users. Also, the increase in the number of the elements at RIS has not only enhanced the performance of the proposed system with the developed algorithm but also proved to be one of the great energy-saving schemas. In [57], the UAV acts as a MEC server to provide computational services to the ground users (GTs). This UAV was considered to be integrated with RIS to achieve improved performance on mobile computing. This article studies the joint optimization of UAV trajectory, task off-loading, and phase-shift design to enhance the energy efficiency of the proposed UAV-RIS system. An SCA-based algorithm was proposed to perform the optimization. The obtained simulations, which demonstrate the performance of UAV trajectory, energy consumption, and data transmission rate, in UAV-GT pairs, have the highest data transmission rates in comparison to the existing benchmark models, which generally do not consider dynamic off-loading of GT tasks.

In [58], the authors have considered a simple UAV-RIS system with NLOS communication between the RIS and the user on the ground. The authors have focused on maximizing the average achievable rate of the system by combining optimizing the UAV trajectory and passive beamforming at RIS with an SCA-based algorithm. The simulation results demonstrated that the involvement of RIS significantly enhances the signal quality in UAV networks. The authors, along with their proposed algorithm, compared the results with other three benchmark algorithms including UAV trajectory without passive beamforming and heuristic trajectory with and without passive beamforming. The simulations based on trajectory show that the proposed algorithm has better efficiency in balancing the channel gain links, compared to other algorithms,

TABLE 3. Summary of UAV-RIS optimization.

Reference	Problem	Optimised parameters	Technique
[54]	Maximising the sum-rate	1. UAV Placement 2. Transmit power 3. RIS reflection matrix 4. NOMA decoding order	SCA technique and BCD algorithm
[55]	Minimising the BER	1. UAV trajectory 2. Phase shift of RIS	Penalty-based algorithm
[56]	Enhancing the target rates	1. Beamforming vectors at base station 2. Phase shift of RIS	SDR based iterative algorithm
[57]	Enhancing the energy efficiency	1. UAV trajectory 2. task-offloading 3. Phase shift of RIS	SCA-based algorithm
[58]	Maximising the average achievable rate	1. UAV trajectory 2. Passive beamforming at RIS	SCA-based algorithm
[59]	Maximising the sum-rate	1. UAV trajectory 2. Phase shift at RIS	Conjugate grading algorithm and alternating optimization algorithm

showing considerable performance improvement. In [59], the authors have considered a RIS-assisted UAV system with LoS channels suffering blocking. The authors have focused on maximizing the sum rate of the users by optimizing the UAV trajectory and phase shift at RIS in a multi-user environment. To achieve the required sum rate along with satisfying the trajectory and phase shift constraints, the authors have proposed two efficient algorithms including conjugate grading algorithm and alternating optimization algorithm. The authors have performed the simulation analysis in comparison with proposed algorithms, random scheme, and without RIS, for convergence behavior, performance comparison, and trajectory design. The manifested results show that the proposed scheme in the multi-user environment is efficient compared to other schemes.

Understanding the above studies, an overall view can be presented that optimization of a few parameters either at UAV or at RIS shows improved performance of the system. UAV might just be a tool to assist RIS in transmitting the radio signals, but the studies show that the placement, trajectory, and velocity of the UAV, when considered, play a major role in improving the efficiency, compared to the traditional systems. To our observation from the studies, in most of the cases, the phase shift optimization and effect of its error at RIS have been considered ideal. But few papers which consider the same have shown a significant effect on the numerical results either positively or negatively, depending on the system characteristics. Considering a non-ideal case in this scope could be possible future research.

B. EFFICIENCY ENHANCEMENT

The efficiency of any system plays a pivotal role as it becomes the key factor for the practical implementation of the system. The studies we have considered on UAV-assisted RIS systems are majorly considered efficient in terms of spectral, energy, error rate, and secrecy of the system. In the previous subsection, we have already seen the behavior of UAV-assisted RIS systems in PLS and secrecy efficiency. In the following studies, we see the remaining studies. Table 4 provides a brief summary of papers discussed in this subsection.

In [60], the authors have considered a downlink communication between the base station with multiple antennas and users with a single antenna. The system was assisted by a UAV to aid the cell-edge users and perform quality data transmission. In this system, the authors investigated the utilization of RIS mounted to a UAV to enhance energy efficiency. To obtain this, the authors considered optimizing the beamforming vectors in the base station and phase shifts at the RIS. To perform the optimization, an iterative algorithm is developed based on maximum radio transmission. The simulations were performed to analyze the energy consumption in AF relaying assisted UAV and RIS assisted UAV. With a sufficient increase in the number of meta-surfaces at RIS, the system can achieve 50 % more efficiency than the AF relaying method. The numerical results show that using the higher number of passive reflecting elements has led to efficient power consumption, meanwhile, the distance between the RIS, UAV, and users also play important role in achieving higher energy efficiency. A similar system with a similar goal was considered in [61] with NOMA to perform uplink data transmission. In this paper, the authors utilized minimum mean square error and semi-definite relaxation techniques to obtain a transmit beamforming and phase-shift matrix at BS and RIS respectively. This research adds support to the [60] mentioning that RIS provides enhanced efficiency in power consumption than relaying.

