The research project, DEMETRA (DEMonstrator of EGNSS services based on Time Reference Architecture) is funded by the European Union in the frame of the Horizon 2020 program and aims to develop and experiment new or improved time services based on the European Global Navigation Satellite System (GNSS) and introducing important new features such as certified time stamping, improved accuracy, or integrity, not yet provided by GNSS systems.

The Project involves institutes and industries from Belgium, Finland, France, Italy, Poland, Spain, UK.
**OVERVIEW of the PROJECT**

**DEMETER**a is developing a prototype to trial innovative time dissemination related services, based on Galileo, the European Global Navigation Satellite Systems (EGNSS).

**Market sectors of potential interest** are Energy, Finance, Media, Science, Surveying, Telecommunications, and Transport.

The demonstrator is designed to ensure a full operative architecture for the services delivery to final end users. It is composed of two infrastructures:

1) The Time Service Infrastructures (TSI) is in charge of the specific functions and corresponds to the nine services to be developed in the frame of DEMETRA. Each service is composed of a Time Signal Generator (TSG), a Service Data Handling (SDH) and a User Terminal(s) (UT).

2) The Core Infrastructure (CI) is the hosting structure which provides common signals and services to the TSI and the final users. CI is composed of three main facilities:

- Time Reference Facility (TRF), providing the reference time to be disseminated
- Service Provision Facility (SPF), a data base and a web page to interface the users
- Service Monitoring Facility (SMF), to measure, monitor, and validate the service
The nine different services proposed in DEMETRA are described in the following.
SERVICE01: Time Broadcasting over TV/Radio Links

DEVELOPER: INRIM (Italy)

"Disseminate your time via Radio and TV at millisecond level, everywhere in your country and in Europe."

This service allows the dissemination of time, by adopting the Radio and TV signals, conceiving analog and digital modulations.

Features and benefits:

- Already existing infrastructure usage
- Wide areas coverage (national and international level)
- Millisecond accuracy performance
- Ready for current/future market devices and solutions

A specifically designed code, carrying on time information, expressed in terms of Year, Month, Day, Hour, Minutes, seconds, plus additional information like the introduction of the winter/summer time, modulates Radio and TV analogic signals, as well as is carried on by the digital audio and video broadcasting systems (i.e. DAB and DVB, respectively). This is an “open service”, achievable everywhere. Interested users, can chose among two different user terminals, depending on their needs. A standard one, small, portable and cheap, for basic applications, or “special” user terminal for professional use, with included monitoring features allowing to be always informed about the proper function of the required service.
This service allows the dissemination of UTC time over Internet using NTP (Network Time Protocol). It enables remote assessment of the client clock synchronization by providing audits with advance reporting. It distributes authenticated UTC to client in a way that time of the client can be verified, also retrospectively, as VALID or INVALID (e.g. for the purpose of litigations in B2B transactions). The service uses public-key cryptography (PKI: Public Key Infrastructure) providing properties such as: integrity, non-repudiation, validity and authentication. End-users can use several advanced tools, including NTP server with trusted UTC and cryptographic RFC3161 stamping of file documents provided by build-in TSA (Time Stamping Authority).

Features and benefits

- Trusted (authenticated) UTC time distribution using std. NTP
- Remote (client) clock performance auditing and reporting.
- Ex-post client time validity verification available from a database (DB).
- 1-10 millisecond accuracy for Internet connection with microsecond resolution.
- Performance can be increased up to ultra high accuracy over LAN.
- Equipped with extra TSA (Time Stamping Authority) server RFC 3161.
- Public-key encryption for integrity and non-repudiation.
- Scalable, suitable for any business requirements, regardless company size or domain.
- Designed for National Time Authority UTC distribution via TCP/IP.
SERVICE03: Time and Frequency Distribution over Optical Link

DEVELOPERS: INRIM (Italy), VTT Mikes (Finland)

“Time and Frequency dissemination with the best accuracy and stability and extreme resilience to external perturbations”

A time signal referenced to INRIM is disseminated using optical fibers. Different architectures and different techniques are available to meet user needs. An accuracy beyond the GPS level can be achieved through open source techniques (White Rabbit) and the more innovative Modulated Coherent Time (MCT).

