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Design and Development of a Universal Verification System for Satellite Data Management System Based on AOS

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***Abstract*—In this paper, a universal verification system for satellite data management system based on AOS is proposed, in which a special digital satellite can produce original data for universal verification system liking an actual satellite. Original data obtained from the digital satellite are processed by satellite data management system, and then are transferred to data management system of earth station. After being processed by the data management system of earth station, the verification data will be compared with the original data obtained from digital satellite to prove that the satellite data management system can work normally. A configuration program is established to ensure the flexibility and consistency of the verification system. An example is introduced and it further shows that the verification system can verify the key technologies of satellite data management system based on AOS.**

Keywords-Data Management System, AOS, Digital Satellite

I. INTRODUCTION

With the spacecraft platform becoming more complex and the payload increasing, the requirements of space missions for effective data transmission are higher, especially when dealing with multiple types of space data and processing emergency information. The advanced orbiting system (AOS) [1-3], which can provide a flexible and convenient data processing service, has been developed by the international consultative committee for space data system (CCSDS) [4-6]. In view of the complexity of satellite data management system based on AOS, which is not only a data transmission and communication mechanism, but also a data-processing and management system to space-to-space, space-to-surface measurement [7-8], a universal verification system in simulated actual flight conditions is very important. This paper summarizes the key technology of satellite data management system, analyzes the ideal functions of a verification system, and then the universal verification system is developed. A typical example shows the verification system can verify the key technologies of the satellite data management system based on AOS.

II. SATELLITE DATA MANAGEMENT SYSTEM

The satellite data management system to be verified is implemented on FPGA, which includes encapsulation service, multiplexing service, virtual channel data unit service and virtual channel access service. The framing process of the satellite data management based on AOS is shown in Figure1.

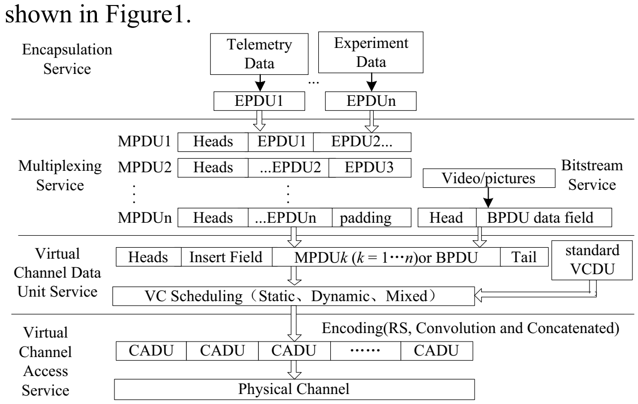

Figure 1. The framing process of satellite data management system

A. Encapsulation Service

In encapsulation service, telemetry data and experiment data with different format are converted into unified CCSDS standard to form packets (EPDU).

B. Multiplexing service

Multiplexing service includes two-level multiplexing mechanism. The first level refers to different types and rate of packages can use the same virtual channel. The second level means different virtual channels can share a physical channel. Multiplexing service conducts the first-level multiplexing by itself, and prepares MPDU for the second-level multiplexing.

C. Virtual Channel Data Unit Service

The main function of virtual channel data unit service is to send data, which are stored in the buffer of different virtual channel, to physical channel one by one with a scheduling. The satellite data management system includes four kinds of scheduling strategies: static scheduling, dynamic scheduling based on fixed priority, dynamic scheduling based on dynamic priority and mixed scheduling.

When static scheduling is adopted, the VCDUs in different virtual channels will be sent to a physical channel according to the number of virtual channel. It means that after a VCDU is sent, a VCDU in following virtual channel will be sent in next time.

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When dynamic scheduling based on fixed priority is adopted, a predefined priority will be set to every virtual channel at beginning. The VCDUs in different virtual channels will be sent to a physical layer according to the priority of virtual channel.

