Setting up a NTP Server at the Royal Observatory of Belgium

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ABSTRACT

This poster describes the setup of a NTP server for time synchronization via the internet at the Royal Observatory of Belgium. The time server is realized by a "heart-beat" system of two PC servers connected to a NTS-3000 time server synchronized on 3 different sources: (1) UTC(ORB), our national time scale; (2) UTC broadcast by GPS satellite system; and (3) DCF-77 System.

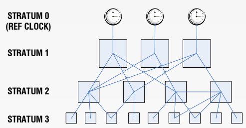

Figure 1 - Hierarchical strata model of servers used in NTP

INTRODUCTION

As a governmental institution, one of the missions of the Royal Observatory of Belgium, and in particular of its time lab, is to integrate Belgium in international space-time reference systems, and hence, to be able to provide precise time to Belgian official institutions, Belgian industry and private users. Even though internet time keeping is well established in the industrial countries all over the world, not so many time servers have a direct link to UTC. By setting up a facility for time keeping via internet, a direct connection to our time scale UTC(ORB), and by extend, to UTC is established.

NTP is a good choice for time synchronization in a variety of circumstances, specifically for Internet environments. Flexibility of the client/server relationship and security methods allow NTP to work well in almost any environment. NTP not only corrects the current time but, it can also keep track of consistent time variations and automatically adjust for time drift on the client. This allows for less network traffic and keeps client clocks more stable, even if the network is unavailable. In addition, the NTP daemon can automatically adjust the time by periodic increments. NTP can also operate through firewalls and has a number of security features.

NTP works on a hierarchical model in which a small number of servers give time to a large number of clients. The clients on each level, or stratum, are in turn, potential servers to an even larger number of clients of a higher numbered stratum. Stratum numbers increase from the primary (stratum 1) servers to the low numbered strata at the leaves of the tree. Clients can use time information from multiple servers to automatically determine the best source of time and prevent bad time sources from corrupting their own time. Figure 1 illustrates the hierarchical strata model of servers used in NTP.

Under good conditions on a LAN (Local Area Network) without too many routers or other sources of network delay, synchronization to within a few milliseconds is normal. Anything that adds latency, such as hubs, switches, routers, or network traffic, will reduce this accuracy. The synchronization accuracy on a WAN (Wide Area Network) is typically within the range of 10-100 ms. For the Internet, synchronization accuracy is unpredictable, so special care is needed when configuring a client to use public NTP servers.

IMPLEMENTATION OF THE TIME SERVER

The time lab of the Royal Observatory of Belgium is presently equipped with 5 clocks: 3 HP5071A Cesium clock and 2 H-Maser clocks (1 active CH1-75 and one passive CH1-76). The UTC realization UTC(ORB) is obtained from the 5 Mhz frequency provided by the active H-Maser clock (CH1-75) of which the cavity autotuning is realized using the 5 Mhz frequency of the passive H-Maser (CH1-76).

The time lab has been installed in a new temperature stabilized room in April 2002. Figure 2 gives a diagram of the time lab emphasizing the implementation of the time server.

After some investigations, we have chosen to buy a modified version of the NTS-3000 server from the company Elproma (www.ntp-servers.com) for our primary server (see Figure 3). The standard NTS-3000 network time server synchronizes its clock via the GPS satellite system and has also a fully redundant second source of time via DCF-77. We have asked Elproma to add a 1 PPS input to our NTS-3000 server. This 1 PPS input is used for connecting UTC(ORB). The advantage of adding a 1 PPS input to the time server, beside the better precision and the link to a national time scale, is that, contrarily of our reference clock, both GPS and DCF-77 are out of control by the users, and may be subject to changes without notice to the users.
We have chosen to not allow a direct synchronization on the NTS-3000 from our LAN or from the Internet. We have rather set up a "heart-beat" system with two servers (Proliant family from Compaq) running under Linux OS. The "heart-beat" system provides a full redundancy both from the software and the hardware point of view. If anything failed on one server, the second one takes the relay transparently. For the clients, this heart-beat system is seen as a single system with one address IP, available both from our LAN and from the Internet (see Figure 4). Strictly speaking, the time server is a stratum 2 time server available for time synchronization over the internet, it synchronizes itself on our stratum 1 time server (NTS-3000), which in turn has 3 UTC sources: UTC(ORB), GPS and DCF-77.

The NTP daemon computes about every 60 seconds a mean and a standard deviation for each of the different sources available (UTC(ORB), GPS, DCF-77, etc …). The server oscillator is then steered to a value based on an internal algorithm in order to minimize the time offset between UTC and the server clock. The NTS-3000 server clock is then used as the source for the synchronization of the heart-beat system.

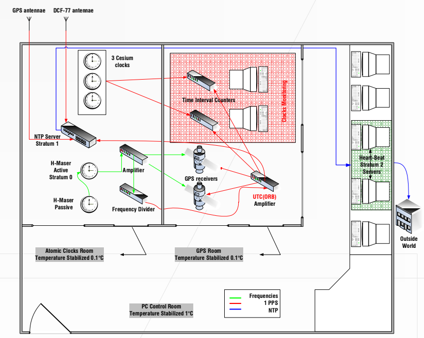

Figure 2 - Diagram of the time lab, emphasizing the implementation of the time server

Figure 3 - ELPROMA NTS-3000 Time Server

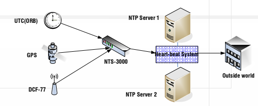

Figure 4 - NTP Servers at the Royal Observatory of Belgium

PERFORMANCE TESTS

In order to evaluate the performance of the NTS-3000 server, we compare its internal clock to the different UTC sources available (UTC(ORB), GPS and DCF-77).

