CENTRALIZED REAL TIME MONITORING SYSTEM BASED ON MULTILAYER NETWORK ARCHITECTURE FOR FLIGHT TEST TELEMETRY

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ABSTRACT

The flight test telemetry real-time monitoring system is an indispensable part of civil aircraft flight test. With the current trend of network system, the traditional real-time monitoring model has difficulties in satisfying the requirements of increasing number of parameters, diversified types, large-scale system and high concurrency data streams. In response to the above issues, this paper proposes a monitoring system based on a three-tier architecture (data layer, business logic layer and presentation layer). The system uses TMoIP technology and Best Data Engine (BDE) to complete the selection of the best data source of multi-site flight test data streams. At the same time, the use of portability and rapid integration enables hundreds of terminals to work simultaneously. The system has been used successfully in China's developing large civil aircraft C919 flight test program. The preparation time of the system has been greatly reduced, and the system performs stably.

INTRODUCTION

Flight test is to verify and validate the aircraft's functions and performances under real flight conditions, which is an essential process in civil aircraft research and development activities. Organizing flight test is a systematic engineering work with strong scientific and practical property, with high risk, long cycle and high cost. Telemetry monitoring, a necessary link between aircraft and ground data acquisition systems, is an important method to achieve the real-time monitoring. With the help of telemetry monitoring, flight controllers make decisions of the flight, flight test engineers monitor the test procedures, and aircraft design engineers keep eyes on the aircraft performances. Hence, Telemetry system is a vital and inevitable part during the civil aircraft flight test, which ensures flight test safety, improves test efficiency and shortens test cycle time.

Modern civil aircrafts use a large number of predecessor technologies and advanced avionics buses, and the systems are becoming more and more complex. With the continuous improvement of the network level of the airborne data acquisition system, the number of flight parameters of civil aircraft is also increasing, and the data types are more diversified. Therefore, we need to use more extensive means and more monitors to monitor every detail of the aircraft performances. The challenge is that much more monitoring terminals must be driven and integrated with many functions such as calculation, analysis, playback, and storage of telemetry data in real time.

A single telemetry station is commonly used in traditional flight test telemetry. This configuration only covers certain distance. Also, some obstacles in the telemetry transmission path may block the signal. When the flight test area is far from the telemetry station or the telemetry transmission environment is complex, the quality of telemetry signal will be greatly reduced. This imbalance between distance and signal quality will directly affect the stability and accuracy of telemetry data. For some important flight test subjects, it is not acceptable.

On the other hand, traditional monitoring software can't satisfy the growing demands. Traditional monitoring software runs independently on terminals. Before the flight test, system technicians need to make the data display screens and calculation methods of parameters in advance. When the calculation methods or display screens change, the technician have to update the monitoring software of every terminal, even although the changes are very small. Also flight test engineers need to analyze the data in real-time to understand the status of the aircraft and determine the effectiveness of the flight test subjects, but the traditional monitoring software on every terminal is difficult to perform complex data analysis in real-time. Traditional monitoring software structure can’t support the complex flight test task very efficiently.

In order to solve the above problems, this paper designs a new telemetry monitoring system. The system uses TMoIP (Telemetry-over-IP) to transmit data from several remote telemetry stations to the central station, so as to enlarge the flight test airspace and ensure the quality of telemetry signal. BDE is used to select the best data stream in the central station, laying a foundation for the monitor to obtain accurate data. At the same time, the system adopts a typical three-tier architecture to conduct the monitoring task, which also support the real-time analysis, storage and playback functions on hundreds of monitoring terminals.

MULTI STATION TELEMETRY

The telemetry monitoring system adopts a multi-station receiving and centralized monitoring mode, and its architecture is shown in Figure 1.

