

# IP TRAFFIC LOAD GENERATOR/ ANALYZER—AE5511 TRAFFIC TESTER PRO

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*The IP traffic load generator/analyzer is a measuring instrument used to test the performance of communications equipment, such as switches and routers configured as the nodes of an IP network, by generating IP data and receiving the data for analysis. In addition, the generator/analyzer is used to evaluate the performance of end-to-end transmissions or transmissions between relay points via a network made up of those pieces of equipment. Our company has developed the AE5511 Traffic Tester Pro, a measuring instrument equipped with various multi-port interface units and capable of flexibly meeting measurement needs in IP network testing. With the Windows-based graphical user interface (GUI) software, the AE5511 supports multi-user, multi-interface operating environments. This paper explains the basic configuration of the AE5511 Traffic Tester Pro, as well as approaches toward the testing of the quality of service (QoS) and the high-precision measurement of full wire rates.*

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## INTRODUCTION

Traditionally, information and communications networks used telephone exchanges. Today, however, information and communications networks are quickly transforming and developing into an IP network, whose main purpose is IP data communication. Sparked by the spread of the Internet, IP networks have been spreading rapidly to underpin communication and network technologies for day-to-day and business use, such as IP phones, B2B communications, and mobile communications.

The technology which makes up the core of IP networks is a data communication technology generally called Ethernet, and it is well known that Xerox Corporation of the United States developed the prototype. Ethernet has become the international standard, 802 Series of the Institute of Electrical and Electronic Engineers (IEEE). The Internet Engineering Task Force (IETF) is

playing a central role in the development of Ethernet.

Because it is a highly flexible data communication format, Ethernet continues to develop with the support of many vendors.

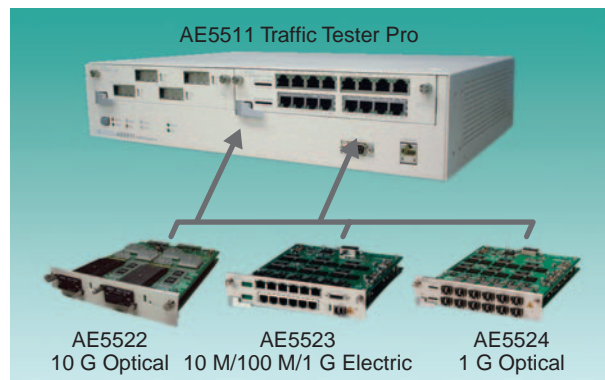
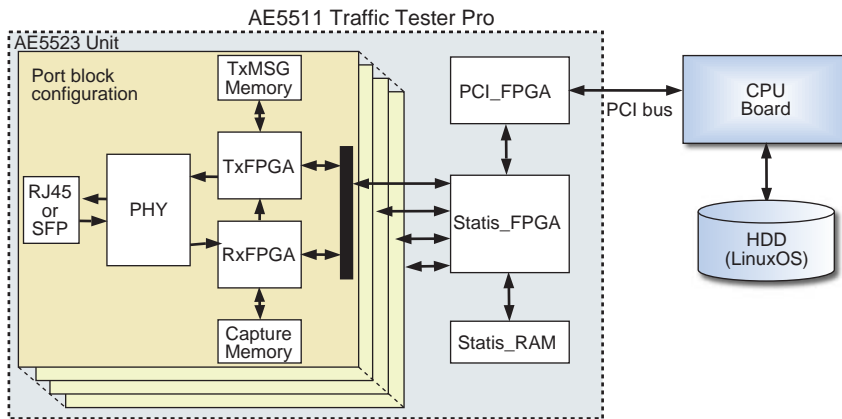


Figure 1 External View

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**Figure 2** AE5511 Hardware Block Diagram

On the other hand, however, unlike traditional data transmission formats, Ethernet does not offer a high level of strictness in performance. Even in the homogeneous Ethernet environment, the performance of network devices is not uniform. The necessity for measurement devices to evaluate the performance of IP data communication is increasing.

In response to this need, Yokogawa has developed the AE5511 Traffic Tester Pro. Via multiple ports, this device enables the easy execution of various test functions that are necessary for the performance evaluation of IP data communication by network devices.

Figure 1 presents the external view of the AE5511 Traffic Tester Pro and its main components.