In [62], the authors have considered an integrated UAV-RIS system that can operate in three different modes such as UAV, RIS, and UAV-RIS. The authors have aimed to achieve and identify efficient spectral and energy-efficient relaying among the three modes. Closed-form expressions for OP, EC, and EE were derived for 3 different modes. In each mode, the authors have optimized respective parameters such as altitude in UAV, meta-surfaces count in RIS, and both in UAV-RIS to achieve efficient results. The authors have considered deriving the optimal solutions for the above-mentioned problems using quadratic transformations, which act as a tool for fractional programming. The extensive simulations of obtained expression manifested that both the altitude and meta-surfaces count play a major role in increasing the SE, while optimal mode selection is important for EE. As expected in the general scenario, the integrated model has outperformed the stand-alone mode in every possible simulation. Therefore, the simulation analysis was performed for RIS-only and UAV-only modes to identify the optimal mode for various aspects such as EE for power allocation, EE for height switching, and EE for LoS. In [63], the authors have proposed to develop optimal beamforming at the base station and UAV trajectory techniques for a UAV-RIS system as both parameters play a major role in improving SE and EE. The authors considered a scenario where one UAV is being assisted by multiple RISs devices installed in the outdoor environment. An efficient framework is proposed to individually optimize the active beamforming and trajectory at UAV, and passive beamforming at RIS. The authors have developed an SCA-based iterative low-complexity joint beamforming and trajectory algorithm to tackle the optimization challenge. The simulations were performed to analyze the proposed algorithm performance in various parameters such as received power and trajectories. The simulations show that the proposed algorithm has the upper hand compared to previous and traditional algorithms.

While the UAV assists the RIS in data transmission, most of the research papers are assumed to have perfect phase compensation at RIS. The imperfect phase compensation was taken into consideration by the authors in [64] and [65] for a UAV-assisted flying RIS system. The proposed system consists of multiple UAVs where one UAV is mounted with a RIS panel that communicates with other UAVs in the network. According to the authors, the phase errors are modeled by using the von Mises distribution. In [64], the authors have derived the closed-form expressions for SER and OP. It was manifested that the number of meta-surfaces used in the RIS plays a major role in the accurate estimation of imperfect phase and it is critical for the smaller number of meta-surfaces. In [65], the authors have investigated the performance of similar systems by computing the EC of the system. The authors have utilized the CLT to derive the expressions for surfaces greater than 4. The results from this research have manifested that SNR of the system plays a major role in system capacity degradation.

In [38], the authors have proposed a simple UAV-RIS system with the base station and user on the ground and RIS installed on a building wall. The UAV is considered to be a relay station and the system completes the data transmission in two stages. The first stage involves the data transmission between the base station, RIS, and UAV. Since the UAV is considered to be a relay station, in the second stage, the UAV performs decode-and-forward relaying protocol to transmit the information to the user. The authors have focussed on analyzing the system performance and developed closed-form expressions for the OP, BER, and average capacity of the system. The results showed that for an increase in the number of meta-surfaces, the BER can decrease and improve the coverage probability of the area. The usage of various techniques and optimizing the parameters have been efficient in enhancing the efficiency of the system in various fields such as capacity, energy, and spectrum usage of the system.

It is felt that the number of articles is quite sufficient to understand the behavior of the system when various parameters are optimized and few techniques are applied. Especially, in [60], [61], and [63], it is clearly shown that optimizing the beamforming vectors play an efficient role in enhancing the performance of the system. Whereas, only a few articles, including from topics, have considered this viewpoint. There is a huge number of articles that performed the research on optimizing the beamforming vectors either at the base station or RIS or UAV, in some cases. All these articles showed significant impact on various performances like secrecy gain, energy efficiency, etc. It is clearly understandable to the imagination that this technique could be more efficient. Therefore, one possible future research directive could be analyzing the effect of optimizing beamforming vectors in UAV-assisted RIS in different environments.

TABLE 4. Summary of UAV-RIS based efficiency enhancement.

