Research on Application Technology of Intelligent Wireless Sensor Network in Flight Test

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ABSTRACT

Aimed at the problems of many test parameters, complicated lead wires, large additional weight, lack of flexibility and expandability as well as low level of intelligence and networkability of existing aircraft test flight test systems, with the application requirements of intelligent wireless sensor network for flight test technologies as the lead, this paper makes research on key technologies of intelligent wireless sensor network in aircraft flight test, and focuses on the synchronous acquisition system architecture, real-time protection method, and data transmission reliability checking method and the development of acquisition and recording system for wireless sensor networks based on the iNET standard for aircraft flight test. Besides, this paper also performs simulation and engine ground test verification which laid the foundation for the application of intelligent wireless sensor network technology in aircraft flight test.

Keywords: Intelligent, Flight test, Wireless Sensor Network, iNET standard

1 Overview

As flight test cycles for new generation of fighter planes, large passenger planes, transport planes and other military and civil aircrafts become tighter and the technology becomes more and more complex, the requirements for test flight test systems are also increasing. However, existing flight test systems have many problems, such as too many test parameters, complicated lead wires, large additional weight, lack of flexibility, scalability, intelligence, low degree of network, and also, the measurement accuracy and efficiency need to be improved. The Wireless Sensor Networks (WSN) [1] provides a good measurement method for realizing high-efficiency, high-precision, low-weight, and intelligent aircraft flight test. The intelligent wireless sensor network can greatly reduce the number of device lead and additional weight; Its local signal processing function and parallel distributed information processing capability will greatly improve the operational speed and decision-making reliability of the aircraft test flight test system; The self-organizing features can be adaptively adjusted to test the monitoring network topology. Structure and monitoring area provide a very flexible test flight test system [2].

In recent years, due to the unique advantages of smart wireless sensor networks, more and more research has been applied in the field of defense and aerospace. In China, since 2002, Nanjing University of Aeronautics and Astronautics has independently developed a wireless strain sensor network node for aeronautical structure monitoring, which is a high-speed wireless piezoelectric node, and a wireless sensor network system; in 2007, an on-site static test for a fighter's nose landing gear was conducted. The on-site static test has successfully monitored the strain of the entire landing gear with a total of 43 points. The test results show that the network system has accurate monitoring, strong anti-interference ability, flexible network configuration, good real-time testing, and high reliability.

2 The Overall Structure of Flight Test Intelligent Wireless Sensor Network Test System

The overall structure of the flight test smart wireless sensor network test system is shown in Figure 1. It consists of an airborne wireless network data aggregation device, subnetwork convergence nodes, distributed test nodes, Ethernet switches, and airborne wireless network monitoring and control software [3].The system can be used as part of the on-board network test system (vNET). The collected data is transmitted to the ground data management system (gNET) through the radio frequency telemetry system (rfNET). Finally, the ground command center analyzes and determines the flight status.

The distributed test node senses the operational status of the aircraft's component under test through the sensor, on one hand; it stores the collected data locally. On the one hand, it sends the collected data to the convergence node of the subnet. On one hand, subnet convergence nodes form a subnet work to respond to network control commands, on the other hand, they complete the network protocol conversion, network packet decapsulation, and then encapsulation to make it conform to the iNET standard telemetry network system data packet structure, and then send it to the network data packet and airborne wireless network data aggregation device. The airborne wireless network data aggregation device collects and stores test data of the entire network by forwarding the measurement and control commands and system configuration parameters. At the same time, the test data is transmitted to the airborne telemetry system through the Ethernet switch. The airborne telemetry system sends the network data flow to the ground. The data management system completes real-time display and analysis of test data

