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Abstract Test Methods for Network Relay System*

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Abstract Abstract test method aims to enable test suite designers to use the most appropriate methods for their circumstances. Most existing methods are end system oriented, rather than relay system concerned. This paper discusses the abstract test methods for relay system testing, introduces the model of the R-SUT (relay system under test), gives the conceptual architecture of relay system testing, and proposes several abstract test methods. Finally, some practical experience for testing the relay system, such as IP router, SMTP email server, and Packet Assembly/Disassembly (PAD), is illustrated with the methods presented. These methods could be used for testing ATM switch too.

Key words Computer network, protocol conformance test, relay system.

With the development of computer networks, lots of protocol software and hardware have been implemented by different manufacturers. At the same time, we have to spend more and more time to ensure the correctness of these different implementations. The aim of protocol conformance testing (PCT) is to verify the conformance between protocol implementation and its corresponding standard. Today, it is one of the most active fields about computer network and distributed system. ISO/IEC 9646[1] provides the OSI conformance testing methodology and framework. It has been widely used in the test practice for end system[2~7]. Notice that there are two kinds of system in the networks: end system and relay system. The traditional theory and practice of PCT usually focus on the end system testing, and the research on relay system testing is rare. Today, relay is an important concept in TCP/IP, switched LAN, and high speed networks. The relay system, such as IP router, LAN switch, and ATM switch, plays important roles in these technologies[7]. Since the peer-to-peer and end-to-end model in ISO/OSI could not fit these relay technologies well, it is very important to study the test theory of relay systems.

Abstract test method aims to enable abstract test suite (ATS) designers to use the most appropriate

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method for their circumstances[8]. The testers test the behavior of implementation under test (IUT) by protocol data units (PDU) and abstract service primitives (ASP). In ISO/IEC 9646, there are some abstract test methods for end system. These methods are based on ISO/OSI reference model. These test methods could be classified by point of control and observation (PCO), test coordination procedure and the position of tester. Because there is difference between the IUT of end system and the IUT of relay system, it is necessary to study the abstract test methods for relay system. Although there are two relay system test methods, "loop-back" (YL) and "transverse" (YT), defined in ISO 9646, their capabilities are limited. The YL test method is used for testing a relay system from only one subnetwork. Thus its disadvantage is that the behavior of the relay on only one side is directly observed[1]. The YT method has two PCOs, one on each subnetwork, and uses two test systems external to the IUT. So the procedures for coordinating the control applied to the two testers would be a big problem. To solve these problems and put the relay test into practice, we propose some new relay test methods. We hope it could help the test laboratory make the real test process continuous and high-efficient.

This paper discusses the characteristics of relay system and presents abstract test methods for relay system testing. The rest of this paper is organized as follows. Section 1 analyzes the R-SUT model and gives a conceptual architecture. In section 2, we propose 6 abstract test methods, RL, DL, LT, DT, CT and RT, then their characteristics are discussed. After a brief review of the protocol integrated test system (PITS) developed by Tsinghua University, we will introduce some practical experience with relay system testing, such as the IP router, the SMTP mail relay, and the Packet Assembly/Disassembly (PAD), using the methods we present in section 3. Finally, we give the conclusion.

1 Conceptual Architecture

There exists a relationship between the test methods and the configurations of the real network system to be tested[1]. There are two main configurations of system in a network: (1) End system; (2) Relay system.

Neither the term "relay system" nor "end system" has been defined by ISO or other standard organizations, even though they are widely used in the field of data communication. The definition given by Cerf and Kirstein[9] is adopted here. It says that the collection of required hardware and software effecting the interconnection of two or more data networks, enabling the passage of user data from one to another, is called a "relay system". This implies that a system connected only to one network will not be regarded as a relay system. All system other than relay system could be classified as end systems.

