Application Note

Advancing beyond

Precise Latency Measurement For 5G Industrial Applications

- Comparison Between Ping and Measuring Instrument -

Network Master Pro MT1000A

Contents

1 Introduction

The mobile 5G communications standards facilitate the three use cases–enhanced Mobile Broad Band (eMBB), Ultra Reliable Low Latency Connection (URLLC), and massive Machine Type Connection (mMTC)–shown in Fig. 1. Above all, URLLC is the key features of 5G. In addition to person-to-person communications using smartphones, etc., this 5G use cases are also finding new applications in industrial fields, such as control of peer-to-peer machine communications.

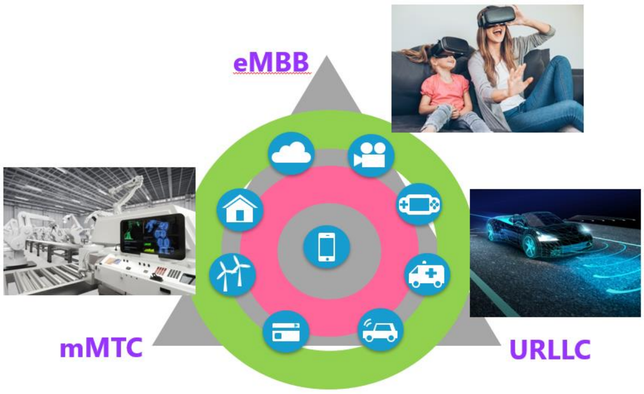


Figure 1. Three 5G Use Cases

Lower latency between wireless links is a target of the new 3GPP Rel 16 and future standards compared to Rel 15 as summarized in the following table.

Table 1 Wireless Access Technologies for Implementing Low Latency

Technology	Outline
Short TTI	Aims to shorten send wait time by making selecting data send period (slot) from 1 ms to 125 μs max.
Grant-free scheduling	Technology for terminal to start transmission without waiting for send permission (grant) from base station
Preemption	Technology for interrupting regular transmission schedule to send high-priority data

5G radio link communications latency can be reduced using these access technologies.

However, in mission-critical industrial applications, just minimizing latency is insufficient. For example, even if the average latency is low, if the latency variation is large, the predicted arrival timing of control signals still cannot be assured. Looking at trains as an example, on a line where trains occasionally arrive 10 minutes early or late, the average arrival time will still be on time according to the train schedule, but a line where trains are always 3 minutes late is more convenient for passengers. Similarly, communications predictability and real-timeness are very important in machine control systems.

The impact of large latency and randomness is not limited to radio links, and evaluation of communications quality for industrial applications requires end-to-end evaluation of the configured system. In addition to measure latency, evacuating latency variance, also called packet jitter, is of importance.

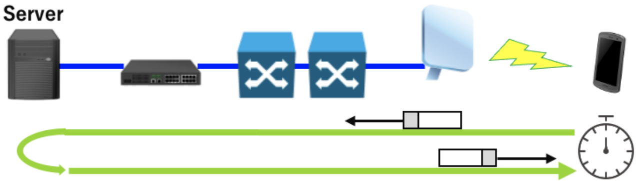
This Application Note explains end-to-end latency measurement solutions using measuring instruments.

2 Latency Measurement Methods

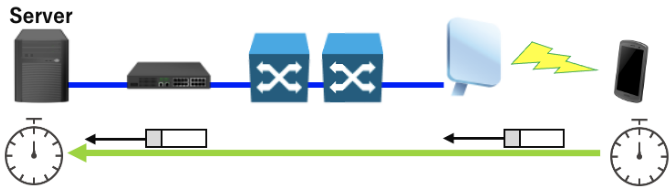
2.1 Round-Trip Time and One-Way Latency

In this Application Note, latency is specified as the time from when user-data stored in one IP data packet leaves the terminal until it reaches the communications partner (another terminal, server, etc.). There are two types of latency: round-trip time, and one-way latency.

1. Round-Trip Time
   This is the time required for data sent from the terminal to return back to the server, etc. Measurement requires one clock.