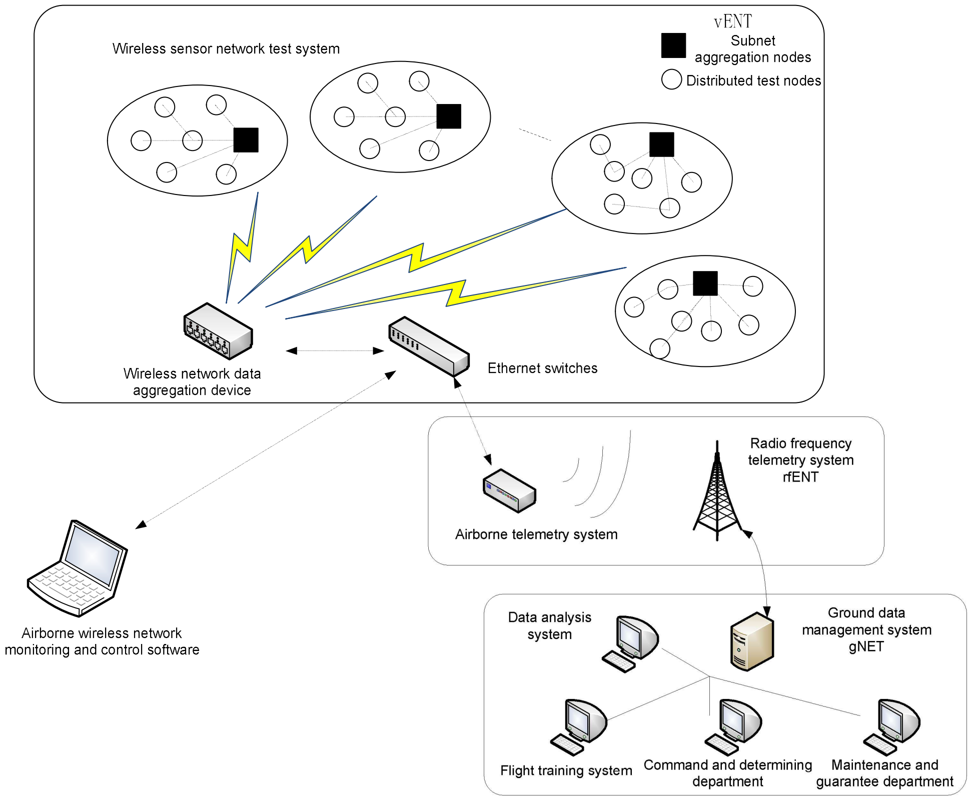

Figure 1 Structure of Flight Test Intelligent Wireless Sensor Network Test System

3 Key Technologies of Intelligent Wireless Sensor Networks to be Solved in Flight Test

The airborne flight test, adopting long-distance measuring technique, is a highly comprehensive system engineering technology and involves many subjects such as electronics, communications, radio, computer, microelectronics, and sensing. Therefore, in order to better apply the intelligent wireless sensor network to flight tests, it is necessary to focus on solving the following issues:

a.Network Time Synchronization and Transmission Reliability Technology of Airborne Wireless Sensor Network Test System

There are hundreds of test nodes in the airborne wireless sensor network test system, which are distributed at different locations on the aircraft. Due to the accumulative nature of the transmission delay, the time synchronization error increases as the wireless communication jump point or the network depth increase. By analyzing the relationship between link bandwidth, time delay, random scheduling of the sensor network and network data transmission traffic and time delay, comparing the congestion detection and control strategy of multiple wireless sensor networks [4], and using equalized multiple hop times and transmission time as the equalization target of the adaptive traffic equalization routing algorithm. The time synchronization method based on the IEEE1588 PTP time synchronization and the pulse-coupled discrete phase correction method are used to solve the synchronization problem [5].

The time synchronization of the airborne wireless network test system is divided into three layers. The first-layer is synchronization between airborne wireless network data aggregation device and primary clock of the switch through the IEEE1588 PTP protocol; the second layer is single-hop synchronization between airborne wireless network data aggregation and the subnet aggregation node through the IEEE 1588 PTP protocol; the third layer is time synchronization between sub-network convergence node and the distributed test node. Each test node is synchronized under the subnet aggregation node clock, and IEEE 1588 cumulative errors are corrected using the random coupled discrete phase method. Random pulse coupling is used at each distributed test node to achieve phase synchronization of the time synchronization period. The short-period phase synchronization results are used to correct the IEEE 1588 time-synchronized multi-hop cumulative error, resulting in relatively high time synchronization accuracy [6]. The time synchronization flow chart of the entire system is shown in Figure 2.

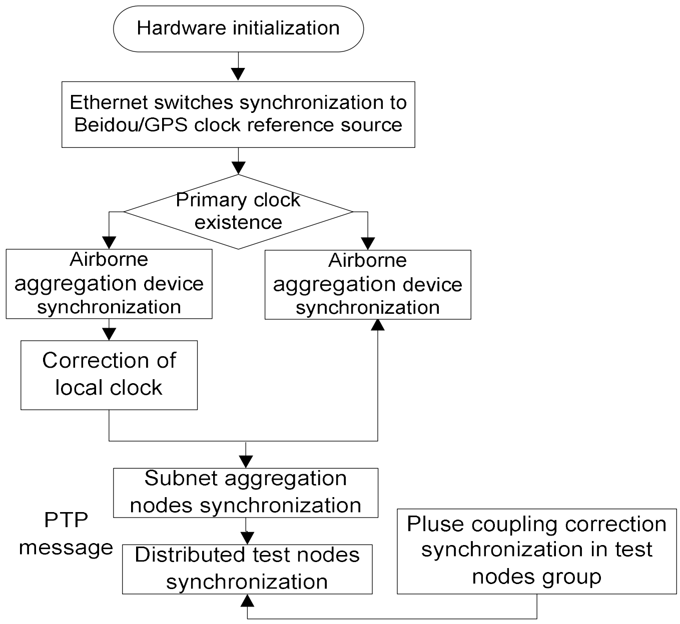

Figure 2 Time synchronization flowchart of the airborne wireless network test system

b. Data transmission reliability technology of airborne wireless sensor network test system

