THE SYNCHRONIZATION OF THE SPANISH R&D NETWORK*

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Abstract

RedIRIS is the Spanish academic network for research and development funded by the National Plan for R&D (Plan Nacional de I&D) and managed by the Centro de Comunicaciones CSIC RedIRIS, which depends on the Scientific Research Council (Consejo Superior de Investigaciones Científicas). Since September 1996 Real Instituto y Observatorio de la Armada (ROA) has been in charge of the synchronization of the RedIRIS network, using the NTP protocol. We have also been responsible of the installation of two Stratum 1 time servers, one at the network operational center in Madrid and the second at ROA in San Fernando. Some modifications on the software and the kernel have been made. In this paper we present an overview of the results of these modifications on the performance of the service and studies on its accuracy and accessibility.

INTRODUCTION

The Network Time Protocol is fully described and explained in [1] [2] [3] [4]. This protocol is used to synchronize the local area network of Real Instituto y Observatorio de la Armada (ROA). ROA is connected to the Spanish R&D network (RedIRIS) through the Red Informatica de Andalucía (RICA) using a point-to-point connection of 64 Kbs. ResIRIS provides the users of the network the necessary support for infrastructure and services.

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RedIRIS

On 1988, the National Plan for R&D started a horizontal special program IRIS for the Interconnection of Computer Resources (Interconexión de los Recursos Informáticos) of universities and research centers, and until the end of 1993 this program was managed by Fundesco. From 1991, when the first promotion stage was finished, IRIS became what RedIRIS actually is: the national academic and research network, still funded by National Plan for R&D and nowadays managed by the Scientific Research Council (Consejo Superior de Investigaciones Científicas). RedIRIS is the main tool of the National Program of Applications and Telematic Services and will assume the responsibility of providing the required network services and actual and future support to the infrastructure, according to the main objectives of the program. About 300 institutions are nowadays connected to RedIRIS, mainly universities and R&D Centers. The services offered by RedIRIS to the Spanish academic and research community require the support of a basic infrastructure of transport technologically adapted to the requirements of the connected centers. These services are provided in collaboration with other academic networks and other international forums.

The operational Center of RedIRIS is located in Madrid, the capital of Spain. Its backbone gives connectivity to each of the 17 main Regions Spain is administratively divided in. The regional administrations are in charge of the deployment of the network inside their respective territory. In order to harmonize the configuration and to get the better results from the Network, RedIRIS organized working groups whose tasks are to study some of the services of the net. One of these WGs is IRIS-NTP, whose responsibility is to study the performances of the implementation of the protocol in the network.

ROA

ROA is the responsible to maintain and distribute the Official Time Scale, UTC(ROA). This Time Scale is produced by an ensemble of commercial cesium clocks and disseminated by the HF Time Signal Broadcast Service, the Telephone Distribution System (using the European standard code), GPS Time Scale comparisons, and NTP. Inside Spain, ROA is the pioneer center in having a Stratum 1 synchronizing its LAN.

ROA has three Stratum 1 NTP servers operating inside its LAN. All of them are PCs using Linux as the operating system and running NTP protocol.

RedIRIS' NTP SERVICE

The synchronization NTP service of RedIRIS is supported by three Stratum 1: hora.rediris.es, titac.fi.upm.es and hora.roa.es. All of them are PCs that receive precise time from a GPS receiver. The first one is located at the RedIRIS operational center, but is managed by ROA. The second one is placed at Universidad Politécnica de Madrid and managed by its Computational Center. The later is placed at ROA. RedIRIS network topology is like a star whose center is Madrid and whose 17 sides correspond to each ofthe Spanish Regions (see Figure 1). ROA is placed in one end of the Andalusian arm, so the shorter synchronization distance of a computer of the network connected on the other arms of the star is the one that connects it with hora.rediris.es.

ROA SERVER

As mentioned above, ROA has three Stratum-1 servers constituted by PCs running Linux and NTP protocol. Hora.roa.es was the first computer to be adapted to be an NTP server. A GN-72 FURUNO GPS was used as time tag and precise time supplier. The original NTP distribution was modified as a result of a study to accommodate the synchronization needs with the signals we have at hand.

