The H2020 european project DEMETRA: Experimental time services based on European GNSS signals

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Experimental Time Services based on European GNSS Signals

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***Abstract*—DEMETRA, the "DEMonstrator of Egnss services based on Time Reference Architecture", is an European Project funded by the European Union in the Horizon 2020 program. The main aim of the project was to develop and test a prototype of Time Service Provider based the European Global Navigation Satellite System (GNSS) providing innovative or improved time services based on different technologies and embedded in a modular architecture. The main innovative features are time certification, non-repudiation, integrity, reliability, resilience. The demonstrator has been developed and tested during the years 2015-2016. Nine different time services were developed and tested also in real environment at users premises. The paper reports the results of the experimental campaigns and the main lesson learned also by the trials with potential users.**

Keywords— EGNSS; time dissemination; time services;

I. Introduction

The GNSSs are disseminating time at 10-20 ns accuracy and the signal is worldwide available. Nevertheless some users are not completely satisfied with the GNSS time service as the GNSS receivers can fail, the signal can be disrupted, anomalies are not identified, and particularly the clock at user level is not certified or validated by the time service provider. We started thinking to the possible features to be added to the European GNSS time dissemination service, and also to independent time dissemination subsystem to be used in parallel with the GNSS receiver to increase the resilience and reliability of the time information.

In parallel, a User Needs Analysis and a Business Plan was carried out during the project, by entering in contact with possible market segments trying to identify their needs. The market analysis of the European GNSS Agency (GSA) in 2015[1] reported for the first time the European timing and synchronisation service available from GNSS, mentioning the Demetra project, and the main strategic markets were deemed to be energy, telecom, and finance. The same time service is reported in the 2017 version of the GSA report [2] .

II. The DEMETRA set up

The concept of DEMETRA Architecture and the nine time services are described in [3] [4] [5] . The demonstrator has been assembled and integrated at INRIM premises in Turin by the end of February 2016. After the integration, it has been tested for six months with two experimentation test campaigns:

- Closed Loop Test (March-May 2016) where the User Terminal (UT) was placed in the same location of the Reference Time Generator [6] .

- End to End Test (July-October 2016) where the User Terminal was located in a real user environment, integrated into the user application to test the real advantages and feasibility of the new time services. In Fig. 1 the demonstrator fully assembled in the DEMETRA laboratory is shown.

Fig. 1: Demonstrator integrated in the DEMETRA Laboratory at INRIM, Italy.

The demonstrator was based on a Common Infrastructure and on 9 time services, five of which based on the European GNSS:

Service 1: Time broadcasting over TV/Radio links
Service 2: Certified Trusted Time Distribution using NTP
Service 3:Time and Frequency Distribution over Optical link
Service 4: Time and Frequency Distribution via GEO Satellite
Service 5: User GNSS Receiver Calibration
Service 6: Certified Time Steering
Service 7: Time Monitoring and Steering
Service 8: Time Integrity
Service 9: All-in-one Time Synchronization Solution.

III. The DEMETRA Experimental Results

In the following the experimental results of the timing services are reported. During the six months of the experimental campaign, all results was available and accessible for the subscribed users on the website www.demetratime.eu.

Service 1: Time broadcasting over TV/Radio links

The goal of the service is to allow the dissemination of the time to the users through the actual and the future Radio/TV transmission technique. In the Fig. 2 is shown the best performances achieved during the experimentation campaign, in with the behaviour of the signal is located in a range of 2ms.

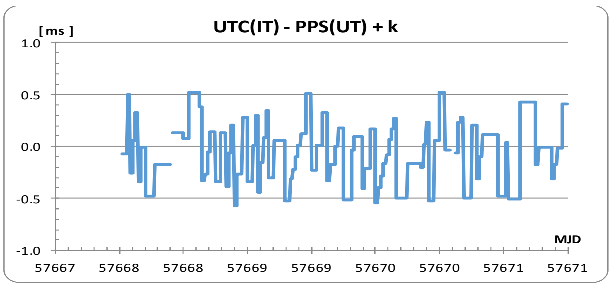


Fig. 2: Service 1 - Difference between the reference time and the time obtained as user level

Service 2: Certified Trusted Time Distribution with Audit and Verification using NTP

The service "Trusted Time Distribution" provides the dissemination of UTC time and frequency over the Internet using an enhanced NTP (Network Time Protocol), with the capacity to certify the time at user level. The service has been tested in different user location and at NPL (Fig. 3). The Service demonstrated an accuracy of 1 ms for LAN application and 10 ms on the internet for time dissemination.