When dynamic scheduling based on dynamic priority is adopted, before each sending a dynamic priority of each virtual channel will be calculated. The dynamic priority of each virtual channel, in the *k*th sending, is defined as:

$$D_{i,k} = B_{i,k} \times m_i \quad (1)$$

Where m_i is the predefined priority, subscript '$_i$' is the number of virtual channel, $B_{i,k}$ is urgency base and is defined as:

$$B_{i,k} = \begin{cases} B_{i,k-1} + 1 & D_{i,k-1} = \max(D_{i,k-1}) i = 0,1,\cdots,n \\ B_{i,k-1} - 1 & D_{i,k-1} \neq \max(D_{i,k-1}) i = 0,1,\cdots,n \end{cases} \quad (2)$$

Where n is the total number of virtual channels. In each sending, the VCDU in the virtual channel which has the max dynamic priority will be selected.

In mixed scheduling, the virtual channel 0~2 use the static scheduling, and channel 3~7 use the dynamic scheduling.

D. virtual channel access service

When virtual channel data unit service sends data, the data don't reach physical channel directly until virtual channel access service encodes them. In this paper, four encoding algorithms including RS(Reed-Solomon) encoding, convolution encoding (2-1-7 and 4-3-7) and RS-convolution concatenated encoding are adopted.

III. IDEAL VERIFICATION SYSTEM

The most basic function of a verification system is to validate the key technologies. However, in order to directly apply the verification results to the engineering practice, the running environment, input data and data-processing of the verification system must be completely consistent with that of the actual system, which is the premise of the verification work. In addition, the verification system should also have good versatility and scalability to be suitable for the diversity of a verification task. Therefore, the ideal verification system for satellite data management system should have the following characteristics: verifying the key technologies of AOS; good applicability and practicability; simulating multiple work conditions; versatility and expansibility.

IV. DESIGN AND DEVELOPMENT OF THE UNIVERSAL VERIFICATION SYSTEM

The verification system for satellite data management system includes four important parts: digital satellite, data management system of earth station, the comparison system and the configuration program. Digital satellite offers the original data for satellite data management system and the comparison system. The original data is processed by satellite data management system and data management system of earth station. The verification data outputted from data management system of earth station and the original data should be identical. In comparison system, an assessment of the consistency of verification data and original data are carried out. The configuration program ensures the flexibility of digital satellite and the consistency of processing method used by data management system of earth station and that used by satellite data management system. The data flow of verification system is shown in Figure 2.

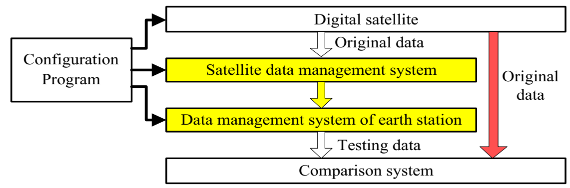

Figure 2. Date flow of the verification system

A. Digital Satellite

The digital satellite, whose model and parameters are consistent with that of the actual satellite, dynamically simulates the working principle and mutual relationship of all subsystems and its parts, to produce data.

Each component of the digital satellite includes four mathematical descriptions: the principle model, telecom interface model, error model and failure model, to reflect the working principle, performance and behavior characteristics in various failure conditions. Telecom interface are generally unchanged. The simulation approximation degree of principle model may need to be adjusted according to the requirements. In some cases, a simple model is established, in others each of the parts and the information process can be realistically simulated. The error model and failure models of each component can be adjusted according to the knowledge and understanding.

The digital satellite is divided into two parts: application software and running platform. The application software includes data processing algorithms and transmission scheduling methods, etc., which consists of the mathematical foundation layer, mechanical foundation layer, algorithm layer and physical layer, as shown in Figure 3. The running platform let the application software run in different platforms.

Mathematical foundation layer is the bedrock of software arithmetic, which includes general mathematical algorithms, such as matrix calculation, space vector calculation and rejection algorithm, etc. All the mathematical algorithms can be used in different satellites.

Mathematical foundation layer, mechanical foundation layer and algorithm layer remain unchanged in different satellites. The framework of physical layer remains the same, but if it is according to work mode that a subsystem is contained in physical layer. The main difference among the different satellites is the number of subsystems contained in physical layer, and a certain satellite can be obtained by trimming physical layer.