## FEATURES

The AE5511, an IP network tester that evaluates and verifies network devices, affords the following features:

- (1) Multi-port capability  
The AE5511 has a 2U small rectangular body for high-density mounting and can perform testing via a maximum of 32 ports.
- (2) QoS evaluation function  
Priority control can be evaluated by the statistical monitoring function per QoS.
- (3) Sequence check function  
Packet loss, maximum burst loss, packet order reverse, and packet duplication can be detected in real time.
- (4) Multi-user capability  
One AE5511 unit can be shared by a maximum of eight users. Each user can use some reserved ports.
- (5) Capture function  
Each port is installed with a capture memory, which can capture trigger conditions set to error frames, sequence check errors, link up/down, etc.
- (6) IPv6 emulation function  
Equipped with the Neighbor Discovery Protocol (NDP) emulation function, the AE5511 can handle IPv6 stateless address automatic acquisition and automatic PING6 reply.

- (7) Multi-field variation function  
Frames can be transmitted while varying up to four fields at one time. For example, Media Access Control (MAC) address, IP address, Virtual LAN (VLAN) ID, and QoS field can vary simultaneously during frame transmission. Testing can be performed in an environment similar to the real network.

- (8) Alarm log function  
This function records alarm logs of Inter Frame Gap (IFG) abnormalities, abnormal packet latencies, and reception rates out of range. The time of day an alarm occurs is also recorded, so the verification of bandwidth guarantee and control functions can be performed for a long time.

## CONFIGURATION

Figure 2 presents the hardware configuration of the AE5511 installed with an AE5523 unit. The AE5511 can be mounted with up to two units of any of the five types, whose features, including interface speeds, are presented in Table 1.

### AE5511 Architecture

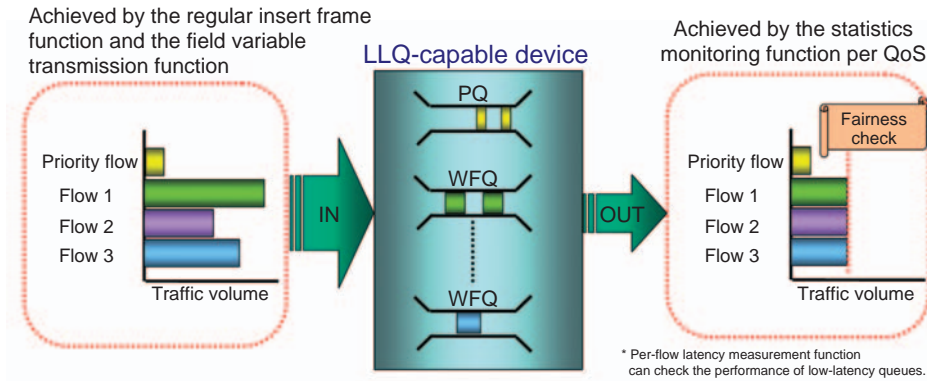
The AE5511 is equipped with a CPU board for the Linux OS, which is connected with each AE552x series unit via a PCI bus. The hardware of each unit plays a major role in the execution of the real-time measurement function. While the traffic and statistical processing increase at the measurement ports, the CPU load remains unchanged. A full-wire rate test on all measurement ports has proven that the measurement performance and the operation response do not deteriorate.

### AE552x Series Unit Architecture

All AE552x series units have a common architecture; the only differences among them are the type of measurement interfaces and measurement port configuration. The units have one physical layer interface IC (PHY) and two Field Programmable Gate Arrays, or FPGAs (one for transmission and another for reception), for each port. Thanks to this feature, the ports of the units do not have to depend on each other even at the full-wire rate. A dedicated interface connects the Transmission

**Table 1** AE552xUnits

Unit Name	Interface Speed	Number of Measurement ports	Signal
AE5520	10 M/100 M bit/s	16	Electric
AE5521	1 G bit/s	4(GBIC)	Optical
AE5522	10 G bit/s	2(XENPAK)	Optical
AE5523	10 M/100 M/1 G bit/s	12+1(SFP)	Electric / Optical
AE5524	1 G bit/s	12(SFP)	Optical



**Figure 3** Priority Control using the LLQ

FPGA (TxFPGA) and the Reception FPGA (RxFPGA), by which specific hardware components handle the network emulation function to achieve a quick reply for ARP, NDP, PING, etc. The setting of the FPGA of each measurement port can be rewritten using software. The functions of the FPGA can be added and enhanced in a flexible manner.

