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Research on High Reliable Multimode Wireless Communication Technology for UAV

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Abstract: High definition image transmission and remote control are typical applications of UAVs, which has spawned a large number of new scenes. This paper proposes a multimode wireless communication method and image transmission strategy for UAV based on the integration of public network and private network. By building at least two wireless communication links including public network and private network, the image data is encoded after obtaining its channel parameters, and the encoded image data is sent through the two links. The experimental results show that the proposed method improves the reliability and efficiency of data transmission.

Keywords: UAV; Wireless communication; Dual link; High definition image transmission.

1. Introduction

With the development of wireless communication technology, unmanned aerial vehicle (UAV) intelligent networking applications such as high-definition image transmission and remote control are gradually emerging [1-2], which are widely used in emergency rescue, agricultural plant protection, urban mapping, electric power inspection, logistics and transportation and other fields. At present, the wireless communication link between UAV and remote controller or ground station is mainly realized based on point-to-point private communication mode, such as Lightbridge and Ocusync built by DJI based on software radio. Due to the limitations of radio management laws and regulations, private wireless communication systems still need to use low-frequency unauthorized frequency bands, which may be interfered by other co-frequency equipment, and cannot seek radio protection, and can only provide local area network coverage in a small range. Therefore, using a single wireless communication method is difficult to meet the growing requirements of users for multiple performance indicators such as delay, image transmission quality and communication reliability, and the user experience is not good.

In order to solve the above problems, this paper proposes a multimode wireless communication method for UAVs, which constructs at least two wireless communication links including at least one public network communication link to improve the reliability and efficiency of data transmission. This method first obtains the channel parameters of these established wireless communication links, then encodes the image data collected by the UAV platform according to the channel parameters, and sends the encoded image data to the ground station or remote controller through the two wireless communication links.

2. Analysis of Multimode Communication Link

In the multimode wireless communication strategy, the first wireless communication link can be a public network communication link, the second wireless communication link can be a private network communication link, and the second wireless communication link can be a public network communication link.

(1) Public network communication link [4-5]

Public network communication link is a wireless communication link based on public network communication, including but not limited to 4G communication, 5G communication, 6G communication, etc. China Mobile and China Radio and Television share and build a 5G network in 700MHz, 2.6GHz and 4.9GHz frequency band, with 700MHz for wide area coverage, 2.6GHz for hot spot coverage and 4.9GHz for indoor coverage. China Telecom and China Unicom share and build a 5G network in the 2.1GHz and 3.5GHz frequency band.

With the development of 5G technology, it is possible for UAVs to connect cellular networks to achieve low latency and high reliability remote control and high-definition image transmission [6-8]. In 2018, China Telecom and Huawei realized the real-time transmission of 360-degree panoramic 4K high-definition video of UAV based on end-to-end 5G network in Shenzhen for the first time. In 2020, China Mobile, together with DJI and other UAV enterprises, carried out ultra-remote control of the UAV in Shenzhen at the Chengdu Command Center based on the 5G network, and send back ultra-remote high-definition images in real time.

(2) Private network communication link

Private network communication link is a wireless communication link based on private communication, including but not limited to Lightbridge and Ocusync based on software radio.

Lightbridge is a dedicated communication link technology independently developed by DJI, which can achieve 720p HD transmission and display with almost "zero delay", and the distance can usually reach more than 2 kilometers, or even more than 5 kilometers in the open and non-interference situation. Both Lightbridge and Wi-Fi use the 2.4GHz frequency band, but Lightbridge technology uses one-way image data transmission, similar to the data transmission form of the TV broadcasting tower located at a high place. There is no need to "shake hands" before establishing a connection.

Ocusync has the same video transmission capability as

Lightbridge, but has stronger reliability and stability. Ocusync can detect nearby interference and automatically switch the 2.4G or 5.8G frequency band. In addition, it also supports multi-device interconnection, and can connect up to two remote controllers and two flight glasses at the same time.

3. Design and Implementation of Wireless Communication Strategy Flow Based on Dual-Link Backup

In order to improve the reliability and efficiency of data transmission between UAV and remote controller, based on multimode wireless communication system, this paper proposes a multimode wireless communication strategy and method based on dual-link backup of public and private network communication. Firstly, the channel parameters of at least two established wireless communication links are obtained through the communication processing module on UAV. The established wireless communication link includes at least one public network communication link. Secondly, the image data collected by the UAV platform is encoded according to the target channel parameters, and the encoded image data is sent to the remote controller or ground station through two wireless communication links to achieve signal backup.