Now, we present a model of relay system under test (R-SUT) and it is shown in Fig. 1. In this model, there are two protocol suites of subnetworks connected by the relay system. These two suites could be named "N" and "M". If the two subnetworks have the same protocol architectures, N is equal to M. The highest layer in the R-SUT is numbered "Nt" or "Mt" (for "top"), and the lowest is numbered "Nb" and "Mb" (for "bottom"). Notice that Nt is usually equal to Mt, and they realize the function of relay. For single-layer protocol R-SUTs, Nt (or Mt) is equal to Nb (or Mb). In the following sections, the same notation will be used to refer to layers within the tester. The R-SUT may implement protocols in layers lower than "Nb", but these are not of interest in the test method descriptions. For all test methods, ATSs specify test events at the lower tester PCO in terms of (Nb−1) ASPs and (Mb−1)-ASPs and/or (Nt) to (Nb)-PDUs and (Mt) to (Mb) PDUs. There are some features in R-SUTs. (1) The relay layer is always the highest layer in a relay system. In other words, there is no upper layer above a relay function. So it is not necessary to control and observe its upper boundary by the (Nt+1)-ASPs and (Mt+1)-ASPs. (2) There are at least two subnetworks under a relay system, so the test events must be controlled and observed by the two sets of ASPs and PDUs.

Abstract test methods are described in terms of what output from the IUT is observed and what inputs to it

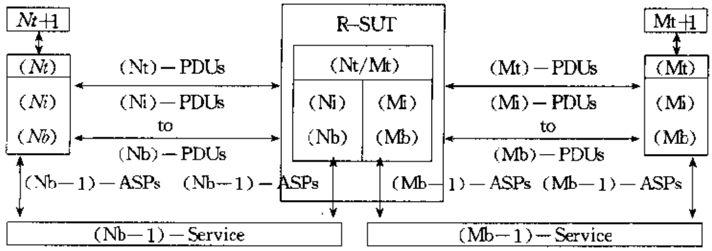

Fig. 1 A model of the R-SUT

can be controlled. The starting point of developing abstract test methods is the conceptual testing architecture[1]. The conceptual architecture of the relay system testing is illustrated in Fig. 2. It is a "black-box" active testing architecture, based on the definition of behavior required by the IUT. The actions in this conceptual tester involve two sets of interactions: one for (N)-protocols and one for (M)-protocols. These can be controlled and observed at PCO1 and PCO2. Because the ASPs above (Nt) are not specified, the tester is only a lower tester (LT). LT would control and observe the (Nb−1)-ASPs including (Nt) to (Nb)-PDUs at PCO1 and (Mb−1)-ASPs including (Mt) to (Mb)-PDUs at PCO2.

2 Abstract Test Methods of Relay System

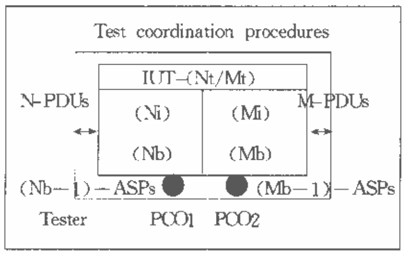

Fig. 2 Conceptual architecture of relay system testing

An abstract test method describes an abstract testing architecture consisting of testers and test coordination procedures, and their relationships to the test system and SUT. Each test method determines the PCOs and test events (i.e., ASPs and PDUs) which shall be used in an abstract test case for that test method. In this section, referring to the concepts and methods provided by ISO/IEC 9646, we propose 6 abstract test methods: RL, CL, LT, DT, CT, and RT (Figs. 3~8). The ATSs should be specified in accordance with these methods.

The abstract test methods we proposed could be generally divided into two kinds: loop-back method and transverse method. The loop-back method is used for testing a relay system from one subnetwork. The advantage is that the procedures for coordinating the control applied to the two PCOs can be realized within a single test system. The disadvantage is that the relay behavior on only one side is directly observed. Thus, its behavior on the second subnetwork can not be properly assessed. The transverse method is used for testing a relay system from two subnetworks. The advantages are as follows. (1) The behavior on each subnetwork could be controlled and observed. (2) This method enables the relay system to be tested in the normal mode of operation. The disadvantage is that the test coordination procedure may be much more complex, because there are two LTs for different subnetworks. It is a big problem for the real test system designers.

