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Design of Broadband Micro-Power Wireless Communication Test System Based on TTCN-3

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Design of Broadband Micro-Power Wireless Communication Test System Based on TTCN-3

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Abstract. In order to optimize the network architecture, narrowband micro-power wireless communication technology is developing towards broadband. In order to ensure the conformance of the functions and protocol standards of the developed broadband micro-power wireless communication module and the interconnection of different manufacturers, it is particularly important to test the products. Based on TTCN-3 and Titan platform, a conformance testing system for broadband micro-power wireless communication protocol is designed. The hardware and software implementation scheme of the conformance testing system is given, and the implementation mechanism and key technologies of each part of the system are described. An interoperability testing platform is constructed to realize the integrated distribution network testing and interoperability testing. Protocol conformance testing cases are designed by using black box testing method. It provides a test basis for the research of broadband micro-power wireless communication.

1. Introduction

At present, the micro-power wireless communication protocol in the power user electric energy acquisition system has the following disadvantages: The air symbol rate is only 10 Kbps; The meter reading efficiency is low; The network topology information update is poor in real-time; the communication protocol is poor in compatibility in the dual-mode meter reading system[1]. In order to overcome the above shortcomings, the research of broadband micro-power wireless (BMW) communication technology has important significance.

In the development of BMW communication protocol, in order to shorten the research and development cycle, it is necessary to synchronously design and study the BMW communication conformance test technology, test system and interconnected test platform. Conformance testing is designed to verify that a protocol implementation is consistent with the protocol specification, and is also the basis for ensuring that communication modules developed by different vendors can achieve interoperability. The interoperability test platform is designed to simulate the real working environment, verify other service functions such as multi-node networking and meter reading, and include interoperability testing of nodes from different vendors in the network.

2. Broadband micro-power wireless communication protocol

The BMW communication protocol is still being developed and perfected, in order to meet the future dual-mode communication system capable of implementing wired communication and wireless communication in the same local communication module, at this stage, the initial concept is to improve on the basis of broadband power line carrier(BPLC) communication protocol[2]. The BMW communication protocol transforms communication channel from power line to wireless channel and designs a physical layer architecture suitable for wireless channels, but maintains the same form as the BPLC protocol in the network architecture and networking mode, so as to be implemented dual mode system combining wireless and power lines in the same communication module in the future. In a BMW communication network, three device types are defined: a Central Coordinator (CCO), a Proxy Coordinator (PCO), and a Station (STA). The CCO is placed in the concentrator, and the PCO and STA are placed in the collector or smart meter.

In the networking process, the BMW communication network will start the networking layer by layer with CCO as the center, and connect the STAs in the whole network with a 15-layer tree topology. Figure 1 shows the topology of a BMW communication network.

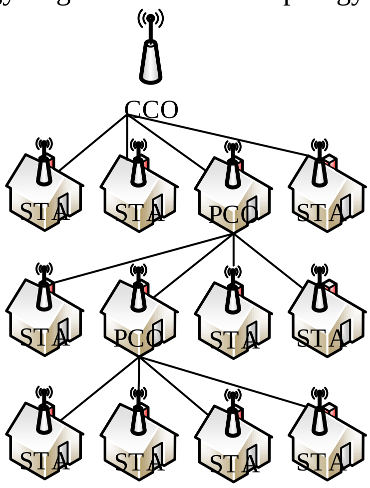

Figure 1. Topology of BMW communication network

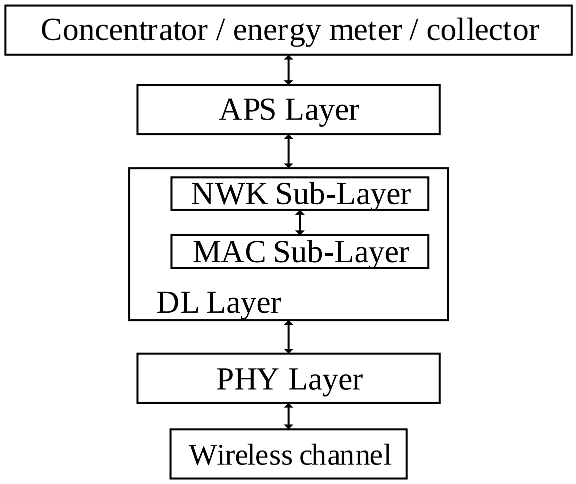

Figure 2. Protocol stack architecture and upper and lower interfaces

The BMW communication protocol includes a physical layer (PHY), a data link layer (DL), and an application layer (APS), wherein the DL layer is further divided into a network management sub-layer (NWK sub-layer) and media access control sub-layer (MAC sub-layer), protocol stack architecture and its upper and lower interface structure are shown in Figure 2.