3.1. Acquisition of channel parameters and determination of target channel parameters

For the convenience of description, without losing generality, we take the dual-link wireless communication as an example, and call the two wireless communication links the first link and the second link respectively. At least one of the first link and the second link is a public network communication link.

The process of acquisition of the channel parameters and determination of the target channel parameters includes the following two parts:

(1) Acquisition of channel parameters.

The channel parameters of the first link and the second link are obtained through the communication processing module on the UAV, including any of the channel bandwidth and the received signal-to-noise ratio.

(2) Determination of target channel parameters.

The communication processing module on the UAV compares and judges the channel parameters of the first link and the second link, and determines the smaller one as the target channel parameter. That is, if the channel bandwidth or received signal-to-noise ratio of the first link is less than the channel bandwidth or received signal-to-noise ratio of the second link, the channel parameters of the first link are determined as the target channel parameters, otherwise the channel parameters of the second link are determined as the target channel parameters.

This method enables both the first link and the second link to transmit the encoded image data after encoding the image data based on the target channel parameters, so as to reduce the congestion of the communication link.

3.2. Image coding scheme based on target channel parameters

After the target channel parameters are determined, the image data will be encoded according to the target channel parameters to obtain the target image data. The image coding scheme based on target channel parameters includes the following steps:

(1) Determine the target coding rate according to the target channel parameters;

(2) The image data is encoded according to the target coding rate to obtain the target image data.

The mapping relationship between channel parameters and coding rate is stored in the UAV platform communication system. According to the mapping relationship and the target channel parameters, the target coding rate can be quickly determined. In general, the mapping relationship follows the principle of "the larger the channel parameter, the larger the coding rate, and the smaller the channel parameter, the smaller the coding rate". The mapping relationship can be set based on the actual situation. By dynamically adjusting the target coding rate through the target channel parameters, the bandwidth utilization of wireless communication links can be improved.

3.3. Image data transmission based on multiple packets

In the image data transmission stage, the basic process of wireless communication strategy based on dual-link backup is to send the target image data to the remote controller or ground station through two wireless communication links at the same time. The remote controller or ground station decodes the target image data after receiving the target image data encoded by two channels, and de-redundant the decoded image data, then display or store the image data after the de-redundancy.

The core of the strategy of wireless communication based on dual-link backup is the segmentation, backup, verification and the dynamic feedback adjustment of the target image data.

3.3.1. Segmentation of target image data

First, the target image data is segmented to obtain multiple data packets, and multiple data packets are sent to the terminal equipment through the first link and the second link at the same time to avoid retransmission of the entire target image data caused by byte loss during transmission. If the data packets transmitted by one link are lost or wrong, and the data packets transmitted by the other link are correct, the correct data packets can be used to recover the complete image data. It greatly improves the reliability and efficiency of data transmission.

The methods of segmentation proposed in this paper include target bit number method, double bit number method and byte order method.

Segmentation based on target bit number method

In this method, the communication system of UAV stores the mapping relationship between the channel parameters and the packet bit number. According to the mapping relationship and the obtained target channel parameters, the target bit number of the packet can be determined. The target image data is divided into multiple data packets according to the target bit number. Each data packet carries a CRC check code, and the terminal equipment can verify the received data packet through the CRC check code.

As shown in the figure below, the target image data is divided into packet queue 11, including 6 packets, and each packet carries CRC check code. When the first link transmits these six data packets, if the third data packet is lost or an error occurs, there is no third data packet in the packet queue 12 received by the remote controller or the ground station. When the second link transmits these six data packets, if the fifth data packet is lost or an error occurs, there is no fifth data packet in the packet queue 13 received by the remote controller or the ground station. At this time, after the remote controller or ground station receives the data packet, it can recover the queue 11 from the queue 12 and the queue 13 to ensure the reliability of data transmission.