Also, the AE552x series units are installed with one Statis\_FPGA for statistical processing. The Statis\_FPGA executes high-speed caching of statistical information in the TxFPGA and RxFPGA of each measurement port of the unit and performs integrated processing of the accumulated data for central management of statistical data.

In this way, the Statis\_FPGA reduces the data processing load on the FPGA of each measurement port. Distributed placement of small FPGA units enables high cost performance even for multi-port interface units.

## FUNCTIONS

This chapter discusses two functions newly integrated into the 1000BASE-T unit of the AE5523 and the 1000BASE-X unit of the AE5524: the QoS test function and the high-precision full-wire rate measurement function.

### QoS Test

IP network devices for “triple play,” which are designed to handle data, voice and sound, and video, have been delivering best-effort services. However, they now need to have the QoS function to offer policy-based priority control.

Network devices provided with the QoS function categorize services (traffic) according to the definitions of explicit service classes. These definitions are based on the priority field value (CoS) of VLAN tag, the DiffServe Code Point (DSCP), and the like.

The categorized traffic is assigned to queues with different priority levels for priority control. Such queues are produced by Priority Queuing (PQ) and Weighted Fair Queuing (WFQ), or by Low Latency Queuing (LLQ), which provides the features of the PQ and the WFQ alike.

The traffic in the queue of the PQ takes absolute priority over those in any other queues. This level of priority is given to types of data flow that cannot be deleted or delayed, such as sound and

voice data flow.

Non-priority flows equally share band-widths in a queue of the WFQ (Figure 3).

The AE5511 is implemented with a function to effectively confirm that priority control is functioning properly.

To test the QoS function, high-priority and low-volume traffic as well as low-priority and high-volume traffic are multiplexed to generate packets and check whether the high priority packets are given priority for outputting during times of traffic congestion.

The multiplex transmission function to assign different priority levels to flows generated from the transmission side is achieved by the insert frame function, which prioritizes multiplexing of high-priority traffic over normal traffic.

The insert frame function can regularly transmit frames at a minimum frequency of 1 ms. Highest priority data flows (sound and voice, etc.) can be generated on a pseudo basis.

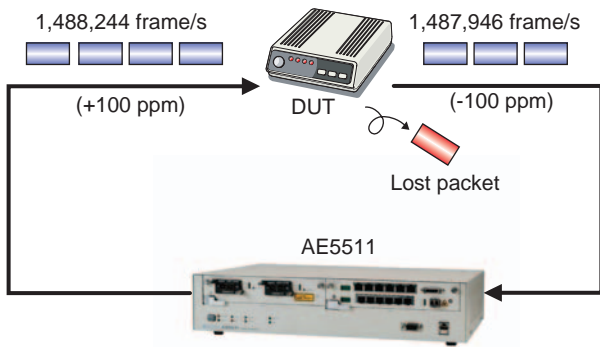
To transmit non-priority flows at different transmission rates, the look-up table method of the field variable transmission function can be used to control the generation of each flow.

On the reception side, the statistical monitoring function per QoS, which measures only frames set according to the conditions of the reception filter, is implemented in a maximum of eight channels in each measurement port.

By setting the reception filter according to the conditions for the priority level, the traffic rate and latency (maximum, minimum, and average) can be measured for each channel (Figure 4). Based on the measurements, the fairness of the WFQ and the latency variation of the PQ can be examined.