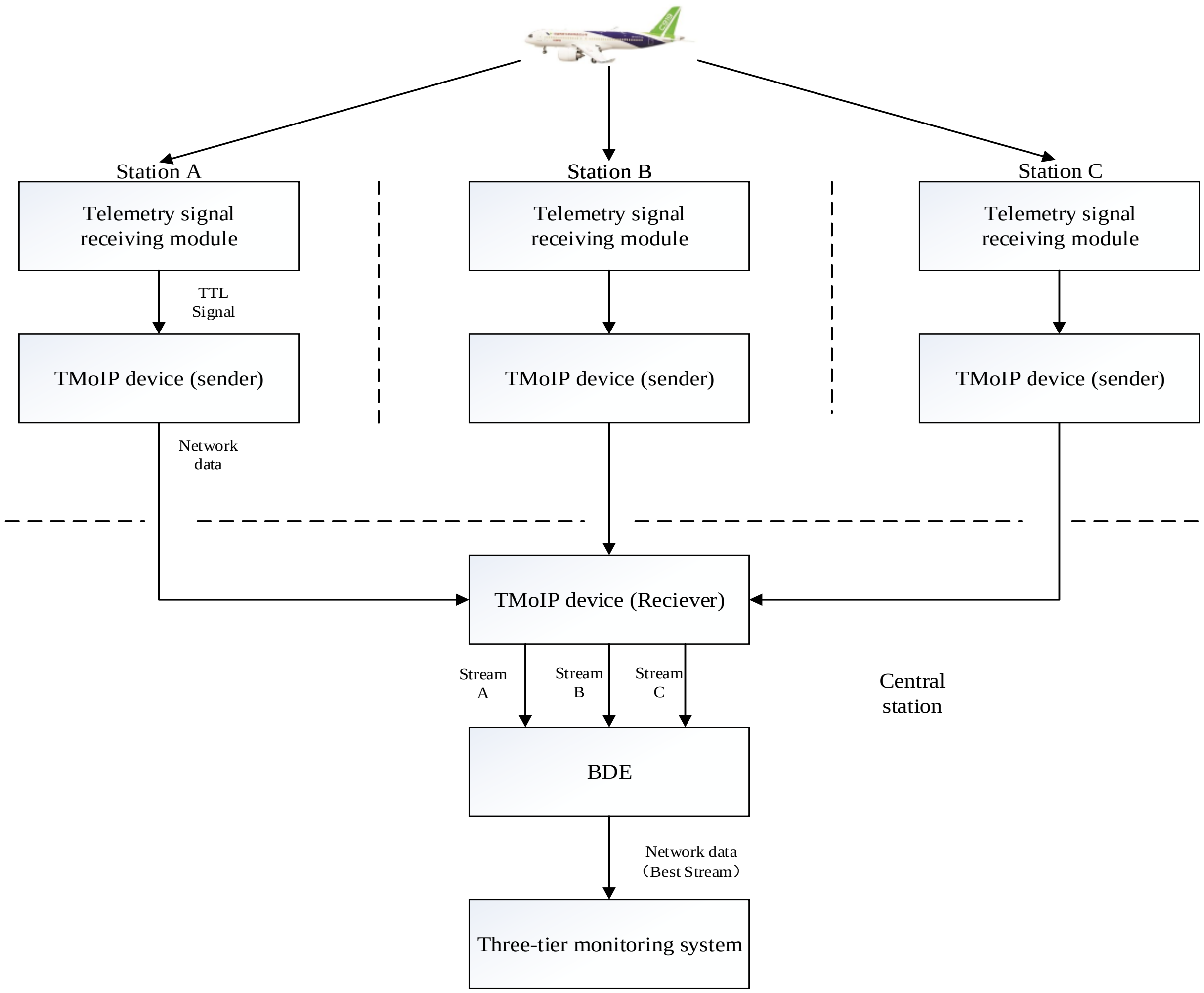

Figure 1 System Architecture.

In Figure 1, the system consists of three remote stations (Station A, B, C) and a central telemetry station. Obviously the number of remote stations can vary. Each remote station contains a receiving module for real-time acquisition of aircraft PCM signals.

TMoIP device in each station is the key for long-distance transmission of telemetry data between stations. Its function is to conversion the TTL signal to network packetized data. TMoIP devices always work in pairs, including senders and receivers. The receiver subscribes to the sender using TCP/IP and restores the network data to a TTL signal.

As shown in Figure 1, the working steps are as follows:

A. Remote stations A, B and C simultaneously receive telemetry signals from the target aircraft. Telemetry signal receiving module will complete signal demodulation and bit synchronization.

B. The TMoIP sender converts the synchronized data into network packets and sends them in real time.

C. The TMoIP receiver of the central station reduces the network data of each remote station to a bit synchronized signal.

D. BDE selects the best data stream from three bit synchronized signals. Three-tier structure using this stream to complete data analysis and distribution, which will be described later.

