SIPRNET NETWORK TIME SERVICE

Richard E. Schmidt
Time Service Department
U.S. Naval Observatory
Washington, DC 20392

Abstract

SIPRNET, the Secret Internet Protocol Routing Network, is DoD's wide area network for encrypted hosts handling classified traffic. It is managed by the Defense Information Systems Agency. In 1997 the U.S. Naval Observatory established network time synchronization service on SIPRNET, with dedicated servers providing Network Time Protocol (NTP). These servers are synchronized to the USNO Master Clocks. An overview of time server design is presented, with details on expected accuracy and accessibility.

INTRODUCTION

At the 26th meeting of PTTI in December, 1993, USNO reported on the establishment of two Internet stratum 1 Network Time Protocol (NTP) servers. Synchronized to the USNO Master Clocks in Washington, DC, these servers were at that time handling 155,000 NTP packets per month[1]. Today USNO operates 14 stratum 1 Internet NTP servers, currently handling 180 million packet requests per month. These servers, at the locations listed below, are *Hewlett-Packard* 9000/747i industrial workstations with embedded VME synchronized generators. The sync-gens (*TrueTime* GPS-VME, VME-SG and *Datum-Bancomm* bc637vme) are disciplined by Master Clock IRIG-B timecode and GPS. The NTP servers provide millisecond synchronization over TCP/IP networks. Time transfer is performed by exchange of local timestamps using User Datagram Packets detailed in the Internet Standard RFC-1305[2].

USNO PUBLIC INTERNET NTP SERVERS 1997

LOCATION	IP ADDRESS	SYNC	CNAME
Time Service Dept., USNO, Washington, DC	192.5.41.40 192.5.41.41 192.5.41.209	IRIG	tick.usno.navy.mil tock.usno.navy.mil ntp2.usno.navy.mil
USNO AMC Falcon AFB, CO	204.34.198.40 204.34.198.41	IRIG	tick.usnogps.navy.mil tock.usnogps.navy.mil
Washington Univ., St. Louis, MO	128.252.19.1	GPS	ntp-wustl.usno.navy.mil
Digital Equipment Corp., Palo Alto, CA	204.123.2.72	GPS	ntp-dec.usno.navy.mil
MIT, Cambridge, MA	18.145.0.30	GPS	ntp-mit.usno.navy.mil
UCLA, Los Angeles, CA	164.67.62.194	GPS	ntp-ucla.usno.navy.mil
Univ. Houston, Houston, TX	129.7.1.66	GPS	ntp-uh.usno.navy.mil
Georgia Institute of Technology, Atlanta, GA	130.207.244.240	GPS	ntp-gatech.usno.navy.mil
Columbia University, New York, NY	128.59.39.48	GPS	ntp-cu.usno.navy.mil
Univ. Washington, Seattle, WA	140.142.16.34	GPS	ntp-uw.usno.navy.mil
Ohio State University, Columbus, OH	198.30.92.2	GPS	ntp-oar.usno.navy.mil

SIPRNET, the *Secret Internet Protocol Routing Network*, is a Department of Defense Internet for classified operations. The SIPRNET backbone is primarily T1 (1.54 Mb/s) with about 40 hub router sites in the U.S., a dozen sites in Europe, and about ten sites in Southeast Asia and the Pacific. SIPRNET is operated by the Defense Information Systems Agency (DISA).

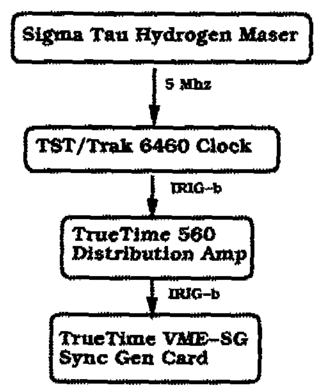
In response to a number of requests from SIPRNET customers, including the Global Command and Communications System (GCCS), USNO has recently joined with DISA in establishing NTP network time synchronization service on SIPRNET. DISA has extended SIPRNET hubs (128Kb fractional T1) to the USNO Master Clocks at the Alternate Master Clock Facility, Falcon, CO (November 97) and at the Time Service Department in Washington, DC (December 97). USNO has provided NTP servers which are steered to USNO Master Clocks.

