Research on a new improved UAV anti-jamming and optimization model

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ABSTRACT

In complex environments, UAV wireless sensing networks suffer from path loss, incomplete channels, swarm access security and other problems, and the signal fading and packet loss rates are very obvious. In order to solve the problem of user control data security, this paper gives full play to the characteristics of blockchain technology and builds a blockchain-based UAV cluster anti-interference communication network in UAV cluster applications to achieve anti-interference performance. Meanwhile, Markov decision process is used to optimize and realize the research of UAV air-ground integrated radio wave anti-interference.

Keywords: UAV, anti-jamming, blockchain

1. INTRODUCTION

In traditional wireless sensing networks, the wireless signal propagation path is not an ideal obstacle-free free space in most cases. Especially in complex environments, such as cities with tall buildings, mountainous areas with heavy mountains, and hills with thousands of rocks and ravines where there are multiple obstacles to block, reflections, scattering and bypassing are prone to occur, and the signal attenuation and packet loss rate will be very obvious. Usually, in complex environments, researchers achieve wireless transmission by deploying UAVs.

In the civilian sector, due to the limited communication distance of UAVs, repeaters are usually required for UAV communication in complex urban environments with many obstacles. The connection between the UAV and the relay is called a relay link, which has a longer communication distance, faces a more complex environment, and is more susceptible to interference[1]. In the process of UAV swarm link communication, the nodes within the UAV swarm often lose node functionality due to attacks, energy depletion, etc., when there is access control disorder within the swarm around the initial task of the swarm[2]. When a threat is encountered, one of the UAV nodes in the sub-swarm may be destroyed or lose its function, resulting in higher access control cost for the swarm. The massive, dynamic, distributed, and lightweight nature of the current UAV swarm likewise makes the UAV swarm access control mechanism suffer from insufficient stability, low performance of privilege judgments, and reduced security[3-8]. The complex urban environment has the problems of path loss, incomplete channel state, and swarm access security, therefore, it is important to study an air-space integrated radio wave swarm anti-interference communication.

According to the above analysis, UAV swarm communication brings new problems and challenges in complex urban environments. This topic introduces blockchain smart contracts for UAV swarm access control mechanism to make user control data more secure and realize UAV air-ground integrated radio wave anti-interference research.

2. REVIEW

In complex environments, it is difficult to work with a single device while maintaining a continuous connection for a long time due to the mobility of UAVs, the fading effect of wireless transmission, and limited power supply. In this case, multiple relay UAVs need to be deployed in the path to form a swarm network in the sky by establishing an UAV-to-UAV link (UAV) between numerous source nodes and ground control stations. With its flexible mobility and strong battlefield adaptability, UAVs have been widely used in various fields[9].

With the development of cooperative control system of multi-intelligence system, UAV radio wave swarm system has wide application prospects in military and civilian fields. In the conflict between Azerbaijan and Armenia, the

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performance of UAVs was remarkable, and UAVs may become the main force of future warfare[10-13]. However, UAVs also have an Achilles' heel. Currently, UAV communication mainly relies on wireless communication means, and their signals are exposed to free space and are highly susceptible to various kinds of interference. In order to ensure that UAVs can effectively accomplish their missions, UAV communication systems need to have some necessary swarm link anti-jamming performance.

Since it is hard to entirely eradicate interference, UAV communication anti-jamming refers to adopting specific steps to reduce interference sources' impact on UAV communication and ensure proper UAV communication[14]. Additionally, the radio wave swarm anti-interference for air-ground integrated unmanned aerial vehicles primarily focuses on military considerations.

In August 2015, the Defense Advanced Research Projects Agency (DARPA) announced the launch of the Distributed Low-Cost UAV Swarm "Pixie" research program, which plans to launch swarms of small, retrievable UAVs from large aircraft outside enemy defense ranges to suppress the enemy through swarming tactics[15-16], and in April 2018, DARPA announced that the project had entered the flight test phase.

In January 2018, the National University of Defense Technology tested 20 fixed-wing UAVs for autonomous operations and successfully achieved the first domestic dual low-altitude drop and modal shift test of miniature folding-wing UAVs[17]. 2017 UAS Education and Development Workshop had proposed the decision of using multiple UAVs to form MAS and combining with Ethernet blockchain technology to build UAV communication system[18].

Duke et al. also calculated coverage probability and area spectral efficiency (ASE) by taking into account both line-of-sight (LoS) and non-line-of-sight (NLoS) transmissions between aerial base stations and ground users[19]. Three path loss models—the high-altitude, low-altitude, and ultra-low-altitude models—are researched and contrasted. The simulation findings reveal that while the ultra-low-altitude model deviates greatly from the network performance of the two models above, the high-altitude and low-altitude models display comparable patterns in terms of network performance.

