Fostering the Innovation Potential of Research Infrastructures

INFRAINNOV-2-2016: Support to Technological Infrastructures

CLONETS – CLOck NETwork Services
Strategy and innovation for clock services over optical-fibre networks

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LIST OF PROJECT PARTNER ACRONYMS

AGH / AGH-UST	Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie, Cracow, Poland
CESNET	CESNET, zájmové sdružení právnických osob, Prague, Czech Republic
CNRS[*]	Centre National de la Recherche Scientifique, Paris, France
INRIM	Istituto Nazionale di Ricerca Metrologica, Turin, Italy
GARR[#]	Gruppo per l'Armonizzazione delle Reti della Ricerca, Rome, Italy
Menlo	Menlo Systems GmbH, Martinsried, Germany
Muquans	Muquans, Talence, France
NPL	National Physical Laboratory, Teddington, United Kingdom
OBSPARIS[¶]	Observatoire de Paris, Paris, France
OPTOKON	OPTOKON a.s., Jihlava, Czech Republic
Piktime Systems	Piktime Systems sp z o.o., Poznan, Poland
PSNC	Instytut Chemii Bioorganicznej Polskiej Akademii Nauk – Poznańskie Centrum Superkomputerowo-Sieciowe, Poznan, Poland
PTB	Physikalsch-Technische Bundesanstalt, Braunschweig, Germany
RENATER	Groupement d'interêt Public pour le Reseau National de Telecommunications pour la Technologie, l'Enseignement et la Recherche, Paris, France
SEVENSOLS	Seven Solutions S.L., Granada, Spain
TOP-IX	Consorzio TOrino Piemonte Internet eXchange, Turin, Italy
UCL	University College London, London, United Kingdom
UP13	Université Paris 13, Villetaneuse, France
UPT AV CR (ISI)	Ustav Pristrojove Techniky AV, v.v.i., Brno, Czech Republic

[*] linked third party to OBSPARIS
[#] third party to INRIM
[¶] coordinator

EXECUTIVE SUMMARY

The project has produced a series of electronic newsletters, which summarize recent results of the project and announce the project's training events. The newsletters are made available on the project's website (http://www.clonets.eu/clonets-newsletters.html) and sent out to interested parties.

1 ISSUE #1

CLONETS
CLOCK NETWORK SERVICES

Newsletter Issue #1

June 2018

Clock Network Services:
strategy and innovation for clock services over optical fibre networks

WELCOME

Dear Colleagues,

welcome to the first issue of the CLONETS newsletter. In this first issue, we would like to introduce the CLONETS project, its objectives and partners and present some of the first results.

We hope that you enjoy reading this newsletter and learning more about the project and its progress. Any feedback regarding this newsletter is much appreciated, in particular as this is our first issue. Please email your comments and suggestions to contact@clonets.eu to help improve our newsletter.

Best wishes,
Eva Bookjans
CLONETS Project Manager

CLONETS – an Introduction

CLONETS (Clock Network Services) is a European funded project, which strives for the creation of a sustainable, pan-European optical fibre-based network providing high-performance time and frequency services to European infrastructures as well as support to a wide range of industrial and societal applications. CLONETS is motivated by recent progress in time and frequency (T&F) metrology and the increasing number of applications, which either are in demand for more accurate and stable T&F reference signals than are currently available through satellite techniques, or cannot rely on broadcasted signals due to, for example, security concerns or reception issues. Optical fibre links have been shown to outperform satellite systems by orders of magnitudes over distances up to the continental scale, while research infrastructures have been developing several different types of fibre-based T&F distribution technologies specifically designed and adapted for their needs. For example, national metrology institutes are installing and operating long-distance fibre links, in order to compare their optical clocks and pave the way for a new definition of the second and consequently for significantly improved time scales. The project aims to strengthen the coordination between research infrastructures and research and education telecommunication networks, to aid the transfer of this new generation of technology to industry, to define a global vision for a European optical fibre-based T&F service and to define a European core network and prepare a strategy for its deployment.