The APS layer mainly implements the interaction between the communication module and the service data of the concentrator, the collector and the smart meter, and sends commands to data link layer and physical layer before sending them to radio frequency, finally completes the data interaction through the wireless channel. The NWK sub-layer mainly implements functions such as networking, route creation, and network maintenance. The MAC sub-layer accesses physical channels through CSMA/CA and TDMA channel access mechanisms to ensure the reliability of packet interaction. The PHY layer performs coding and modulation at the transmitting end, and performs signal detection, reception, demodulation, and decoding at the receiving end.

3. Protocol test technology

Due to its incompleteness and complexity, communication protocols inevitably generate ambiguity in the process of implementation. Therefore, communication systems designed for the protocol may not be interconnected during real network deployment. In order to maximize the compatibility of communication systems, protocol conformance testing technology emerges as the times require. The International Organization for Standardization (ISO) first developed a set of international standards for conformance testing, the ISO conformance test method and framework, which describes the protocol testing process, concepts and method based on the OSI seven-layer reference model[3].

In the power industry, the State Grid Corporation has also issued micro-power wireless communication protocols and performance test standards, and the relevant test specifications have not clearly given specific test implementation plans. After that, China Electric Power Research Institute, a research institute directly under the State Grid Corporation, proposed a micro-power wireless communication test technology method [4]. However, the above research and design were based on the micro-power wireless communication protocol which has been used maturely, and can not be fully applied to the BMW communication protocol. It is necessary to redesign the test system and test scheme for the BMW communication protocol.

4. Protocol conformance test

4.1. Protocol conformance test based on TTCN-3

Protocol conformance testing is the foundation of interoperability testing. A single BMW communication module has two data interfaces, that is, a communication interface with a concentrator module or a smart meter module at the upper layer, and a radio frequency interface with other communication modules at the lower layer. Such objects are suitable for use in the local test model of ISO/IEC 9646. The local test method is shown in Figure 3 below.

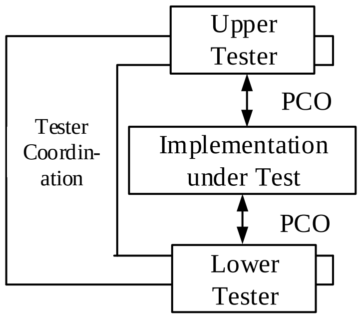

Figure 3. Local testing method

In this test model, the Upper and Lower tester and the Test Coordination are run in a unified system. This model assumes that there is an access interface on the upper and lower boundary of the object under test. The test system applies an excitation to the IUT (implementation under test) through the interface, and judges whether the test is successful by comparing the actual output response and the expected at the Point of Control and Observation(PCO). ISO9646-3 defines the protocol standardized test language, the latest version is TTCN-3 (Testing and Test Control Notation). This language is maintained by ETSI (European Telecommunications Standards Institute) and has been widely used in conformance testing of various communication protocols such as 3GPP, IPv6, and 5G [5].

TTCN-3 based test development platform using Eclipse Titan. Titan is an open source TTCN-3 integrated test development and execution environment based on the Eclipse platform developed by Ericsson[6]. The Titan GUI provides an Eclipse platform plugin for easy writing of test scripts, running, and test log viewing. As an open source test platform, compared to other commercial test software (such as TTworkbench), the Titan platform is used for test development, which is more convenient for test platform promotion and technical exchange.

4.2. Design of protocol conformance test platform

4.2.1. Design of test platform based on QEMU. After the protocol specification is implemented based on a programming language, before programming to the target chip to make the communication module, in order to facilitate testing and code debugging, we first use the virtual operating system simulator (QEMU, Quick Emulator) to simulate the ARM chip, so that the protocol stack could runs in the QEMU environment[7]. The QEMU supports multiple architectures, with open source, scalable, portable, and fast simulation. Testing based on this environment reduces test costs and shortens development cycles. Figure 4 shows the protocol conformance test platform combining the Titan platform and the QEMU.

