FINAL PUBLISHABLE REPORT

Grant Agreement number	15SIP04
Project short name	TIMEFUNC
Project full title	Time Synchronisation IMpact Enabling FUture Network Communication

Project start date and duration:	01 June 2016, 36 months	
Coordinator: Mr. Erik Dierikx, VSL Project website address: not applicable	Tel: +31 15 269 1688	E-mail: edierikx@vsl.nl
Primary Supporter: Reindert Hommes, Tallgrass	Tel: +31(0)203080072	E-mail: reindert@tallgrass.nl
Internal Funded Partners: 1. VSL, Netherlands	External Funded Partners:	Unfunded Partners:

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

TABLE OF CONTENTS

1 Overview

The aim of this project was to support the uptake by industry and/or commercial organisations of time and frequency synchronisation techniques via optical fibre networks as developed in previous EMRP project JRP SIB02 NEAT-FT. This project has been focused on the application of White Rabbit Precision Time Protocol (WR-PTP) in existing telecommunication networks. To stimulate the uptake of WR-PTP, a hands-on training programme was organised for the supporters, Tallgrass and OPNT, on the design, implementation, operation and maintenance of a WR-PTP synchronised network. The training material was made publicly available in the form of a best practice guide on the VSL website and on the WR website.

2 Need

JRP SIB02 NEAT-FT developed the technology and knowledge to be able to transfer accurate time and frequency (TF) signals through optical fibre networks, one particular synchronisation technique investigated was the WR-PTP.

The network service provider and primary supporter, Tallgrass, has recognized that improving synchronisation of nodes in the telecommunication network beyond the current limitations of GPS-based synchronisation is the key to enhancing network performance in terms of increasing data transfer capacity for developing new data-intensive services such as video and audio streaming. Tallgrass also recognises that embedding accurate "Timing as a service" in the network is a strong concept for a wider range of new telecom-based applications such as positioning services based on a cellular network. Implementing Timing as a service requires that timing signals are efficiently distributed through the network and easily accessible to the consumers. Therefore, Tallgrass (and other telecom service providers) need the knowledge obtained in JRP SIB02 NEAT-FT to design optical fibre time and frequency distribution networks. Tallgrass selected WR-PTP as network synchronization technique, because of the high technology readiness level, the low cost compared to other optical fibre synchronization techniques, the performance which is at about the same level as other existing techniques

For implementation and maintenance of the WR-PTP technology, Tallgrass relies on services from OPNT, an industrial party that provides the required hardware and implements time distribution services. Both Tallgrass and OPNT are aware that the timing service will be most valuable if it guarantees traceability to SI units. Therefore, OPNT intends to set up an accredited calibration service for equipment to be installed in the optical fibre time and frequency distribution networks. The knowledge regarding delay calibration and delay asymmetry calibrations obtained in JRP SIB02 NEAT-FT is of great value and needs to be made available to commercial calibration laboratories.

3 Objectives

The specific technical objectives of this project are concerned with providing detailed practical guidance in the design, implementation, operation and maintenance of optical fibre-based TF distribution networks for industrial end users of the outputs from JRP SIB02 NEAT-FT. The project's objective is:

1. To provide Tallgrass with knowledge on how to design and implement a TF distribution network based on WR-PTP at an uncertainty level of 1 ns for time and 10^{-13} Hz/Hz for frequency.

   In addition, to provide OPNT with knowledge on how to operate, maintain and calibrate a TF distribution network based on WR-PTP at an uncertainty level of 1 ns for time and 10^{-13} Hz/Hz for frequency.

   To write a best practice guide on the design, implementation, operation and maintenance of a TF distribution network based on WR-PTP, as well as a plan describing the steps towards the dissemination of the best practice guide amongst commercial organisations.

4 Results

In order to provide Tallgrass and OPNT with specific knowledge on TF distribution networks based on WR-PTP at an uncertainty level of 1 ns for time and 10^{-13} Hz/Hz for frequency, a series of hands-on training sessions was organised. Since both Tallgrass and OPNT already have a lot of expertise in their organizations, the challenge of this project was to find the specific gaps in their knowledge relevant for building a WR TF distribution network with metrological accuracy and traceability. Hands-on training was found to be the most suitable way for transfer of this specific knowledge, because it allows for a flexible adaption of the training program to the users' needs and gaps in the users' knowledge.