In accordance with the system structure, we set up three remote telemetry stations, besides the central station. Station A is 10km away from the central station to improve the telemetry quality in the airport. Station B and C are about 60km and 150km away respectively, to improve the telemetry converge in flight test area. The central station is where the flight controlling center locates. The relative position between stations is shown in Figure 2. This structure enlarges the telemetry scope, and makes better use of the flight test area, especially when the aircraft is at the relatively lower altitude.

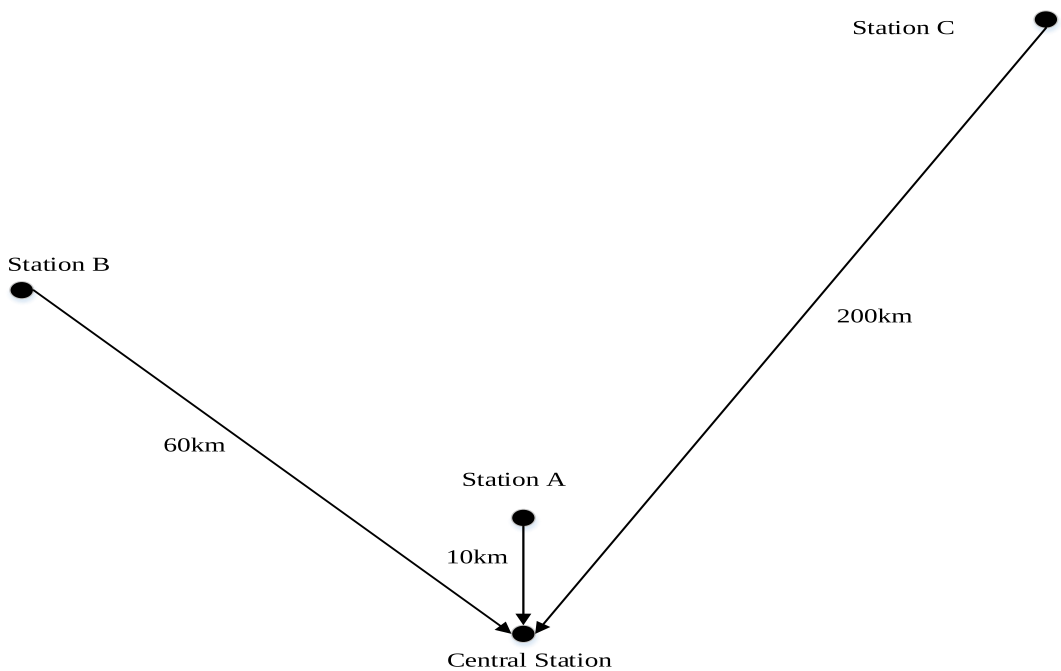

Figure 2 The Location of each station.

BEST DATA STREAM SELECTION

The best data stream selection is to select the most qualified data stream from multiple data streams according to the set threshold. This function is done by the BDE module of the central station. The BDE module selects the best data stream from multiple bit synchronized signals output by the TMoIP devices. Regarding the difference in distances of each stations, the time delays that signal received by monitoring center are also different, so the first step is to align different data streams under same timeline (Figure 3.).