Objectives:

- **Strengthen the European coordination** between research institutes, NMIs, NRENs and industry
- **Study applications** of fibre-based T&F reference signals and their requirements
- **Identify key technologies** for T&F transfer over optical fibre
- **Transfer knowledge and technology** to society and industry
- **Define a global vision for a T&F service** over optical fibre
- **Define the pan-European core network** and a deployment strategy
- **Inform** stakeholders, users, policymakers
- **Train** engineers, researchers

CLONETS is a Coordination and Support Action (CSA), which receives funding from the EU's Horizon 2020 Research and Innovation Programme under grant agreement no. 73177.

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THE CONSORTIUM

The CLONETS project brings together a large variety of organizations with complementary fields of expertise from across Europe. Among the 19 partners are 4 National Measurement Institutes (NMIs), 4 National Research and Education Networks (NRENs), 5 academic laboratories and 6 industrial partners. Their collective knowledge and experience in time and frequency (T&F) applications, optical fibre networks and instrumentation is extensive.

The NMIs, with their state-of-the-art atomic clocks and expertise in T&F transfer, are among the leading institutes in T&F metrology constantly pushing the boundaries of the field. The participating NRENs are strongly invested in T&F dissemination through optical fibre and have a long-standing experience in transferring T&F signals through optical telecommunication networks. Similarly, the involved academic laboratories are continuously investigating new T&F transfer techniques and novel frequency standards. The industrial partners are specialists in developing and commercializing innovative products for T&F applications. Their expertise includes amongst others precise electrical measurements, digital electronics for time transfer through internet protocols, optics, telecommunication platforms and internet exchange and ultra-precise quantum sensors.

In Numbers

19 Partners
16 Consortium Members / **3** Third Parties
4 Types of Institutions
7 European Countries
30 Months – project duration

Kick-off meeting Observatoire de Paris

28th Feb. 2017

National Measurement Institutes

- Observatoire de Paris* (FR)
- National Physical Laboratory (UK)
- Physikalische Technische Bundesanstalt (DE)
- Insituto Nazionale De Ricerca (IT)

National Research and Education Networks

- GIP Renater (FR)
- CESNET, z.s.p.o. (CZ)
- Poznańskie Centrum Superkomputerowo-Sieciowe (PL)
- Consortium GARR** (IT)

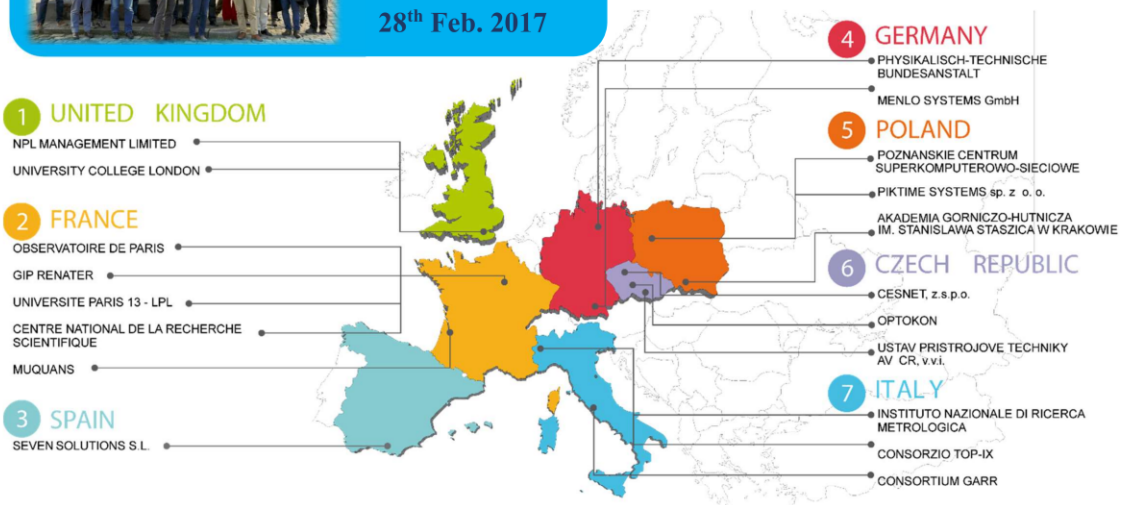
Academic Laboratories

- Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie (PL)
- Université Paris 13 –LPL (FR)
- University College London (UK)
- Ústav přístrojové techniky AV ČR, v.v.i. (CZ)
- Centre National de la Recherche Scientifique** (FR)