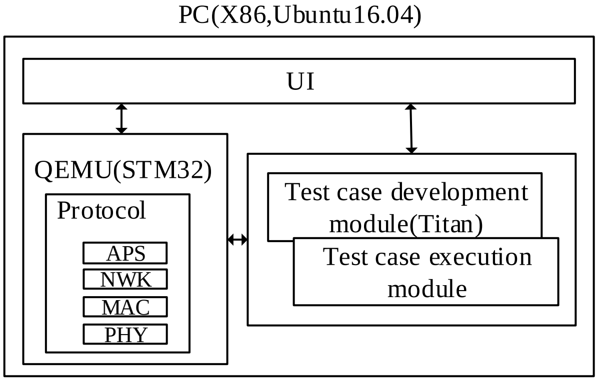

Figure 4. QEMU protocol conformance test platform

The PC operating system adopts the Linux distribution Ubuntu16.04 system. The protocol stack code is first compiled in the simulation environment and then runs in the STM32 simulated by QEMU. On the Titan platform, the upper test point simulates a concentrator or smart meter, and the lower test point simulates the air interface information sent by other nodes. QEMU simulates three serial ports in STM32, one for data interaction between protocol stack and concentrator or smart meter, the second for data interaction between protocol stack and other nodes, and the third is to print out the running information of protocol stack for debugging. Through the UI (user interface), we can configure the data interaction interface between the protocol stack and the Titan platform, select execution test cases, observe test progress, test results and test reports.

4.2.2. Design of Test Platform Based on Single Communication Module. Due to the limited processing capability of the STM32 simulated in the QEMU environment, the data processing time of the protocol stack is longer than that in the real hardware board, and the analog port communication is used to interact with other node data instead of the real air interface wireless communication, which makes some limitations in testing. In order to achieve a more complete test, the protocol stack code needs to be programmed onto the target board, combined with the actual hardware to form a complete communication module, and finally a complete single-module test.

Figure 5 shows the single-module test platform architecture. The Titan platform simulates concentrator or smart meter and other nodes in the network interact with the communication module under test and determine whether the data interaction process is correct. When the Titan platform simulates a concentrator or smart meter, it is connected to the bottom plane through the RS-232 bus to communicate with the communication module. When the Titan platform simulates other nodes in the network, the data is transmitted to the standard protocol signal generation source through the serial port. The standard protocol signal source is connected to the shielding box through the RF line, and the internal antenna is converted into the air interface signal, thereby simulating communication between other nodes and the module under test. The channel monitoring module can monitor the air interface wireless signal, receive the air interface signal generated by the communication module and upload it to the Titan platform, and the Titan platform makes a test judgment according to the response data of the communication module.

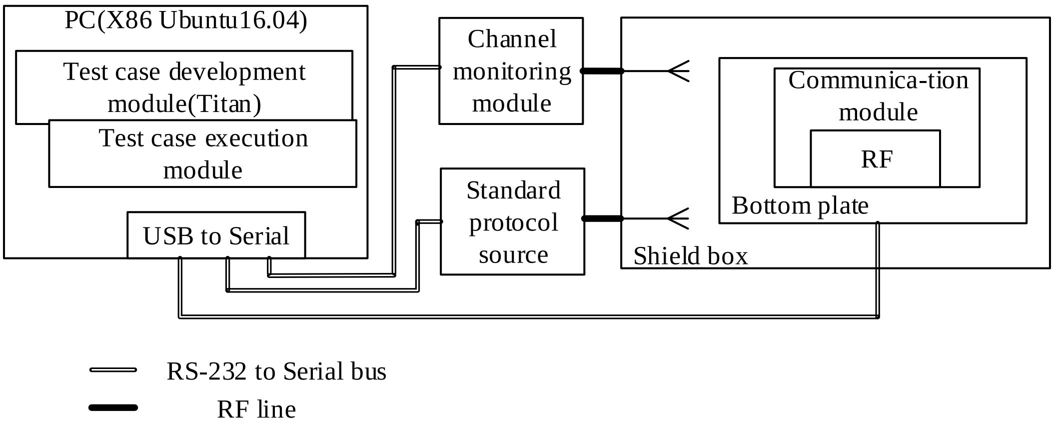

Figure 5. Single module test platform

5. Interoperability test

5.1. Interoperability test method

In order to ensure the interoperability between communication modules developed by different vendors, after the protocol conformance test, the communication module needs to be tested for interoperability in the actual communication environment. In the interoperability test, the data interaction process and performance indicators between communication module of different products are mainly detected. There are many interoperability test standards in the world. The European Telecommunication Standard Institute (ETSI) has proposed the ETSI EG 202 810 test standard in the interoperability test, which describes test methods, test frameworks and test systems. The proposed general interoperability testing framework is shown in Figure 6 [8].