USNO SIPRNET NTP SERVERS 1997

Location	IP Address	Sync	CNAME
AMC, Falcon	140.49.231.138	IRIG	ntp-amc.sipr.smil.mil
USNO Washington	140.49.183.70	IRIG	ntp-usno.sipr.smil.mil

SIPRNET NTP SERVER DESIGN

USNO MASTER CLOCK FEEDS

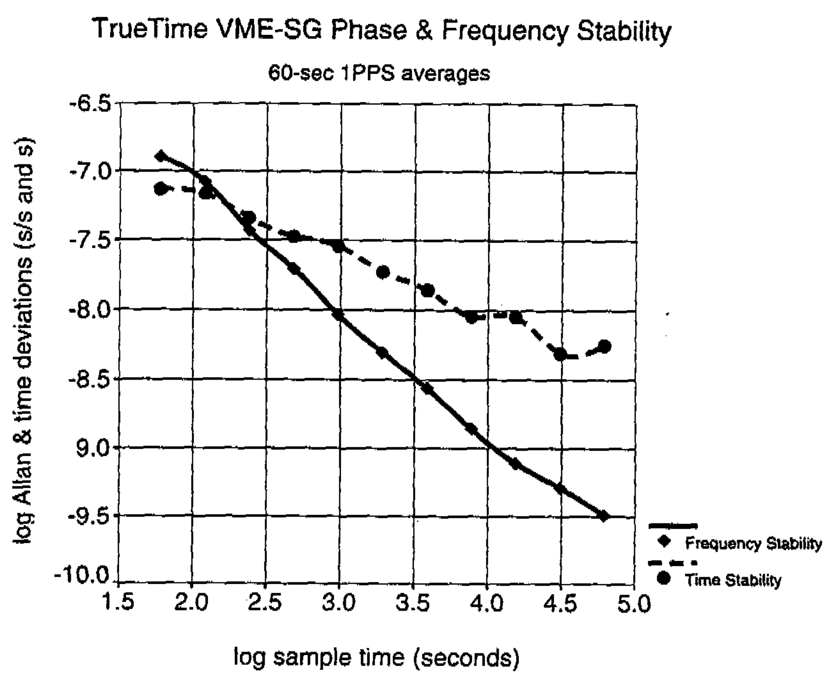


The USNO SIPRNET NTP servers are dedicated UNIX workstations with dual embedded TrueTime VME-SG sync-gen cards. The *Hewlett-Packard* 9000/747i is an industrial VMEbus workstation running HP-UX 10.20. NTP release 3-5.90 was provided by David Mills, University of Delaware (web address*http://www.eecis.udel.edu/~ntp/).* A C-language NTP refclock driver, developed by the Time Service Dept., USNO, provides a memory-mapped interface to VMEbus registers on the TrueTime VME-SG. From these, BCD timecode can be read with essentially zero latency. Two sync-gen cards are installed in the NTP server. Each card is synchronized to one of USNO Master Clocks #1 or #2. Each Master Clock is a *Sigma Tau* Hydrogen Maser providing 5Mhz to *TST/Trak* 6460 Clocks, which generate IRIG-B timecode that is distributed by *TrueTime* 560 distribution amps with parallel output to multiple NTP server inputs.

The NTP servers receive and transmit only unclassified data, but are located in a secure facilities. The Washington connection to SIPRNET uses a *Larscom* Access-t DSU/CSU and a *Cisco* AGS+ router. Between these units an *Allied Signal* KIV-7HS (KG-84) provides keyed encryption.