Industry

- Muquans (FR)
- Menlo Systems GmbH (DE)
- Piktime Systems sp. z o.o. (PL)
- Seven Solutions s.l. (SP)
- Optokon a.s. (CZ)
- Consorzio Top-IX** (IT)

* Project Coordination
**Third parties



MASTER IN PHOTONICS FOR DATA NETWORKS AND METROLOGY

POLITECNICO DI TORINO

INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

Pilot Master
January 2019 – March 2020

Applications Open!
Deadline: Sept. 28th 2018

In close collaboration with CLONETS, Politecnico di Torino and INRIM have created a Level-2 Master specializing in Photonics for Networks and Metrology. This pilot Master Program focuses on fibre optic networks and their application for T&F metrology and includes lectures, hands-on laboratory courses and an internship in a European company or research institute providing on the job training in the field of photonic technologies. Through this 12 month multidisciplinary Master Program, the students will be trained to design and manage state-of-the-art photonic networks, which support the ever-increasing IP traffic as well as distribute T&F reference signals.

The Master Program is scheduled to start in January 2019 with applications open until end of September 2018. For more information see: https://didattica.polito.it/master/photonics/2019/glance

KEY TECHNOLOGIES AND TRENDS

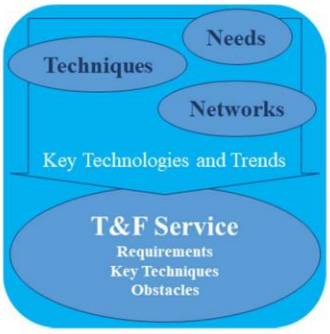
In the first year of the project, CLONETS has gathered information from the time and frequency (T&F) metrology community, NRENs and research infrastructures on state-of-the-art fibre-optic T&F transfer techniques, the fibre-optic networking technologies employed and the need for high performance T&F references via an optical fibre network.

The consortium has identified and surveyed research infrastructures, including NMIs, the result of which indicates a growing awareness of the potential of a fibre-based T&F service and at the same time an increasing need for better performance than currently available via classical satellite based technology.

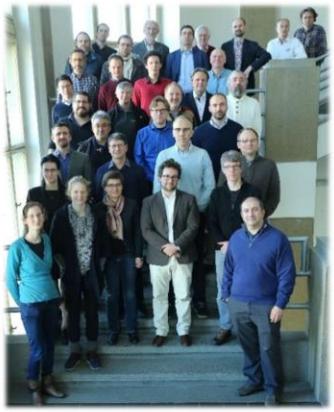
In parallel, the fibre optic networks of NRENs and their capacity for integrating a T&F service into their networks was studied since the fibre-optic networking technologies deployed in telecommunication networks will determine which measures need to be taken to allow for T&F transfer over the network. A special focus was placed on the suitability of "Alien Wavelength" or "Dark Channel" methods for a T&F transfer, with the involved NRENs reporting on their experience with such methods, the accompanying constraints and the considerations that need to be made for their deployment in a network.

Additionally, the consortium has provided a comprehensive overview of high performance T&F techniques including fibre noise compensation and signal regeneration techniques.

The information collected has been summarized in reports that can be found on the projects website (http://www.clonets.eu/) and serve as building blocks for the formulation of a common vision for a fibre-based T&F service.



CONSORTIUM MEETING



The second CLONETS Consortium Meeting was held on the 15th-16th January 2018 at CESNET in Prague and was followed by a workshop during which

- the likely key T&F transfer techniques of the future,
- the potential role of fibre compared to satellite based services,
- the requirements for the implementation and integration of fibre based T&F services into an NREN network and
- the key obstacles to implementation

were discussed, evaluated, summarized and agreed upon.