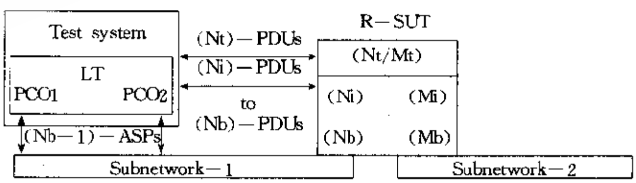

Fig. 3 The remote loop—back test method (RL)

DL is illustrated in Fig. 4. It uses a test responder (TR) in the extra destination host on the second subnetwork to send/receive the PDUs to/from R-SUT. In test system, there are two PCOs for both side functions of R-SUT. When LT sends a PDU from PCO1 to the destination host, it would be relayed by R-SUT. TR located in the second subnetwork then controls and observes the events from R-SUT and returns the result to LT through subsidiary test path (STP). This returned message could be obtained by LT from PCO2. The STP is also used for the test coordinating messages. In fact, this method combines the two lower testers (one should be in test system, and the other in destination host) into one test system. Because the test suite including two PCOs is executed in one test system, the coordination of PCOs for both sides of R-SUT could be solved. It makes the test process automatic, continuous and high-efficient.

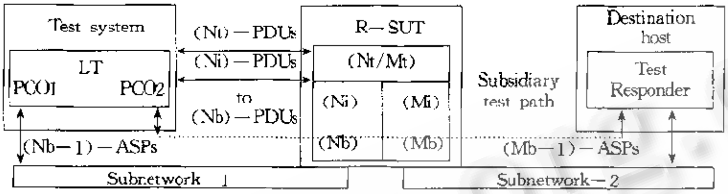

Fig. 4 The distributed loop—back test method (DL)

In DT and CT, two LTs are located in two different test systems separately. So they could be used in the distributed test environment. In a real test system, the former is more simple but the test coordination procedure is more difficult. If the coordination could not be solved well, the test process would not be automatic and continuous. The latter method could solve the coordination successfully. However, because of the implementation of test management protocol, there will be more system cost.

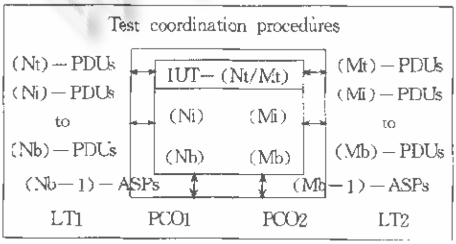

Fig. 5 The local transverse test method (LT)

In LT and RT, two LTs are located in one test system. So their test coordination procedures could be solved well. LT method could be used for an IUT which has clear interface. Because the tester and SUT are in the same system, its application would be limited. So, we think the realization of RT method has the following advantages.

(1) The two LTs are in one test system, so the common model and software could be used by these two testers when developing a real test system. It would reduce the system cost.

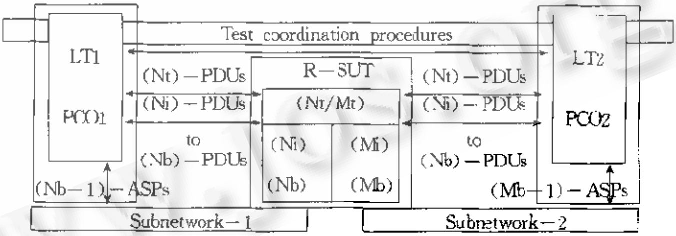

Fig. 6 The distributed transverse test method (DT)

(2) Test coordination procedures are simple and high-efficient. It could be realized as inter-process communication. It is better than TMP.

(3) The design of abstract test suite is simple. The designer only concerns the test events of two sides of R-SUT and do not need pay attention to the coordination of the two sides.

(4) Use "black-box" testing and we do not need the upper interface of IUT. So we need not add extra model in R-SUT. It could be used for different IUTs.