SOFTWARE

To use the 1 Pulse Per Second (1PPS) coming from GPS, a PPS_ROA device driver was written. In this, one serial port was used to get the NMEA code from GPS, and the functions of the UART of the second serial port were modified to eliminate any other duties than those relating to the DCD status line. One can select the edge of the 1PPS incoming signal to originate the interruption that transfers the variables to the 'hardpps' subroutine which calculates the time and frequency offset of the clock. An IOCTL was included to adapt the information coming from the PPS_ROA driver, at daemon level, because the original 'ciogetev' subroutine was written for SunOS, and there was a need to translate it for Linux.

As the driver needs to be continuously debugged while in the development state, it was rewritten to be included as a module. This allowed us to make changes without modifying and compiling the kernel and it gave us more flexibility in programming. As a predominant result, the frequency correction has been divided into two tasks:

- a coarse frequency correction that is made by the kernel, and
- a fine correction that is made by the Time daemon.

The time that the clock spends in synchronizing, when the daemon is started, is reduced following this procedure:

a) when PPS_ROA module is installed, it gives the kernel the frequency offset of the clock derived from continuous measurements of phase offsets; and

b) when the daemon is started, the coarse frequency correction is already made and all that it must do is make a fine correction of few parts per million.

Following this procedure, the offset of the computer scale is within few microseconds two hours after the daemon's start. Figure 2 shows the offsets of a computer started with an initial offset of 20 milliseconds, following the explained procedure and the original NTP procedure.

HARDWARE

The explained setup uses one of the external serial ports to get the time code and the other serial port for the time synchronization signal. When we need to use these external ports for controlling other laboratory devices, a PC card was designed to use a Motorola ONCORE VP

GPS receiver. The NMEA output from the GPS is sent to the PC bus using a UART. Its 1PPS signal is split to get an external monitoring output of the injected signal in the proper ISA BUS IRQ line. See Figure 3 for more details. An external 1PPS, coming from other precise time source can be applied to the card, being then the IRQ line controller.

RESULTS

We have made some measurements using the PC card described above. Installed in a PC with Pentium, a 1PPS from a cesium clock was supplied as an external reference. A subroutine allows us to record the cycle count of the PCC immediately after a 1PPS arrives the computer and the corresponding IRQ is attended. Figure 4 plots the differences of the readings with the mean, multiplied by the period of the frequency of the crystal. This demonstrates that, using the reading of PCC as the internal time reference, an uncertainty of 1.3 microseconds is obtained with a single measurement and a time stability of 47.6 ns is expected for 64 s intervals (see Figure 5).

Another experiment was carried out measuring the time differences between the time provided to the computer, and a signal produced by changing the status of the DTR line of the UART when the IRQ is attended. Figure 6 plots these differences. When the activity of the computer is low, a usual mean offset of 9 microseconds is obtained, that is mainly due to latency of the call to get the time of the system [5] and other contributions related to hardware delays. This offset increases when the activity is higher, as shown in Figure 6, where the computer has a higher network information transference. Figures 7 and 8 show Allan time deviations of these measurements.

Having access to two Primary NTP servers with precise time from GPS, assuming that the time offset between the GPS is less than one microsecond, we can measure the asymmetry of the link. Using the rawstats files one can determine the delay of the outgoing and returning path. Figure 9 shows the asymmetry of the round trip and the filtered offsets measured in one of the NTP servers. These asymmetries are assumed as increments of the offset to the server and consequently as phase jumps of the internal clock by a client computer. This figure also shows that the daemon filter removes short-term variations of the round trip.

Information about the daily performance of the service can be found at: http:/hora.rediris.es/ntp/stats From this page the offsets of the Stratum 1 and 2 servers and some of 3's can be obtained, giving clear information as to its performance.

An NTP service has also been established, with the collaboration of the Instituto de Ciencias de Mar de Barcelona, aboard the Spanish Navy's Oceanographic Ship *Hesperides*. This service is been evaluated while serving in the Antarctica Continent.