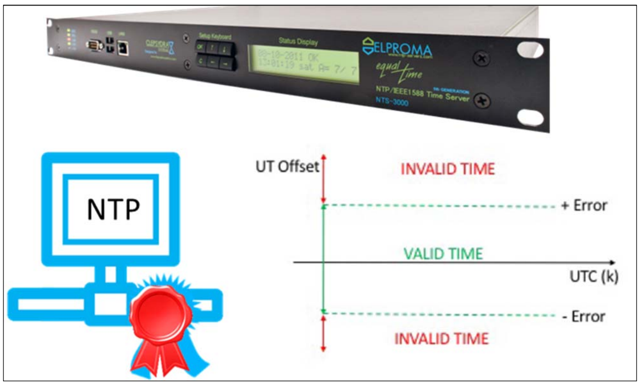


Fig. 3: Service 2 - The User terminal installed at National Physical Laboratory

A fully explanation of the service and some results obtained during the period of the experimantantion are reported in [7] [8]

Service 3: Time and Frequency Distribution over Optical link

The Time transfer over optical fiber offers resilience, security, continuous self-calibration, continuous traceability to UTC and the time accuracy at sub nanosecond level. The White Rabbit method was tested over a distance of more than 100 km. As shown in the Fig.4, the difference between the time at user location with respect to the master station in INRIM was below 0,5 ns.

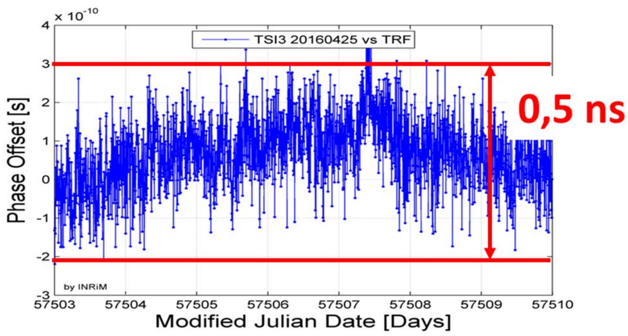


Fig. 4: Service 3 – Phase offset at the user location with respect to the master station in INRIM

Service 4: Time and Frequency Distribution via GEO Satellite

The service "Time and Frequency Distribution via GEO Satellite" could be used as a back-up with respect to traditional synchronization systems based on GNSS. The system allows to synchronize user stations by means of a geostationary satellite and a set of two-way ancillary stations. As shown in Fig. 5, the time received at user level (the Czech UFE laboratory), remained in a range narrower than 100 ns with respect to the reference time in INRIM.

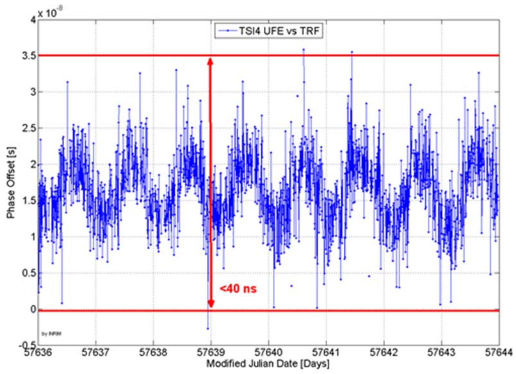


Fig. 5: Service 4 - Phase/time offset of the UT with respect to the reference time

Service 5: User GNSS Receiver Calibration

Time laboratories need to repeat the calibration of their equipment almost every year as mentioned in [9]

During the DEMETRA development, two kind of calibrations of the GNSS receivers were carried out:

- Absolute calibration realized by CNES [10] with an Uncertainty of 1 ns.
- Relative calibration realized by ORB for each GNSS stations involved in DEMETRA with an uncertainty of 3 ns.

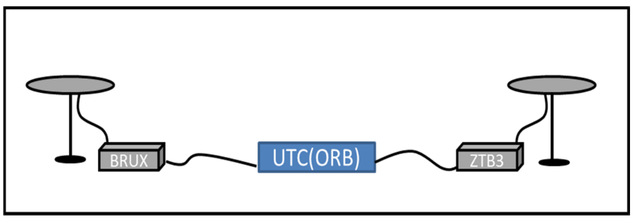


Fig. 6: Service 5- Relative calibration

Service 6: Certified Time Steering

The service "*Certified Time Steering*" is based on a remote steering and synchronization of the user oscillator and a monitoring of the time offset between the Time Reference and the User clock in real time. Other important aim of the service is to provide a certification of the phase and frequency offsets of the user oscillator with respect to the reference [11] .

