A Study on IRS-assisted Communications: Problems, Challenges, and Solutions

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This paper studies the Intelligent reflecting surface (IRS)-based communications, including the fixed and UAV-mounted IRSs. IRSs can be deployed in locations that are difficult to receive or transmit signals due to obstacles or remote areas by passively reflecting the signals received from base stations (BSs). The IRSs can reflect signals in the designed way to enhance the transmitted signal or enable line-of-sight (LOS) communications. They can be fixed on the side of high buildings to reflect signals or mounted on the UAVs to provide temporary wireless communications in the remote areas. This paper conducts an overview on IRS-based communications including the existing problems, challenges, and possible solutions.

***Index Terms*—IRS, UAV-mounted IRS communication, optimization, security.**

I. Introduction

[1] Research on critical technologies for 6G communications has been carried out to achieve the seamless connections of existing communication systems to form a three-dimensional fusion network spanning the sky, earth, and sea. 6G aims to use the terahertz frequency band to increase the network capacity significantly. The 6G communication requirements are much stricter than 5G. Specifically, the peak transmission speed of 6G reaches 1Tbps compared to 10Gbps in 5G[1]. The positioning accuracy reaches 10cm and 1m for indoor and outdoor, respectively, ten times less than 5G. The communication delay is as low as 0.1ms, ten times less than 5G. The reliability has increased from the current 99.9% in 5G to 99.999%. The density of interconnected devices reaches more than $100/m^3$, which is an ultra-high density, and the coverage ratio is increased from 70% in 5G to 99%[1].

To achieve the above goals, more advance communication technologies are needed especially to support aerial users, such as low-orbit satellites, unmanned area vehicles (UAVs), and intelligent reflecting surface (IRS). In particular, UAV-assisted communications have received tremendous attention in the past years. Compared to terrestrial cellular links, UAV mobility can rapidly facilitate connectivity in hotspot environments, and IRSs can significantly improve the communication coverage in remote or complicated areas where signals from terrestrial base stations cannot reach, transmission capacity, energy efficiency, and spectral efficiency of mobile networks [2].

IRS is an emerging technology potential to improve the performance of 6G network systems and can define new wireless transmission and propagation modes and control communication channels. An IRS is a metasurface containing electronically controllable and low-power analog processing elements. The absorption, reflection, refraction, and phase of passive reflective elements can be adjusted in real-time to direct incoming electromagnetic signals in the desired direction. The phase and amplitude of the reflected signal maximize the effective channel gain, helping maintain good data transmission quality when obstacles in the data transmission path degrade signal quality. IRSs are typically made with lightweight and conformal geometries, requiring no radio frequency (RF) chain and operating only over short distances. Thus, they can be densely deployed/removed on/from walls, ceilings, and building facades[3] [4] with minimal cost and effort, requiring no hardware changes but only a communication protocol implementation. In addition, IRSs consume low energy, thus needing no complex interference management between passive IRSs.

In IRS-assisted communications, both the direct signal from base stations (BSs) and the reflected signal from IRS can carry the same useful information, so they can be coherently added at the receiver to improve the decoded signal strength[2]. Thanks to the advantages mentioned above, IRSs are expected to be used in various applications, especially for users that cannot communicate with the BSs due to obstacles. IRSs can be deployed above the obstacles and in between the BS and users to reflect the Bs signals to users to provide a virtual line-of-sight link, extending the transmission coverage of mmWave communications. In addition, IRS can be used to reduce signal leakage to eavesdroppers by appropriately deploying it between the BS and legitimate user, taking into account the location of eavesdroppers[4].

For applications requiring temporary extension of communication range, IRSs can be mounted on the UAVs to be flexibly deployed above the required area. The maneuverability of drones can quickly facilitate connections in hotspot settings compared to terrestrial cellular links. IRS-equipped UAVs can optimize positioning to help edge users who may not have direct access to base stations, nonetheless, suffering from challenges such as UAV flight time restriction, susceptibility to environment like wind, rain, etc.

This paper studies the IRS-assisted wireless communica-

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tions, focusing on the scenarios of fixed IRS and mobile IRS, i.e., UAV-mounted IRS. We study the key issues, challenges, and possible solutions in the two scenarios, respectively. The remainder of this article is organized as follows. Sections II and III introduce the fixed and mobile IRS communications, respectively. Section IV discusses the open challenges. Section V concludes the paper.

