APPLICATION OF NX4000 40-Gbps TRANSPORT ANALYZER

DAIRI Kenji [*1] *SHIDA Hideo* [*1] *TSUTSUMI Seiichi* [*1] *TAKAHASHI Kenji* [*1]

The 40-Gbit/s transport networks that will meet the communication demand of Next-Generation Networks (NGN) are starting to be deployed commercially. To meet the increasing measurement needs of the 40-Gbit/s networks and transmission equipment, we have developed the NX4000 Transport Analyzer. This can accurately and efficiently measure the transmission quality and characteristics of the networks, transmission equipment corresponding to 40-Gbit/s Synchronous Digital Hierarchy (SDH), Synchronous Optical NETwork (SONET), and Optical Transport Network (OTN). This paper describes the various measurement applications of the NX4000 Transport Analyzer.

INTRODUCTION

Today, the term "next-generation network (NGN)" is widely used not only in the communications industry but also in daily life. Many households enjoy high-quality images and videos in real time through the Internet using broadband communications, i.e. FTTH (Fiber to The Home) or xDSL (a collective term for high-speed digital communications using telephone lines such as ADSL, HDSL, SDSL, and VDSL; DSL means Digital Subscriber Line). The latest mobile phones can browse PC sites on the Internet, in addition to their many calling and e-mail functions. Communication traffic is surging as such services increase.

The networks that support these communication needs have been developing. Since it was established twenty years ago in the International Telecommunication Union - Telecommunication Standardization (ITU-T) G.707 in 1988(1), the Synchronous Digital Hierarchy (SDH) format has become the globally accepted optical transmission network, and is compatible with the Synchronous Optical Network (SONET), the basic format of SDH (collectively, SDH/SONET). The maximum basic frame rate of SDH has now reached 40 Gbps, which is 256 times the initial speed of 156 Mbps. For long-haul transmission, the Optical Transport Network (OTN) which has an error correcting function was created as one of the ITU standards to maintain communication quality.

To create the NGN, equipment vendors and telecommunications carriers are working hard to improve the quality and capacity of networks. Among them, Yokogawa has developed the NX4000 transport analyzer to efficiently and accurately measure the transmission quality and characteristics of networks and transmission equipment compliant with the 40-Gbps SDH/SONET/OTN frame. We previously described the basic functions of the NX4000 in Yokogawa Technical Report 2008 No. 45(2). This paper reports on the wide range of its measurement applications.

Figure 1 External View of NX4000 Transport Analyzer

*1 Communications and Measurement Business Headquarters, Optical Communication Measurement Development Department

Table 1 Lineup of Optical Interface Modules

Model name	Optical modulation format
NX4120	NRZ
NX4121	DQPSK
NX4122*	DPSK
NX4123*	ODB

*Under development

BASIC FUNCTIONS OF NX4000

Figure 1 shows an external view of the NX4000 transport analyzer.

The analyzer consists of a transmitting part and a receiving part. The signals output from the transmitting part are input into a unit under testing such as transmission equipment, and the signals output from the unit are then measured at the receiving part. Error signals can be added to the signals output from the transmitting part to test or generate an alarm.

The NX4000 uses signals compliant with Serdes Framer Interface Level 5 (SFI-5)[3] for the inter-module interface to enable the system to be constructed to meet customers' needs.

Compatibility with various optical modulation methods

In 40-Gbps transmission, the Non Return to Zero (NRZ) modulation format has a limitation on transmission reach. Therefore, Differential Phase Shift Keying (DPSK), Differential Quadrature Phase Shift Keying (DQPSK), or Optical Duo Binary (ODB) modulation formats are used for long-haul transmission.

In the NX4000, the user can easily change the optical interface modules, which offer four types of modulation formats including the above-mentioned format for long-haul transmission (Table 1).

OTN mapping

In the OTN, various broadband services such as SDH/SONET are sent by mapping them on the OTN frame. The NX4000 is designed to handle various mapping. Figure 2 shows a mapping configuration of Optical Channel Transport Unit 3 (OTU3).