Reference	Problem	Optimized Parameters	Technique
[60], [61]	Enhancing the total energy efficiency	1. Optimising beamforming vectors at base station 2. phase shifting at RIS and	Iterative algorithm based on maximum radio transmission, Minimum mean square error and semi-definite relaxation techniques
[62]	OP, EC and energy efficiency analysis in 3 different modes	1. Optimising UAV altitude 2. meta-surface count at RIS	Quadratic transformation using fractional programming
[63]	Improved spectral efficiency and energy efficiency	1. Optimal beamforming at base station 2. UAV trajectory	SCA-based low complexity iterative algorithm
[64], [65]	SER, OP and EC analysis	1. Co-efficient of imperfect phase compensation	Von Mises distribution
[38]	Analysis of OP, BER and average capacity	1. Modelling RIS-UAV 2. ground channels	Exact and Asymptotic Analysis using various mathematical functions

C. UAV-RIS WITH SECRECY PERFORMANCE

PLS has been an emerging technology since the security of the system has the utmost importance. The UAV has the potential to establish communication in any kind of open environment, but this ability also opens high-level concerns on the security of the system. Using the feature of generating random wireless channels, the UAV has shown the potentiality in safeguarding the data transmission. Meanwhile, in RIS, the numerical results of many studies have demonstrated that the RIS has the ability to elevate the performance gain and PLS, particularly when there is a huge number of meta-surfaces are employed. In this subsection, we present various studies performed on the secrecy performance of UAV-assisted RIS systems. Table 5 provides a brief summary of the studies presented below.

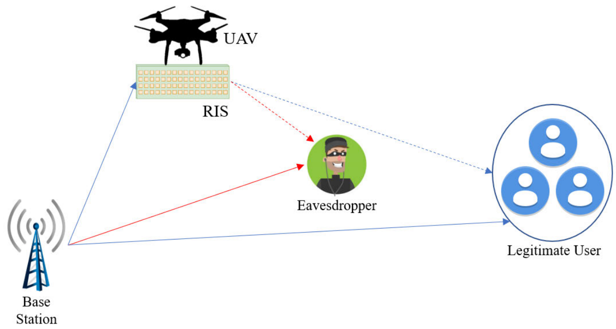

FIGURE 3. PLS in RIS-assisted UAV communications.

In [66], the authors have considered a RIS-assisted UAV system with a legitimate user and an eavesdropper. The authors aimed to maximize the secrecy rate by modifying various parameters at both UAV and RIS from a PLS perspective. Formulated non-convex problems are power control and trajectory at UAV and phase-shifting at RIS. The authors have derived the closed-form expressions for sum-rate and secrecy rate maximization by proposing an alternating algorithm. Simulations show a significant impact in the enhancement of secrecy rate with the integration of RIS. The placement of an optimal number of phase shifters, in this case, 64 and 256, has higher secrecy efficiency than choosing the random number of phase shifters. Also, the number of reflecting elements at the RIS has potentially increased the average secrecy rate of the system.

In [67], the authors have developed a UAV-mounted RIS model with the base station and users on the ground, performing the uplink data transmission in the network. The authors aimed to maximize the secrecy energy efficiency, the ratio of minimum secrecy rate to the power consumption. To achieve this, an iterative algorithm developed using SCA and alternating methods was utilized to jointly optimize the UAV trajectory, phase shift at RIS, user association, and transmit power. The achieved results illustrate that the proposed system and method can efficiently enhance the secure energy efficiency of the system by 38 % compared to the traditional no RIS schemes. In [68], the authors have developed a UAV-RIS system that utilizes TDMA to perform the uplink and downlink communication in two-time slots respectively. The research was focused on maximizing the secrecy rate of data transmission in presence of an eavesdropper, assuming having imperfect CSI about real-world scenarios. To create a robust design with such research motivations, the authors formulated three non-convex problems, UAV trajectory, passive beamforming at RIS, and transmit power at legitimate user, that need to be optimized. An efficient algorithm was designed based on alternating optimization, SCA, and s-procedure to handle the non-convexity of the proposed problems and uncertainty of the CSI. The simulation results demonstrate that the addition of RIS with the proposed algorithm significantly benefits in maximizing the secrecy rate of the legitimate user, and also

TABLE 5. Summary of UAV-RIS based secrecy performance.

Reference	Problem	Optimized Parameters	Technique
[66]	Sum-rate and secrecy rate maximization	1. Power Control at UAV 2. Trajectory of UAV 3. Phase shift at RIS	Alternating algorithm
[67]	Maximizing secrecy energy efficiency	1. Trajectory of UAV 2. Phase shift at RIS 3. User association 4. Transmit power	SCA-based iterating and alternating algorithms
[68]	Secrecy rate maximization	1. Trajectory of UAV 2. Passive beamforming at RIS 3. Transmit power	SCA, s-procedure and alternating optimization algorithms
[69]	Efficient secrecy transmission and sum secrecy rate	1. Active and Passive beamforming 2. UAV Trajectory	TDDRL based algorithm

results are efficient compared to the benchmark algorithms. With a similar system and non-convex problems in [68], the authors in [69] employed a machine learning technique to increase the robust secure data transmission with mmWave communications. The authors have proposed a TDDRL algorithm to enhance the effectiveness of the secure transmission and sum secrecy rate. The numerical results show that, for the proposed algorithm, involvement of RIS has significantly enhanced the secrecy performance of the system.