Aiming at transmission reliability of flight test data, establish data transmission check method and reliability transmission mechanism for wireless sensor networks, including network packet loss rate modeling and analysis; data transmission check method suitable for flight test requirements; the method of retransmission of packet loss data during flight test [7].

c. Airborne electromagnetic environment adaptability technology for airborne wireless network test system

The electromagnetic environment adaptability design of airborne wireless network test system mainly solves the existing space electromagnetic interference, internal electromagnetic interference and shared-frequency interference within wireless network test system from several aspects such as the selection of working frequency band of wireless network test system, redundancy design and node electromagnetic compatibility design [8]. Firstly, when frequency band is selected, avoid the more sensitive frequency band of the onboard device; secondly, if the device is more sensitive to node communication, you can choose to avoid deploying nodes around the device to prevent interference, or change the orientation of the node transmitting antenna to avoid the main flaps interfere with sensitive equipment.

d. Network node energy pick-up technology of airborne wireless sensor network test system

The airborne wireless network test node provides three power supply methods, namely node battery, airborne power supply and environmental energy acquisition. Each node can select one or several methods for use according to the specific test environment and selecting power supply method for designing power management module [9].

The battery power supply is the main power supply mode of the node, which can reduce the cable connection and ensure the flexibility of the node arrangement. The on-board power supply is mainly used to implement data recovery, a small number of sub-network convergence nodes with high energy consumption, and airborne wireless network data aggregation devices.

The environmental energy acquisition power supply method is to convert mechanical vibration energy and light energy existing in the on-board test environment into electrical energy to supply power for nodes [10]. Since the output power of the energy acquisition module is closely related to the available energy density of its working environment, this method is mainly used for test nodes that can meet the energy acquisition conditions. As shown in Figure 3, the energy acquisition module includes a transducer and energy storage. Among them, the transducer is mainly responsible for converting vibration energy or light energy into electric energy, and the proposed vibration energy transducer is a cantilever beam type piezoelectric vibration acquisition device as shown in Figure 4.

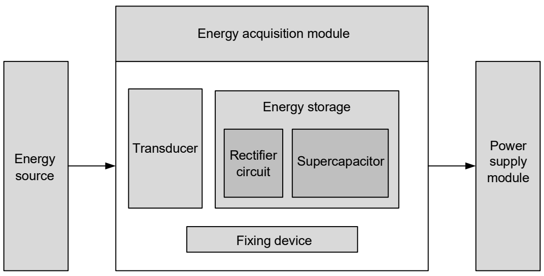

Figure 3 Energy Acquisition Module

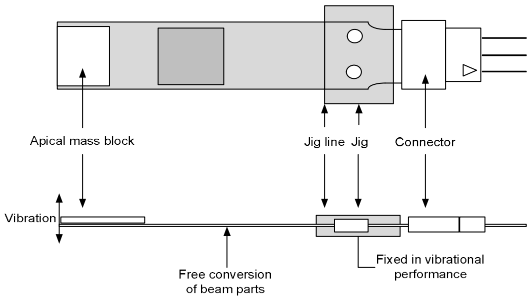

Figure 4 Piezoelectric Vibrating Reed Structure

The power management module mainly performs power selection for nodes that use multiple power supply methods. The power management module uses battery power by default. When the onboard power supply is connected, the power management module will switch to the onboard power supply and charge the battery that meets the charging conditions. For a node adopting the environmental energy acquisition method, the power management circuit is switched to the power supply of the energy collection module only when the super capacitor storage energy in the energy collection module satisfies the node operating condition. By repeating the above logic control, the power management module can switch between the battery power supply and the other two power supply modes, thereby maximizing the power saving working time.

4 Conclusions

In this paper, combining with the requirements of flight test and the complex test environment on board, the overall structure of the flight test intelligent wireless sensor network test system is proposed, and key technologies such as the time synchronization, data reliability transmission and power supply of the intelligent wireless sensor network in the flight test are presented. In short, intelligent wireless sensor network technology can be flexibly and reliably used for flight test tests without changing existing aircraft structures, avionics and other systems, and the optional communication frequency bands involved can work simultaneously with C-band, L-band, and S-band that are commonly used in aircraft flight test systems without disturbing each other. Therefore, intelligent wireless sensor network technology has a good application prospect in the field of aircraft test flight testing.

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