ACKNOWLEDGMENT

We must be grateful to Mr. Francisco Mier from GRAFINTA SA for allowing us to use on loan a SATREL GPS clock to make the software modifications for the server installed aboard BIO *Hesperides*.

[1] D. L. Mills, *Internet time synchronization: the Network Time Protocol*, **IEEE Trans. Communications COM-39**, 10 (October 1991), 1482-1493.

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

[3] D. L. Mills, *Unix kernel modifications for precision time synchronization*, **Electrical Engineering Department Report 94-10-1**, University of Delaware, October 1994, 24 pp.

[4] D. L. Mills, *Improved algorithms for synchronizing computer network clocks*, **IEEE/ACM Trans. Networks** (June 1995), 245-254.

[5] D. L. Mills, *Precision synchronization of computer network clocks*, **ACM Computer Communication Review 24**, 2 (April 1994), 28-43.

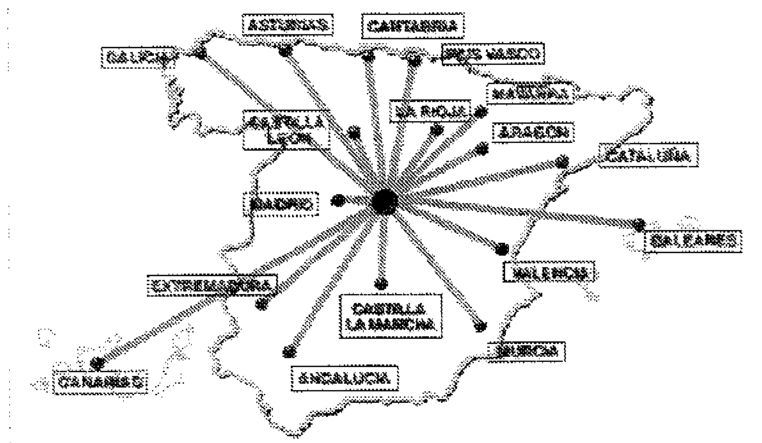

Figure 1: RedIRIS Network topology

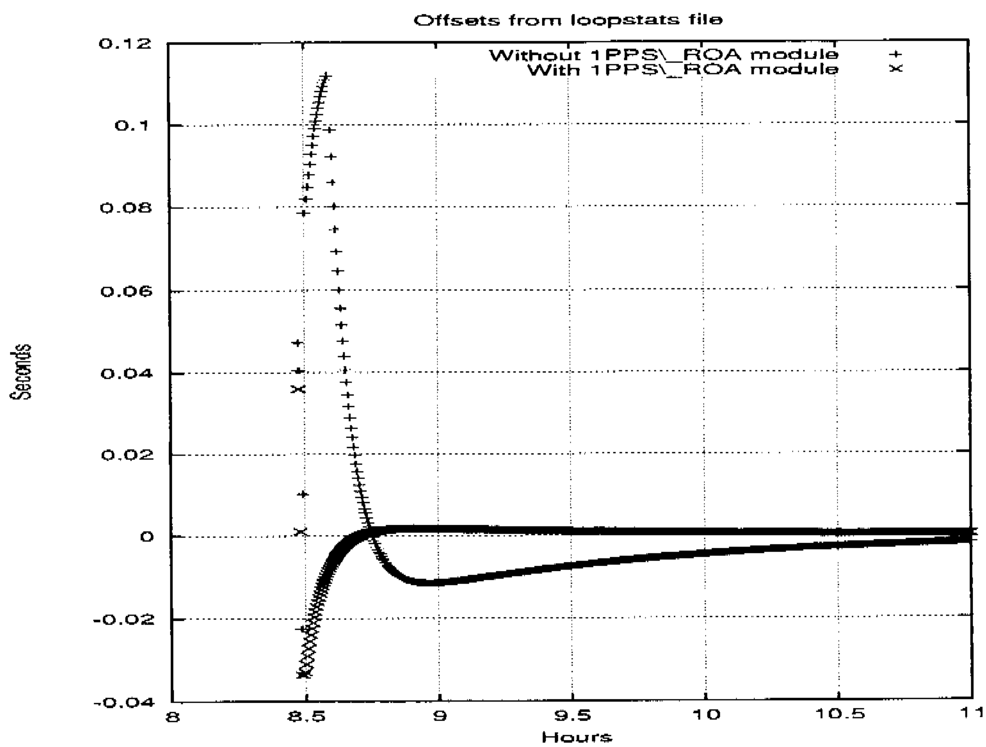

Figure 2: Initial transient response

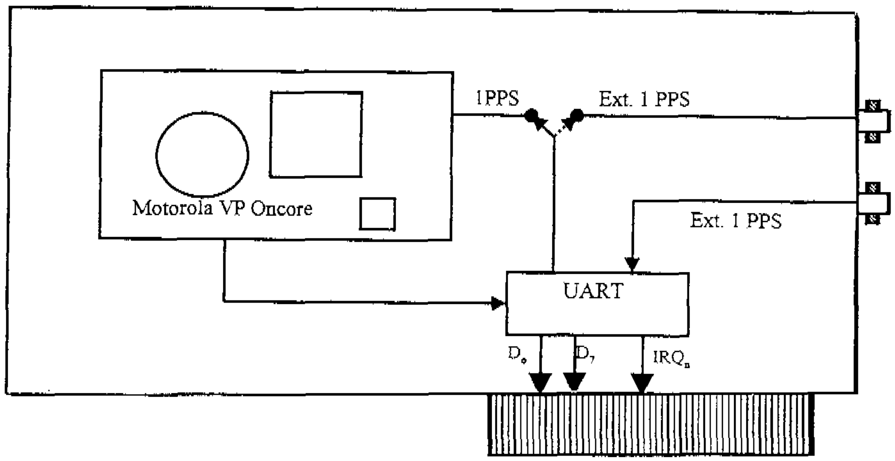

Figure 3: Diagram of the PC card prototype

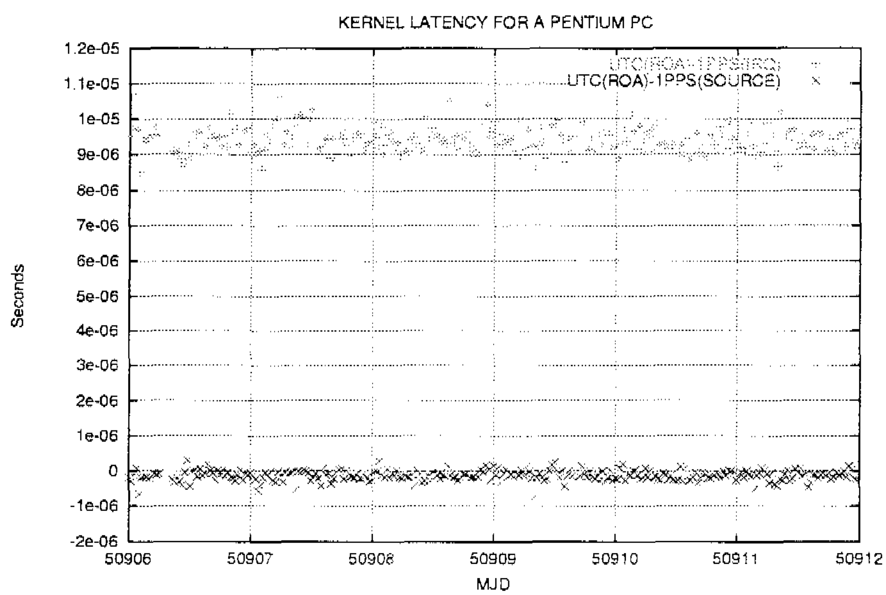

Figure 4: Time offset between 1PPS(input) and 1PPS(IRQ)