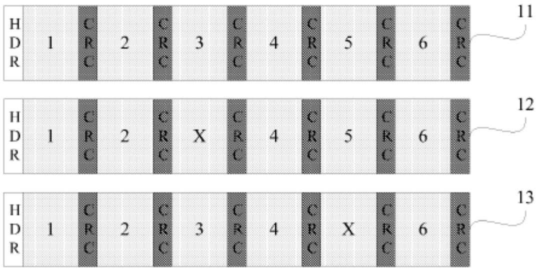

Fig.1 Schematic diagram of segmentation and transmission based on target bit number method

Segmentation based on double bit number method

In this method, the first bit number is determined according to the first link channel parameters, and the target image data is segmented according to the first bit number to obtain multiple first data packets. The second bit number is determined according to the channel parameters of the second link, and the target image data is subcontracted according to the second bit number to obtain multiple second data packets. Then send multiple first data packets to the remote controller or ground station through the first link, meanwhile send multiple second data packets to the remote controller or ground station through the second link. The first bit number and the second bit number can be the same or different. In case of data error, the remote controller or ground station will determine the data location to be recovered according to their respective bit number.

Segmentation based on byte order method

Similar to the double bit number method, the coding transmission strategy of breaking the whole into parts can also be implemented based on the byte order method. In this method, the packet size is completely determined by the two wireless communication links. For example, the first link constructs a data packet per 1000 bytes, and the second link constructs a data packet per 4000 bytes. The remote controller or ground station can recover the original data by byte order. For example, if the data between the 1000th byte and the 2000th byte transmitted by the first link is received incorrectly, the corresponding data between the first byte and the 4000th byte transmitted by the second link can be used to recover.

3.3.2. Transmission and verification strategy

In the above description of segmentation method, the transmission strategy is that the first link and the second link transmit the same data content, only the size or number of data packets are different. With this transmission strategy, data can be backed up. For wrong data packets, data packets from another link can be used for recovery.

In fact, the segmentation methods listed above can also adopt different data content transmission strategies.

Partial transmission strategy

After the target image data is segmented and multiple data packets are obtained, we can adopt the strategy of multiple data packets partial transmission. That is, send the first part of the multiple data packets to the remote controller or ground station through the first link, and send the second part of the multiple data packets except the first part through the second link. The number of packets in the first part and the number of packets in the second part can be the same or different.

As shown in the figure below, the target image data is divided into data packet queue 20, which includes 6 data packets (packet 1 to packet 6), and each packet carries CRC check code. Transmitting the first part of the queue 20, including packet 1 to packet 3, through the first link. And the second part of the queue 20 is transmitted through the second link, including data packet 4 to data packet 6.

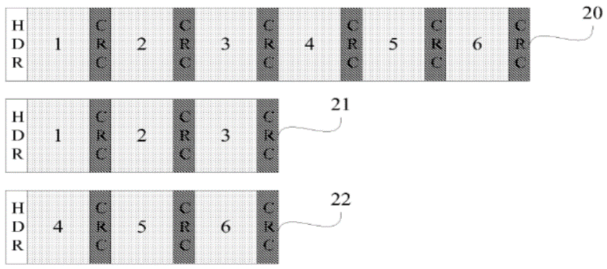

Fig.2 Schematic diagram of partial transmission strategy

Exchange and transmission of multiple data packets

On the other hand, after transmitting the first part and the second part of the data packets, the second part of the data packets is sent to the remote controller or the ground station through the first link, and the first part of the data packets is sent through the second link. Through this step, the exchange and transmission of the data packets can be realized, and the reliability of data transmission can be improved. As shown in the figure below, at T0, the UAV platform divides the target image data into six data packets. At T1, the first transmission begins. The first link sends data packets 1 to 3 to the remote controller or ground station, and the second link sends data packets 4 to 6. After transmission, the second transmission begins. The first link sends packet 4 to packet 6 to the remote controller or ground station, and the second link sends packet 1 to packet 3. At T2, the remote controller or ground station receives the data sent by the first link and the second link. Because the transmission delay of the two links is different, T2 is subject to the longest transmission delay. If there is no packet loss in the transmission process, then at T2, the remote controller or ground station can receive six complete data packets sent by the two links within the time of receiving only three data packets in the aforementioned transmission scheme.