Features and benefits

- Advanced Timing provision with best accuracy and stability
- Superior resilience to interference and attacks to ensure safety requirements and integrity.

The reference time signal generated at INRIM is encoded by modulating the amplitude of a laser radiation, then routed on a commercial optical fiber network. The user is equipped with a receiver that demodulates the incoming light generating a set of useful reference signals for time stamping and frequency reference (1PPS and 10 MHz). The accuracy of the time reference is better than 1 ns with respect to the INRIM timescale UTC(IT). A set of Key Performance Indicators monitors the system and the performances at the user-end.
“Accurate time and frequency distribution through a geostationary satellite for network reliable synchronization”

The system disseminates time and frequency in real-time via geostationary satellite. The proposed technology is based on consolidated telecommunication techniques (FDMA) that are applied in an innovative way, thus allowing for a reliable, competitive and cost-effective final system.

Features and benefits

- Stand alone synchronization system, with no dedicated satellites required
- Sensible reduction of the disturbances due to interference, typical of GPS/Galileo, thanks to a different spectral band and different receivers (intrinsic)
- Same coverage capability as for GPS/Galileo system (national scale)
- GPS/Galileo independence and full technological redundancy
- Reliable and competitive service relying on already largely experimented techniques
This Service aims at calibrating GNSS stations for timing applications, i.e. determining the hardware delays in the antenna, cables and receiver. Two methods can be used: absolute or relative. The absolute calibration uses a GNSS signal simulator and a Vector Network Analyzer which compares the simulated signal with the signal measured by the receiving equipment; the uncertainty on the measured delays is at the level of 1 ns. The relative calibration determines the hardware delays of the receiving chain with respect to a reference station already calibrated, with a combined uncertainty lower than 4 ns.

Features and benefits:

- The user will know the hardware delays of its GNSS receiving station, and will hence be able to determine accurately from the GNSS measurements the offset between its local clock and the GNSS time scale.
- This service will allow GNSS time transfer with an uncertainty lower than a few nanosecond.
“Improvement of the medium term stability of oscillators slaved to Galileo by real-time correction streaming”

The Certified Time Steering service aims to disseminate precise and accurate time using GNSS (mainly Galileo) Time Transfer techniques and a real-time internet link, allowing the real-time monitoring and certification of the time offset between the User Terminal (UT) and the Time Reference Facility (TRF).

The setup of the system consists of two main components:

1) The Time Signal Generator (TSG) is a server operating as part of the Time Service Infrastructure. It receives real-time streams with the observations of the receivers at the Time Reference Facility and the User Terminal and broadcasts the real-time correction stream which is the time offset between the Time Reference Facility and the User Terminal.

2) The User Terminal (UT) is composed of a high precision GNSS receiver, a steerable oscillator, and a computer with internet connection. It collects the real-time correction stream in order to discipline the steerable oscillator, and hence to improve its medium term stability.

Features and benefits:

- Real-time monitoring of the time offset between the User Terminal and Time Reference Facility
- Real-time broadcasting of the correction stream in order to improve the medium term stability of the steerable oscillator
This Service consists in monitoring the user atomic clock or time scale in near real time at the nanosecond level, alerting the users about any abnormal phase or frequency jump of their clock or time scale. The system will be based on the Precise Point Positioning using the GNSS collected by the user receiver driven by its atomic clock. A set of indicators about the user GNSS station well-functioning will also be provided. The service will additionally provide to the user daily information for the steering of its atomic clock or time scale to be aligned with UTC, as well as a prediction of the difference between its time scale and UTC during the next days.