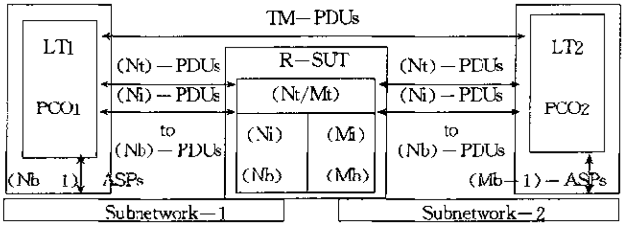

Fig. 7 The coordination transverse test method (CT)

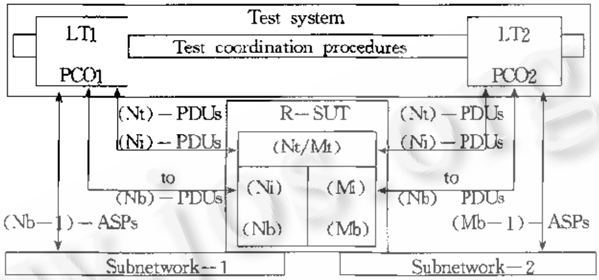

Fig. 8 The remote transverse test method (RT)

Moreover, the characteristics of these methods are shown in Table 1.

Table 1 Characteristics of these test methods

	Loop-Back		Transverse			
	RL	DL	LT	DT	CT	RT
Observation of two subnetworks	indirect	direct	direct	direct	direct	direct
Test systems	1	1	1	2	2	1
Test coordination procedures	inter-process, simple, automatic	inter-process, simple, automatic	inter-process, simple, automatic	by human, and may be single step	using TMP, complex, automatic	inter-process, simple automatic
Need extra TR	no	yes	no	no	no	no
IUT independence	yes	yes	no	yes	yes	yes

3 Practical Experience with Relay System Testing

In this section, we will introduce some practical testing experience with the relay test methods using PITS. The PITS aims to provide a basic platform to test different protocols by different test methods. It could be used for the conformance testing, the interoperability testing, and the performance testing. It has been used for testing many implementations of end systems and relay systems. The PITS is composed of the following main components: test presentation and test report, test management[10], test execution[11], test suite generator, reference implementations, formal support tools and test software environment. The TTCN test suite is generated from EBE specification, which could be translated from LOTOS and Estelle specification[12]. The Reference Implementation (RI) is a very important part in this test system. It is the special protocol implementation and acts as the lower communicating support for controlling and observing the events occurring in test execution (TE).

Today, the IP router is one of the most important relay systems in Internet. The function or purpose of IP is to move datagrams through an interconnected set of networks. This is done by passing the datagrams from one Internet module to another until the destination is reached. The IP modules reside in hosts and routers in the Internet. The datagrams are routed from one IP module to another through individual networks based on the interpretation of the Internet address. Thus, one important mechanism of the Internet protocol is the IP addressing. In the routing from one IP module to another, datagrams may need to traverse a network whose maximum packet size is smaller than the size of the datagram. To overcome this difficulty, a fragmentation mechanism is provided in the IP protocol. Errors detected may be reported via the Internet Control Message Protocol (ICMP).

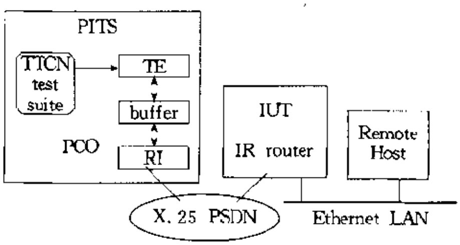

Fig. 9 Testing IP router with DL

We use PITS to test IP router with DL method. It is shown in Fig. 9. This IP router connects two subnetworks: Ethernet LAN and X. 25 public data network. When PITS sends an IP/ICMP datagram (for example ECHO) to the remote host, after routing and addressing, it will be forwarded by IP router from X. 25 PSDN to Ethernet LAN. The response IP datagram could address to PITS and be observed at PCO. We have designed a TTCN based test suite for IP router. This test suite contains 32 test cases and the following is an example. The test purpose is shown in this test case. Now the test suite is only a prototype for verifying the new test architecture. We are developing the complete IP test suite. Then we will be able to test IP from more subnetworks and test more IP options.

