Network Conformance Test System for IP Networks

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Abstract

The use of IP networks has recently been expanding from the simple transfer of data to the handling of voice and video signals and to communication within and between business enterprises. Evaluating the performance of such complex IP networks requires sophisticated expertise to comprehend protocol mechanisms and test results. Moreover, as the scale of a network increases, the effort of analyzing the results will increase exponentially. Here, we introduce a NCT (Network Conformance Test) system that offers test scenarios including sophisticated expertise, so operators do not require these skills. Moreover, this system can perform several kinds of tests automatically, changing network and measurement equipment configurations, generating and measuring traffic, and analyzing test results, which greatly reduces the workload on the user.

1. Network conformance test

The network conformance test (NCT) system is used to verify proper operation of the IP network when multiple networks are interconnected prior to the beginning of service and to test the limits of network performance. The system automatically performs a series of processes, including configuring network equipment (i.e., routers and switches) and measurement equipment and performing traffic generation, observation, and analysis, according to a scenario written as a time series. Multiple tests can be run consecutively by preparing multiple scenarios. So if the user has many choices of network settings, the NCT system lets him/her choose the best setting.

The system can generate traffic that ranges from simple traffic for confirming the operation of protocols to the complex traffic that arises when multiple networks are interconnected. Furthermore, the advanced testing expertise that is incorporated into the traffic analysis function makes advanced analysis available even to users who do not possess such expertise.

Tests that conventionally require multiple hardware systems and testing personnel in 24-hour continuous testing can be performed with small equipment and personnel requirements with this system. This makes it possible to shorten the time until the beginning of service, reduce the cost of facilities, and construct a stable network environment backed by test data. One technical point of this system is that the test flow is based on scenarios that include sophisticated expertise, and it automatically performs tests, analyzes them, and draws test result graphs. A scenario can easily be reconstructed by the user.

2. Problems in IP network evaluation testing

The router is the key component of an IP network. It does more than simply transfer packets; it also performs message processing for the exchange of the routing information contained in routing tables, computational processing for route optimization based on routing data exchanged with other nodes, and encapsulization processing for encryption and destination address concealment. In addition to these functions, the router collects various kinds of statistical data for use in network management. In ordinary routers, the

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processing for packet transfer, encapsulization, and message handling is all implemented on the same processor, so the processing load has a large effect on the packet transfer performance. Measurement devices for evaluating these router functions are available, but simultaneous measurement of multiple items and automatic testing over a long period of time has not previously been possible.

Although the evolution of IP networks has centered around the Internet service provider (ISP) in the past, telecommunication companies and system integrators have appeared recently to provide means of transmitting voice and video data on IP networks and using IP networks for communication within business enterprises. Furthermore, IP networks have attained a global scale through the interconnection of network enterprises, and failures that occur in networks often propagate to other networks in the far corners of the world. This situation has created the need for a system that can support and automate the performance evaluation of IP networks by modeling the traffic of large-scale networks assuming network interconnection and running multiple types of load tests simultaneously and multiple tests consecutively.

3. Procedure employed in the NCT system

The NCT system (Fig. 1) was developed to solve the problems described above.

① First, the test configuration, which includes the simulated network that is being tested, is studied. A LAN is set up to control the measurement equipment. A general-purpose workstation and a Windows terminal with a Web browser are connected to the control LAN.

② The test scenarios are input via a Web interface. Here, events are described in terms of time elapsed since the beginning of the test. The events that can be described include the test start time, the onset of load generation, the cessation of load generation, the end of measurement, and changes in settings.

③ The load generation patterns are described. For packet transfer load, large-volume loads are generated by controlling commercial measurement devices such as the SmartBits 2000 (Spirent), IXIA 1600 (IXIA), and AX/4000 (Spirent). The addition of the general-purpose workstation makes it possible to generate loads that have biased distribution characteristics (the number of sending and receiving IP addresses and the number of their combinations, the frequency distribution of sending and receiving IP addresses, the packet length distribution, total bandwidth, etc.), which is difficult to do with commercial measurement equipment. For the message processing load, the protocol classification is selected. The available protocols are I-BGP (Internet Border Gateway Protocol), E-BGP (External BGP), SNMP (Signaling Network Management Protocol), and PPP (Point-to-Point Protocol). When a routing information load is to be applied, we set the id numbers of the autonomous systems, the AS path, network address, and network mask for use in exchanging information. When an SNMP load is to be applied, the management information base tree address and continuous load speed are set. For a PPP processing load, the authentication load for PPP over L2TP (layer 2 transfer protocol) can be confirmed. The password error

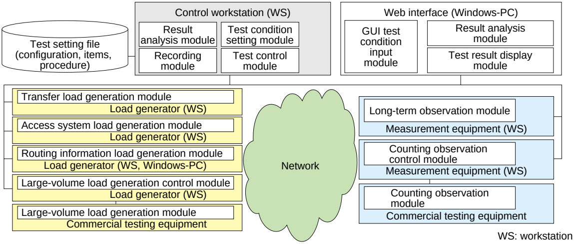

Fig. 1. NCT system.

rate and continuous load speed for PPP authentication are set.

④ The flow of attention to be used in the measurements is set. Specifying this attention flow makes it possible to evaluate fluctuations in the transfer speed, transient loss, and path convergence time under simulated failure. It is also possible to measure the encapsulization processing performance because the delay for various packet lengths can be analyzed at the same time.