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CLONETS CLOCK NETWORK SERVICES

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2 ISSUE #2

CLONETS
CLOCK NETWORK SERVICES

Newsletter Issue #2

January 2019

Clock Network Services:
strategy and innovation for clock services over optical fibre networks

Upcoming Training Events

The CLONETS project is envisioning a sustainable European time and frequency network including a community of engineers and researchers capable of contributing to the development and deployment of time and frequency services over optical fibre. Towards this aim, CLONETS is engaged in various training and dissemination activities and would like to announce two upcoming training events, which are described in more detail below.

Time and Frequency Transfer over Fibre Networks

A **CLONETS** Introductory Training Event at NPL, UK

Free 1-day Workshop

NPL National Physical Laboratory

26th February 2019

Register Now!
Limited Participation

NPL, in close collaboration with CLONETS, is hosting a free one-day entry level workshop on the current state-of-the-art time and frequency transfer techniques relevant to a European-wide optical fibre network infrastructure. This workshop includes presentations from international experts, poster sessions from industry, and the opportunity for a tour of the Time Scale lab where the UK's national time scale UTC(NPL) is generated. The event is open to all interested in learning more about topics such as precise time, optical clock comparisons, time and frequency dissemination over optical fibre networks, the relevant techniques and technologies and their applications in both research and industry. To register and for more information see: https://nplclonets2019.eventbrite.co.uk .

High Precision Physics using an Optical Fibre Link and Optical Frequency Comb

A **CLONETS** supported International Physics School at les Houches School of Physics, France

SFO Société Française d'Optique
LPL Laboratoire de physique des lasers
UNIVERSITE PARIS 13
FIRST TF
CLONETS CLOCK NETWORK SERVICES

22nd - 26th April 2019

Applications Open!
Deadline: 22nd Feb. 2019

This Physics School provides a unique opportunity to learn from leading experts about optical fibre links and optical combs in light of their increasing relevance to high precision measurements replying on ultra-stable and accurate frequency references. The lecturers and presentations cover important basic concepts, the performances and limitations of these two tools, their most recent developments and their application to a wide range of fields, including tests of fundamental physics, atomic and molecular high-resolution spectroscopy, radio astronomy and geodesy. The school has been organized by the French Optical Society with support from First-TF, LPL-UP13 and CLONETS and is open to all researchers, engineers, and PhD students interested in this topic without restriction of age, status or nationality. For more information and to apply:
https://www.sfoptique.org/pages/ecoles-thematiques/fiber-links-and-frequency-combs/

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CLONETS CLOCK NETWORK SERVICES

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3 ISSUE #3

CLONETS
CLOCK NETWORK SERVICES

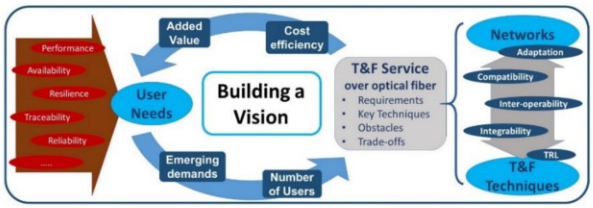
Newsletter Issue #3

August 2019

Clock Network Services:
strategy and innovation for clock services over optical fibre networks

ENVISIONING A TIME AND FREQUENCY SERVICE OVER OPTICAL FIBRE IN EUROPE

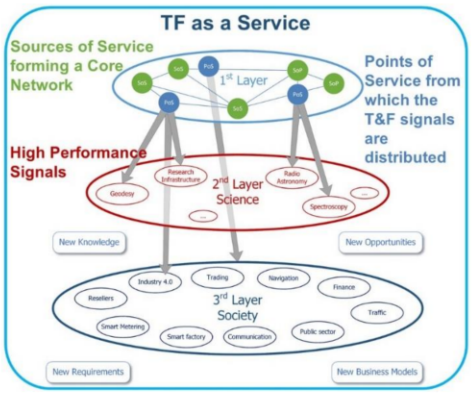
The CLONETS project has outlined an overall vision of a time and frequency (TF) service over optical fibre in Europe based on the TF needs of current and future users, the currently available and emerging TF transfer techniques and the capabilities of optical networks to support and integrate TF signals. The main results are summarized below, while more details can be found on the project's website (http://www.clonets.eu/).



