NATIONAL TIME AND FREQUENCY STANDARD DISSEMINATION SYSTEM IN ICT ERA

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ABSTRACT

We are developing a new national time and frequency standard dissemination system by using information and communications technology (ICT). This is called TFDN (Time and Frequency Dissemination system via Network). The TFDN is a compact and all-in-one system which automatically compares time, calibrates a local oscillator, and supplies time and frequency. A local clock in the TFDN is calibrated by using GPS common-view / all-in-view to the national time and frequency standard. The TFDN also supplies time information into IP networks as a hardware time server. Slaves can be synchronized within tens of nano-second accuracy in the same network (LAN). The all functions, include a rubidium oscillator, are packed into a 1U size case. NICT has been operating the public NTP service using the hardware NTP servers in these two years, ntp.nict.jp, and more than a hundred million NTP packets per day are requested to this service.

I. INTRODUCTION

Time information and frequency are infrastructure of modern society. Many systems need to adjust their clocks or oscillators. Furthermore, some applications need sub-microsecond accuracy [1]. We are developing a new national time and frequency standard dissemination system by using information and communications technology (ICT). This is called TFDN (Time and Frequency Dissemination system via Network). The TFDN is a hybrid system with GPS common-view / all-in-view [2, 3] for long distance and IP network for short distance and coarse time synchronization. The TFDN is a compact and all-in-one system which compares time, calibrates a local oscillator and supplies time automatically. The TFDN can creates GGTTS data by using IGS precise data [4]. Then The TFDN also collects GGTTS data from NICT Web site and compares it and local one. A built-in oscillator will be also automatically steered by the time difference. The all functions, include a rubidium oscillator, are packed into a 1U size case. Imae although developed GPS common-view system, it did not provide time information via network [5]. The assumed applications of the TFDN are remote frequency calibration, trusted time stamps, precision time synchronization for measurement, control and communications in the local area networks, network time server, and so on.

Two time protocols on IP network are implemented; Network Time Protocol (NTP) [6] and Network Space-Time Protocol (NST) [7-9]. NTP (RFC1305) is a de facto standard for network time synchronization. On the another hand, NST is a newly proposed protocol and NST server broadcasts location and time (space-time) packets. These protocols are implemented on a dedicated hardware (FPGA). The resolution of time-stamping of the TFDN space-time packet is 4 nanosecond and the TFDN can process over one million NTP packets per second (wire speed of one gigabit per second). Slave personal computers on the same Local Area Network (LAN) can be synchronized within tens of nanosecond accuracy to the national standard. Conventional 1 PPS and 10MHz signals are also supplied. NICT has been operating the hardware NTP server to provide Japan Standard Time for these two years. More than 100 million of packets are requested in a day [10].

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II. SYSTEM OVERVIEW

The system overview of the TFDN is shown in Figure 1 and 2, and the specifications are listed in Table 1. The TFDN is a hybrid system with GPS common-view / all-in-view and IP network. National time and frequency standard is disseminated by GPS common-view / all-in-view for long distance and by IP network for short distance. The TFDN is a compact and all-in-one system which compares time, calibrates a local oscillator and supplies time automatically. The TFDN can creates GGTTS data by using precise Ephemeris and clock information provided by the International GNSS Service (IGS). Then the TFDN also collects GGTTS data from NICT Web site and compares it and local one. A built-in oscillator (OCXO or Rubidium Atomic clock) will be also automatically steered by the time difference. The all functions, include a rubidium oscillator, are packed into a 1U size case.

A local clock of the TFDN is calibrated within a few nanosecond accuracy using GPS common-view / all-in-view to the national time and frequency standard. The TFDN also supplies time information into IP networks. Slave personal computers on the same LAN can be synchronized within tens of nanosecond accuracy to the national standard too. Two time protocols on IP network are implemented; NTP and NST. NTP (RFC1305) is a de facto standard for network time synchronization. On the another hand, NST is a newly proposed protocol and NST server broadcasts location and space-time packets. These protocols are implemented on a dedicated hardware (FPGA). The resolution of time-stamping of the TFDN space-time packet is 4 nanosecond and the TFDN can process over one million NTP packets per second (wire speed of one gigabit per second). The slave software of NST for personal computers is supplied freely in the Web site "http://groups.google.com/group/network-space-time." Conventional 1 PPS and 10MHz signals are also supplied.