Smart contract is an assembly language programmed on blockchain,which is applied in blockchain 2.0.Smart contract is essentially a computational program that records the node state and requires multiple approvals to update the state. As long as specific writing conditions are met, the smart contract can respond automatically[20-22]. The combination of smart contracts and various methods such as consensus algorithms fundamentally solves the traditional security problem[23-24].

Smart contracts are currently mostly used on the decentralized trading platform of Ether, and CellETF is a typical application scenario of smart contracts. all transactions on CellETF are executed through smart contracts, and at the same time CellETF, as a decentralized exchange on Ether[25], eCell is the basic governance pass and core function token of the platform, which is created through Ether smart contracts token, which is an ERC20 token. It will aggregate decentralized protocols such as ETF clearing, automatic market making, liquidity pooling, liquidity mining, and cross-chain price fact prophecy machine for smart contracts to provide users with diverse derivatives and strategy options.

3. MODEL BUILDING

In order to give full play to the characteristics of blockchain technology and highlight the excellent performance of anti-interference in UAV cluster applications, this paper builds a blockchain-based UAV cluster anti-interference communication network, and the specific anti-interference communication network is shown in Figure 1.

Among them, the anti-interference communication network operates as follows.

- When the communication network starts to operate, the UAV on-board terminals send interrogation messages with their own terminal verification codes (on-board terminal ID numbers) to each other and answer the interrogation signals from the remaining on-board terminals, so that the number of terminals participating in the network during this communication can be confirmed, and a new block is created for each UAV on-board terminal.

- When the ground station sends operational commands or flight data via the communication system, the nearest communication airborne terminal is selected to receive the sent commands, and the terminal sends the sent inquiry message with the terminal's authentication code (airborne terminal ID number) to other airborne terminals in the form of webcast, and the other terminals receive the inquiry signal and reply. During the query process, the blockchain nodes decide on the access rights of the drone nodes according to a predefined access control logic. Therefore, an attacker cannot tamper with the access rights of a node simply by compromising a single node. The message is sent only when the number of responding terminals is greater than (n-l)/2, which increases the difficulty of attacking nodes and improves the security of distributed access control in the UAV cluster network.

- Whenever a node in this network performs data transmission or data reception, a new block is generated and the new block is chained into the existing block chain, and the block chain of the terminal that performs data transmission or data reception is defined as the global block chain. During data communication, the elliptic matrix encryption algorithm is used for encrypted transmission. Each on-board terminal stores, in addition to the complete blockchain, a log chain consisting of only the checksum information of each block, which will all be stored in the behavior database. Combined with the group voting decision mechanism, every certain time, each terminal will broadcast its own log chain to the rest of the terminals, and if the received log chain information is different from the one stored in this terminal, it will reply its own block chain to the sender of the log chain. Similarly, when a terminal receives a number of blockchain replies greater than(n-1)/2, it updates its own blockchain to the global blockchain.

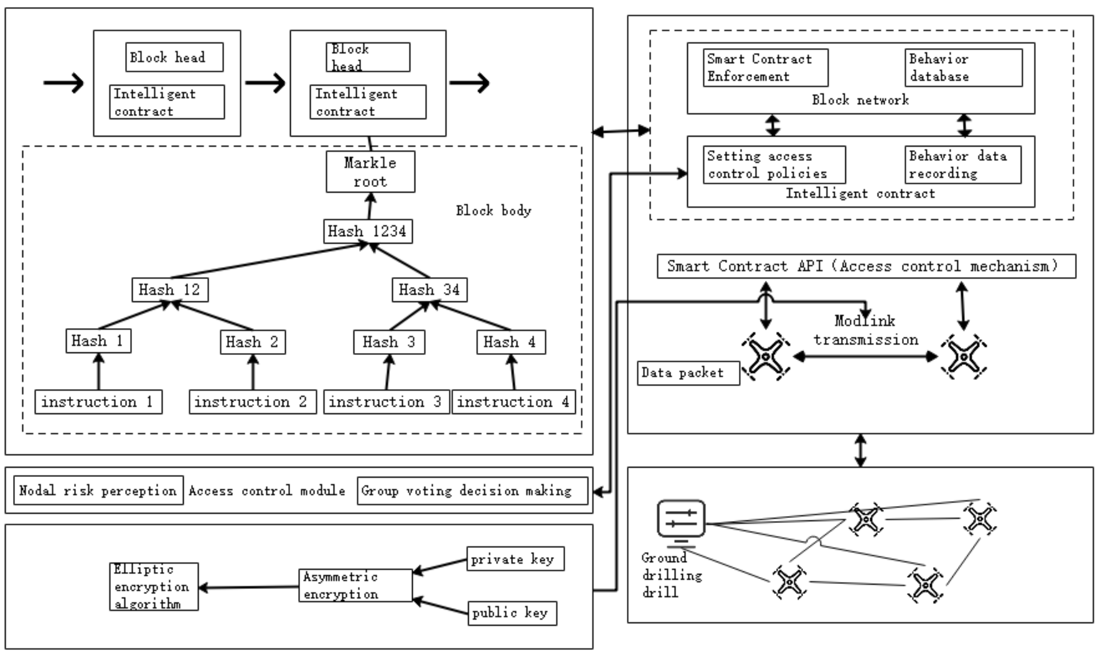

Figure 1. Diagram of anti-interference communication network.