UNIT1-PORT01		UNIT1-PORT01	
[CH1]Frame	971	[Latency]Max IPG(us)	349.257.7
[CH1]Byte	62,144	[Latency]Min IPG(us)	6,661.7
[CH1]Rate(%)	0.23520	[Latency]Avg IPG(us)	6,932.6
[CH1]Rate(Frame/s)	35	[Latency]Max Packet Latency(us)	1.9
[CH1]Rate(pps)	17,920	[Latency]Min Packet Latency(us)	1.7
[CH2]Frame	971	[Latency]Avg Packet Latency(us)	1.8
[CH2]Byte	62,144	[CH1]Max Packet Latency(us)	1.9
[CH2]Rate(%)	0.23520	[CH1]Min Packet Latency(us)	1.7
[CH2]Rate(Frame/s)	35	[CH1]Avg Packet Latency(us)	1.8
[CH2]Rate(pps)	17,920	[CH2]Max Packet Latency(us)	1.9
[CH3]Frame	971	[CH2]Min Packet Latency(us)	1.7
[CH3]Byte	62,144	[CH2]Avg Packet Latency(us)	1.8
[CH3]Rate(%)	0.23520	[CH3]Max Packet Latency(us)	1.8
[CH3]Rate(Frame/s)	35	[CH3]Min Packet Latency(us)	1.7
[CH3]Rate(pps)	17,920	[CH3]Avg Packet Latency(us)	1.8
[CH4]Frame	971	[CH4]Max Packet Latency(us)	1.8
[CH4]Byte	62,144	[CH4]Min Packet Latency(us)	1.7
[CH4]Rate(%)	0.23520	[CH4]Avg Packet Latency(us)	1.8
[CH4]Rate(Frame/s)	35		
[CH4]Rate(pps)	17,920		

**Figure 4** Example Result of QoS Statistics



**Figure 5** Mechanism of Packet Loss Caused by Frequency Deviation

### High-precision Full-wire Rate Measurement

Recent years have seen rapid progress in the hardware performance of layer-3 switches. Now even at 10 Gbit/s, the full-wire rate performance is possible.

Ethernet is an asynchronous system, each of whose nodes is run by an independent clock. In a full-wire rate test, the difference in the interface clocks between nodes (frequency deviation) is a problem.

According to IEEE802.3, the maximum permissible frequency deviation is  $\pm 100$  ppm for interface clocks. In Gbit Ethernet, the theoretical full-wire transmission rate of 64-byte frames is 1,488,095 (frame/s). If the frequency deviation is to be considered, the actual rate transmission ranges between 1,487,946 and 1,488,244 (frame/s).

Under normal conditions, the frame buffer helps network devices to withstand a certain degree of burst caused by frequency deviation due to the output interface clock of network devices running faster than their input interface clock. However, when tested at the full-wire rate, even the frame buffer of IP network devices, which is designed for such rates, overflows, thereby causing packet loss (Figure 5).

To prevent packet loss caused by frequency deviation and ensure that wire-rate testing can be performed, the AE5511 has a transmission clock adjustment function and a precision measurement function for the reception clock.

The reception clock can be measured in units of 1 ppm based on the received data and idle data at the time of linkup. The transmission clock transmits data variable in units of 1 ppm in the range of  $\pm 100$  ppm.

Packet loss is caused by frequency deviation when the output interface clock of the DUT is slower than that of the AE5511. To prevent this problem from occurring during a full-wire rate test, the speed of the transmission clock of the AE5511 should be decreased.

To conduct a real full-wire rate test, the output interface clock of the DUT should be measured by the measurement function for the reception clock of the AE5511, and the transmission clock of the AE5511 should be made a little slower than that of the DUT's. Then a real full-wire rate test can be conducted under conditions free from packet loss.

The sequence check function is useful in confirming that packet loss does not occur during continuous testing for a long time under the real full-wire test environment so constructed. When this function is enabled, sequence numbers are embedded in the packets to be transmitted, and the ports receiving the packets check whether or not packets are received according to the numbers. In this way, real-time detection of packet loss and burst loss is made possible by the sequence check function.

Conventionally, transmission traffic has had to be stopped to count the number of frames transmitted and received, in order to confirm that frame loss is not occurring. The sequence check function achieves real-time monitoring of packet loss while transmission traffic continues to flow, so that full-wire testing can be efficiently conducted for a long time.

### CONCLUSION

This paper has discussed how efficiently the IP network tester AE5511 evaluates IP communication devices and IP networks.

We will use the AE5511 Traffic Tester Pro as a platform for IP network and device testing. To enhance this system, the addition of new interface units and compatibility with new protocols will be consistently pursued. We are hoping to contribute to the development of next-generation IP networks in the forthcoming ubiquitous society. ◆

### REFERENCES

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- (2) Ishida Osamu, Seto Koichiro, 10 Gbit Ethernet Textbook (Revised), Impress, 2005, 389p. in Japanese

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