Airborne gateway: key technology of earth observation system in the space-air-ground integration network

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Abstract. In traditional system of remote-sensing emergency services in space-air-ground integration network, the existing units of earth observation system operate independently from each other, the rate of data transmission and process can not meet the requirements, which makes the efficient actions taken after at least ten hours of the emergency. This has become a bottleneck for effectively responding to emergency events. The airborne gateway is the key technology to break through this bottleneck. The result of the rate test shows that our airborne gateway rate has reached 937M/s. Besides, it can also effectively detect moving target after preprocess. With the gateway, the three independent units are connected to a network, which works well and improves the efficiency of data processing and shorten the response time.

1. Introduction

The traditional data-processing-emergency services are separated, so that the timeliness of remote sensing information services can not meet the emergency needs. The existing units of earth observation system in the space-air-ground integration network operate independently from each other, and the work mode of independent task planning have become a bottleneck for effectively responding to emergency events. The airborne gateway is the key technology to break through this bottleneck.

The airborne gateway is an important key to realize the high-precision observation and transmission of space-air-ground integration network at full time. The network consists of three separate systems, data source, ground processing center, and data transmission center. We integrated them to a network with airborne gateway, demonstrated the collaborative work and testified the space-air-ground integration network. The realization of online processing and real-time transmission of source data in the network can shorten the response time of the ground monitoring center to a certain extent. With it, data exchange between multiple systems can be realized, multiple systems can work together and the efficiency of data processing can be improved, which will reduce response time, provide data transfer and processing between multiple systems and make sure data transmission both timely and efficiently.

2. Design

The design of the airborne gateway is based on the characteristics of the application scenarios, current major problems, system requirements, and key technologies. Besides, according to the requirements of the indicators, we designed the airborne gateway hardware system and data processing algorithm. There are variety of communication protocols and a large amount of data carried on the UAV, which is required by the ground. To transfer these data, the airborne gateway is designed with the ability to
identify and process different types of data frames and provide quick data transmission. We design the module ring through the data forwarding, protocol conversion and control functions separation; realize the dynamic combination and flexible configuration of the function modules through the middleware technology; and achieve the flexibility of management and control through the underlying and upper layer of standardized interface design and control.

![Diagram of the gateway's internal structure](image)

**Figure 1. Internal structure of the gateway**

2.1. **Frame type identify**
In addition to image data frames, there are telemetry frames, GPS data frames and processed data frames. They have different processing methods, so airborne gateway needs the ability to identify different types of data frames and process them accordingly. We have formulated a uniform format in the data fields of the frame. The data field of each frame starts with 20bit 0F_0F. For example, if the head parser gets the head of a frame, which is 0F10F, which means, it is a telemetry frame, and the output decide will transfer it to the data transmission center. The head of GPS frame is 0F20F. As for image data and processed image data, the heads are 0F20F and 0F30F.

2.2. **Quick data transmission**
To improve the rate of data transmission, we designed and implemented two modules: direct transmission module and preprocess module. In the design of the direct transmission module, we used two important technologies, the bus and the pipeline. The bus is efficient in facilitating the processing and control of data packets. The pipeline mechanism requires a synchronization mechanism between modules at all levels. Its basic idea is to re-integrate the modules of the complex data processing path, so that the operations that need to be completed within one clock cycle are divided into multiple clock cycles, which requires the functions of the modules of the pipeline to be separated from each other and processed. The processing of this pipeline can greatly improve the throughput of the hardware system.

The image taken by the data source is large, so that its transmission time is longer than small image, which will affect the emergency response efficiency. In order to offset this effect and minimize the processing time of the ground processing center, we do a preliminary process on board. It is mainly for the initial detection of the target in the image data, extracting the information and encapsulate the result according to the image format of the ground processing center. It realized automatic real-time detection and extraction of emergency information, fast real-time feature extraction while ensuring accuracy, accurate identification and geolocation of time-sensitive targets such as aircraft, vehicles, ships, and crowds in airborne imagery.