II. Fixed IRS communication

In the following sections, we discuss the existing work on the key research issues of the fixed IRS-assisted data communication systems, mainly on the power optimization and communication security. Table I summarizes the related work of the associated papers.

TABLE I
IRS Research Survey

Reference	Research Objectives	Solutions
[6]	Power minimization	Penalized Dual Decomposition (PDD) and Nonlinear Equality Constrained Multiplier Alternative Direction Method (neADMM)
[7]	Power minimization for NOMA systems	Sequential rotation algorithm
[8]	Minimize the transmit power of the base station	Alternating optimization algorithm
[9]	Maximize confiden- tiality	AO-MM algorithm and element-wise BCD algorithm
[10]	Minimize secrecy rate for legitimate users Limit transmit power	Alternative optimization algorithms and SDP relaxation
[11]	Improve physical layer security	Alternate Algorithm

A. Power Optimization

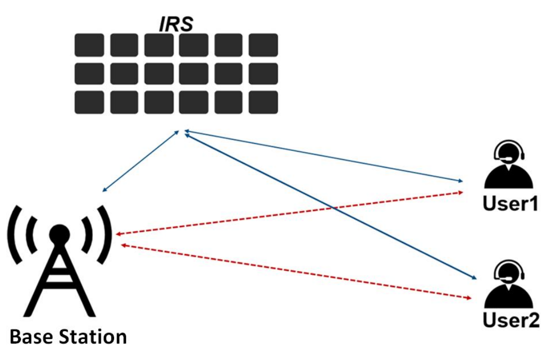

Fig. 1. IRS Assisted User Communications

There are many articles discussing the issue of minimizing BS transmit power in IRS-assisted wireless networks. The IRS can configure the wireless channel, which is helpful between the transmitter and the receiver, and can make the communication more energy-efficient. In this subsection we will review the power minimization problem in IRS-assisted communication systems and solutions. Figure 1 shows the model of IRS-assisted communications. The IRS is deployed in the wireless network to assist multiple users to communicate with the BS which we denote by the red arrows. Utilize the IRS to assist user communications (indicated by the blue arrows) for our purpose of increasing efficiency.

In [6], the authors considered the use of IRS deployed in typical uplink MISO wireless network to assist multiple single-antenna mobile users to communicate with access points (APs). The authors mainly consider weighting and power minimization under Quality of Service (QoS) constraints in the network in perfect and imperfect CSI scenarios. First, there is a new sufficient condition to guarantee any information rate constraint, that is, the user has sufficient transmit power. Then the authors design a solution based on Penalized Dual Decomposition (PDD) and Nonlinear Equality Constrained Multiplier Alternative Direction Method (neADMM) to address the QoS constraints, feasibility checks, and power minimization problems associated with IRS. In the perfect CSI scenario, the author mainly implements the solution of summation power minimization based on neADMM. In imperfect CSI scenarios, neADMM or PDD methods can still be used. Finally, the author built a system including an AP, 4 single-antenna mobile users(MUs)and an IRS for testing. The final data results show that IRS improves feasibility and sum-power capability.

In [7], the authors investigated the effectiveness of IRS in terms of transmission power consumption in NOMA systems. The system is mainly composed of a single-antenna base station and multiple single-antenna users. NOMA serves all users at the same time, while the IRS unit is located within the coverage of the BS. In this system, the authors study the power minimization problem of an IRS-assisted NOMA system. To this end, the authors considered optimal combined power control and IRS phase shift. To perform the optimization, the authors consider the relationship between the transmit power of a single user and the phase shift variable, and then solve the phase shift determination problem through a sequential rotation algorithm. In the simulation analysis, the authors consider four baseline scenarios, namely IRS with zero phase shift, IRS with random phase shift, NOMA with IRS, and NOMA without IRS. From the simulation results, compared with the scheme without IRS, the scheme with IRS can reduce the power consumption by more than 15dBm. Furthermore, the power consumption of an IRS with zero phase shift is close to that of an IRS with random phase shift. Finally the authors also consider the effect of IRS on the total power for different numbers of reflective elements. The results show that the total transmit power decreases as the number of elements increases.