At last, to conclude, there is still a large requirement to perform secrecy analysis for integrated UAV-RIS system. There are various articles that explain the secrecy performance of UAVs and RIS as stand-alone systems. Each article has its own implementation of algorithms and techniques to achieve better results. Specifically, in [70], the authors have demonstrated up to 120% of higher secrecy gain. Similar results were also obtained in UAVs. The findings from the studied articles above have shown significant secrecy performance enhancement considered to the traditional schemes such as [67]. Implementation of SCA and s-procedure techniques was much helpful for the authors to achieve the enhanced results.

D. UAV-RIS WITH EMERGING COMMUNICATIONS

Communication technology plays a major role in any system as it carries the data from one point to another. In this subsection, we study different types of communication techniques that are being utilized in UAV-assisted RIS systems such as FDMA, TDMA, NOMA, THz, FSO, VLC. Different algorithms were deployed in the system to enhance the efficiency using various communication techniques. Table 6 provides a brief summary of the discussions below.

In [71], the authors have proposed a UAV-assisted RIS system aided by a terahertz (THz) communication network.

The proposed system consists of two users aiming to achieve maximization of the minimum average rate of the users. To achieve this, the authors have proposed to optimize UAV trajectory, RIS phase shift, power control, and THz sub-band allocation. To identify the location of the UAV, an SCA-based Rate constraint penalty algorithm is proposed, and a self-developed algorithm was proposed to optimize the other parameters. The simulation analysis was performed depending on three cases of the algorithm using randomly generated parameters in each case with trajectory fixed. It is observed from the simulations that smaller distance movement of UAV trajectory and optimization of other parameters have shown substantially increases the performance rate of the proposed system. Moreover, the effectiveness of the proposed algorithm demonstrates its efficiency in reducing energy consumption for long time usage of UAVs.

In [72], the authors have considered a UAV-mounted RIS utilizing FSO communications for the network. The authors have considered atmospheric turbulence at the UAV and utilized Gamma-Gamma distribution to level and Hoyt distribution to model the pointing error loss caused due to the UAV vibration. Closed-form expressions of EC are derived to evaluate the performance of the system and verify the system throughput. It is noted that the atmospheric influences, UAV steadiness, and configuration of the system influence the EC and throughput performance of the system. In [73], the authors have considered a VLC enabled UAV network that simultaneously communicates with the users on the ground with illumination. The RIS is employed in the system to enhance the data transmission between the user and UAV, either communicating directly or indirectly. To minimize the transmit power of the UAV, the authors have considered optimizing the phase shift at RIS, adjusting the UAV deployment, and user-RIS association. A semi-definite algorithm along with the phase alignment method is proposed to optimize the phase shift at RIS, whereas, SCA algorithm is employed to adjust the UAV deployment. A greedy algorithm is developed to optimize the user-RIS association. Simulation analysis demonstrated that the proposed systems and algorithms combined show a significant reduction in energy consumption of 34.85 % and 32.11 % compared to the cases without RIS.

In [74], the authors have considered a UAV-assisted RIS system following the OFDMA technique for communication between the base station and the users. In the proposed system model, the UAV acts as the BS with a direct link between the RIS to users, and the UAV to RIS and users. The authors focused on enhancing the system sum-rate by jointly optimizing the trajectory of UAV, scheduling at RIS, and resource allocation. Due to the presence of multiple channels and RIS elements, the system suffers frequency and spatial selective fading. The authors have proposed an alternating optimization approach to tackle the non-convex problems to enhance the sum rate. Closed-form expressions are computed for the average system sum rate. The performance of RIS in the system model is compared with non-RIS users and it shows significant channel gain because of the passive beamforming performed by RIS. RIS also proved to be beneficial in adjusting the trajectory of the UAV as it directly travels to centroid formed by three users in the ground instead of traveling to each user. The results manifested that the size of RIS affects the UAV trajectory and enhances the achievable rate of the users in the network. In [75], the authors have considered a simple UAV-assisted RIS system to achieve optimized power consumption. The proposed system considered the downlink TDMA technique for serving many ground users. To optimize the power consumption, the authors have optimized the few non-convex problems; User scheduling, Resource allocation, phase shift at RIS, power allocation, beamforming vectors, and UAV trajectory and velocity. The authors have proposed an alternating optimization algorithm and SCA-based algorithm that supports flexible reduction in power consumption and enhances the sum rate of the system. The numerical simulations performed for the achieved power consumption expression demonstrate a better utilization and consumption of energy resources as compared to baseline schemes. A simple UAV-RIS system was considered in [76] with 3GPP channels as the link between the ground and air. In this model, the RIS is installed on a building wall and reflects the signals from the base station to the UAV to increase the strength of the transmitted signal. The performance of the system was estimated in terms of channel gain and it was proved from the results that, even with a small number of meta-surfaces installed, the gain of UAV devices can be significantly increased while hovering over the base station.