**Features and benefits**

- Knowledge of the synchronization difference between your atomic clock and the reference
- Notification on clock jump or frequency jump of your time scale
- Visualization of the performances of your GNSS station in terms of multipath, visibility, etc...
- Reception of a daily parameter to steer your timescale on the reference and a prediction of the difference between your timescale and UTC if you apply this steering
The Time Integrity Service aims to test the capability to deliver a time integrity service to the GNSS users providing integrity information to improve user timing accuracy as well as positioning. The status of Galileo satellite clocks is continuously monitored, detecting in real time possible anomalies and generating automatic alerts in case the satellite is considered unusable. The Service is additionally monitoring the timing parameters broadcast in the Galileo Navigation Message, providing to the users a validation and performance assessment of the timing information disseminated by the Galileo System.

Features and benefits:

- Check of the status of Galileo satellite clocks, receiving information about which satellite clocks are not behaving well and consequently about which SV should be excluded from the timing information and position determination to improve accuracy.
- Monitoring of the timing parameters broadcast in the Galileo Navigation Message
- Visualization of the performance at user level of the timing information disseminated by the Galileo System.
- Verification that the accuracy of the time estimated at user level is within certain limits with respect to a reference time
“High accuracy, Secure, Robust, Scalable, Distributed and SLA based synchronization solution for new or existing systems/infrastructures”

SynchroNet is a Thales Alenia Space Italia patented system for high performance network synchronization exploiting GNSS (GPS and GALILEO) based synchronization algorithms and techniques into a higher level distributed infrastructure matching even critical systems requirements.

SynchroNet offers several benefit and features that are normally available using different timing products in single, integrated and monitored solution.

SynchroNet can work both using a flat network topology or using a hierarchical one and is designed around the concepts of scalability and robustness both in terms of service coverage (number of terminals and terminals geographical distribution) and in terms of performances.

SynchroNet wants to deliver added values to the timing service, that why it doesn’t just deliver timing signals; each SynchroNet user terminal is factory calibrated and tested in terms of reachable performances; the result of factory tests is then translated into a per terminal SLA that is then continuously monitored during operational life as part of integrity assessment and as part of other important monitoring parameters (network connection, NTP performances, GNSS signal availability, etc.) that allows to detect and intervene in advance in case of failures. The outcomes of continuous monitoring are made available to the user that can eventually exploit these information at system level.
Features and benefits:

- **Scalable and distributed** high accuracy clock synchronization problem allowing ease of management of network topology without overall service interruption

- **Synchronization products:**
  - NTP over secure network channel
  - Synchronized 10MHz reference frequency
  - Synchronized 1PPS TTL signal
  - Clock statistical model
  - Performance and integrity indicators computed vs SLA

- **Performances:** <10ns when clock model is applied and <10-14 ADEV @24h. Performances can be scaled at each node depending on the selected HW clock performances and allowing cost planning without having to redesign the whole synchronisation sub-system.

- **Availability and Robustness:** can compensate/mitigate effects of downtime of GNSS (also in case of jamming or spoofing) as well as of ground network used for data exchange

- **Integrability:**
  - ease of integration in new as well as existent systems and infrastructures, all is needed is an network connection (not necessarily Internet) and a place to mount a GNSS cable and antenna
  - Different synchronisation realisation matching different applications:
    - Phase adj. based: introduces jumps in time forward or backward but guarantee time is always aligned
    - Frequency adj. based: guarantees time to be monotonic but may require time for time to be perfectly aligned
    - Algebraic: no correction is applied to distributed time and frequency, but a clock model is provided indicating the offset in terms of time, frequency and frequency drift

- **Integrity and monitoring:** continuous monitoring of functions and performances with per-UT specific thresholds determined during a specifically designed calibration process

- **Integration and security:**
  - All nodes communicate over encrypted tunnels that guarantee authenticity and secrecy.
  - Exclusive tunnelled link between each nodes pair (single hop encrypted point-to-point communication)
  - Redundant status monitoring on TSG and UT
  - Ready to exploit GALILEO Commercial and Regulated services
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