In [8], the authors considered IRS-assisted communication in a broadcast environment, which includes a BS with multiple antennas and an IRS with multiple reflectors and multiple single-antenna terrestrial users. The author's main research problem is the power control problem of broadcasting under QoS, the main purpose is to minimize the transmit power of the base station, and deduce the minimum transmit power lower limit of the BS. The authors propose to optimize the transmit beamforming of the BS and the phase shift of the IRS and optimize it using an alternating optimization algorithm. Then the author deduces the minimum power lower limit by studying the influence of the transmit power, established a

TABLE II
IRS-ASSISTED UAV RESEARCH SURVEY

Reference	Objective	Optimized parameters	Technique
[12]	Maximize throughput	UAV Trajectory and Transmit Power	Algorithms for Deep Reinforcement Learning (MADRL)
[13]	Improve energy efficiency	Beamforming vectors for base stations and phase shift matrices for UAV passive reflectors	Iterative Algorithms Based on Maximum Ratio Transfer, Alternate Optimization Techniques and Convex Programming
[14]	Improve anti-interference ability	Trajectory and passive beamforming of UAV	Adversarial Dual Deep Q-Network Multi-Step Learning Algorithm
[15]	Maximize the secrecy rate	Cooperative beamforming weights of sensor nodes, trajectories of UAV and reflection coefficients of IRS elements	Non-Iterative Suboptimal Solution
[16]	Analyze security performance	The distance between UAV and eavesdropper	Confidentiality outage probability (SOP) assessed
[17]	Improve confidentiality and coverage	IRS size, power consumption, carrier frequency, UAV height	New particle swarm method

channel model between the BS minimum power lower bound and the number of antennas of the BS, the number of IRS units, and the number of MUs in line of sight (LoS) between the BS and the IRS. The final simulation results show that the transmit power decreases with the increase of the number of IRS units and the number of BS antennas and the transmit power increases with the increase of the number of MUs.

The power control issue is a notable one. Improve system efficiency through power control. In this section we summarize different solutions for implementing power control in IRS-assisted communications. The PDD method and neADMM method designed by the authors of [5] outperform existing methods in terms of performance, addressing the problem of power minimization. The author of [6] is aimed at the power control problem in NOMA system. The authors hope to minimize the power consumption by jointly designing the power allocation of the BS and the passive beamforming of the IRS. Then, the required power of a single user is calculated by the phase shift of the IRS, which transforms the original joint optimization problem into a phase shift optimization problem. Finally, the phase shift determination problem is solved by a sequential rotation algorithm. The authors of [7] study a solution to the power control problem of IRS-assisted wireless networks. The method of use is to perform multivariate optimization in an alternate way to solve the transmission at the BS, and the beamforming and phase shift of the IRS achieve the purpose of power control. It is proved that the transmit power of the base station has been significantly improved with the help of the IRS.

B. Security Issue

Security within the system is paramount. The ability of the IRS to improve safety within the system has been demonstrated in numerous studies. In this subsection we will review various IRS studies on improving the secrecy rate within the system. Figure 2 shows the presence of an eavesdropper in an IRS-assisted communication system. This subsection of our investigation is based on this.The IRS is set up in the communication system to assist the communication between the user and the BS, which we denote by the blue arrows. There is an eavesdropper trying to eavesdrop on the BS's information, which we indicate with the red arrow. The IRS acts to improve safety.

