CLONETS – Clock Network Services

Optical-fibre network for clock services in Europe : recent progress

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Abstract—Dynamic development of long-distance methods of time and frequency signals transmission over optical fibers is giving the opportunity to create optical network with dedicated

clock services. In order to prepare the deployment of this technology for a sustainable, pan-European fibre network, providing high-performance clock services to European research

infrastructures and supporting wider services to industry and society, the CLONETS project, funded by the European Commission in H2020 program, is a coordination and support action intended to accelerate the transfer of these technologies to industry and to strengthen the coordination between research infrastructures and research and education network providers.. The optical network will cover a European area, and will be providing highest available performance for research infrastructures, commercial entities and other organisations. (Abstract)

Keywords— optical fibre, network, clock time, dissemination, service

I. INTRODUCTION

Long-distance methods of time and frequency transmission based on optical networks have been developing rapidly in recent years. They have proven their excellent performance in long-distance transmission, both in laboratory tests and in real-field environments, on dedicated fiber or in parallel to data traffic of an active telecom network. They are a promising alternative or complementary solution to other methods of time and frequency transfer due to their superior performance, which enables remote optical clock comparisons, and their enhanced reliability and resilience compared to satellite-based methods, which are used in many other industrial and societal applications.

II. CLONETS PROJECT

The development of time and frequency dissemination techniques using optical fibre networks has led to a rich panel of situations for connecting optically laboratories in and across Europe. Some of them are established over telecommunication networks [1-5], some over dedicated dark fibers or a mixture of these two solutions as in references [6,7].

However, all these connections are separate networks and a unified and sustainable vision is required, given that the high cost of optical fibre rental can be an additional challenge to create a permanent and sustainable clock service over a network.

Therefore, a new European project was needed that would start the process of designing a network and creating a strategic roadmap for clock services over an optical fibre network that could cover the whole of Europe [8].

The CLONETS consortium brings together the different stakeholders: NMIs, academic research groups, National Research and Education Network providers (NRENs), an internet exchange and small and medium-sized high-technology companies (see Fig. 1). All of them are interested in creating a time and frequency optical fiber network.

CLONETS is a coordination and support action, whose function is to identify scenarios and prepare strategies for the future evolution of optical fibre-based time and frequency networks.

All the results of the project described below are available publicly on the project website www.clonets.eu.

III. COMPREHENSIVE SURVEYS

Fig 1. Map of the 19 institutions from 7 participating countries in Europe.

We report first on two surveys we have conducted, and report on the information we have obtained on future needs of research infrastructures. Based on questionnaires on-line, we have scanned 37 research institutions, including 11 laboratories realizing time scales contributing to TAI, 26 research laboratories, and more than 30 companies. These surveys confirm that there is a wide spectrum of applications benefitting from fiber based services. The strongest scientific cases are optical clock comparisons, contribution to the future re-definition of the SI-second, chronometric geodesy, high resolution spectroscopy and GNSS supervision. Network synchronisation would also benefit from fiber based dissemination techniques, either as the fiber can provide better performances, or as the fiber can provide an alternative and a complement to GNSS signals. The most prominent scientific case is VLBI, see for instance SKA and pioneering work at INRIM [8-13]. In the industrial sector there is a need for an alternative to GNSS services, due to their lack of resiliency and security. Finally, fiber based time and frequency standard dissemination has applications in fiber sensing [14-15].

This statement was also confirmed with a market study focussing on the industrial sector, specifically telecommunication, smart grid, and finance. We have subcontracted a market study that underlines however that so far, the fiber technology is hardly standardized. Several techniques, based on optical carrier or on RF modulation have reached high technical readiness level (TRL 8) and are available off the shelf by one or several manufacturers. But the only technology on the way for standardisation to date is White-Rabbit PTP [16]. WR-PTP is expected to be adopted as a high-performance profile in the next release of IEEE-1588.

IV. TECHNICAL REVIEWS AND STRATEGIC VISION

We discussed also at the conference the key optical fibre telecommunications as well as time and frequency transfer technologies expected to have a growing impact on the telecom

backbone. The major evolutions of the telecom network that were considered are 1) the increase of the required bandwidth for ultra-fast communication (600 Gbps), 2) transparent optical networks, 3) dynamic allocation of bandwidth (aka flexible spectral grid) and 4) dynamic path routes. Modern networks allow to beam DWDM T/F service to any point of the network for a given amount of time [17]. We focussed our study on the networks operated by National Research and Education Network. The study revealed that more than 100 000 km of fibre were operated by NRENs in Europe. In these networks, established to be run as an infrastructure for wide variety of secured services, about 30 to 50% of the fiber capacity is used. It was demonstrated in the project that for now and for the upcoming 10 years, the NRENs have the fiber capacity to host a T/F service.

A very detailed analysis of the T/F service was achieved within the project. At the conference, we listed the possible configurations that can arise in practice regarding the network access, as 1 or 2 fibers, 1 or 2 wavelengths, DWDM networks, dedicated networks etc... Deliverables with many details can be found at [18].

We used the results of the surveys to define the contours of the future optical fibre network for time and frequency and the services it will support. We reported at the conference on our work towards the design of such a clock service over fiber network. Trade-offs between performances, number of interested users, and the deepness of the required network modification were analysed. Based on existing developments and fiber availability, using cost efficiency as a key driver, we produced and presented at the conference a vision with logical layers that could organize such a network (see Fig.2). Such a network will not be homogeneous, at least at the start.

Various scenarios were studied and developed for the definition of the clock service. These scenarios were based on either dedicated network, a dedicated channel, or a mixture of these two, and available technology off the shelf from industrial vendors. The first estimate for the cost to create the core network was in the range from 20 to 30 millions of euros.

The current work, at the time of writing these proceedings, focusses on explicating the requirements that need to be included into the network design and produce a technological roadmap for reaching highly mature technology. The deployment of such a time and frequency dissemination system based on optical fibre network in Europe will be strongly dependent on the network access that NRENs and the pan-European Education and Research network GeANT can provide to the T/F community.

V. TRAINING AND MASTER PROGRAM

The CLONETS project promotes topics related to time and frequency transmission methods for stakeholders. It prepares training days devoted to academia and industrial stakeholders, and in close collaboration with Politecnico di Torino, INRIM have created a Level-2 Master specializing in Photonics for Networks and Metrology. The Master is now fully organized and all necessary steps were implemented. The Master should be opened in 2019.

Fig 2. Logical network vision under construction. It shows three layers, one connecting the service providers, one connecting the highly demanding users in term of performances, and a third layer with wide impact for society.

VI. CONCLUSIONS

CLONETS is a coordination and support action funded by the European Commission. We conducted surveys and subcontracted a market study that confirms the interest of a fiber-based network for dissemination of time and frequency standard. A first estimate of the necessary funding to start such a network in Europe is in the range from 20 to 30 million euros. Possible partnership with NRENs for a T/F service in parallel to data traffic is possible in some countries, and sounds more difficult to be implemented in other countries. GÉANT acting at the European level is also considering the development of such a service in its infrastructure.

Fiber-based technology is nowadays well matured, but we still lack standardized methods for time and frequency dissemination. Some technical challenges need to be faced, such as the question of gateways and interoperability in a heterogeneous network. For such a network to be created we believe that further integration activities of the widest possible range of users need to be fostered: fundamental physics/spectroscopy, VLBI, geodesy, space, NMI. The design of the first stage of such a T/F network, its integration into existing NREN and or GÉANT network should be answered within a future project, provided that full support from the EU and National bodies is committed.

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