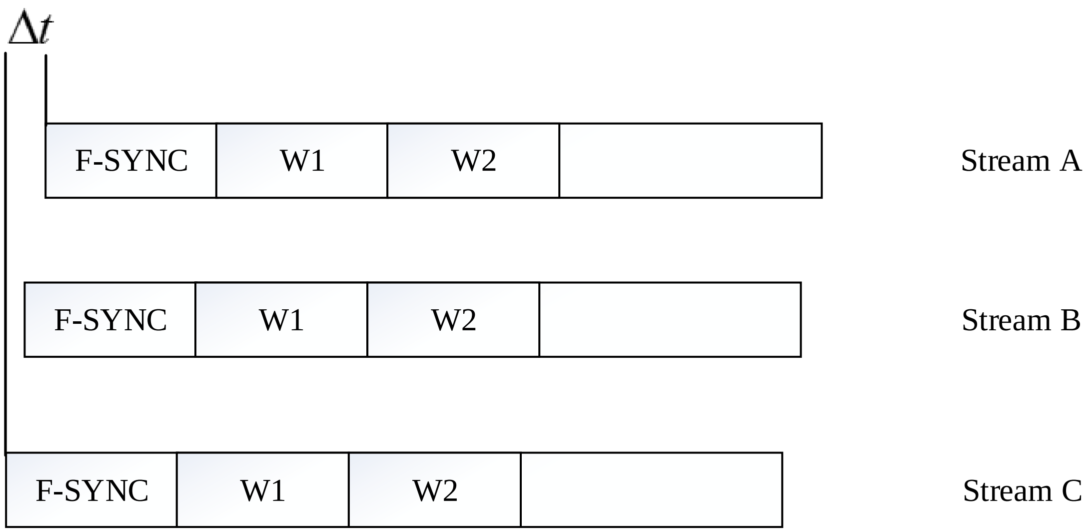

Figure 3 Stream Synchronization.

After synchronization, BDE performs a weighted calculation on the relevant information and selects the best data stream with the highest score. BDE compares the information in the data stream and does not change the data. We select the first 6 words of each sub-frame as a criterion for selecting the best data stream, includes PCM sync word, SFID, and GPS time (Figure 4.).

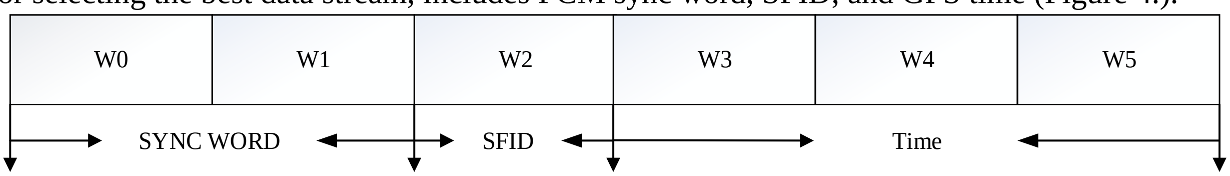

Figure 4 BDE Judgment Conditions.

The sync word is used to determine if the PCM sub-frames are synchronized, and it is easy to exclude data streams whose sub-frames are not synchronized. Therefore, the sync word has the highest weight.

Whether the SFID is continuous determines whether the main frame is synchronized or not. Therefore, SFID is also a very important decision condition.

GPS time is dynamically changing. In the case where the sub-frame and main frame weight calculation scores are the same, it is easy to eliminate high bit error rate data streams by comparing GPS time.

At the same time, BDE selects a data stream as the reference stream so that this data stream can be output when all streams have the same score. The process is as shown in Figure 5.