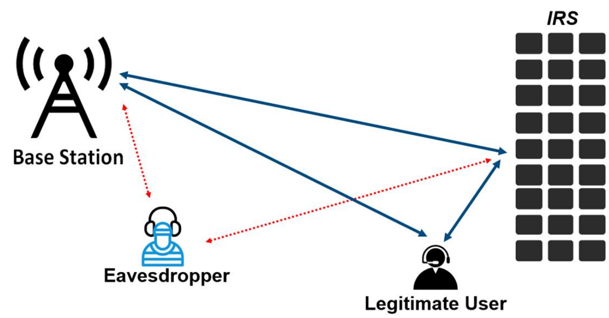

Fig. 2. Eavesdroppers in IRS-assisted communications

In [9], the authors consider an IRS-assisted communication system consisting of a legitimate receiver, a transmitter, an IRS and an eavesdropper. The author's main goal is to maximize the secrecy rate of this system. The authors propose to optimize the beamformer and IRS phase shift at the transmitter to maximize the secrecy rate.Then, to solve small-scale and large-scale non-convex optimization problems, the authors develop block coordinate descent (BCD) and minimization-maximization (MM) techniques. Among them, the element-wise BCD algorithm has a higher complexity but an optimal solution than the Minimize Maximize Alternate Optimization(AO-MM) algorithm, while the AO-MM algorithm has a lower complexity but a suboptimal solution. The simulation results show that the element-wise BCD algorithm is more suitable for small-scale IRS auxiliary systems, and the AO-MM algorithm is more suitable for large-scale IRS wireless systems. The simulation results evaluate average secrecy by comparing systems with and without IRS deployed. The obtained results show that IRS has a significant performance gain on the average secrecy rate of the system.In [10], the authors considered IRS-assisted multi-antenna secure transmission when a multi-antenna BS established a reliable link with a single-antenna legitimate user in the presence of a single-antenna passive eavesdropper. The authors' main objective is to minimize the secrecy rate-constrained transmit power at legitimate users. The authors propose an optimization for safe transmit power allocation and surface reflection phase shift, and solve it using an alternative optimization algorithm and semi-definite programming (SDP) relaxation. Simulation results verify the effectiveness of the algorithm by evaluating the convergence of alternative optimization algorithms. The obtained results show that the auxiliary scheme with IRS deployed outperforms the auxiliary scheme without IRS in terms of secure transmit power allocation. Furthermore, the increased number of reflective surface elements on the IRS makes this scheme more efficient.In [11] the authors consider an IRS-assisted multi-antenna system in which there is a source, a receiver, an eavesdropper and an IRS. The authors aim to maximize the secrecy rate of the system. In order to achieve this purpose, the author proposes to optimize the source emission covariance and IRS phase shift matrix to maximize the secrecy rate. The authors develop an alternating algorithm that solves the non-convex problem under study. Simulation results show that the presence of IRS provides greater security performance than the absence of IRS. In addition, the proposed scheme has almost the same secrecy performance as the optimal solution.

In conclusion, the need for confidentiality analysis of IRS systems remains high. There are various articles explaining the secrecy properties of the IRS system. Each article has its own implementation of algorithms and techniques to achieve better results.Specifically, in [9], the authors consider an IRS-assisted communication system in which the transmitter is multi-antenna and both eavesdroppers and legitimate receivers set up a single receive antenna. The main method used is the BCD method. This method optimizes the objective function on a different subset of the optimization variables in each iteration. Firstly, the optimization matrix of beamforming vector with fixed phase shift is studied, and the design problem of beamformer is obtained and two optimization methods are proposed. The first is to use element-wise BCD to optimize the phase-shift matrix. The second is to use element-wise BCD to optimize the phase shift matrix.

In comparison, the authors of [10] use a different method in a similar setting. The authors minimize the secrecy-rate-constrained transmit power at legitimate users by transmitting power allocation and optimizing the IRS surface reflection phase shift. The authors propose an alternative optimization algorithm and SDP relaxation to alternately optimize safe transmit power allocation and surface reflection phase shift. And the optimal safe beamformer is derived according to the closed-form expression, and the rank relaxation method of the reflection phase shift matrix is given.

Authors in [11] maximize the system secrecy rate according to the source transmit power constraint and the unit modulus constraint imposed on the IRS phase shift. Alternative optimization algorithms are proposed to design safe transmit beamformers and phase shifters. Besides, other methods exist. In [12], in order to improve the secrecy rate of transmission, alternating optimization and path tracing algorithms are used. In [13], a DRL-based algorithm is proposed for IRS assistance Multi-user MISO system with enhanced beamforming and phase shifting for BS and IRS, respectively. An IRS-assisted cooperative NOMA system was proposed in [14] to improve the performance of weak users by optimizing various parameters such as beamforming and power allocation.

III. UAV-mounted IRS Communication

In the next section, we investigate related research on drone-mounted IRS communication systems. This part studies trajectory optimization and safety performance during data transfer. For your convenience, we have created Table 2. In Table 2, we briefly summarize our survey.