The digital satellite can simulate various actual satellites and ensure the verification system can simulate multiple work conditions. The multi-layer design method keeps the versatility and expansibility of the verification system [9].

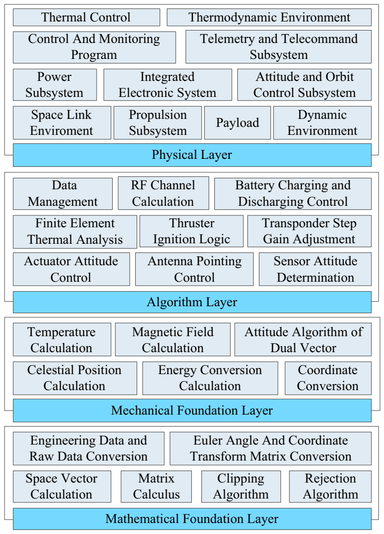

Figure 3. Multi-layer in digital satellite

Take attitude and orbit control subsystem for example, as shown in Figure 4, orbit and attitude dynamics can calculate the position, velocity, attitude and attitude angle velocity of satellite in real-time, and send the data to the sensors as the measurement results. According to the measurement results of sensors, running mode and the algorithm of attitude and orbit, the attitude and orbit control computer can calculate the value of actuators and send the value to actuators. Take camera (one of payload) for example, according to the satellite track getting from orbit and attitude dynamics and camera parameters, the camera simulator extract all relevant tiles from offline map database, montage and intercept to form verification images. Digital satellite not only simulates the normal situation, but also can simulate the abnormal situation by injecting fault, which ensure the verification system having good applicability and practicability.

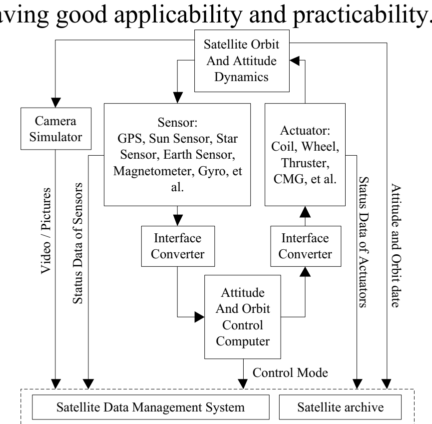

Figure 4. Date flow in attitude and orbit control subsystem and payload

B. Data Management System of Earth Station

The processing procedures of data management system of earth station diametrically opposed to that of satellite data management system. The output data should be completely consistent with the original data from digital satellite. So the correctness of satellite data management system can be verified by comparing the output data with the original data.

C. Comparison System

The output of data management system of earth station contains status information and video/picture, as shown in Figure 5. The status information, including the information of attitude and orbit, status data of sensors and actuators, etc. is saved to database by packet telemetry. The correctness of satellite data management system can be proved by comparing the data in earth station database with that in satellite archive. Video/Picture is saved as bmp/avi file. The uniformity of video/picture can be validated by image processing software.

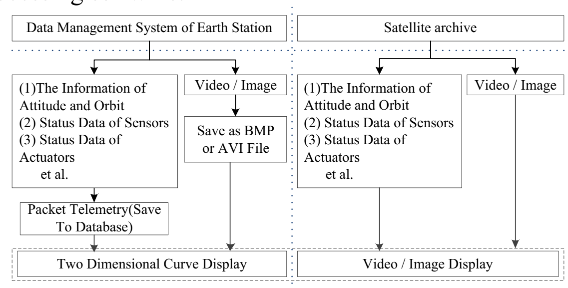

Figure 5. The verification module of earth station

D. Configuration Program

The parameters of digital satellite, including orbit elements, mass, inertia, etc. can be set by the configuration program, and an .xml file is generated. The multiplexing type, virtual channel scheduling algorithm and its priority and encoding algorithm of AOS also can be configured. Then, an .INI file is generated, which is shared by the satellite data management system and data management system of earth station.

V. VALIDATION

The physical satellite data management system which will be verified is as shown in Figure 6.