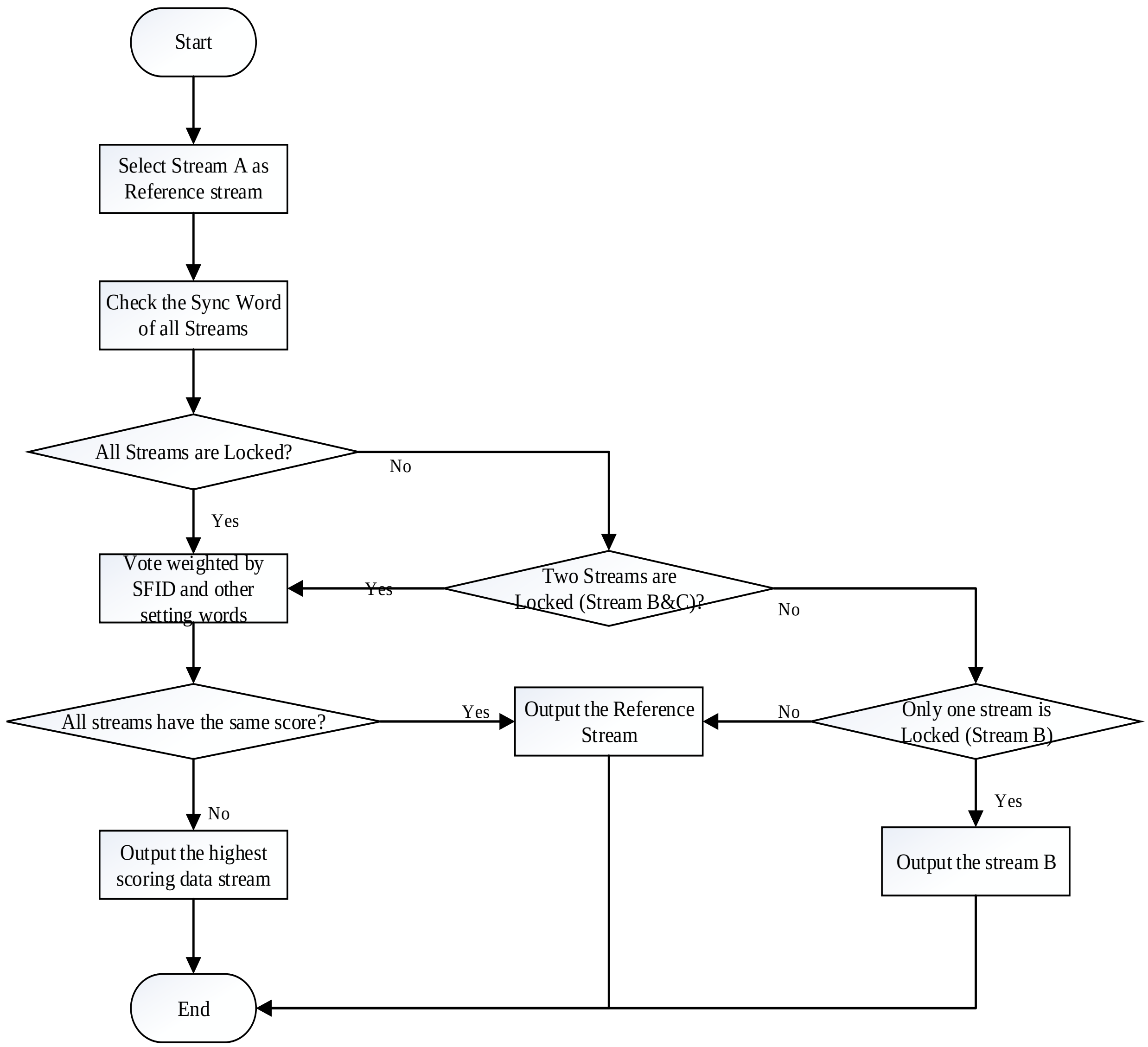

Figure 5 Best Data Stream Selection.

As described the Figure 2, we set the stream of the central station's data as the reference stream. When the aircraft is at the ground, sometimes the stream of station A has higher score. When the aircraft is far from central station, the stream of station C may have better quality. With this system described, always the data stream with best quality is chosen automatically.

REAL-TIME MONITORING OF FLIGHT TEST DATA BASED ON THREE-TIER ARCHITECTURE

Traditional monitoring software runs on individual terminal independently. Obviously its maintainability and portability have limitations, especially in the real-time analysis of flight test data. The direct cause of this phenomenon is that traditional monitoring software centralizes data reception, parameter calculation and display. They interact with each other. The optimal approach is to reduce the coupling between each functional module. Therefore, we propose a monitoring system based on a typical three-tier architecture, including data access layer, business logic layer and presentation layer (Figure 6.).