40-Gbps Non-Frame, Synchronous Transport Module level 256 (STM-256), Synchronous Transport Signal level 768 (STS-768), or four Optical Data Channel Unit 2 (ODU2) can be mapped on the client frames of OTU3. 10-Gbps Non-Frame, STM-64, STS-192, and 10GbE-LANPHY (physical layer standard of Ethernet) can be mapped on the client frames of ODU2.

The NX4000 can independently control ODU2 × 4 and their client frames. For example, each offset frequency can be set separately at the transmitting part and the ODU2 × 4 and their respective STM-64 can be measured simultaneously at the receiving part.

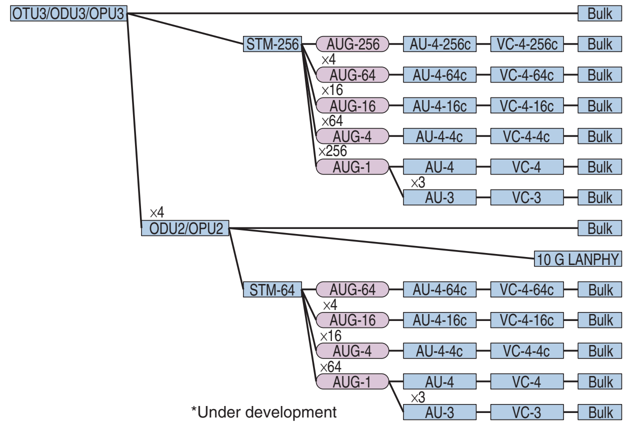

Figure 2 Mapping Configuration of OTU3

APPLICATIONS OF NX4000

The NX4000 is suitable for various applications including the following.

Bit error test

One of the major functions of the NX4000 is the bit error test. This test consists of a pass test and a bit error rate characteristics test.

In the path test, the system sends frames including pseudo random binary sequence (PRBS) patterns to the network and tests the frames which have passed through the network. If no bit errors are detected, it confirms the existence of the path. In the case of multiple paths, a PRBS pattern which will not synchronize except the channel to be measured is mapped on the frames.

Figure 3 shows a connection example in the bit error rate characteristics test. The NX4000 is connected with the optical module via an optical attenuator (OATT) and characteristics of the optical input power to bit error rate are measured as the amount of optical attenuation is changed.

The NX4000 can change the alarm detection conditions or stop the pattern synchronization, as well as measure even error rates of 1×10^{-2}.

Alarm detection condition test

Transmission equipment issues an alarm to other instruments upon detecting an abnormality in transmission. Most alarms are assigned to specific bits of the overhead (OH) of the frame. If any error occurs in these bits, the equipment may detect it by mistake,

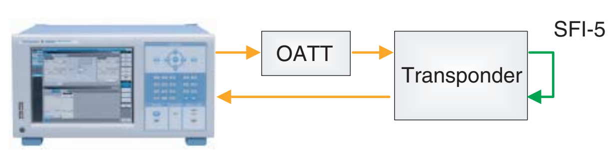

Figure 3 Connection Example for Bit Error Rate Characteristics Test

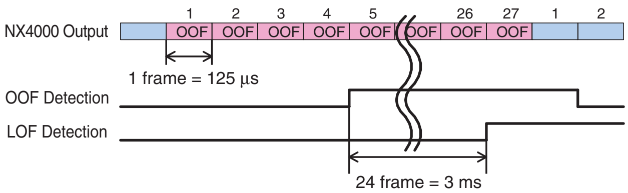

Figure 4 Detection Timing of OOF and LOF

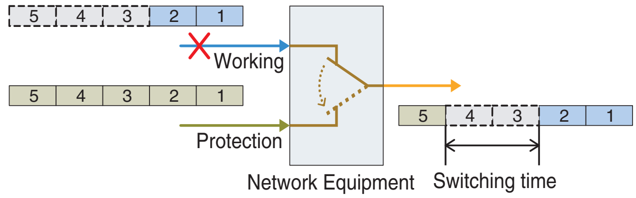

Figure 6 Schematic Diagram of APS Operation

so the number of consecutive frames having the same alarm is set as a detection condition.