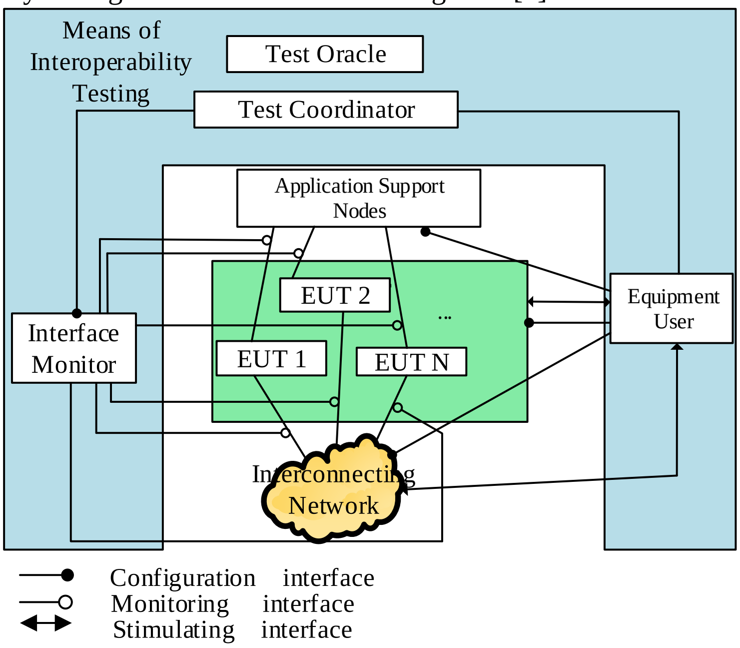

Figure 6. ETSI EG 202 81 universal test framework

5.2. Interoperability test platform design

Based on the interoperability test framework proposed in ETSI EG 202 81, after analyzing the specific application scenarios of the BMW communication network, the general framework is implemented and the BMW communication module interconnection test platform is designed. As shown in Figure 7.