A. Trajectory Optimization

Many papers discuss optimization of various parameters regarding UAV. Trajectory optimization for UAV is one of them. UAV performance is all related to these optimizations, so optimizing these parameters can significantly improve UAV performance. In this subsection we mainly review some studies on trajectory optimization of UAV.Figure 3 represents the trajectory optimization model in the UAV-mounted IRS communication system.The UAV carries the IRS to assist the user in communicating with the BS, which we denote by blue arrows. Because of the flexibility of UAV, we can move to the ideal position in the face of different situations by optimizing the UAV trajectory. We use the green line to represent the UAV trajectory.

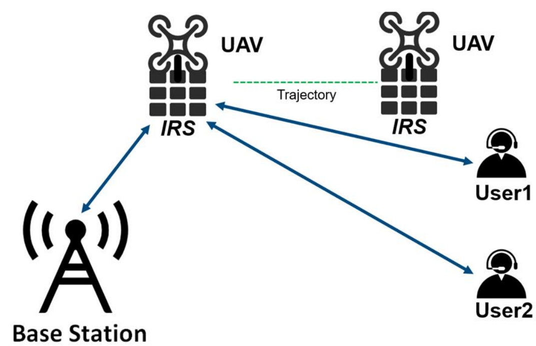

Fig. 3. UAV-mounted IRS Trajectory optimization

In [15], the authors considered a secondary UAV (AUAV) carrying IRS to assist the primary UAV (MUAV) to drive the Internet of Things (IoT) network. The authors propose the problem of maximizing throughput by jointly optimizing MUAV's trajectory and transmit power. The authors address the formulation problem by improving an algorithm based on deep reinforcement learning (MADRL), proposing Pre-Activation Penalized Multi-Agent Deep Deterministic Policy Gradient (PP-MADDPG). In the simulation, the authors compare the performance of the PP-MADDPG algorithm, MADDPG algorithm and DDPG algorithm in a scenario with 10 ground sensor nodes (GN). From the simulation results, PP-MADDPG outperforms other algorithms in terms of cumulative throughput and convergence speed. In addition, the simulation results show that under the PP-MADDPG algorithm, the UAV can adjust its own trajectory to keep the beam reachable and synchronously move to the same GN .

In [16], the authors considered a simple UAV-assisted IRS system with NLOS communication between the IRS and terrestrial users. The authors aim to maximize the average achievable rate of the system by optimizing the trajectory of the UAV and passive beamforming of the IRS combined with an SCA-based algorithm. The simulation results show that the signal quality in the UAV network is significantly improved under the action of IRS. The authors compared the results from their proposed algorithm with three other benchmark algorithms, including UAV trajectories without passive beamforming and heuristic trajectories with and without passive beamforming. Finally, trajectory-based simulations show that, compared with other algorithms, the proposed algorithm has better efficiency in balancing channel gain links and significantly improves the network quality of UAV.

In [17], the author considers that there is a jammer to interfere with the communication node on the ground when the BS communicates with the user, and the UAV carrying the IRS assists in the air against the jamming signal. The author mainly studies the optimization of UAV trajectory in jamming environment, with the aim of improving the anti-jamming communication performance of mobile users. The authors propose a joint optimized trajectory and passive beamforming to achieve this. The authors propose an adversarial dual-deep Q-network multi-step learning algorithm to solve complex decision-making problems. Simulation results show that the proposed scheme can significantly improve the energy of anti-jamming communication for mobile users. In addition, the increase in the number of originals on the IRS can also improve the user's anti-interference performance.

From the above studies, an overall view can be drawn that optimizing some parameters on UAV or IRS can significantly improve system performance. UAV's position, trajectory, and speed all play an important role in improving system efficiency. In the above research, we mainly consider the help brought by the trajectory optimization of UAV. Specifically, the authors of [15] augment the signal of the primary UAV with a secondary UAV mounted with an IRS device. The algorithm of PP-MADDPG is designed to optimize the trajectory of the auxiliary UAV. The authors of [16] aim to maximize the average achievable rate within the system through trajectory optimization of UAV and passive beamforming design of IRS. First, the authors align the phase of the received signal at the user to maximize the received signal energy. Then, a closed-form phase-shift solution for any given UAV trajectory is obtained. Finally, the optimal solution of UAV trajectory is obtained by SCA method. The authors of [17] proposed a multi-step learning algorithm for a duel-depth Q-network to optimize the trajectory of the UAV, achieving the purpose of improving the anti-jamming performance of the user.