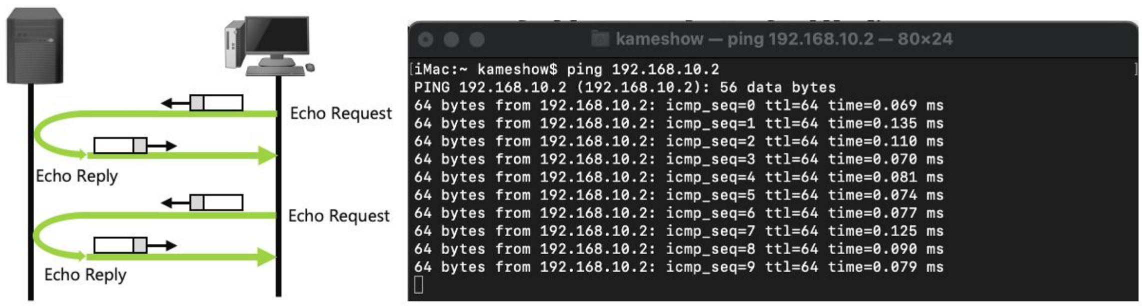


2. One-Way Latency
   This is the time required for data sent from the terminal to arrive at a server, etc. Measurement requires two clocks.



2.2 Latency Measurement using Ping

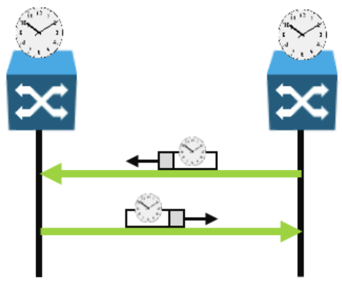
The PC-application Ping is commonly used to measure round-trip time. Almost all devices supporting IP communications, such as PCs, can measure round-trip time without requiring additional software.



The above figure shows an example of using Ping. When the Ping command is issued at a terminal (console screen), an Echo Request is sent and the time when the sender receives the Echo Reply is measured; the difference between the send time and receive time is the measured latency result.
Using a PC, the Echo Request minimum send interval can be set to 100 ms.

2.3 Latency Measurement using Specialist Tools

The Ping application can only measure round-trip time. TWAMP standardized by RFC 5357 supports one-way latency measurement. TWAMP can measure one-way latency by embedding a timestamp in the packets.



This method presumes that the clock times at each end of the path are synchronized. Mismatched clock times cause measurement error. Tools supporting TWAMP are supported generally by specialist network equipment, such as routers and appliances called NID (Network Interface Device). Usually, NTP (RFC 5905) is used to synchronize clocks between equipment.

Instead of equipment supporting TWAMP, Ethernet/IP measuring instruments, such as Anritsu's battery-operated, portable MT1000A can be used. The touch-panel LCD facilitates easy on-site setting and measurement. The clocks of two MT1000A units can be synchronized with high accuracy using GPS.

Figure 2. Network Master Pro MT1000A

3 Comparison of Latency Measurement Results using Ping and Measuring Instrument

This section explains latency measurement results for a test Local 5G network. It compares the results measured using a PC and the MT1000A.

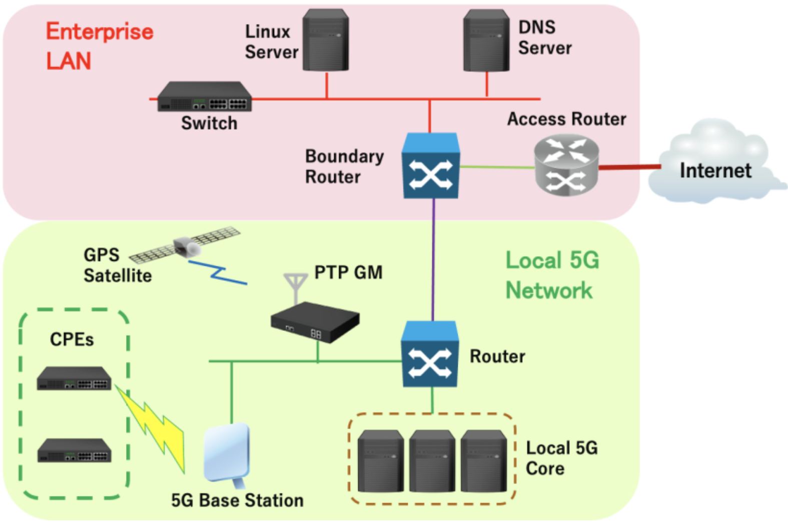
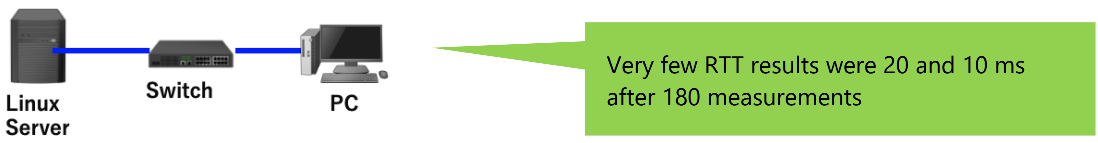


Figure 3. Test Local 5G Network

3.1 Round-Trip Time Measurement using Ping

First, the round-trip time was measured using Ping with and without inclusion of the radio link. The PC was a general-purpose commercially available Windows PC with no special customization.