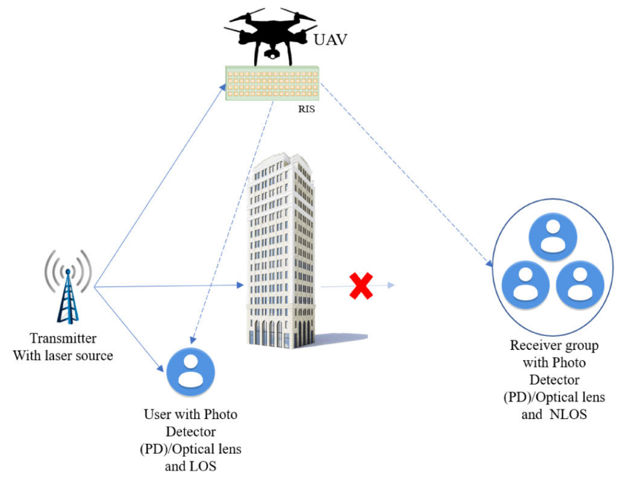

FIGURE 4. UAV-integrated RIS Optical Wireless Communications (FSO, VLC).

Considering the communication techniques, implementation of respective techniques in the respective system has its own advantages. But when we look all together combined, it is obviously understandable that adjusting different parameters like velocity, altitude, and the number of elements plays a pivotal role in achieving the required or effective results. Most of the contributions were primarily discussed in terms of

TABLE 6. Summary of UAV-RIS based communications.

Reference	Problem	Communication technique	Optimized Parameters	Technique
[71]	Maximising the minimum average rate	THz	1. UAV Trajectory 2. RIS phase shift 3. Power Control 4. THz sub-band allocation	SCA based Rate constraint penalty algorithm
[73]	Minimised the energy consumption of system	VLC	1. UAV Deployment 2. RIS phase shift 3. User-RIS association	Semi-definite, SCA and greedy algorithms
[74]	Enhancing the system sum-rate	OFDMA	1. UAV Trajectory 2. RIS scheduling 3. Resource allocation	Alternating Optimization algorithm
[75]	Optimizing the power consumption	TDMA	1. UAV Trajectory 2. UAV Velocity 3. UAV beamforming vectors 4. User scheduling 5. Resource allocation 6. Phase shift at RIS	Alternating Optimization and SCA-based algorithm

analysis such as EC, OP, or energy consumption. But looking at the numerical results the authors have demonstrated, the proposed system with respective characteristics is beneficial in enhancing the performance.

E. DEEP REINFORCEMENT LEARNING IN UAV-RIS

Machine learning, since its evolution, has been a booming technology since it plays a major role in automating a machine according to external world conditions by learning with thousands of data sets. Different papers were studied to implement DRL and federated learning in UAV and RIS separately to elevate their performance capacity in the real-time environment. There are only a few papers that considered integrated UAV-RIS systems. The studies of these papers are briefly summarized in Table 7. Implementation of machine learning techniques probably be advantageous to the UAV-assisted RIS system, but to prove this, there are still numerous studies required in this field. In this paper, we have reviewed all the UAV-assisted RIS implemented with machine learning technique papers.

Authors in [77] have considered the integration of UAV-RIS with NOMA communications networks, considering the random movement of users on the ground and UAV in the air, which is closely related to the real-world scenario. The authors are aimed to minimize the power consumption in such scenarios by optimizing the UAV movement, RIS phase shift, and power allocation for data transmission between the UAV and the users. To achieve this, D-DQN is employed to develop an algorithm, where a central controller will act as an agent to monitor the characteristics of the proposed system and adapt to its behavior. Compared to the traditional DQN which does not solve the above-mentioned non-convex problems jointly, the proposed D-DQN technique provides efficient power consumption by optimizing the minor constraints. The numerical calculations show that the involvement of RIS in the model has been a great advantage to the system since it has reduced energy consumption greatly. With RIS, the simulations have demonstrated a major reduction of 23.3 % energy usage at UAV, and compared to a similar system with orthogonal multiple access (OMA), the proposed system consumed 11.7 % reduced energy.