3. **Network system**
When regional emergencies occur, in order to identify, respond and act in time, the airborne gateway is needed to construct an integrated Space-earth cooperative scheduling platform and a real-time observation and transmission network. To transmit the scene video (data source) captured by UAV to the ground processing center immediately, and transmit the results of image processing and
recognition to the data transmission center for timely detection and processing of emergencies, the airborne gateway is required to have sufficient data processing rate to realize full-time observation and real-time transmission network.

![Network Structure Diagram]

**Figure 2. The structure of the network**

Airborne gateway is responsible for data interaction between UAV airborne multi-system (control system, remote sensing system, camera, etc.) and ground processing system, as well as data transmission system. Besides, it also provides guarantee for data interaction and integration. On-line processing and real-time transmission of airborne image data can shorten the response time of ground monitoring center to a certain extent. At the same time, the airborne gateway can realize the data exchange among multiple systems, improve the efficiency of data processing and shorten the response time.

4. **Preparation**

We build a system to model the air-space-ground integration network. We connect three independent units into a system. The airborne gateway provides a safe and effective channel for communication between the three units, and determines the data format used by the three independent units, allowing them to interact with each other through the corresponding communication interface according to the communication rules of each unit. To make sure the demonstration goes well, we did some preparation as follows:

1. Rate detection on the gateway.
2. Enable the data source to deframe data, send data, and add a corresponding trigger.
   The data at the data source is encoded image data. We need to decode it and revert it to RGB image data for transmission. The deframing function is to decode the encoded video stream data obtained by the UAV. The sender function is to send the decoded data to the gateway. The trigger function is a condition to start to send.
3. Add the forwarding function at the ground processing center and debug.
   The corresponding receiving interface is added to the ground processing center, the image information is received first, and the image data is received and processed according to the image information.
4. Add the receiving program and debug at the data transmission center.

5. **Result**

We will present our result from two perspectives, one is the connected integrated system debugging demonstration, the other is the performance test report of the airborne gateway.
5.1. Performance test report

In the experiment, we used iperf to measure the network throughput, loss rate and jitter of UDP and TCP. Packet loss rate shows the performance of the airborne gateway in the harsh network environment, especially in the case of broadcasting storm. Jitter is an important parameter for real-time transmission, describing the quality of service or network stability of the network. We designed different test sets by simulating the actual application requirement and test repeatedly to get reliable jitter, packet loss and delay data. We designed the following five tests, in which the UDP test set up 100 times the amount of data to give a certain pressure.

The theoretical bandwidth in this test is 1000 Mbits/s. Removing the bandwidth occupied by the control information in the network, the remaining bandwidth should be greater than 900M. These test items are showned below.

![Figure 3. Characteristic test result](image)

![Figure 4. Single Thread UDP](image)

5.2. Preprocessing result

Due to different sizes of targets, the targets present a variety of different scales in the image. Therefore, in order to improve the accuracy of detection, we designed a multi-scale target detection scheme to adapt to different scales through multi-scale sliding window. The detection process is as follows: firstly, a sufficient number of candidate frames are obtained through the sliding window, and then the regional features are extracted through the depth network, and finally the features are input into the classifier to obtain the category results, and the position coordinates are input into the regression device to perform the position and adjustment. The figure below is the original image and the processed image. In practice, we perform the multi-scale sliding window operation on the last layer of the convolution map, and finally enlarge the result of the candidate frame to the original image.
5.3. Demonstration of the system

In the network formed with the gateway, the video from the video source is displayed and sent to the gateway. After receiving and forwarding through the gateway, the ground processing center normally receives and displays the video source data. Which means, a air-space integrated cooperative scheduling platform and a real-time observation and real-time transmission network are constructed.

6. Conclusion

When emergency occurs, it’s important for control center and other units to get photos and data as soon as possible to handle emergencies in a short time. The airborne gateway provides assurance to build an space-air-ground integrated collaborative scheduling platform, full-time observation and real-time transmission network technology, improve data exchange rate and transmission reliability between systems. And it will help to realize the integration of observation, online processing and transmission. So that when regional emergency happens, we can discover, report, and process on time.

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