1) Round-trip time measurement using direct connection without radio link



2) Round-trip time measurement using configuration including radio link

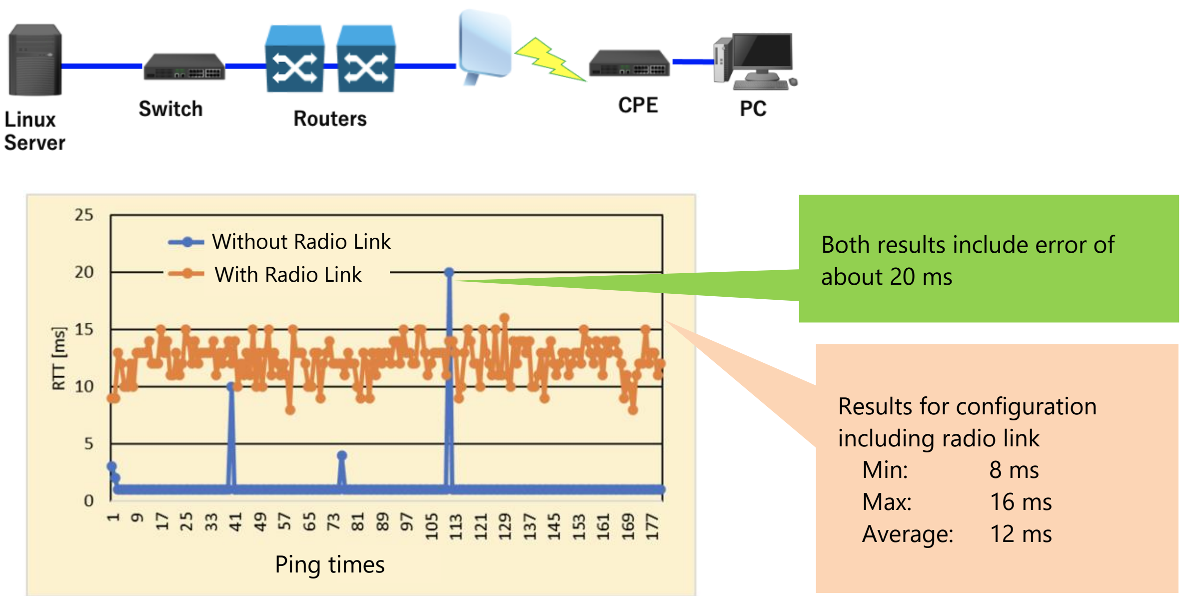
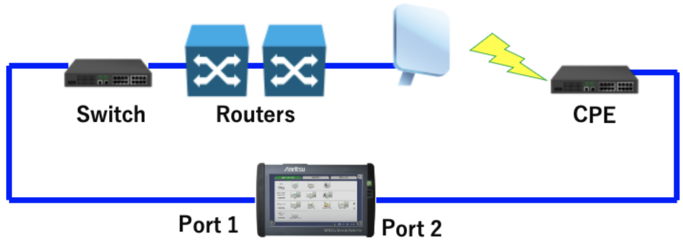


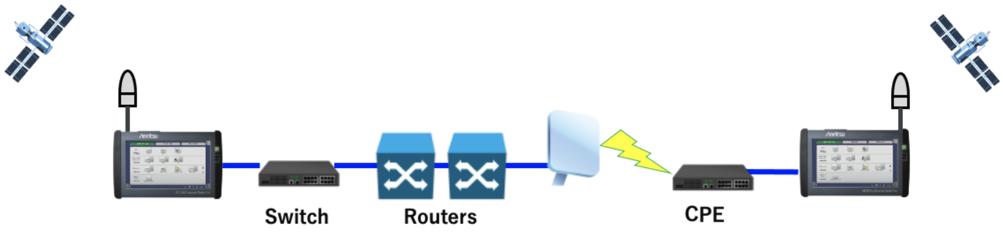
Figure 4. PC Round-Trip Time Results Measured using PC