In [78], the authors have considered a UAV-mounted RIS system with a single base station communicating with various IoT devices on the ground. The research mainly focused on minimizing the AoI, which means the latency in status updating system and applications [79], by optimizing the altitude of UAV, communication patterns, and phase-shift at RIS. Since it is difficult to analyze the activation patterns of IoT devices, the authors have proposed a DRL-based proxiaml policy optimization (PPO) optimization algorithm to understand the randomness of IoT devices' behavior. This algorithm also proved to be efficient in optimizing the non-convex problems mentioned above. The proposed system and algorithm have outperformed other algorithm techniques in reducing the AoI.

In [80], the authors have proposed a multiple UAVs mounted RISs system that communicates in HetNets supported by dual connectivity. The proposed system operated with micro-wave channels at UAVs-RISs while maintaining the LoS communication with the users. The macro-cells are to be operated in the same micro-wave channels with OMA, while the base stations are operated with millimeter-wave channels using NOMA. The authors aimed to minimize the transmit power by optimizing the UAVs' trajectory and velocity, phase shifts at RISs, subcarrier allocations, and active beamforming at base stations. To solve the UAVs' trajectory, velocity, RISs' phase shift, and subcarrier allocations at micro-wave channels, the authors proposed a DQN learning approach by developing a distributed algorithm. To solve active beamforming and subcarrier allocation for millimeter-wave, the SCA method is applied. The proposed algorithm

TABLE 7. Summary of UAV-RIS with benefits achieved by deep reinforcement learning.

Reference	Problem	Optimized Parameters	Technique
[77]	Minimising the power consumption	1. UAV mobility 2. RIS Phase shift 3. Power allocation	Decaying deep Q-networks (D-DQN)
[78]	Minimising the age-of-information (AoI)	1. UAV altitude 2. RIS Phase shift 3. Communication patterns	DRL-based PPO algorithm
[80]	Reducing transmit power consumption	1. UAV trajectory 2. RIS Phase shift 3. UAV velocity 4. Sub-carrier allocation	DQN based distributed algorithm

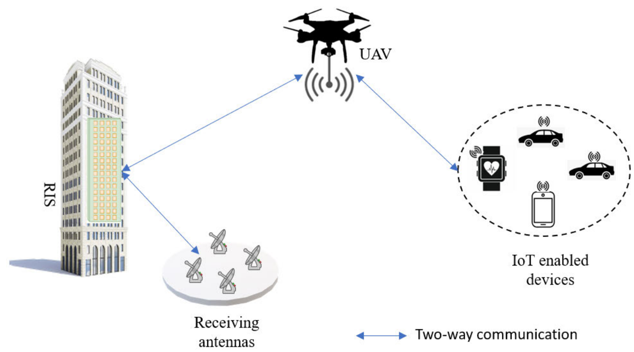

FIGURE 5. RIS-assisted UAV IoT networking.

was able to reduce the transmit power consumption by 6dBm while maintaining the same QoS.

Along with these studies, [81], also implemented the DRL-based algorithm to increase the number of devices the UAV can serve in the network. It has also shown a specific enhancement in energy consumption. To conclude, there are very few number articles on implementing machine learning or deep learning techniques in UAV-assisted RIS systems. Because these techniques are meant to replace the hardware as much as possible. But in our case, the hardware i.e. the UAV and the RIS, are the primary components. Therefore, the application of these techniques in this particular field is quite complicated. Still, the studies above have successfully implemented these techniques and achieved better and enhanced results. As we discussed in the previous sections, the primary issue in the UAV device is energy consumption. Implementing the DRL techniques has shown effective performance in reducing power consumption and making the UAV work for a longer time. Even though the occupied results are not as effective as the results from previously studied papers like [73], this study shows that there is a huge possible research scope ahead in this field for better achievements like reduced latency.

F. UAV-RIS BASED INTERNET-OF-THINGS

IoT has been a trending technology for a decade and there are a lot of research studies that are being published in this field. There are numerous studies published on utilizing the IoT in UAV and RIS independently which provides solid evidence that they play a major role in enhanced data transmission between IoT devices and the base station or cloud. In a particular point of view, a UAV can also be considered as an IoT device, which sometimes may act as a MEC as shown in [83]. There are only a few studies that explained the performance of UAV-assisted RIS systems with IoT networking. Those studies are discussed in this subsection. The studies mainly aim to enhance the system performance and data transmission with minimal power consumption. These studies are briefly summarized in table 8.