B. Security Issue

Because of UAV's mobility, it can establish communication in any type of open environment, which leads to research on the system security of UAV. In the IRS we mentioned that the IRS can enhance the security within the system. In this subsection, we examine what the IRS has done to improve the safety of drone communications.Figure 4 shows the presence of IRS in a UAV-mounted IRS communication system. We installed the IRS on the UAV to facilitate the communication between the user and the BS, indicated by the blue arrows. Red arrows and dotted lines indicate the eavesdropping behavior of eavesdroppers on BS. The IRS reflects the BS's signal, and through a series of optimizations, the purpose of improving the confidentiality rate is achieved.

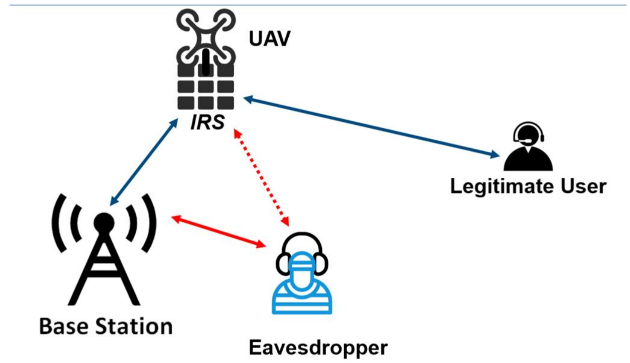

Fig. 4. Eavesdroppers in UAV-mounted IRScommunication

In [18], the authors consider when a UAV carries an IRS to assist a physically noncommunicating base station to receive the reflected signal from a transmitter (Alice). The main goal of the authors is to maximize the secrecy rate in noisy channels. The authors propose to achieve this goal by jointly optimizing the cooperative beamforming weights of the sensor nodes, the trajectory of the UAV, and the reflection coefficients of the IRS elements. For the problem of maximizing the confidentiality rate, the author designs a non-iterative suboptimal solution. The authors then evaluate the performance of the proposed algorithm through numerical simulations and compare with other baseline schemes. The simulation results show that the IRS can improve the secrecy rate by increasing the phase difference of the eavesdropper, and the scheme proposed by the author is effective.

In [19], the authors considered that in a complex environment with obstacles and a random number of eavesdroppers between the BS and the legitimate receiver, the UAV carries the IRS as a passive relay to assist the communication between the BS and the legitimate receiver. The purpose of the authors is to analyze the secrecy performance of an IRS-assisted UVA relay system. First,the authors model the distribution of eavesdroppers and account for errors, extracting expressions for the statistical representation of the noise ratio between legitimate receivers and eavesdroppers. Then the authors evaluate the secrecy outage probability (SOP), showing that deploying a large-scale IRS and deploying UAVs close to legitimate receivers and away from eavesdroppers has a positive effect on the performance of SOPs. Finally, the simulation results show that the proposed IRS-assisted UAV relay system is superior to the AF relay system in terms of security performance.

In [20], the authors consider the essential features to be aware of when IRS is installed on a UAV. Including the size of the IRS, power consumption, carrier frequency, and the height of the UAV. These all affect the flight time and path loss of the

UAV. The author's purpose is to improve the confidentiality rate and coverage in data transmission scenarios. To achieve this, the authors propose a new particle swarm method. The simulation results show that deploying IRS on UAV can improve the security rate of the system. At the same time, the security rate of the system increases as the number of IRS elements increases. And neither the flight altitude nor the loss of road strength will affect the average secrecy rate.

From the above study we can understand that the security of the system is of paramount importance. UAVs have the ability to establish communications in any type of open environment, but this ability also raises serious concerns about system security. In order to improve the security, the authors of [18] proposed the method of optimizing the position of the UAV, optimizing the coefficients of the IRS surface element and optimizing the cooperative beamforming weights of the sensor nodes. The authors of [19] considered the situation where there are multiple eavesdroppers in the communication environment. It is proposed to use an IRS-equipped UAV as a passive repeater to relay the base station's signal to the user. Specifically, the authors introduce the secrecy protection zone technique to protect the transmission. Assuming that drones can physically detect eavesdroppers in the security guard zone, UAV-IRS relays aid communication when there are no eavesdroppers in the detection zone.The authors of [20] installed the IRS on the UAV, using the mobility of the UAV and the high network configurability provided by the IRS to achieve the purpose of improving the quality and security of the communication channel. After considering the influence of IRS size and IRS power consumption on UAV flight time, and the influence of IRS size, carrier frequency and UAV flying height on path loss, a new particle swarm based method is proposed. The method improves the coverage of the UAV carrying the IRS and improves the security of data transmission.