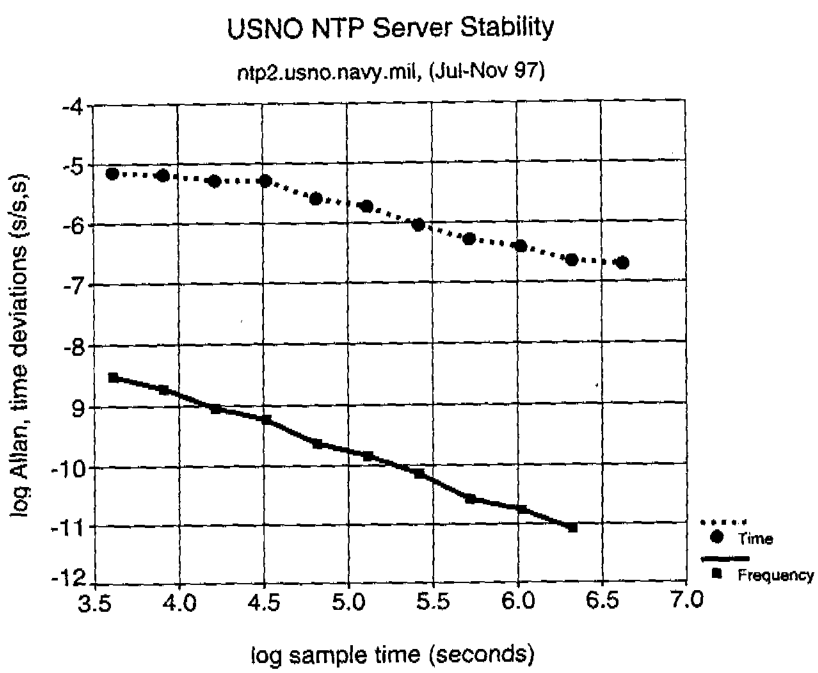
SERVER TIMING CHARACTERISTICS

The *TrueTime* VME-SG phase locks to IRIG-B in order to discipline its VCTCXO. Phase shifts are internally applied in 100 ns steps[3]. Phase calibration was performed using a time-interval counter with 1PPS reference from a USNO Master Clock. A mean phase bias correction was then be programmed on the VME-SG. This oscillator is internally stable to about 200 ns. Allan and time deviation plots of the VME-SG frequency and phase stability are shown below. These are based on 60-second averages of 1pps phase comparisions with a USNO Master Clock.



NTP software is used to discipline the phase and frequency of the UNIX system clock, which alone is a poor oscillator, showing drifts as much as parts in 10^{-4}. The NTP driver software keeps the system clock frequency error to generally below 2 parts in 10^{-7}. Time is buffered through system calls to the UNIX system clock to provide readily accessible timestamps with a flywheel frequency in the event of loss of the sync-gens. In addition, the server peers with other NTP stratum 1 servers on the network and will maintain network synchronization with ~20 millisecond accuracy in the event of hardware clock failure.

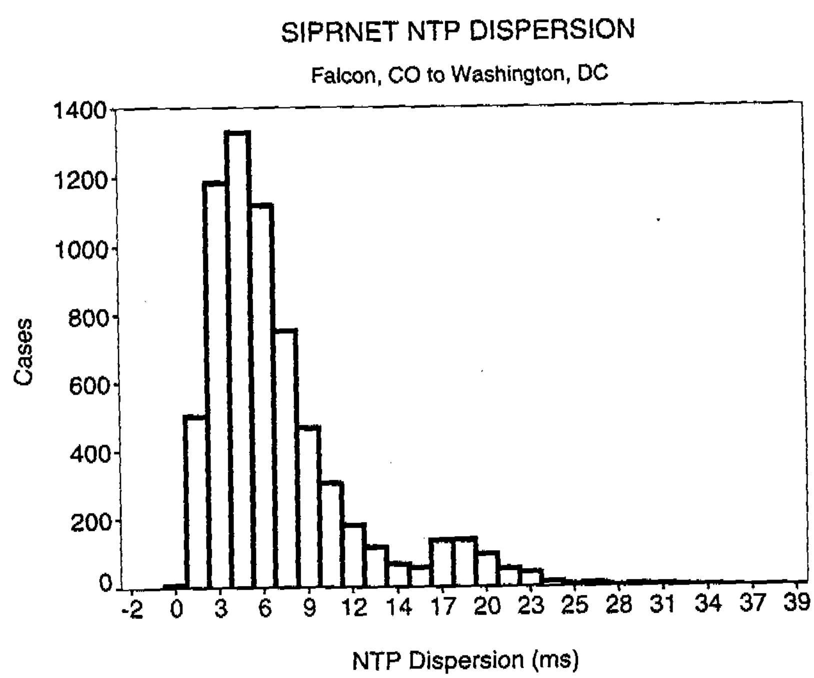
Internal frequency and time stability are shown in the Allan deviation and time deviation data shown below, which is based on five months of 16-second NTP phase comparisons of a server's system clock vs. the *TrueTime* VME-SG phase.