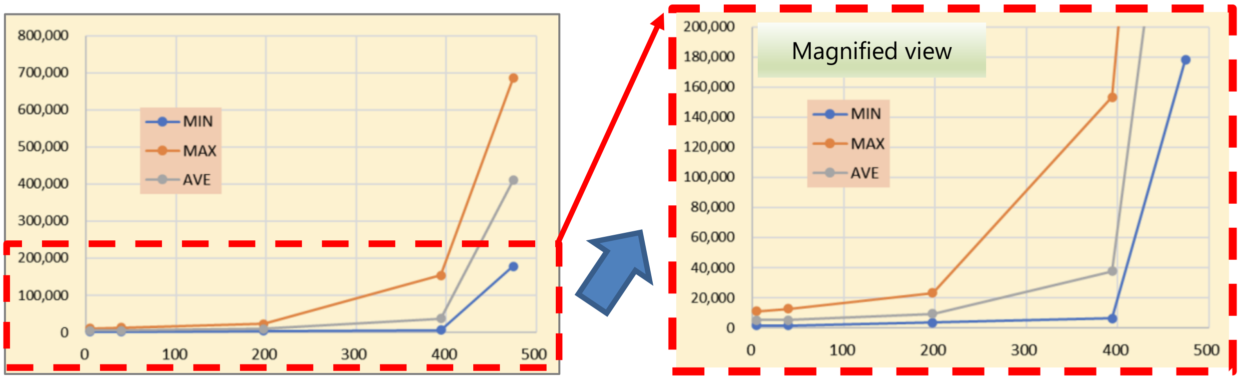
3.2 One-Way Latency Measurement using MT1000A

Next, the one-way latency of a configuration including a radio link was measured up and down using the MT1000A. The test traffic used UDP with a packet size of 1482 bytes.



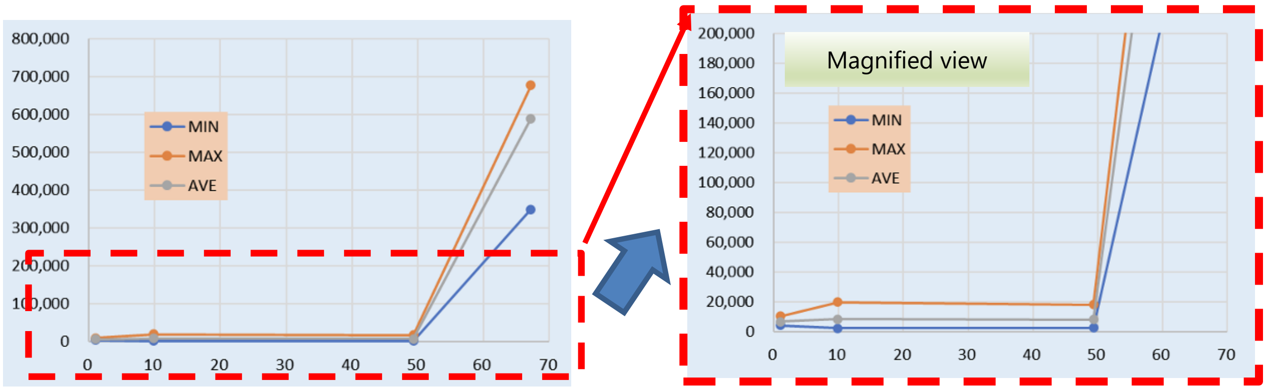
The test configuration shown above can be used in a laboratory, and the following configuration with GPS can be used for two separated terminals outdoors. In this latter case, the maximum time synchronization is ±2 μs (using GPS receiver equivalent to Anritsu G0325A).





y-axis: Latency (μs); x-axis: average throughput (Mbps)

Figure 5. DL Latency Results Measured using MT1000A (UDP, 1482-byte packets)



y-axis: Latency (μs); x-axis: average throughput (Mbps)

Figure 6. UL Latency Results Measured using MT1000A (UDP, 1482-byte packets)

Unlike Ping, when using the MT1000A to send a packet with a timestamp for measurement, it is possible to precisely specify the traffic load. As is clear from the results in Figs. 5 and 6, latency is dependent on traffic load. When the DL throughput approaches 200 Mbps, the latency starts deteriorating and becomes extremely high beyond 400 Mbps. Similarly, we can see inflection points when the UL throughput is close to 10 and 50 Mbps.
With Ping, since a maximum of 10 packets are returned each second, the tendency is to always obtain good measurement results.