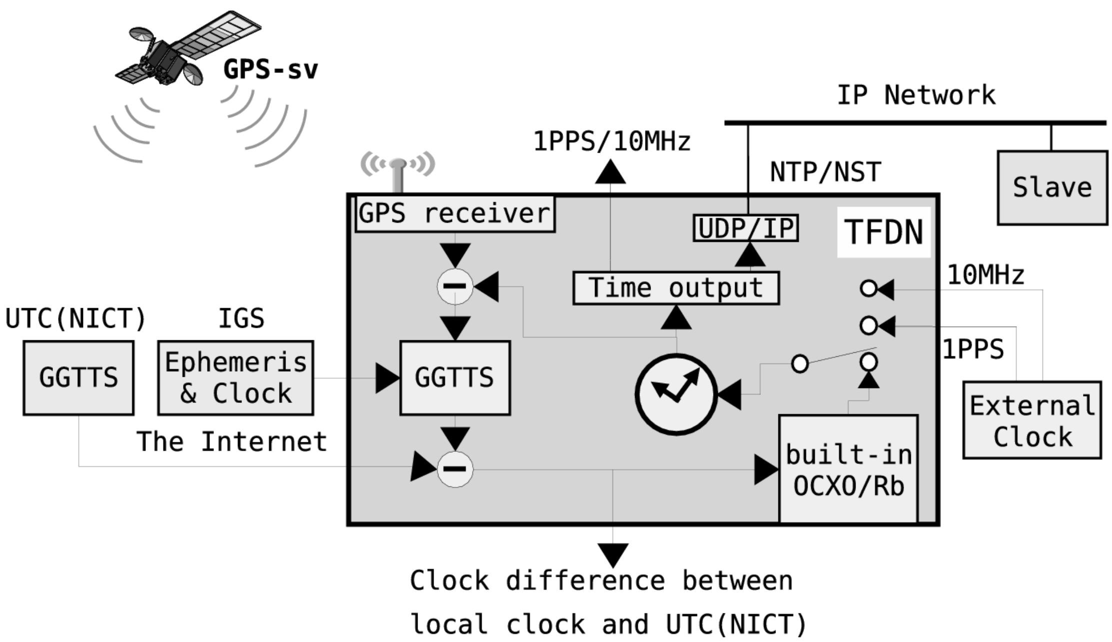

Fig. 1. System overview of the Time and Frequency Dissemination system via Network.

Table 1. Specification of the TFDN

Item	Spec.
GPS receiver	L1 C/A code
	16ch
	-142dBm (cold starts)
Signal IN	1PPS, 10MHz, GPS ANT.
Signal OUT	1PPS (Int. clock), 10MHz, 1PPS (GPS)
Built-in Oscillator	OCXO (< 1 E-12 @ 1day)
	Rb (< 1E-13 @ 1day)
Time transfer	Uncertainty: +/- 5ns
	Frequency: 2 E-14 @ 1day
Network time service	NTP / NST: Accuracy 8ns, 1 million request/s
Precise GPS information	IGS
Size	302 x 328 x 43 mm (WxDxH)
Weight	2.1kg (2.7kg with Rb)
Power	Max 10W (47W with Rb)
GGTTS	NICT