Mounting the IRS on drones to enhance physical layer security is very effective. Because IRS-enabled drones provide a configurable network that can prevent attacks by illegal users. The mobility advantage of drones gives the IRS the flexibility to optimize deployment to ensure the best rate of secrecy. In addition, when an illegal user can be identified, the drone tracks the location of the illegal user, providing continuous secrecy for communications. Finally, IRS-enabled drones can also be used for physical layer authentication, provided to legitimate users when they need dynamic access to network services. Compared with UAV without IRS, IRS-enabled UAV is more suitable for physical layer authentication, in which IRS plays a big role. By using the IRS to provide communication authentication between the BS and the legitimate user, it has a good performance against attacks without the eavesdropper knowing the IRS configuration of the channel between the BS and the legitimate user[21].However the energy of the UAV affects the flight time limit, the system is unstable.

Currently, UAVs are not mentioned in most review surveys on the IRS. But research proves that combining this IRS technology with UAV technology will have a positive impact on future enhanced communications. In [22], the challenges faced by IRS in channel estimation/acquisition, passive beamforming/reflection design, and hardware limitations/deficiencies were investigated, as well as the results of IRS channel estimation under different architectures and system settings. In [23], machine learning for IRS-based wireless communication was mainly investigated. In [24], the authors discuss and investigate the channel modeling, channel estimation, system architecture, hardware impairments, IRS deployment strategies, phase optimization, mobility management, and near-field environments in order to make IRS assistance systems more effective and efficient. Compared to other survey and application papers that deal only with stand-alone IRS systems, our survey paper additionally provides an additional survey devoted to UAV-assisted IRS. Because research has shown that integrating IRS devices with UAVs as a tool to enhance various functions of the overall system can lead to better performance for the device.

IV. Open Challenges

A number of research questions on IRS and IRS-assisted UAV communications are investigated in this paper. But there are still many research questions and challenges that have not been addressed.

A. Centralized Beamforming for IoT Devices

IoT is an important part of wireless networks. Some IoT devices are limited in size and power consumption. If the size is too small, it cannot support the antenna array required to achieve sufficient beamforming gain to establish a link with a remote base station. IRS can be used to provide large beamforming gains for these devices. The IRS and the BS will be fixed in place and probably with limited surrounding scatterers, which simplifies the centralized beamforming optimization between the IRS and the BS.Compared with traditional beamforming methods that control wavelength allocation, centralized beamforming provides higher wavelength utilization efficiency and can control the beam direction without explicit control of the BS[25].

B. UAV Energy Consumption Problem

It is feasible to install the IRS on the UAV to assist communication, but the flight time of the UAV is determined by the energy consumption of the UAV, and the stability of the system is also determined. Energy consumption plays an important role in the overall system. However, most studies do not consider the practical limitations of UAV energy. Therefore, the research on UAV energy optimization is very critical. In [26], trajectory optimization of UAV-BS is proposed to optimize energy consumption. This approach allows UAVs to reduce energy consumption while meeting the quality of service requirements of ground users.

C. Channel Modeling and Estimation

Channel modeling determines many parameters in wireless communication that determine the performance of the system. In UAV, when the UAV is used as an air device, there are many factors that lead to the link between the UAV and the ground user. In the IRS, the number of reflective elements and the location of the IRS deployment will affect the performance of the channel link. In practical applications, because the IRS-assisted UAV system can reduce power consumption according to channel requirements, it is necessary to study the channel estimation of this system.

V. Conclusions

This paper surveys key research questions and related technologies for IRS-assisted communications. We investigated fixed and mobile IRS-assisted communications separately. For the first case, we mainly investigate power optimization and safety issues for stationary IRS-assisted communications. For the second case, we investigate the UAV trajectory optimization design and safety issues for IRS-aided communication. Finally, we discussed some open challenges.

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