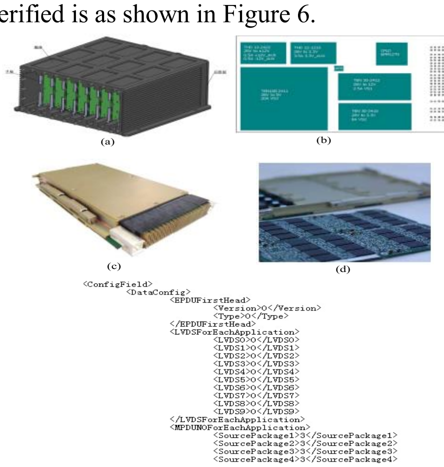

Figure 6. Satellite data management system: (a) Chassis, (b) Power supply module, (c) CPU master control module, (d) Solid state storage module, (e) parameters

A verification system based on Visual C++ and C# is established. Taking a remote sensing satellite for example, a digital satellite is developed. The parameters, program, 3D display result and 2D display results of the digital satellite are shown in Figure 7.

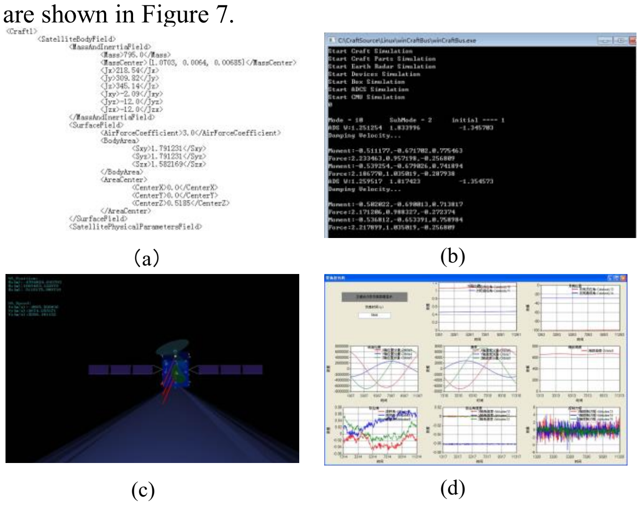

Figure 7. Digital satellite: (a) Parameters, (b) Program, (c) 3D display, (d) 2D display

The data management system of earth station is shown in Figure 8. The pictures in the 8(b) are obtained from data management system of earth station.

Figure 8. Data management system of earth station: (a) Parameters, (b) Display module, (c) Program

The comparison system is shown in Figure 9. The data in the left column is obtained from the digital satellite, and that in the right column is from the data management system of earth station. The two are completely consistent.

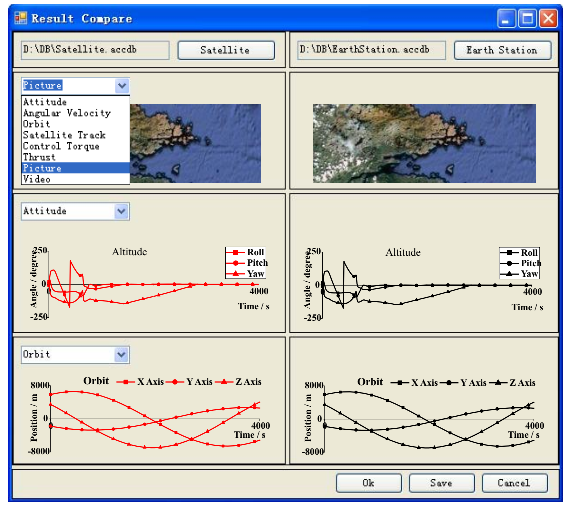

Figure 9. Comparison system

VI. CONCLUSIONS

A universal verification system for satellite data management system based on AOS is established by software. The digital satellite specially designed as the date source ensures the verification system having good applicability, practicability, simulating multiple work conditions, versatility and expansibility. Data management system of earth station contains all of the key technologies of AOS. Comparison system can verify the consistency of verification data and original data. Verifying example demonstrates that this universal verification system can verify the key technologies of the data management system based on AOS.

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