2021 Workshop on High-Performance Time and Frequency Transfer over Optical Networks - Summary of Discussions

Introduction

The EMPIR TiFOON (Time and Frequency Over Optical Networks) project held a stakeholder workshop on 9-10 February 2021, with more than 100 participants. A discussion session at the end of each day collected feedback and ideas from the participants, addressing 4 questions:

- **What applications are likely to benefit from high-performance T&F dissemination over fibre links, and when will they need it?**
- **What dissemination methods and network types would be most suitable to meet the needs of these applications?**
- **What steps are needed to enable high-performance fibre T&F dissemination methods to be set up and operated?**
- **What should the TiFOON project do to support this process?**

This note summarises the information collected during those discussions.

Things we already know

There is a significant barrier between commercial network and service providers, and non-commercial research.

Access to fibre is essential, preferably leased or owned dark fibre, or else bi-directional dark channels. Clear access procedures, affordable price, and allocation of the required resources are essential**.** Fibre access (cost) is the main limitation. The last few km are an issue even when using NREN fibres.

Applications likely to benefit from high-performance T&F over fibre

Only a few academic applications require high specifications. These higher-performance applications are the drivers of new technology and services, but no high-priority “killer application” has been found that would justify the considerable cost of implementing high-performance T&F dissemination over fibre links.

Several commercial for-profit applications for fibre T&F distribution exist, but the main driver is resilience not performance. Commercial services have to pay for themselves, and this leaves little room for experiments given the high cost.

However, services with medium performance requirements could run off the back of a widespread high performance network, with the extra benefit of being less dependent on GNSS. It is unlikely that there will be several pan-European services with different levels of performance, and a single integrated one would be more efficient and more economically viable.

Current demands are not very urgent and in most cases would benefit more from increased convenience or incremental improvements, rather than demanding a step change. However, improvements to the available performance will likely trigger new applications.

APPLICATIONS MENTIONED

- International research facilities, including Gran Sasso neutrino experiment, Max4, Eiscat, ESS, CERN.
- Time & frequency metrology (NMIs) – time transfer over fibre would be a significant enhancement to current methods; biggest gains will be made if everything else improves too, but this is happening (EMPIR ROCIT project; "synthetic" time scales).
- Universities – applications include high-performance spectroscopy.
- Coherent radio astronomy, VLBI (high spec) – but benefits are unclear.
- T&F distribution to telescopes – but they are often in remote locations.
- Relativistic geodesy – including improved coordinate frames; monitoring slow geophysical effects such as permafrost changes.
- Next generation Galileo – fibre T&F links between ground facilities.
- Advanced sensing.
- Fibre infrastructure security.
- National security agencies.
- Telecom companies: 5G, 6G deployment and operation
- National power grids – require redundancy and sub-microsecond timing
- Financial markets, big datacentres – requirements currently met by PTP
- Railway systems - no current needs for high performance T&F.
- Advanced manufacturing - 1 µs timing accuracy and 1E-12 frequency accuracy may be sufficient for most users.

MOST SUITABLE DISSEMINATION METHODS AND NETWORK TYPES

The optimal choice of dissemination method depends on the specific application. Many industry and services applications require only microsecond-level timing accuracy, and White Rabbit or PTP (packet- based) methods are sufficient for them (White Rabbit is being addressed in the EMPIR WRITE project).

For activities requiring ultra-stable frequency, the preferred method is direct dissemination from a stabilized laser in the C-band (though there is increasing interest in the L-band), with this laser locked to an optical frequency standard. The method needs a dark fibre pair or dark channel (alien wave) in a CWDM or DWDM network. L-band has the advantage that it is less heavily used by existing services.

Bi-directional links and phase coherent networks provide the best performance.

Time transfer can in principle be added, based on modulation of the carrier frequency.

It is not easy to switch between network type or wavelength band once a specific method or technique has been selected.

Flexible setup, including time-sharing or intermittent use, would be suitable or indeed preferred for some applications, but the sync accuracy must be repeatable. This might work well with research network infrastructures, or more generally with the advance of software-defined networking.

ENABLING HIGH-PERFORMANCE FIBRE T&F DISSEMINATION

Individual countries have chosen their own technologies, and it is unlikely to be possible to establish one system across Europe. There is therefore a need to connect and cooperate between different systems. Interoperability and standardisation is therefore essential. TiFOON should support this by developing methods to connect different systems.

Agreed international standards are needed for handover of T&F services across borders and between carriers. Once a system has been established, it is very expensive to switch between network types, wavelengths, and T&F dissemination techniques.

Standardised, off-the-shelf, reliable optical platforms, coherent T&F transceivers, and affordable bidirectional amplifiers are required. There is also a need for improvements to resilience, remote control and maintenance-free operations. Scientific solutions can become standardised, commercial products.

The current 70% link reliability is much too low for practical applications. More test and development is needed to improve resilience and provide better remote control, with the aim of maintenance-free systems.

Non-profit and academic users need guidelines for what T&F services and technologies are available and what is feasible to develop.