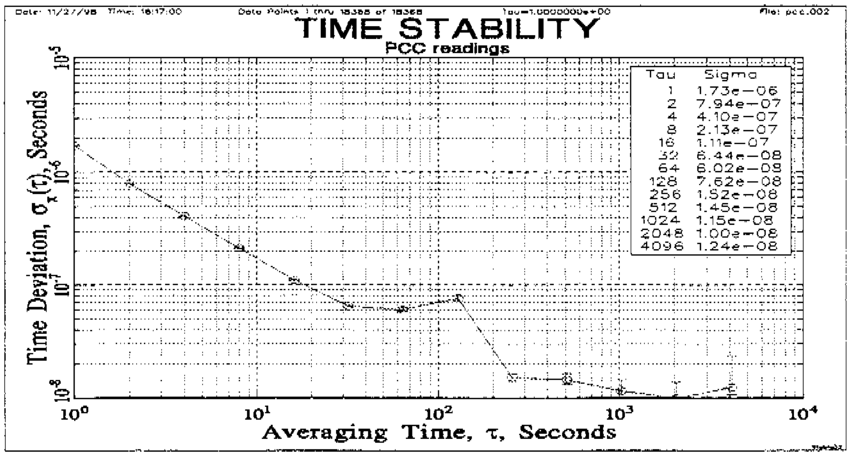

Figure 5: TDEV of PCC time stamps

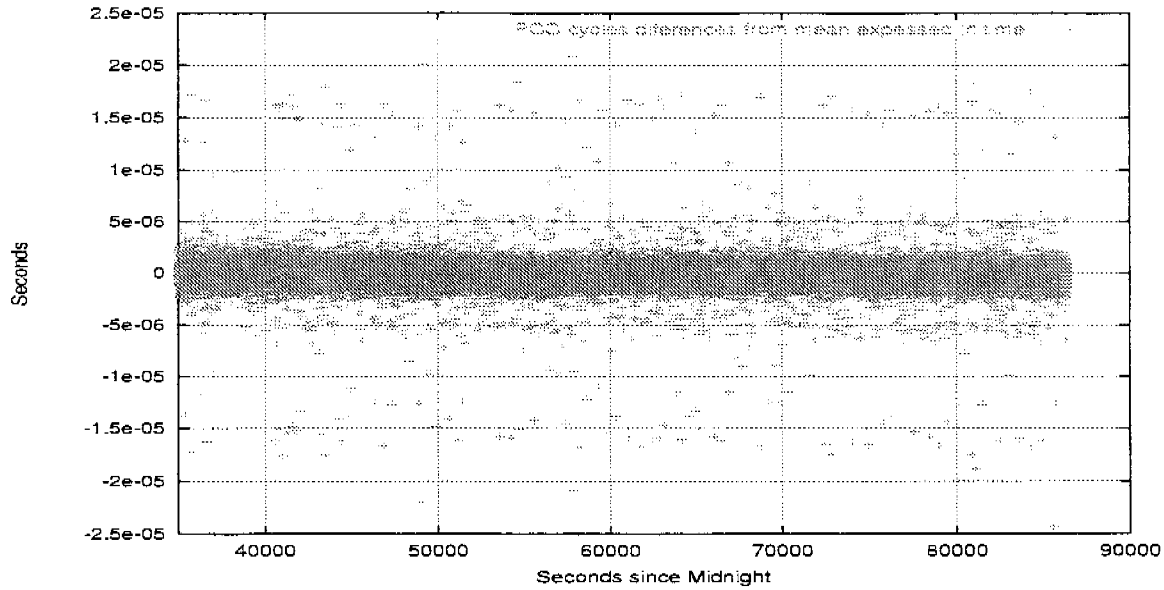

Figure 6: PCC stamps readings changed to time

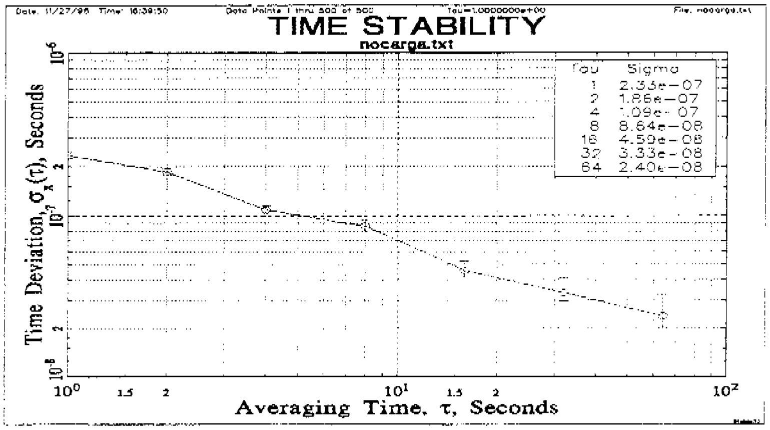