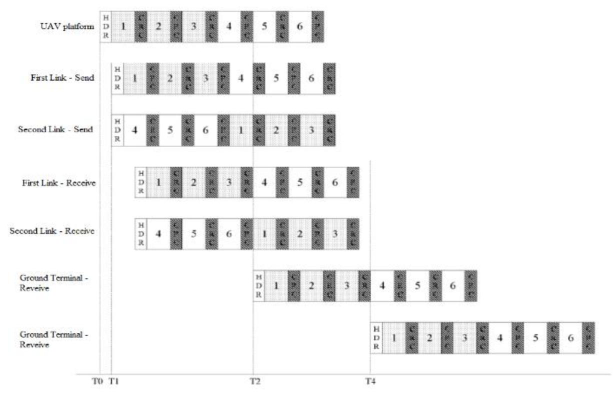

Fig.3 Schematic diagram of exchange and transmission of multiple data packets

If there is packet loss during the first transmission, it indicates that the channel quality of the link with packet loss is not high or there is interference. Assuming that the first link does not successfully transmit packet 2, and during the second transmission, the first link and the second link exchange the order of the transmitted packets. That is, packet 2 will be transmitted on the second link. In a short time, the interference will not change too dramatically. Therefore, the probability of the second link successfully transmitting packet 2 will increase, so that the remote controller or ground station can receive the complete 6 packets sent by the two links. In the worst case, when the data packets of the two links are transmitted at T4, the remote controller or the ground station can receive six complete data packets.

Transmission strategy based on verification and feedback

In addition to adopting the above multiple data packets exchange and transmission strategy, we can also determine whether data packets exchange or error data packet retransmission is required through verification and feedback.

On the one hand, a packet exchange strategy based on verification is designed to improve the reliability of data transmission and save link resources. First, obtain the feedback information sent by the remote controller or the ground station, and determine whether the transmitted data packets have errors according to the feedback information. If the feedback information carries an error tag, it can be determined that the transmitted data packets have an error, and then the data packet exchange is carried out, that is, the second part of the multiple data packets is sent through the first link, and the first part is sent through the second link. If the feedback information does not carry an error tag, it can be determined that the transmitted data packets have no error, and no packet exchange is required.

On the other hand, a packet error retransmission strategy based on verification is designed to further improve the reliability and efficiency of data transmission. First, obtain the feedback information sent by the remote controller or the ground station, and determine whether the transmitted data packets have errors according to the feedback information. If there is an error in the transmitted data packets, determine the data packet to be retransmitted from multiple data packets according to the feedback information. If the data packet to be retransmitted is in the first part of the multiple data packets, retransmit the data packet through the second link. If the data packet to be retransmitted is in the second part, the data packet is retransmitted through the first link.

For example, as shown in the figure below, at T0, the UAV platform divides the target image data into six data packets. At T1, the first transmission begins, that is, the first link sends data packets 1 to 3 to the remote controller or ground station, and the second link sends data packets 4 to 6. At T2, the remote controller or ground station receives the data sent by the first link and the second link. Because the transmission delay of the two links is different, T2 is subject to the longest transmission delay. At T3, the remote controller or ground station sends feedback information to the UAV platform. Through the feedback information, it can be seen that the data packet 2 transmitted by the first link has not been received, and requests retransmission. After receiving the feedback, the UAV platform retransmits packet 2 on the second link. At T4, the remote controller or the ground station receives the retransmitted data packet 2 and recovers six complete data packets.

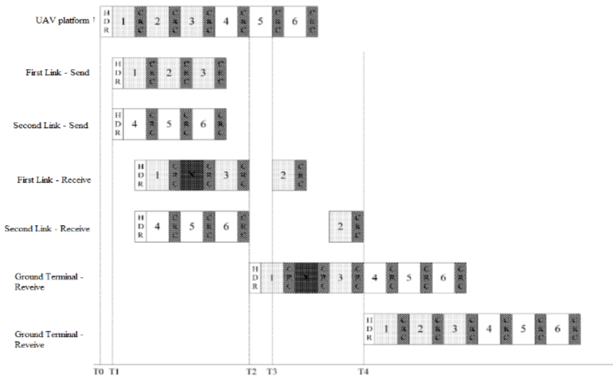

Fig.4 Schematic diagram of transmission strategy based on verification and feedback

4. Conclusion

In this paper, a multimode wireless communication method of UAV based on public and private network integration and an image transmission strategy based on dual-link backup are proposed. This method can effectively improve the reliability and efficiency of UAV data transmission. Based on this strategy and method, we will improve the link switching and adaptive image coding schemes in different scenarios to further improve the image transmission reliability.

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