OVERALL VISION FOR TIME AND FREQUENCY SERVICE DELIVERY

A major challenge in creating a vision for TF service delivery over optical fiber are the various different requirements placed on the TF signal by the different users. The type of signal, the performance level and the service characteristics all depend on the needs of the specific applications. CLONETS has identified three major types of signals, which should be supported by the core TF network in order to meet user needs:

- 1 pulse per second (PPS), which is a common output signal of clock devices. The sharp leading edge is synchronized with a reference timescale, often the local realization of UTC.
- 10 MHz or 100 MHz, which are standard operational radio frequencies derived from H-masers monitored by primary clocks. The signal is typically sinusoidal.
- Ultra-stable optical carrier, which is a high-end technology providing the best stability and accuracy crucial for the most demanding and cutting-edge applications.



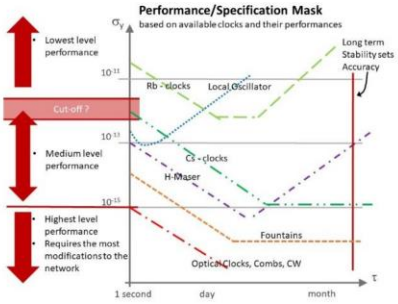
The TF service delivery has been conceptualized as consisting of three different logical layers. The first layer consists of the service providers, which can function as a source of service (SoS), a point of service (PoS), or both. A SoS provides the actual TF signals to the network, while the PoS provides access to the TF network. The PoS can either directly serve the end user or connect a regional network, which then redistributes the TF signals to users within its network. The second layer represents the users with the highest performance requirements on the TF service, generally scientific entities. Access to the TF network allows these users to further push the boundaries of their field, advancing science and technology. The third layer includes commercial and other entities, such as Industry 4.0, communication, smart grids, public sector, finance, etc., which depend on TF for their operations. The overall vision for a time and frequency delivery is described in Deliverable D2.1.

ARCHITECTURE OF THE CORE NETWORK

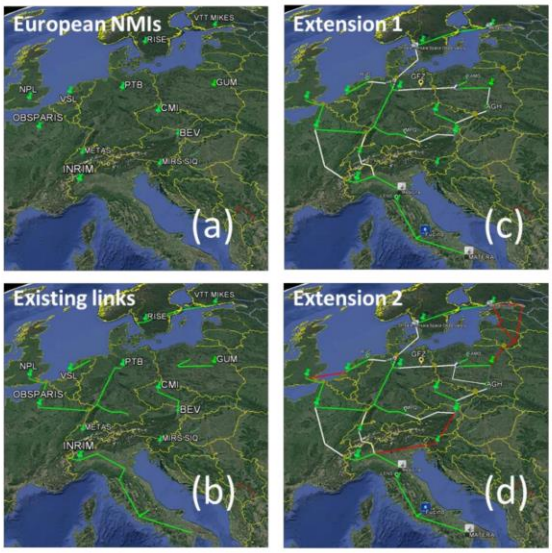
CLONETS envisions a core network with the highest stability and accuracy in frequency and timing. The service providers will be National Metrology Institutes or other UTC-laboratories, since these well-established institutions already maintain state-of-the-art time and frequency standards and have extensive experience in the dissemination of TF signals. This will allow the core network to provide reliable TF signals with the highest stability and accuracy across Europe and support the applications with the highest demands.

The following performances are required from the TF signals in the core network:

- For frequency applications, the frequency instability should be better than 10^{-15} at 1 s and reach below 10^{-19} after several hours of integration. Moreover, for routine operation the frequency transfer uncertainty should be better than 10^{-18} and should be traceable to a realization of the SI-second.
- For timing applications, the jitter should be lower than 1 ps for measurement intervals shorter than a few minutes and less than few 10 ps for one day of averaging. Additionally, the traceability to UTC(k) within 100 ps should be supported.