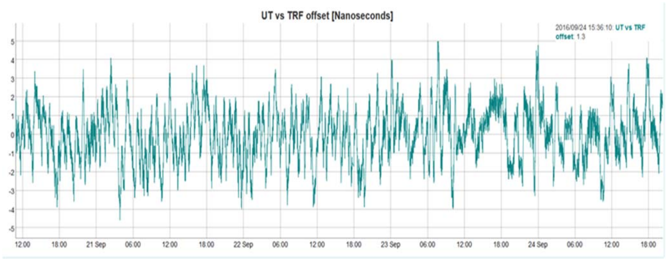


Fig. 7: Service 6 - Time Offset of the User with respect to the Reference Time

As shown in the plot the difference between the Time Offset of the User with respect to the Reference Time was maintained below 12 ns.

Service 7: Time Monitoring and Steering

"Time Monitoring and Steering" provides the monitoring of the user atomic clock or time scale in near real time at the nanosecond level based on the Precise Point Positioning technique alerting the users about any abnormal phase or frequency jump. The service additionally provides to the user daily information for the steering of its atomic clock or time scale to be aligned with UTC.

During the DEMETRA experimental phase, all the user atomic clocks were monitored with a latency of max 75 minutes, and any clock phase jump larger than 1.5 ns was detected successfully giving rise to an alarm.

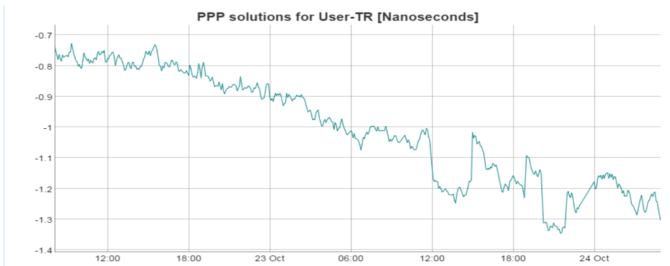
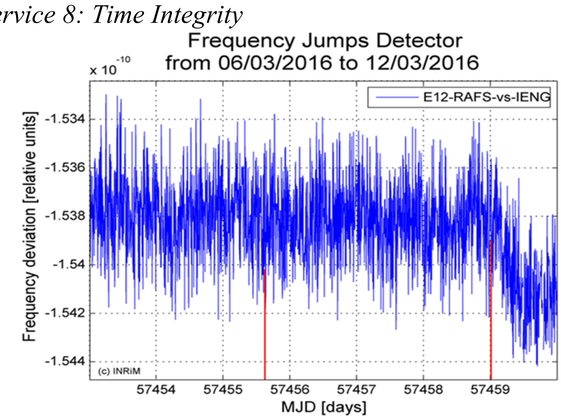


Fig. 8: Service 7 - Hourly PPP monitoring of the time offset of the User time scale

Service 8: Time Integrity



###SVN###	####MJD####	#########DATE#########	###AMPLITUDE###	###UNITS###	###DETECTED ANOMALY##
E12	57455.6285	2016-03-08 15:05:00	4.72e-13	[rel.units]	Frequency Jump
E12	57459.0035	2016-03-12 00:05:00	4.86e-13	[rel.units]	Frequency Jump
E19	57456.0000	2016-03-09 00:00:00	3.22e-09	[seconds]	Phase Jump

Fig. 9: Service 8 - Space clock jumps detection and list of not usable satellites

A Time Integrity service was developed with the aim to check possible anomalies in the Galileo transmission of GGTO and UTC and possible frequency jump on the Galileo clocks.
The service provides to the GNSS user timing information, complementary to broadcast Navigation Message data, allowing user positioning and timing accuracy improvements [11] Example of space clock detected jumps and the possible list of usable satellite is reported Fig. 9 ([9] , [12]).

Service 9: All-in-one Time Synchronization Solution

Service 9 is based on a Thales Alenia Space Italia patented system for high performance network synchronization known as SynchroNet. SynchroNet is able to slave a network of clocks connected to GNSS receivers ensuring high synchronization, resilience, certification, and integrity. Details about the service and experimental results are reported in [13]

Fig. 10: Service 9 - Installation of the equipment in the DEMETRA Lab

IV. Conclusions

The time service demonstrator, funded by the European project DEMETRA, has been designed, developed, qualified, and integrated at INRIM. All the test campaign has been carried out in March-October 2016 and monitored on the website www.demetratime.eu. The experimental time services and the exchange with different market segments has allowed the assessment of the potential interest for the time services based on the European GNSS.

Acknowledgements

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