Figure 5 shows the time offset and jitter (due to interrupt latency, processing delays, and similar effects) between the NTS-3000 server and the 1 PPS UTC source: UTC(ORB), over a period of 23 days. It can be seen from Figure 5 that the NTP daemon is able to synchronize the clock in the NT-3000 server with a mean of 0.6 microsecond (μs) and with a standard deviation of 5.3 μs. We see also that there is a clear correlation between peaks in the time offset and jitter.
Figure 6 shows the time offset and jitter between the NTS-3000 server and the GPS UTC source over the same period. Due to the fact that our UTC realization is kept very close to UTC and by extend to GPS time (maximum difference of 0.1 μs), the results are very similar (mean of 0.8 μs and standard deviation of 5.2 μs).
Figure 7 shows the time offset and jitter between the NTS-3000 server and the DCF-77 UTC source over a few hours. As we can see, the DCF-77 signal is much less precise than the two other sources. But, at the level of precision generally needed for time synchronization (millisecond), the DCF-77 can act as a valuable backup in case of failure of the two main UTC sources.

TIME SYNCHRONISATION BY LAN

For testing purposes, we have set up a PC which synchronizes its clock by NTP protocol to our stratum 2 NTP server system.
Figure 8 shows the delay, time offset and jitter between this client and the NTP server over a period of 10 days. It can be seen that the NTP daemon is able to synchronize the clock in the client PC with a mean of 0.038 milliseconds (ms) and with a standard deviation of 2.12 ms. Like for the nts-3000 performance tests, there is a clear correlation between peaks in the time offset and jitter. The delay remains very short with a mean of 0.29 ms and a standard deviation of 0.21 ms. Only two peaks of a few ms have appeared during the 10 days period.

TIME SYNCHRONIZATION BY INTERNET

In order to emphasize the effect of the distance between the client and the PC, we have synchronized the clock of our test PC with the stratum 2 time server of our Internet Provider (BELNET), located in Brussels at a few kilometers from the Observatory.
Figure 9 shows the delay, time offset and jitter between this client and the NTP server of BELNET over a period of 7 days. It can be seen that the NTP daemon is able to synchronize the clock in the client PC with a mean of 0.69 ms and with a standard deviation of 6.66 ms. The delay is of course more important than over our LAN with a mean of 1.56 ms and a standard deviation of 0.89 ms. A lot of peaks of a few ms in the delay appear now during the 7 days period.

HIGH TRAFFIC LOAD

In order to see if our time server is able to handle many requests at the same time, we simulated high traffic load condition by stressing the CPU with benchmark programs as well as by flooding the time server with millions of ping request. After one hour of tests, no impact was seen on the offset or on the delay between a client and the NTP server. Of course, this could not be the same under real high traffic load coming from many NTP requests which could not be simulated.

CONCLUSION

We have described the implementation of a time server system at the Royal Observatory of Belgium for time synchronization via the Internet.
One advantage of this system is its direct traceability to UTC via our local realization UTC(ORB). Another advantage is the reliability; the time server is composed of 2 time servers linked together with an heart-beat system which is in turn synchronized to a NTS-3000 time server connected to 3 different UTC sources: the primary UTC source is UTC(ORB), the second UTC source is a GPS receiver and the third is a DCF-77 receiver. All these components are located in a temperature stabilized room.
Performance tests show that the NTS-3000 server is synchronized to UTC(ORB) or GPS within a precision of less than 6 μs, while a synchronization based on DCF-77 has a precision limited to a few ms. Time synchronization on our time server over the LAN from a client PC gives a precision of less than 3 ms with very small delay or jitter. Synchronization over the Internet increases the delay as well as the jitter, resulting in a precision of about 7 ms in the time synchronization on a baseline of a few kilometers.

Note: *The internet address of the time server at the Royal Observatory of Belgium is ntp.oma.be. The time server is not official as of November 2004 and a full service is not guaranteed until the server is declared officially operational.*

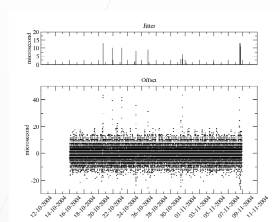

Figure 5 - Time offset and jitter between the NTS-3000 server and UTC(ORB)

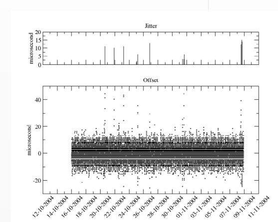

Figure 6 - Time offset and jitter between the NTS-3000 server and GPS

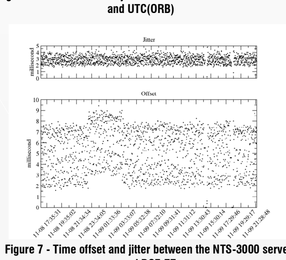

Figure 7 - Time offset and jitter between the NTS-3000 server and DCF-77

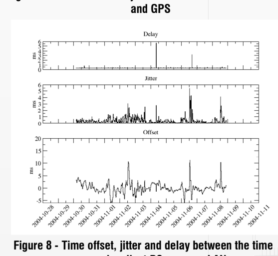

Figure 8 - Time offset, jitter and delay between the time server and a client PC over our LAN

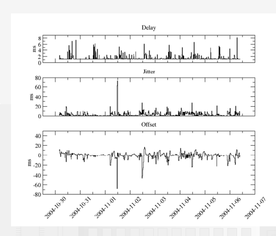

Figure 9 - Time offset, jitter and delay between the BELNET time server and a client PC over the Internet