CCITT defined three recommendations (X. 3/X. 28/X. 29) about packet assembly/disassembly device (PAD) in public network. PAD is a special relay system. One side of a PAD is the X. 25 public data network for packet mode DTE, and the other side is asynchronous lines for terminals. We use RT method to test PAD. There are two PCOs in the test suite. So we implement two RIs to control and observe the test event in/out the IUT. When TE interprets and executes the TTCN based test suite, the test events would be sent to the corresponding RI from the buffer according to their PCOs. Figure 10 shows how to use PITS to test the relay function of PAD. Because of RT's advantages, we think this architecture is a good approach to test switch equipment in LAN and WAN. The TTCN based PAD test suite we designed contains 234 test cases.

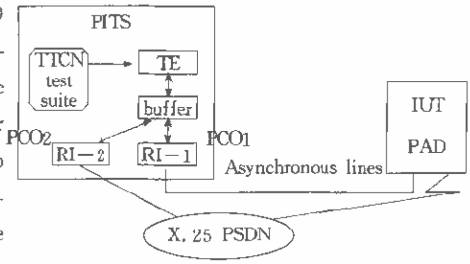

Fig. 10 Testing PAD with RT

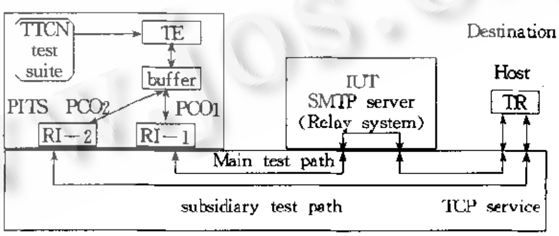

Fig. 11 Test architecture of relaying email

SMTP is designed according to the RFC standards. RFC 821 specifies the definition of SMTP and RFC 822 specifies the syntax of test message that is sent as email with BNF (Backus-Naur Form). The objective of SMTP is to transfer email reliably and efficiently. SMTP is independent of the particular transmission subsystem and TCP is the most popular transmission subsystem. An important feature of SMTP is its capability to relay mail across transport service environments. A transport service provides an interprocess communication environment (IPCE). Emails can be communicated between processes in different IPCEs by relaying through a process connected to two (or more) IPCEs. More specifically, mail can be relayed between hosts on different transport systems by a server on both transport systems. We use the DL method to test the relay function of SMTP mail server. Fig. 11 shows this testing architecture. There are two PCOs for both side functions of IUT. The TTCN test suite contains 89 test cases in total[13].

4 Conclusions

In ISO 9646, there are some standard abstract test methods for the end system and two methods for the relay system. For testing a real relay system, these methods are too simple to direct the test activities well. We have proposed six abstract test methods (RL, DL, LT, DT, CT, and RT) for relay system testing. They are the recommendations for real test system. The characteristics of these test methods are discussed in section 4. These test methods would be selected according to their characteristic and the situation of SUT. We have implemented three test methods (RL, DL, RT) in PITS using the Sun Sparc workstation and Solaris 2.4. It is shown to be very successful in the testing of IP router, SMTP mail server, and PAD. Now we are focusing on the other three test methods (LT, DT, CT) in the testing of ATM switch, and the more complex relay system such as the Internet routing protocols. We believe that relay system will be more important in the future, especially for Internet and high speed network. We hope there come more efforts for relay system tesing using the test methods proposed in this paper.

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网络中继系统的抽象测试方法研究

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摘要　抽象测试方法为测试集设计者提供在不同条件下最合适的方法.目前现有的测试方法主要为端系统设计,很少有关于中继系统的测试研究.该文讨论中继系统的抽象测试方法.首先引入被测中继系统模型R-SUT,然后给出中继系统测试的概念结构,在此基础上提出几种中继系统抽象测试方法.最后给出用该文提出的方法对因特网路由器、SMTP电子邮件服务器和分组装/拆设备PAD等中继系统的测试实践经验.这些方法还可以用于ATM交换机的测试..

关键词　计算机网络,协议一致性测试,中继系统.

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