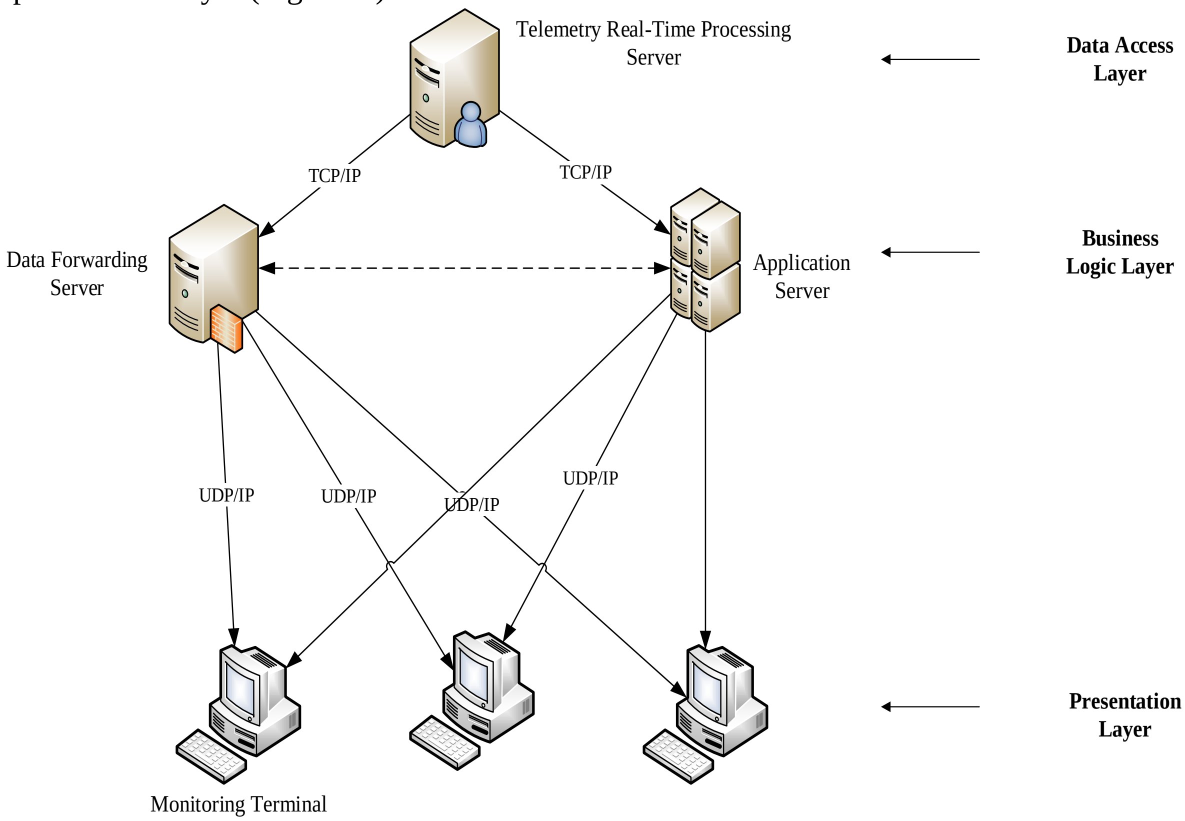

Figure 6 Real-Time Monitoring System.

The first layer is data access layer. In this layer, the telemetry real-time processing server receives the best data stream and performs engineering conversion of all data.

The second layer is business logic layer, which is consisted of a data forwarding sever and an application server. Two servers are independent of each other. The main function of the logical business layer is to conduct complex analysis and distribution of flight test parameters.

The application server responds to the requests of terminals, such as real-time playback, FFT and other complex operations. Then the server sends the analysis results to terminals. Real time playback means operators can look up the historical data at any time during the flight test, which was often used in data validation and abnormal point shooting. If needed, the application server receives playback requests from terminals and extracts corresponding historical data based on the playback spread to satisfy the requests. This system is able to provide a data playback of five to ten minutes. Playback process is independent with monitoring data link and after the playback, the software is switched back to monitoring process.

The function of the data forwarding server is relatively simple. It broadcasts data to each terminal based on UDP/IP.

The advantage of this design is that data distribution and analysis are independent from each other, and complex algorithms can be integrated on the premise of ensuring the real-time performance of the system. At the same time, the use of broadcast protocols reduces the pressure on the data access layer and drives more monitoring terminals.

The third layer is the presentation layer, which is consists of various terminals and applications on them. We design a display screen editor and interpreter platform, with which the engineers can make several display screens efficiently, by dragging and dropping the display widgets. e. The interpreter runs on the terminal and automatically downloads the configuration file to complete the update of the monitoring software. This approach significantly shortens the development cycle of monitoring software.

Due to the independence between layers, the maintainability of the system is better. Any changes of one layer will not affect the other functions.

Based on these advantages, approximately 10,000 telemetry parameters were processed and monitored in real time. The system also drive about 100 terminals. Real-time analysis and playback functions of telemetry data get good responds from monitoring engineers. This system also provides several other monitoring tools, such as CAS information, onboard video, flight test simulation and flight trajectory.

CONCLUSIONS

This paper designs a multi-station centralized monitoring system for telemetry data. The system uses TMoIP and BDE to achieve long-distance transmission and best data stream selection of telemetry data. The system not only expands the flight test airspace, but also improves signal quality and data stability. The three-tier architecture monitoring model proposed in this paper overcomes the shortcomings of traditional monitoring software. The design improves the maintainability and portability of the system. The system has the ability to support several remote stations and more than 100 monitoring terminals, while the time to set up and maintain the system has been greatly reduced. The system has been successfully used in China's developing large civil aircraft C919 flight test program.

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