The performance of a TF service is, however, not only determined by the available clocks and oscillators, but also by the TF transfer technique employed. Therefore the network must be comprised of bi-directional TF fibre links, which allow for a maximal compensation of the optical fibre noise. This requirement is necessary to ensure that TF signals of the highest performance can be disseminated without a significant loss of stability and accuracy. There are two suitable approaches. The first relies on the use of dark fibres, which are exclusively dedicated to the transmission of TF signals. The second approach uses so-called dark channels. In this case, the bi-directional TF signal is integrated into an otherwise uni-directional data network and occupies a channel in parallel with the data traffic, with the difference that it bypasses any uni-directional elements in the network. Both approaches have been shown to provide the best possible overall performance in terms of stability and accuracy, but have their different advantages and disadvantages with regards to implementation, network management, maintenance, costs, etc. Four different scenarios based on these two approaches have been considered and are discussed in Deliverable D2.2 including an initial preliminary estimation of the costs.



The selection of potential routes forming the first phase of the core network has been discussed extensively in view of available clocks, already existing TF links, institutes involved in the development of TF transfer, presence of NRENs (in particular those involved in TF issues) and GEANT, and strategic points for future possible extensions and synergies with eventual TF users (such as radioastronomy stations).

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CLONETS CLOCK NETWORK SERVICES

4 ISSUE #4

CLONETS
CLOCK NETWORK SERVICES

Newsletter Issue #4

October 2019

Clock Network Services:
strategy and innovation for clock services over optical fibre networks

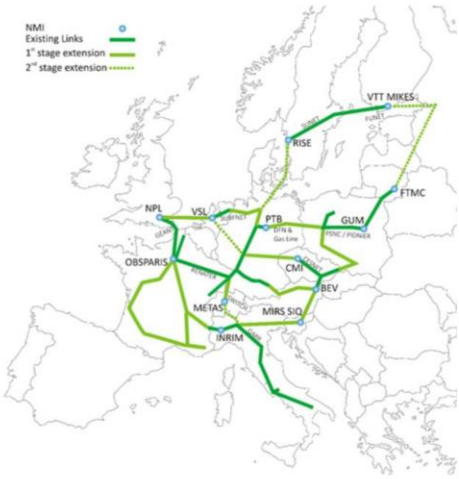
PROJECT SUMMARY

The CLONETS project during its duration has made important steps towards the creation of a sustainable, pan-European network providing high performance clock services via an optical fibre infrastructure. It has brought together key players in the field of time and frequency (TF) transfer over optical fibre networks, strengthening the interactions and collaborations between researchers and engineers of NRENs, NMIs, academic laboratories and industry. This coordination has been crucial and continues to be necessary for harmonizing research activities, developments in optical networking technologies and experimental link deployments throughout Europe. The aspects explored by the project include: scientific and industrial applications; status of and needs for telecommunications network equipment and equipment for time and frequency transmission over optical fibre; the general characteristics of a pan-European infrastructure and possible scenarios for its implementation. The corresponding reports can be found on the project's website: http://www.clonets.eu/clonets-summary.html

OUTLOOK

With the end of CLONETS, the feasibility and remaining challenges of implementing a sustainable pan-European fibre-based TF infrastructure are better understood. The project partners intend to capitalize on the progress made and to continue working towards the realization of the envisioned TF infrastructure. While the project has addressed many important aspects, a more focused study is possibly needed in order to develop a preliminary design supporting the subsequent development phases of the detailed design of the infrastructure followed by its implementation. A call such as INFRADEV-01-2019-2020: Design Studies could be an appropriate context for this next phase of the CLONETS project.

The deployment of the envisioned TF network is expected to benefit a variety of research fields (including amongst others metrology, fundamental physics, geodesy, astronomy and high-resolution spectroscopy) through the prevision of high-performance TF reference signals. Ultimately, the proposed TF service is therefore expected to contribute to the long-term competitiveness of European research infrastructures and to innovative technological developments.



TF Links in Europe and Planned Extensions

CLONETS is a Coordination and Support Action, which receives funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement no. 73177.

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CLONETS
CLOCK NETWORK SERVICES

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