Figure 4 shows the condition of the transmission equipment to detect Out of Frame (OOF) and Loss of Frame (LOF) when OOFs are sent from the NX4000. In SDH, OOF is detected after five consecutive frames containing OOF are received, and LOF is detected after OOF continues for 3 ms.

Incrementing or decrementing the number of OOFs from the NX4000 helps to confirm the detection conditions.

Error detection condition test

Transmission equipment uses parity to monitor the error rate of the received data and issues an alarm to other instruments upon detecting deterioration in the quality of transmission. The NX4000 has various error adding functions to test the thresholds of raising alarms. Among them, Repeat Bit and Repeat Frame are described below. Figure 5 shows a schematic diagram of error adding.

In Repeat Bit mode, errors with a specific number of bits are repeatedly added at regular intervals within a given frame interval. In Repeat Frame mode, errors with any bit sequence are added to the consecutive frames with a specific length within a given frame interval. For example, as for B1 of bit interleaved parity (BIP-8) in SOH, the number can be set to a specified one bit or all eight bits.

Delay measurement

To ensure efficient use of network throughput, the latency of the transmission equipment should be as short as possible. The NX4000 inserts time stamp data in the payload in the frame and measures the latency of the transmission equipment during up to 10 seconds at the resolution of 0.1 µs (payload is the data to be transmitted excluding the header). Thanks to measurement with time stamp, it is not necessary to set the measurement cycle and the result can be obtained at all the time stamps, which is different from the method to output a unique pattern at a certain interval.

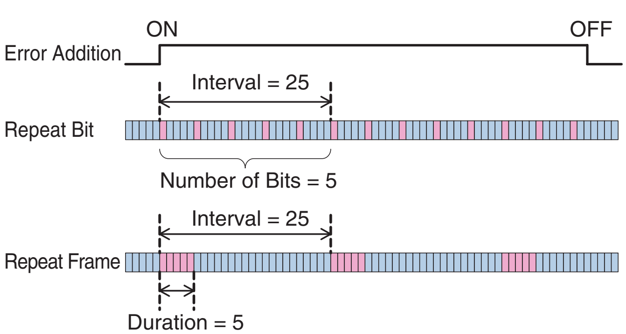

Figure 5 Schematic Diagram of Error Adding

Measurement of automatic protection switching (APS)

In SDH/SONET, to recover immediately from failures such as a transmission equipment failure or disconnection of fibers, two lines are provided: a working line for usual use and a protection line for back up. If the working line fails, the transmission equipment immediately switches to the protection line and maintains communications. Figure 6 shows a schematic diagram of APS operation. The NX4000 can measure this switching operation with a resolution of 0.1 ms.

Consecutive identical digit (CID) test (under development)

The transmission equipment recovers the clock signal from the received data. The function or device for recovering the clock signal and re-timing the data is called clock data recovery (CDR). In the NRZ modulation, the changing points from 0 to 1 or vice versa are used for recovering the clock signal, so the continuation of 0 or 1 prevents the clock recovery and causes an error. Such continuation also causes a temporary imbalance of DC and creates an error if the AC amplifier does not extend to a low frequency. The NX4000 has a function to test the tolerance to such consecutive data of 0 or 1. Figure 7 shows the measurement frame.

The system decides the limitation of the length of CID by inserting CIDs which are changeable by 1 byte into payload and measuring the bit error of PRBS patterns. This CID measurement frame sends correct SOH and path overhead (POH), so parity errors and alarms do not occur. Therefore, the system can test the transmission equipment which terminates OH, detects errors, and transmits alarms.