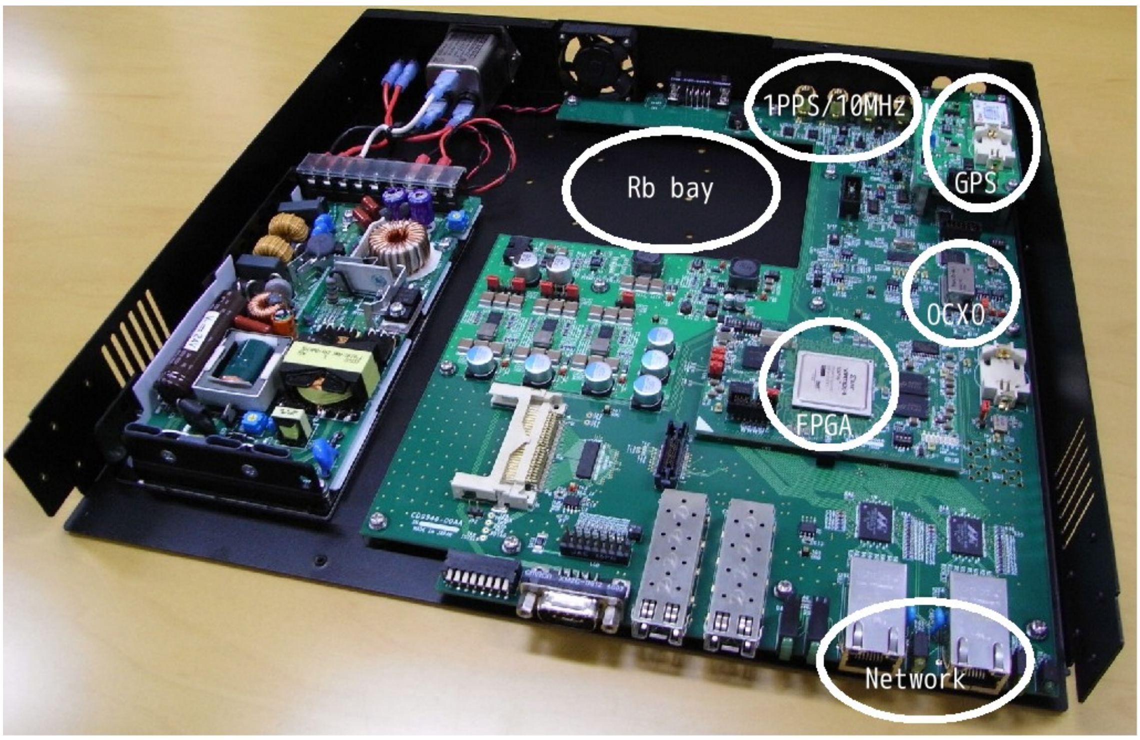

Fig. 2. Inside of the TFDN system.

III. PERFORMANCE EVALUATION

A. GPS COMMON-VIEW

Figure 3 shows the root Allan variance of the TFDN, when the UTC(NICT) signal is put in as external clock in GPS common-view mode (no IGS data is used). No IGS data is used. 2E-14 is achieved for one day average. The GGTTS data of NICT which created by using Septentrio PolaRx2 GPS receiver are compared. The antenna of TFDN is 16.8m apart from the antenna of PolaRx2.

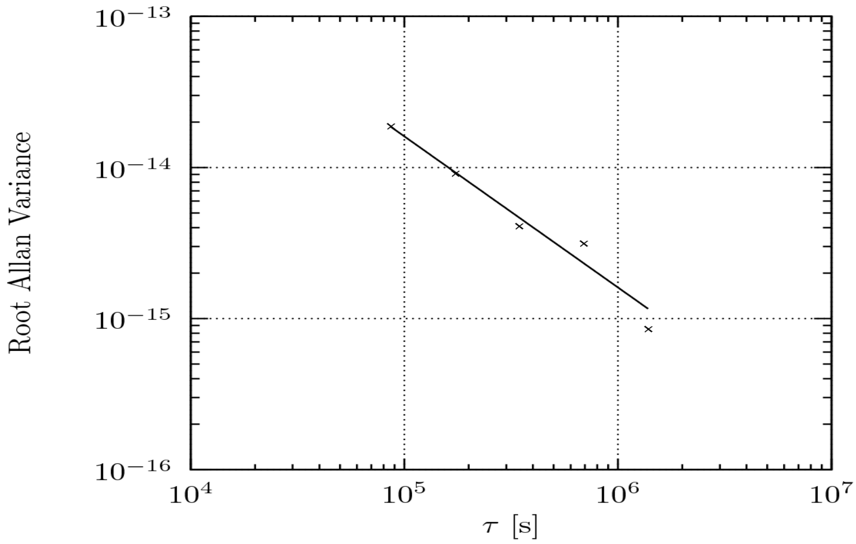

Fig. 3. Frequency estimation by using TFDN.

B. NETWORK TIME SYNCHRONIZATION

Figure 4 shows the accuracy of a slave personal computer via LAN. The standard deviation of the jitters is 76 nanosecond. The NST server and the client are connected each other via two ethernet switches and the network is lightly loaded. The ordinary timing distribution system, like 1PPS and IRIG, can be replaced with the ethernet.

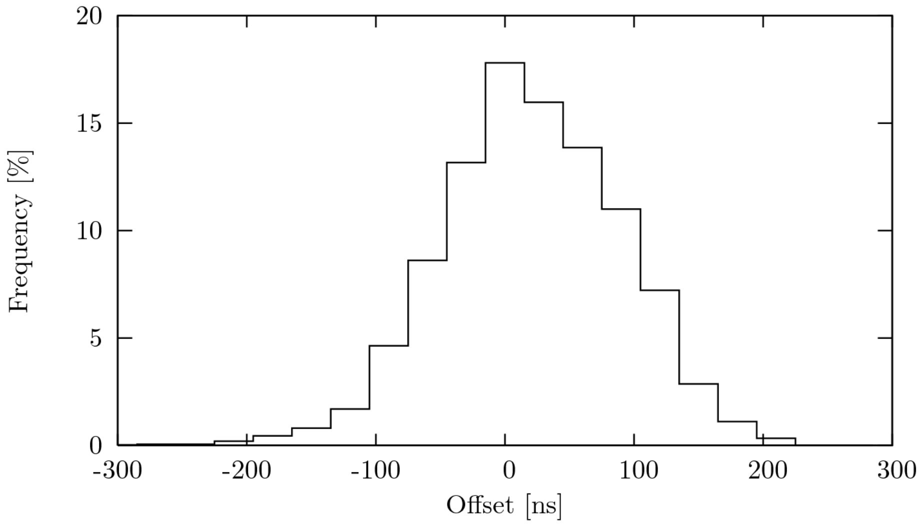

Fig. 4. Accuracy of a NST client.