In [82], the authors have mounted the RIS device to the UAV to enhance efficient data transmission by improving the spectral efficiency of IoT networks. The system was considered to be having a BS-UAV link and a UAV-user link and no direct link between the BS and the user. Closed-form expressions were derived for OP, EC, and SER with upper and lower bounds of average SNR. The results have manifested that to efficiently increase the SER, the RIS plays a major role and the system shows ten times the higher capacity performance compared to traditional UAV systems. Whereas in [81], to increase the efficiency of data collection using UAV, the authors have proposed a DRL-based Proximal Policy Optimization technique. The main goals were considered as maximizing the number of served IoT devices in a single UAV network. Meanwhile, the BCD algorithm was used to handle the configuration at the RIS. The results show that along with the number of serving devices, the energy consumption at the UAV is reduced by 5 times.

UAV-RIS system was employed in [37] to deliver the URLLC short data packets between the IoT-enabled devices on the ground with finite blocklength. The primary objective of this paper was to minimize the decoding error rate, allowing the short packages to be delivered with high reliability. To achieve this, the authors have considered passive beamforming, optimizing the blocklength and UAV position. The proposed approach has produced ultra-high reliability with the increase in the number of meta-surfaces in RIS. The authors have also mentioned that the position of UAV is important for achieving high reliability for short data packets. Whereas in [83], the authors have considered multiple RIS systems installed on the walls of the buildings to support the communication between the ground base station and UAV which acts as a ground relay and aerial relay respectively, which performs MEC functionalities. The users on the ground are assumed to be connected Internet-of-Vehicles. Phase estimation errors during data offloading are considered at RIS due to the high movement of mobile vehicles. The authors primarily focused on minimizing the energy consumption of vehicles and UAVs by optimizing the power constraints, time-slot scheduling, and task allocation.

TABLE 8. Summary of UAV-RIS based internet-of-things.

Reference	Problem	Optimized Parameters	Technique
[82]	Enhancement of system capacity performance	OP, EC and BER	Mathematical Analysis
[81]	Increasing the number of IoT device connectivity and reducing energy consumption by 5 times at UAV	1. UAV Trajectory 2. RIS phase shift 3. IoTDs scheduling	DRL-based PPO technique and BCD algorithm
[37]	Enhancing URLLC short data packet transmission	1. Passive beamforming at RIS 2. blocklength and UAV positioning	Polytope-based method
[83]	Minimizing the energy consumption at receivers and UAVs	1. Power constraints 2. task allocation 3. time-slot scheduling	Lagrange dual method along with a subgradient-based algorithm

Closed-form expressions are derived and the results demonstrate that the phase error impact on overall power consumption is considerably reduced as there is an increase in the number of the meta-surfaces.

An in-depth study explains the importance of power consumption at UAVs since it runs on battery power. Minimizing the power consumption by optimizing the weight and various physical parameters can be a future approach in this field as it can increase the life span of a UAV before each recharge.

IV. SUMMARY

To summarize, based on our observation, there are few published studies in this field as of now. The discussions related to each topic in the above section have been already provided at the end of each subsection. To explain briefly the findings, the optimization of parameters such as UAV trajectory, placement, mobility, phase shift at RIS, and power allocation at the base station will play a major role in enhancing the performance of the system in terms of error rate, sum rate, outage probability, ergodic capacity, and throughput. Implementation of UAV-assisted RIS system in machine learning and deep learning techniques has shown better results in enhancing energy efficiency and minimizing the latency in data transmission. Implementation of IoT Technology has enhanced the data rate transmission with higher capacity performance.

In many optimization techniques, SCA, s-procedure, and alternating algorithms were utilized to enhance the secrecy performance of the system. Compared to other technologies such as standalone UAV system and standalone RIS system with various emerging technologies, the combined system with the same technologies such as NOMA, OFDMA, VLC, FSO, IoT, and machine learning provides enhanced performance in various parameters and real-world scenarios. Compared to the surveys provided on RIS [44]–[47] and UAV [12], [49]–[51], our survey paper provides a combined view of recent research towards the UAV-assisted RIS field. Table 9 provides a summary of the survey in comparison to the various performance parameters. It can be seen that in most of the cases, each application has shown significant performance efficiency. Whereas, the issue of latency was only considered in very few applications. Therefore, in future research, it would be optimal to consider the latency issue as the UAV's main applicable area is to collect and transmit the data and this either directly or indirectly depends on the data transmission time.

V. OPEN CHALLENGES AND FUTURE RESEARCH DIRECTIONS

This survey conducted in this article has addressed many key challenges on the UAV-RIS system. Due to limited research on this topic, there are still a few open problems that need to be addressed.

A. ENERGY CONSUMPTION AT UAV

As already mentioned in the above discussions, energy consumption plays a major role in analyzing the performance of the overall system. In most of the studied cases, the fuel capacity of the UAV is not considered. Even if considered also, there are no practical conditions or scenarios that were taken into the picture. Realistic assumptions are required such as payload weight, speed, weather conditions, and temperature of the UAV after working for a certain period. There are various energy models of UAV proposed in [52] basing the different parameters as mentioned above. Implementing these scenarios in theoretical calculations would be helpful to overcome unforeseen challenges during the practical implementation of such systems.