According to the provided UAV swarm communication network model, it is deployed in the UAV swarm, and the communication between each UAV node in this communication network model is realized through the improved Modlink communication protocol, and the specific Modlink protocol format is shown in Figure 2. The CRC checksum in the UAV Modlink communication protocol is a 16-bit CRC checksum to ensure high security of data transmission.

4. MODEL OPTIMIZATION

In this topic, the process of interaction between an intelligent body and its environment is described as a Markovian decision process through optimization theory, and based on the above modeling, the following definitions are made in this paper.

Suppose user nodes marked N in the scene, the observation vector o is the distance $d_{i,k}$ between an intelligent body i and a node for a certain intelligent body k

$$\mathrm{o}_i = \left[d_{i,1}, \ldots, d_{i,N} \right]$$

Correspondingly, the action space u is defined as the direction of flight and the flight step per unit time slot, using polar coordinates to represent the movement of the UAV at the moment.

STX	FUC	LEN	SEQ	SYS	COMP	MSG	PAYLOAD	CKA	CKB

	Byte index	Content
STX	0	Address code
FUC	1	Function code
LEN	2	Payload length
SEQ	3	Package serial number
SYS	4	System ID
COMP	5	Component ID
MSG	6	ID of a message packet
PAYLOAD	7-N+7	Payload data
CKA	N+8	Check and low bytes
CKB	N+9	Check and high bytes

Figure 2. Improved Modlink communication protocol.

$$\mathrm{u}_i = \{\vec{a}_i, \varphi_i\}$$

where $\vec{a}$ is the direction and step in flight and φ is the azimuth.

Then the distance reward function is constructed as

$$r_d = -k_1 \cdot d_{i,k}$$

where, k_1 is the discount factor, which means that the closer to the node k , the less points will be deducted.

Also, for a connectable user, we define the communication vector $\mathbf{c}_{x,t}$, which can be expressed as $\mathbf{c}_i = [b_{i,k}]$. where $b_{i,k}$ is the signal-to-noise ratio determination in Eq. (1.4). Based on the service time $\delta_{i,k}$ defined in equation, the service time vector $\tau_i = [\delta_{i,k}]$ can be defined similarly.

Therefore the service reward function is constructed as follows:

$$r_t = +k_2 \cdot \mathbf{c}_i \times \tau_i$$

where, k_2 is the discount factor, which means the longer the service node time, the higher the score reward.

Considering the UAV range, we define the UAV offshore penalty function. We assume that the distance from shore is l , and that the further offshore the greater the risk. $r_l = -k_3 \cdot l$

The optimization problem is reduced to the following form.

$$\begin{aligned} \max_{\pi_i} \quad & J_i = R_i, \quad R_i = \textstyle\sum_{t=0}^{\infty} \gamma^t r_{i,t} \\ \text{s. t.} \quad & o_{i,t} \in O_{i,t}, \\ & u_{i,t} \in U_{i,t} \\ & t \in [1, T] \end{aligned}$$

Ultimately, the complete state in the Markov decision is represented as equation (1):

$$\mathrm{s_n} = [\mathrm{b_{1,n}}, \cdots, \mathrm{b_{K,n}}; \mathrm{c_{1,n}}, \cdots, \mathrm{c_{K,n}}; \mathrm{x_n}, \mathrm{y_n}; \zeta_\mathrm{n}] \tag{1}$$

where $b_{K,n}$ indicates whether the user and the UAV meet the transmission signal-to-noise ratio, and $c_{K,n}$ indicates whether the user has been served, and x_n, y_n denotes the coordinates of the UAV, and ζ_n is the residual state information from the previous time step.

5. CONCLUSION

In view of the problems that the massive, dynamic, distributed and lightweight characteristics of the current UAV group making the access control mechanism of the UAV group unstable, the low authority judgment performance, and the reduced security, this paper introduces the blockchain intelligent access control mechanism to the UAV group communication in the complex urban environment, and optimizes the Markov decision process to realize the anti-interference research of the UAV air ground integration radio wave.

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