IV. PUBLIC NETWORK TIME SERVER OPERATED BY NTA

Default IP address or server name of network time servers of network appliances should be set to the national time standards to keep the trusted time. Though, RFC4330 [11] states as below,

> *"If a firmware default server IP address is provided, it MUST be a server operated by the manufacturer or seller of the device or another server, but only with the operator's permission."*

it is difficult for private companies to continue operating the network time service for a long time (life time of their products) by their absorption and bankruptcies. National time authorities (NTA) should operate the public network time services which refer their own national standard time.

The public network time services operated by NTA are often over-crowded. People tends to use the NTA's servers. Although, NIST has more than twenty network time servers, they cannot reply sometimes because of over loaded. PC based software time server can handle only 5,000 requests a second. The hardware NTP server is suitable for stratum 1 NTP servers supplying national time and frequency standard. It can handle more than one million requests a second (two hundreds times greater than ordinary time servers). NICT has been operating a public NTP service using the hardware NTP servers in these two years, ntp.nict.jp, and more than a hundred million NTP packets per day request to this service. On the other hands, conventional software NTP servers can be overloaded for such a lot of requests.

If NTA is the leaf site of the Internet, NTP servers may be located near to the Internet exchange point (IXP) and the time is transfered by GPS common-view / all-in-view.

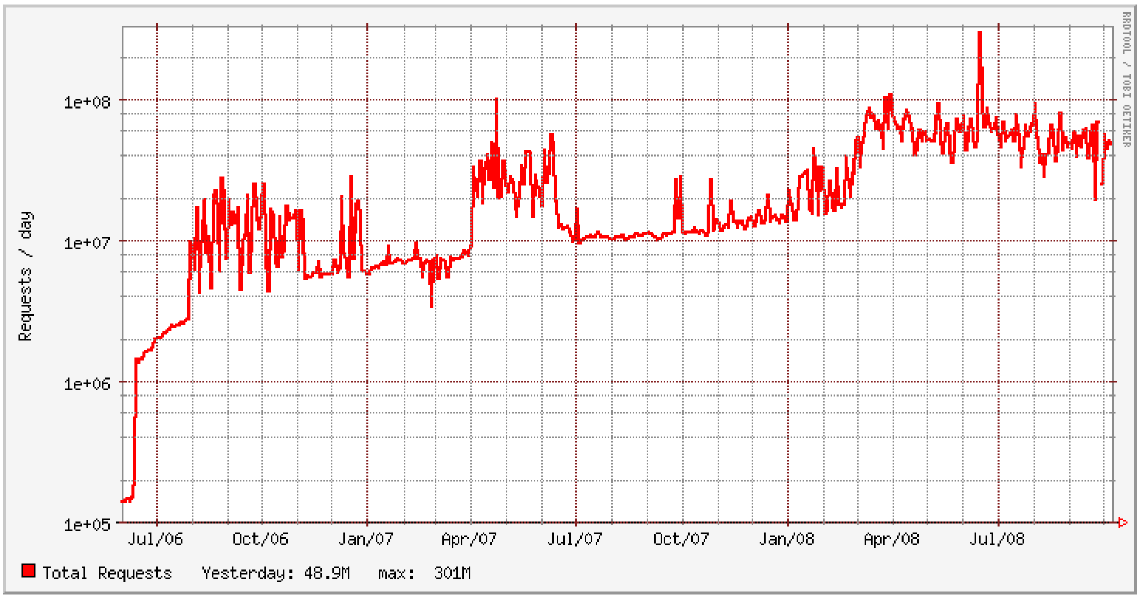

Fig. 5. Number of requests for the NICT public NTP service.

IV. CONCLUSION

We proposed a new national time and frequency standard dissemination system by using information and communications technology. The TFDN is synchronized to the national standard time by using GPS common-view / all-in-view and provides the national standard time into IP network. The TFDN is a compact and all-in-one system which compares time, calibrates a local oscillator and supplies time automatically. The TFDN can creates GGTTS data by using IGS precise data. The all functions, include a rubidium oscillator, are packed into a 1U size case. The assumed applications of the TFDN are remote frequency calibration, trusted time stamps, precision time synchronization for measurement, control and communications in the local area networks, network time server, and so on.

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