B. FEDERATED LEARNING-BASED UAV-ASSISTED RIS

For future wireless networks, such as 6G, AI is assumed to play a key role. The Federated learning-based UAV-RIS model could be a possible definite solution towards various problems we talk about such as secrecy performance, energy efficiency, and spectral efficiency. In [77]–[80], the authors have identified that implementation of various DRL techniques has enhanced the energy performance of UAVs and reduced the latency in data transmission. Whereas, few other stand-alone systems work also indicated that implementing federated learning in their proposed system models has shown significant performance gain. In [84], it is particularly mentioned that federated learning could be a potential and attractive candidate to integrate with RIS.

Another similar potential technology for UAV-assisted RIS is Artificial Intelligent and Internet of Things (IoT). Since it has been only a couple of years since this concept came into the limelight, there are not many research articles on this technology or about being integrated with UAV or RIS. But,

TABLE 9. Comparison of the related articles with different performance metrics.

Reference	UAV-RIS Application	System Performance Rate	Energy Efficiency	Reduced Latency
[54] - [59]	Optimization	✓	✓	×
[38],[60] - [65]	Efficiency Enhancement	✓	✓	×
[66] - [69]	Secrecy Performance	✓	✓	×
[71] - [76]	Communication techniques	✓	✓	×
[77] - [80]	Deep Reinforcement Learning	×	✓	✓
[37],[81] - [83]	IoT	✓	×	✓

with present research articles, it can be clearly understood that AIoT has immense potential to obtain optimal settings and reduce energy consumption, assisted by various training models [85]–[87]. Since most of the UAV-assisted RIS research is based on optimizing the various parameters, the implementation of AIoT would be another great advantage in reducing the complexity and enhancing the performance of the system.

C. CHANNEL MODELING AND ESTIMATION

Channel selection is a primary factor in wireless communications as many parameters depend on it which characterizes the performance of the system such as fading, scattering, shadowing, etc. As UAV works as an aerial device there are a lot of external parameters that affect the channel link between the UAV and user [88]. In the RIS, the number of elements, position of the RIS, the material of the meta-surfaces also affect the performance of the channel link. In real-world scenarios, UAV-assisted RIS makes channel modeling sophisticated and challenging [89], [90]. Therefore, there is a major requirement to perform a thorough evaluation of the channel models to identify and understand the effects in various applicable cases. The UAV-assisted RIS system also required investigative study in channel estimation as it can help reduce the power consumption depending on the requirement of the channel.

D. PHASE SHIFT CONTROLLER AT RIS

In a UAV-assisted RIS system, most of the considered cases are shown to be that RIS is either installed on a wall or in the stationary position. In this scenario, where there is a requirement for a phase shift computation at RIS, the data transmission between RIS and the computing node will have perfect channel conditions without any effect of channel fading or latency. But in the scenario where UAV-mounted RIS needs to follow a similar case for attaining the phase shift modifications, the link between the computation node and RIS will face time-varying channel conditions and might face the effects of fading and shadowing. In the case of a large number of RIS elements, the link might also face latency. Therefore, investigations for analyzing a stable link need to be done where the effect of the above-mentioned factors needs to be limited for efficient phase shifting and data transmission.

VI. CONCLUSION

UAV has gained significant importance because of its ability for wide coverage, easy deployment, and efficient data transmission. RIS can reflect the impinging radio waves on its meta-surface according to the requirement of the user. The integration of UAV and RIS has paved the way for possible approaches to enhance data transmission, spectral efficiency, and distant communications while optimizing energy consumption. In this article, we provided a focused survey on a wide range of technologies that are being applied with optimization strategies in UAV-RIS systems. While the RIS efficiently plays a major role in enhancing spectral efficiency, energy efficiency, data rates, and secure communication among the users, the UAV aids the RIS system to extend advantages to a wide range of areas. In this survey paper, we mainly focused on UAV-assisted RIS systems with optimization, secrecy performance, deep reinforcement networks, efficiency enhancement, emerging communications, and IoT. A detailed explanation for each surveyed paper has been given in the section depending on the various problems, optimizing parameters, and techniques used in that particular paper. Various insights are provided at the end of context which could trigger a larger discussion and research options. After this immense study, in the end, we have provided various open challenges and possible research directions that could take forward the research in this field.

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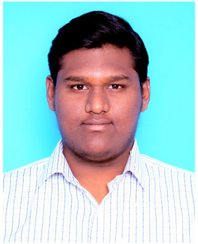

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