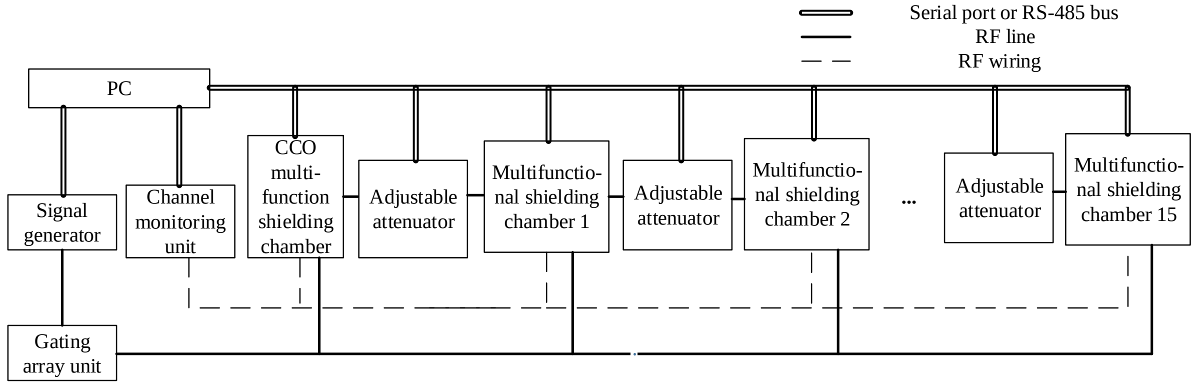

Figure 7. BMW communication module interconnection test platform

In the Figure 7, the computer is designed with the main control software, which can configure the connection interface of each hardware device in the platform. The interfaces to be configured are: 1. Signal generator interface; 2. Channel monitoring unit interface; 3. Adjustable attenuator interface; 4.The bottom plane interface carrying the communication module in the shielding chamber. The main control software can control the operation of the executable test case designed by the Titan platform, display test results, generate test reports and test logs. The signal generator can generate noise signals in various scenes, and is connected to the shielding chamber through the gating array unit to achieve the effect of simulating a real working scene. The channel monitoring unit can collect the wireless air interface signal of the communication module in the shielding chamber, transmit it to the main control software in the computer. The main control software can observe the data interaction between the communication modules, and provide data support for the fault detection. The CCO is operated separately in a shielded chamber. The PCO or STA operates in other shielded chambers. Each shielded chamber is connected to an adjustable attenuator. A multi-level topology is constructed by signal attenuation. Each shielded chamber contains two or more nodes. When networking, a test case can be constructed to verify the inter-network coordination function when multiple CCOs are simultaneously networked in different networks or the PCO selection mechanism. Through the adjustment of the signal generator and the adjustable attenuator, different working environments can be simulated to meet different test requirements. Through the above platform, multi-node integrated network test can be realized, and the nodes of different manufacturers can be included in the platform to perform interconnection test of the communication module.

6. Test case design and test verification

6.1. Test case design

The design of the test suite mainly meets the following principles:

(1) It can test the basic process and basic performance requirements of the protocol;

(2) Consider the abnormal scene and boundary conditions;

(3) Try to improve the complete coverage of the test set and cover all the business requirements of the electricity information collection system;

(4) Avoid redundancy in test cases and reduce the workload of test development.

Using the black box test method, the protocol conformance test case is designed by equivalence partitioning and boundary value analysis. Test cases are designed for the APS layer, DL layer and PHY layer of the BMW communication network. PHY layer testing is mainly used to test the effectiveness and reliability of signal transmission on physical channels. DL layer testing mainly includes beacon mechanism, time slot management, channel access management, etc. The APS layer test case mainly verifies whether the communication module can correctly parse the data frame of the concentrator, the collector or the energy meter and trigger the service process. The designed test suit is shown in Table 1 below.

Table 1.BMW communication protocol test suit

Test Items	Test Suit	Test Items	Test Suit
Physical layer	Communication rate test	Data link layer	Selective acknowledgement frame retransmission
	Signal Intensity Detection Test		Message filtering
	Transmitter performance test		Clock synchronization
	Acceptance performance test		Networking test
Application layer	Node information query test		Network Maintenance
	Node information initialization		Beacon mechanism test
	Node parameter setting		Time slot management test
	Broadcasting Timing Test		Channel access management
	Event reporting		Message processing test
	Meter reading test		
	Node online upgrade		

6.2. Test script writing

The design process of the test case is briefly described in the CCO single-layer multi-STA networking process under a single network.In this test process, the object under test is CCO.The specific data interaction process is as shown in Figure 8.

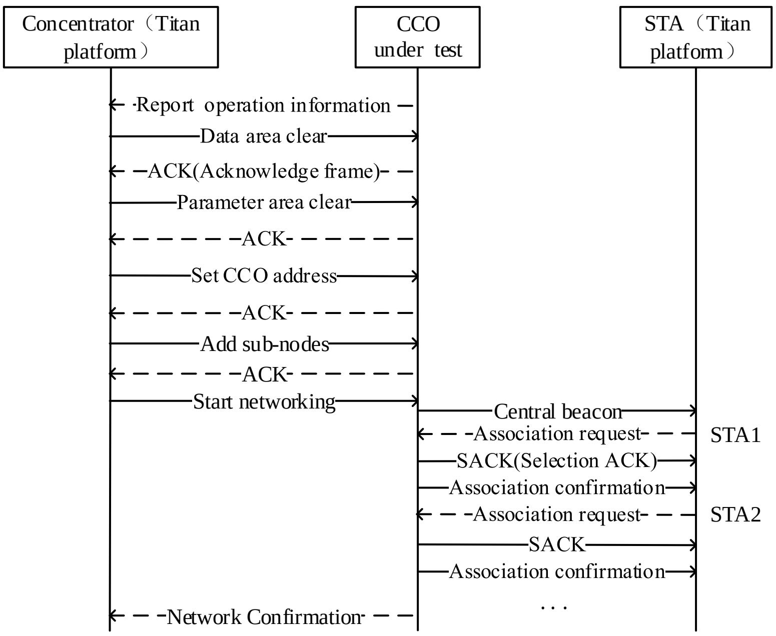

Figure 8. Single network CCO networking process

In the Titan platform, the message involved in the test case is defined using the TTCN-3 according to the frame structure defined in the BMW communication protocol. Taking the central beacon as an example, its frame structure is defined as shown in Figure 9.

```
type record CCO_Beacon
{
   bitstring delimiter length(3),
   bitstring networkType length(5),
   hexstirng networkID length(6),
   hexstring timeStamp length(8),
   bitstring source_TEI length(12),
   bitstring copy_type length(4),
   bitstring symbol_count length(9),
   bitstring block_count length(3),
   bexstirng reserve length(2),
   bitstring version length(4),
}
```