4. Main features of the NCT system

The NCT system automates and increases the efficiency of the entire conventional verification procedure from measurement equipment setup to result analysis, as shown in Fig. 2. Conventionally, the testing work begins after test items have been identified, but with this system, it begins after a test scenario has been created. The testing work is executed automatically from the completion of the test system configuration up to the analysis. Thus, work that took 400 hours in the past can be accomplished in 14 hours, for example. It is also possible to perform unmanned testing that includes simulated failures, a task that required manual intervention in the past. The ability to change the settings of commercial measurement equipment also makes automatic changing of load patterns in long-term stability testing easy.

The features of the NCT system are summarized below.

① Because the settings of the equipment under test and the measurement equipment are changed automatically according to the scenario, it is possible to run consecutive tests with different parameters and tests of different items automatically 24 hours a day.

② The evaluation of message processing, computation, and encapsulization loads, which is difficult to do with existing measuring equipment, can be done by software load generation of the NCT traffic generator.

③ Specifying changes to be made in the testing environment settings over time after the testing has begun makes it possible to repeatedly perform tests that simulate transport path failures and other such transmission path interruptions during communication.

④ Because there is a function for graphing the agreement conditions of test packets, the test result data can be analyzed from various points of view.

⑤ Because tests can be done repeatedly with various network configurations, it is easy to perform comparative studies of network configurations that shorten recovery time after failure and investigate aspects of performance degradation with a large number of users to clarify the criteria for deciding whether to expand facilities.

⑥ Automatic control of commercial network measurement equipment and cooperative testing is possible.

⑦ The system can be implemented by software running on multi-purpose workstations or personal computers rather than on special dedicated equipment.

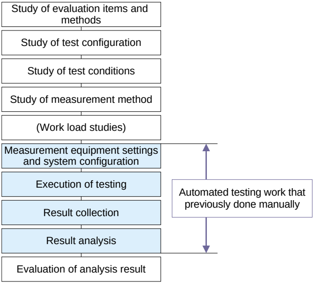

Fig. 2. Automation with the NCT system.

5. Example of IP network evaluation using the NCT system

(1) Evaluation of the number of paths and router transfer performance

The router has a cache for storing packet destinations, but if the volume of destination data (i.e., the number of paths or the number of BGP lines) is large, the time required for looking up the destination decreases the transfer performance (forwarding ratio = number of outgoing packets (number of incoming packets). That tendency increases as the incoming packet rate increases. An evaluation example is shown in Fig. 3.

(2) Evaluation of IP network topology

For networks other than IP networks, a mesh topology generally has the highest performance against failures. For IP networks, the routing information is updated if a router fails. The path information propagates on the network, so the convergence time of the path information varies with the network topology. The NCT system can evaluate the routing information convergence performance by simulating failures within the connected networks and the traffic transactions at the time of failure. The evaluation results show that a parallel topology is desirable from the viewpoint of robustness of performance against failures in an IP network (Fig. 4).

(3) Evaluation of router packet loss rate based on priority and packet length

The results of an investigation of how the number of discarded packets is affected by priority settings and differences in packet length when the router is under a high load are presented in Fig. 5. The router behavior with respect to priority control and other such processing varies with the type of machine, so it is necessary to verify operation in advance. The groups in the figure indicate priority (the larger the number, the higher the priority). For the example shown in Fig. 5, we can see that no 1518-byte packets belonging to the highest priority group were discarded by the router at the time of congestion in the interval from 20 to 30 ms.

(4) Evaluation of priority control

An evaluation of the priority control effectiveness of the router and the network is shown in Fig. 6, where the groups indicate priority classes. From this example, we can understand the delay distribution for incoming packets that have different priorities as they pass through the network and the router. The traffic distributions are shown by packet size and delay time for a test traffic flow that involves mixed protocols with priority control set at the router. These results reveal that router packet processing is not constant with respect to traffic pattern and packet size, even

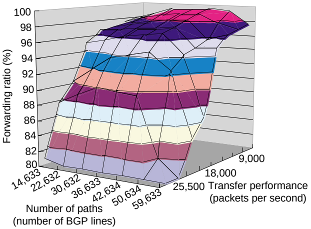

Fig. 3. Example of evaluating the number of network paths and packet transfer performance.

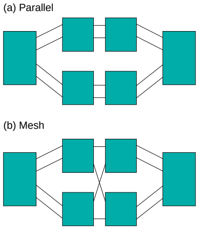

Fig. 4. Example of network configuration evaluation.

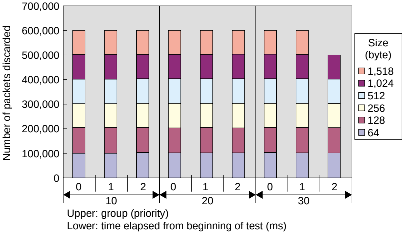

Fig. 5. Example of evaluating packet discarding rate using the NCT system.

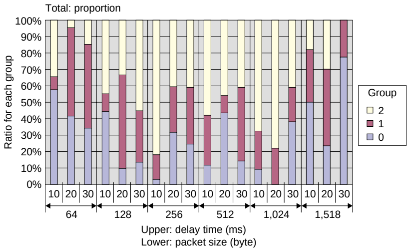

Fig. 6. Example of evaluating the effectiveness of network and router priority control.

with priority control. This shows the need to conduct tests with various traffic patterns before the beginning of actual network service to understand the characteristics of the network and its devices.

6. Future development

The functions shown in Fig. 1 have already been developed. Our future system development plans include evaluating online performance after service has begun, automatically detecting attacks on the network (expanding into the field of security), detecting predictors of service quality degradation or failure, and identifying bottlenecks.

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