Figure 7: TDEV of time offsets with low activity

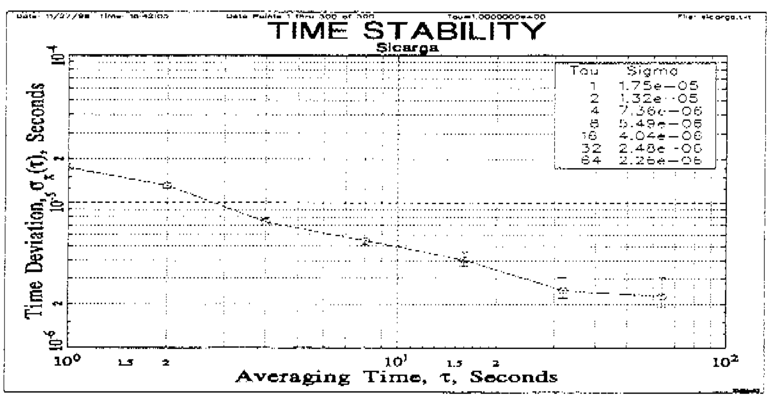

Figure 8: TDEV of time offsets with high activity

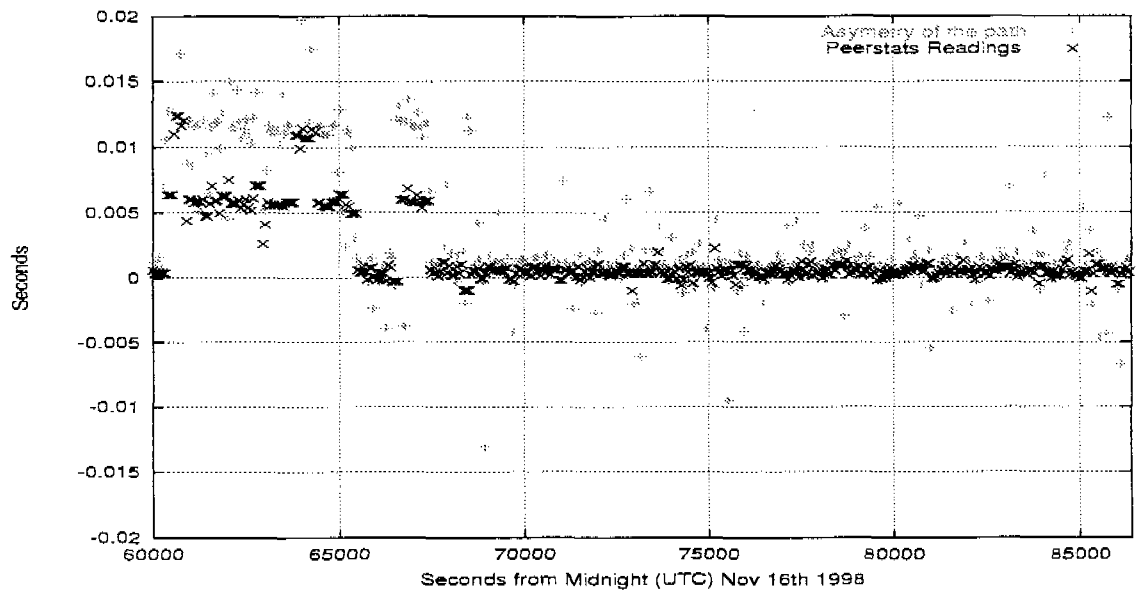

Figure 9: Asymmetry on the link and measured offset of the peer