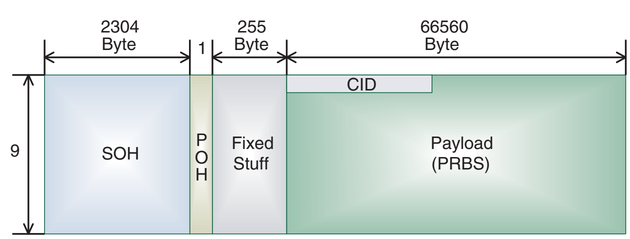

Figure 7 CID Measurement Frame of SDH/SONET

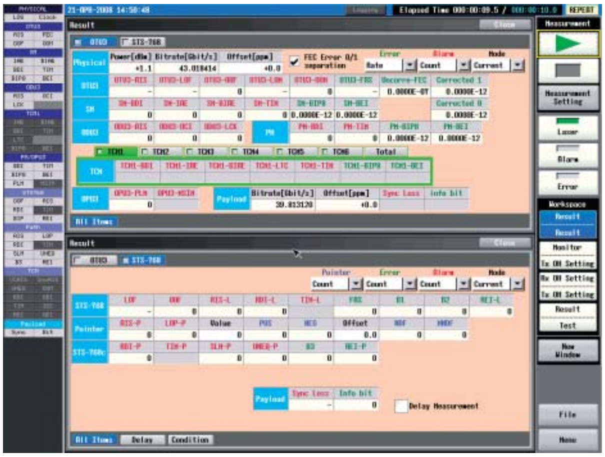

Figure 8 Example of Operating Display

Table 2 Windows of NX4000

Window name	Description
Setup	Setting physical condition and frame structure
Tx OH Setting	Setting OH value to be sent
Rx OH Setting	Setting expected OH value to be received
Monitor	Showing the received value
Test	Operating test function and showing test results
Result	Showing the test results

Table 3 Measurement Display Mode of NX4000

Display mode	Contents
Current	Measurements from start to present
100 ms	Measurement every 100 ms
1 s	Measurement every 1 s
10 s	Measurement every 10 s
Last	Previous measurement

GUI OF NX4000

The NX4000 is designed to be easy to use. When the user operates on the display, the hardware in the system responds to the changes and completes it at almost the same time, so the user need not wait for almost any operations.

The monitor lamps showing the detected status of errors and alarms, monitors for OH, and measurement results display are updated every 0.1 second so that the reception condition can be seen in real time.

Flexible combination of windows

Figure 8 shows a display example. On the left is the monitor lamp display, and on the right are the buttons for controlling measurements and windows. Two windows can be displayed one above the other in the middle workspace.

Table 2 shows windows of the NX4000. The NX4000 has four workspaces; windows can be arranged in each workspace and any one of them can be displayed. As shown in Figure 8, all the alarms and errors can be displayed simultaneously by opening the windows vertically: one for the results of OTU3, the other for the results of STM-256.

Measurement display by setting time interval

Even if bit errors occur during long-time monitor measurements, the NX4000 can be set to continue the measurements and display the current error rates. Other than the current display, it selects time intervals of 100 ms, 1 s, and 10 s. If set to 1 s, the system displays error rates every 1 s without restarting the current measurement. Table 3 shows the measurement display mode of the NX4000.

CONCLUSION

In this paper, we described the versatility and user-friendliness of the NX4000, which will be useful for developing next-generation networks.

40-Gbps technologies are now entering practical use. As new needs emerge and R&D continues, we will continue to work on satisfying customers' requirements. ◆

REFERENCES

(1) ITU-T G.707 (01/2007)

(2) YANAGISAWA Yoshiki, DAIRI Kenji, OMATA Hiroshi, SATOU Hiroyuki, "NX4000 40-Gbit/s Next-generation Optical IP Transport Analyzer," Yokogawa Technical Report, No. 45, 2008, pp. 5-8

(3) "OIF-SFI5-01.0," OPTICAL INTERNETWORKING FORUM (http://www.oiforum.com/)

* 'Ethernet' is a trademark of Fuji Xerox, Co., Ltd.

* 'SONET' is one of the high-speed digital communications formats for optical fibers, which is advocated by Bellcore (currently, Telcordia Technologies) and a trademark of the company.