3.3 Comparison of Latency Measurement Results using Ping and MT1000A

The following section compares the results for each Ping and MT1000A measurement. The MT1000A measurement results are the return times calculated as the sum of the Up and Down latencies.

Table 2 Comparison of Latency Measurement Results

		Latency (ms)			Test with actual traffic load	One-way latency
		Min	**Max**	**Average**		
Ping	**Round Trip**	**8**	**16**	**12.2**	**Not possible**	**Not possible**
MT1000A	**Round Trip**	**6.007 335**	**21.565 935**	**12.056 347**	**Possible**	**Possible**
	Down link (4 Mbps)	1.543 360	11.091 595	5.178 793		
	Up link (1 Mbps)	4.463 975	10.474 340	6.877 554		

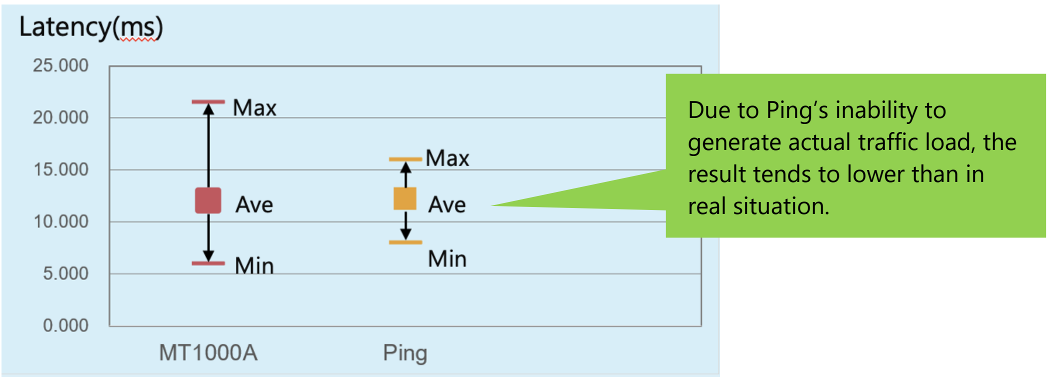


Figure 7. Comparison of Latency Measurement Results

The averages for both are fairly similar but there is a large difference between the maximum and minimum values, which is probably due to the difference in traffic loads described previously.
Additionally, as shown in Fig. 4, when using Ping, there is a possibility of obtaining incorrect large latency results due to the performance and operating conditions of the PC (running other applications). This can be mitigated by tuning the PC interface and using a high-performance PC. However, even in this case, other tools are required to impress the required traffic and precisely generate the target load.

3.4 Relationship Between Frame Loss and Packet Jitter and Between Frame Size and Latency

Latency-related details can be analyzed using the MT1000A. The following figures show the result of changing the packet size.

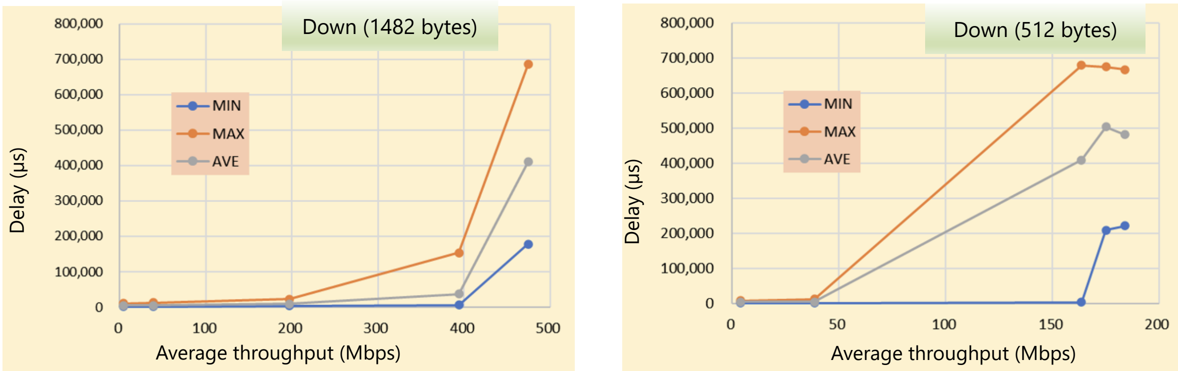


Figure 8. DL Latency Measurement Results (UDP, left: 1482-byte packets; right: 512-byte packets)

At a smaller packet size, the latency becomes larger at the same throughput. This is probably because the number of frames per second becomes larger when the packet size is small.