Figure 9. Definition of central beacon frame structure

In the single CCO networking test, the Titan platform simulates the concentrator at the upper test point and simulates the STAs at the lower test point. This test case passes when the data interaction between the two test points is correct. Taking the upper test point data interaction process in the test as an example, the test written by TTCN-3 is shown Figure 10.

```
testcase cen_networking_start(interger para1) runs on SPReceive
{
   map(self:SerialPort_utp_1376,system:SerialPort_utp_1376)
   t_short.start(20.0);
   alt{
   [] SerialPort_utp_1376.receive(hexstring:?)-> value os {
         if(ture == AF_LOCAL_INFO_REPORT_Match(os)){
            SerialPort_utp_1376.send(data_area_clear())
            os:= ‘’ H;
            goto L1;
         }
      }
   [] t_short.timeout {
        setverdict(inconc, “data_area_clear is error nor received” );
        stop;}
     }
   label L1
   …//some are omitted here
   label L6
   alt{//The last data interaction}
   if(os == ‘’ H)
      {setverdict(pass)}
   else
      {setverdict(inconc)}
}
```

Figure 10. Test case of CCO networking written by TTCN-3

After the test case is written, Titan's embedded compiler compiles the test case code into an executable file and provides an execution script to facilitate the running of the test case.

6.3. Test verification

Take the CCO network test written in Section 6.2 as an example to verify the test process and results of the software. During the test, if the CCO successfully reports the networking completion information to the concentrator, the test is successful.

Run the compiled executable file. After the test is completed, the Titan platform can display the test log in graphical form. The data interaction result between the CCO under test and the test platform can be seen, as shown in Figure 11.

In Figure 11, the box is the port event information log, the “System” is the system under test, and the “Test Platform” is the Titan, the two first perform the port mapping to establish communication, and then perform data interaction. Comparing the networking process in Figure 8, it can be seen that the CCO under test is consistent with the data of the test platform, and the test case is passed.

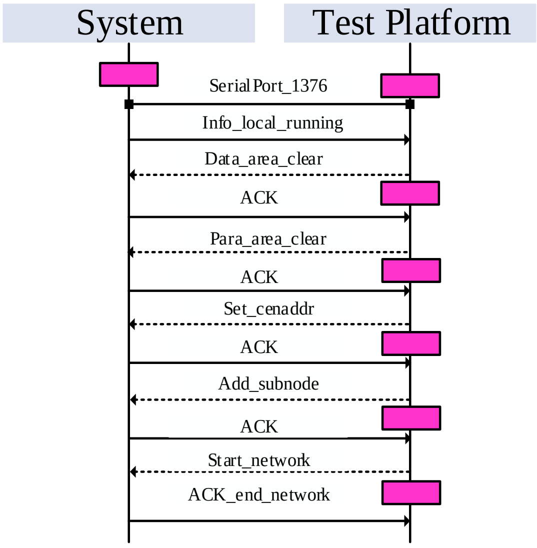

Figure 11. Data interaction between test platform and CCO under test

7. Conclusion

This paper mainly proposes a complete BMW communication protocol conformance test method and interconnection test method. According to the operating environment of the communication module, based on the TTCN-3 test framework, a specific conformance test platform and interconnection are designed. The workflow of the test platform is described, and the function of each module in the test platform is explained. Drawing on the black box test method, the test case is designed through the Titan platform, the test process of the single test case and the design method of the TTCN-3 test case are described. Through verification, the test results show that the Titan test platform can correctly execute the test cases, and can judge the conformance of the protocol implementation of the system under test. The test log can display the data interaction between the system under test and the test platform. The design of BMW communication protocol is still in the process of improvement. The test platform will continue to improve in the formulation of the protocol and accelerate the research and development of BMW communication.

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