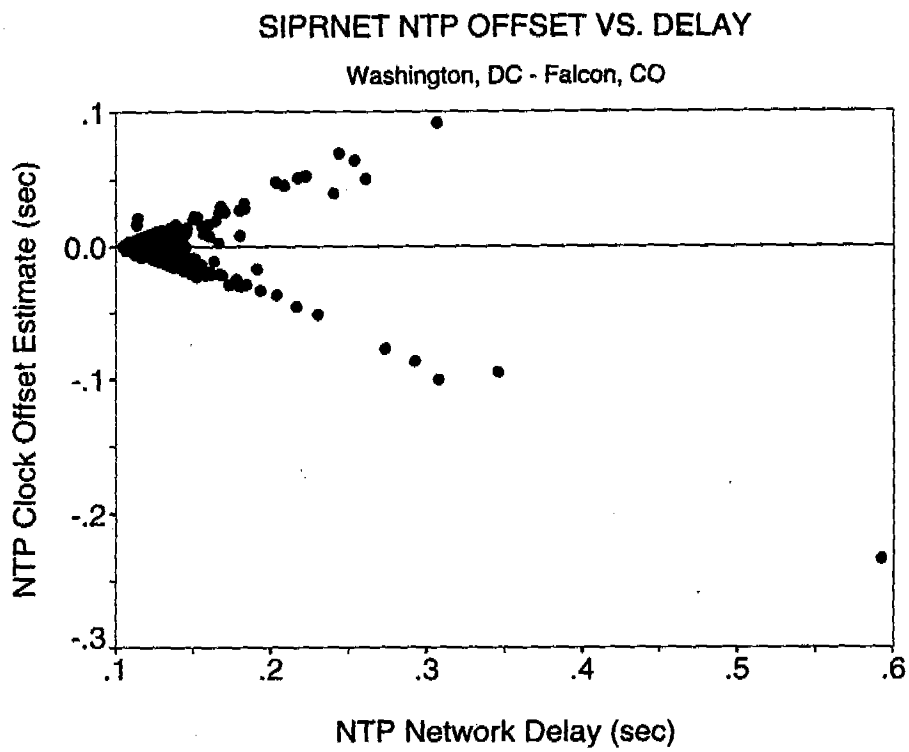
NETWORK TIMING ACCURACY

The accuracy of time transfer over a packet-switched Internet, will be considerably below the internal timekeeping ability of the server. NTP requires round-trip packet exchange between client and server. The inherent asymmetry of packet-switched network paths contributes most of the error in steering NTP clients to servers[3]. NTP observes total round-trip network delay and computes a dispersion which provides an error bound for estimating clock offsets. With atomic or GPS NTP servers located at sites remote from USNO Washington, we can observe the interplay between the NTP values of network delay, dispersion, and clock offset, when the actual clock offset is zero. The standard deviation of Internet NTP clock offset estimations was 20 ms. In previous tests on a circuit-switched ISDN network (with no round-trip asymmetries), the corresponding standard deviation was below 1 ms[4].

The expected accuracy of NTP over 3,000 km network paths is shown in the following histogram of NTP dispersion between the USNO Washington and Falcon, AFB, Colorado SIPRNET servers.



A look at NTP clock offset estimates vs. network delay produces an NTP "wedge plot," as seen below. Points along the edges of the wedge come from busy network routing queues, when round-trip network delay asymmetry dominates[5]. Unfortunately, NTP attributes half of the delay asymmetry to clock offset. By dispersing NTP servers widely across the Internet, we strive to minimize this effect by shortening the total synchronization distance to any client.



REMOTE NTP SERVERS

DISA and USNO plan to extend SIPRNET NTP service to Europe and the Pacific in 1998. P/Y code GPS receivers will provide accurate and reliable timing. USNO's continual monitoring of GPS timing will assure that the performance of these GPS stratum 1 NTP servers will equal that of servers colocated at the Master Clock sites. Typical timing accuracies for NTP time service are summarized below.

Component	Accuracy (peak to peak)
TrueTime VME-SG	0.4 μsec
NTP server UNIX system clock	50 μsec
3000 km circuit-switched network	2 ms
3000 km packet-switched network	20 ms

REFERENCES

[1] R. E. Schmidt, *"Network Time Synchronization Servers at the U.S. Naval Observatory",* Proceedings of the 26th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, pp. 175-183, 1994.

[2] D. L. Mills, *Network Time Protocol Version 3 specification, implementation, and analysis"*, DARPA Network Working Group Report RFC-1305, University of Delaware, March 1992, 113 pp.

[3] *TrueTime Model 560-5608 VME-SG [reference manual 560-5600.ONE],* p 1-5, 1993.

[4] R. E. Schmidt, *"Introduction to Network Time Synchronization with NTP",* presented at the International HP Workstation Users Group Conference, 1995.

[5] G. D. Troxel, *Time surveying: Clock Synchronization over Packet Networks",* Ph.D. thesis, Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, 1994.