The results in the following figures show the relationship between traffic load, Frame loss rate, and packet jitter.

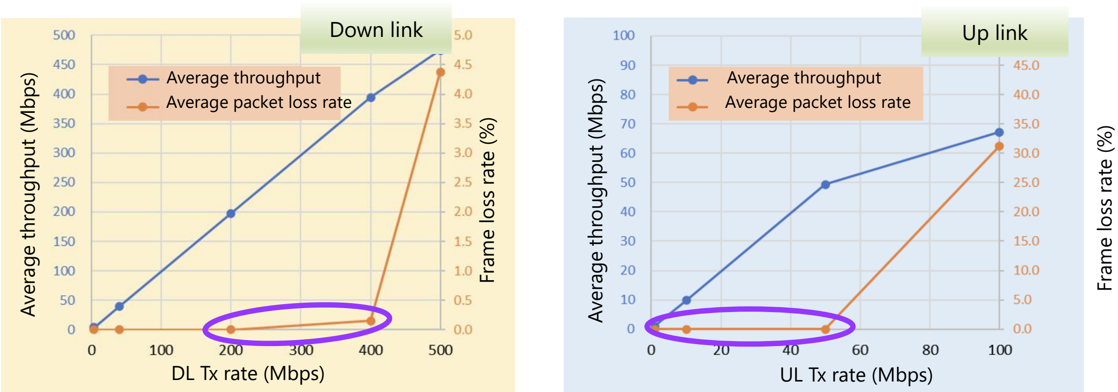


Figure 9. Traffic Load, Throughput and Packet Loss Rate (UDP, 1482-byte packets)

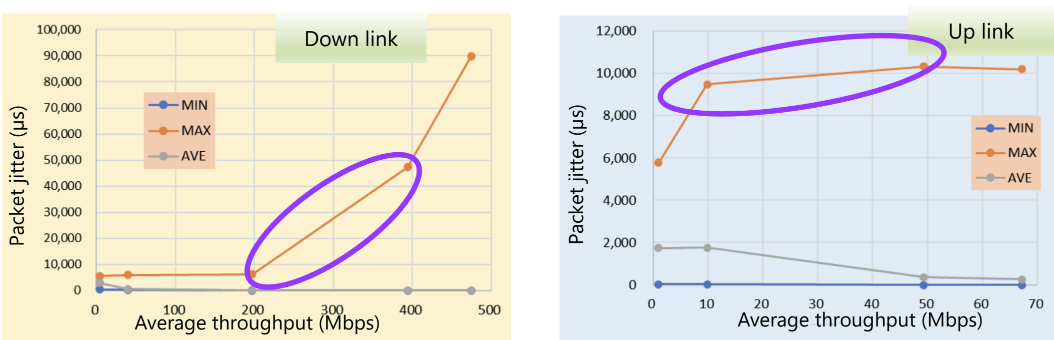


Figure 10. Throughput and Packet Jitter (UDP, 1482-byte packets)

Resending at the radio link occurs more frequently as traffic load increases, which is known to trigger packet jitter. The purple oval in Fig. 9 and 10 show large packet loss even at low Frame loss rates, which is probably caused by resending at the radio link.

4 Conclusions

This Application Note has explained the merits of using the MT1000A dedicated tester for measuring the key latency and packet jitter at evaluation of 5G communications systems in industrial applications.

Item	PC-based Ping Measurement	Measurement using MT1000A
Cost	Low	Higher than PC
High-accuracy latency, packet jitter, one-way latency measurements	Difficult; 1-ms to 100- μs order accuracy	Easy, 100-ns order accuracy
One-way latenct	Not possible	Possible
Accurate traffic load	Difficult	Easy

The issue with high-performance radio systems is how to control radio factors such as multipaths in the surrounding environment. If reproducibility can be assured by using dedicated test equipment for the relatively controllable wired network segments, attention can be focused on solving issues at the radio side. The MT1000A is the ideal test solution for generating traffic on and measuring the wired segments.

Anritsu's know-how and total solutions for both wired and wireless networks can contribute to customers' future business success.

Advancing beyond

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