Tallgrass was already very experienced in building optical fibre networks for general data transfer but was missing the knowledge on specific requirements for the design of an optical fibre network in such a way that accurate TF distribution can be implemented to co-exist in the same network and the same fibres as regular data traffic.

OPNT was already very experienced in building WR TF distribution networks but was missing the specific knowledge on implementing WR links in such a way that metrological traceability and accuracy can be demonstrated and be maintained.

The hands-on training session for Tallgrass provided them with the capability to establish an experimental time transfer link between VSL in Delft and Tallgrass in Amsterdam over a distance of approximately 100 km. The time and frequency transfer link was implemented in fibre links that were simultaneously carrying data traffic. By means of a loop-back of the transferred time, it was demonstrated that the uncertainty was within 1 ns for time and within 10^{-13} Hz/Hz for frequency.

The hands-on training session for OPNT provided them with the capability to establish a calibrated and traceable network for time and frequency distribution within the VSL building. The established network consists of one White Rabbit grandmaster switch, 2 WR boundary clocks and 6 WR time nodes. The traceability of the calibration of the WR devices to the realisation of the SI second from UTC(VSL) was demonstrated and documented in a calibration procedure. The uncertainty of the performed calibration was evaluated in a detailed uncertainty budget table. The uncertainty of the established network was validated by loop-back connections and demonstrated to be within 1 ns for time and within 10^{-13} Hz/Hz for frequency.

As such it can be concluded that the first two parts of the objective of the project have been fully achieved. Both supporters have been able to extend their knowledge and experience to the level required for establishing traceable, metrology grade optical fibre time and frequency transfer links and networks, which is the first step to provide accurate time and frequency to their customers.

The third part of the objective of writing a best practice guide on the design, implementation, operation and maintenance of a TF distribution network based on WR-PTP, as well as a plan describing the steps towards the dissemination of the best practice guide amongst commercial organisations', was mainly done in parallel with the activities for the first two parts. All of the major steps in the hands-on training session for Tallgrass and OPNT were summarized and documented in a generic way, such that this documentation can be used by anyone else in the process of learning how to build accurate and traceable optical fibre time and frequency transfer links based on WR. Calibration procedures for WR devices and recommendations for setting up WR links existed already before this project. The main added value of this best practice guide is that the calibration procedures have been complemented with uncertainty evaluations for all relevant components in the WR-link. These uncertainty evaluations are a major requirement for demonstrating metrological traceability of the transferred time and frequency.

After completion of the guide, a dissemination plan was established, consisting of the following steps:

1. Publication of the guide in open media. The guide is publicly available on the White Rabbit website "https://www.ohwr.org/project/white-rabbit/wikis/Documents/wr-good-practice-guide" and on the VSL website "https://www.vsl.nl/over-vsl/publicaties/white-rabbit-good-practice-guide".
2. Raising awareness of the availability of the guide among the active community of White Rabbit users via a post on the WR discussion forum.
3. Raising awareness of the availability of the guide among other users (not subscribed to the WR discussion forum) by personal contacts or direct e-mail messages.

With the publication and dissemination of the best practice guide, the project’s objective has also been fully achieved.

5 Impact

In this project, dedicated training programmes were set up for dissemination of knowledge on design, implementation, operation and maintenance of time and frequency synchronisation in an optical fibre network with an uncertainty of less than 1 ns on time and 10^{-13} Hz/Hz on frequency, by using WR-PTP. Hands-on training was organised for the supporters Tallgrass and OPNT. For the benefit of other organizations, the training material was collected in a Best Practice Guide for dissemination via the VSL website and via the

White Rabbit project website. The availability of this Guide will be brought to the attention of contact person of relevant organisations via e-mail messages.

The outcome of this project is that its supporters, Tallgrass and OPNT, now have the knowledge to design, implement, operate and maintain time and frequency synchronisation in an optical fibre network with an uncertainty of less than 1 ns on time and 10^{-13} Hz/Hz on frequency, by using WR-PTP. This technique is more accurate and less vulnerable than currently applied synchronisation techniques based on global navigation satellite systems (GNSS). Specifically, based on the results from this project, Tallgrass is now offering a synchronisation service traceable to universal coordinated time (UTC) to financial institutions in the Amsterdam region. OPNT has implemented a demonstration of WR-PTP-based synchronisation in a sub-network of one of the leading providers of mobile phone services in the Netherlands. In the framework of the ASTERICS project, OPNT has also implemented a WR-PTP synchronisation link between two sites for radio astronomy in the Netherlands. Besides the projects mentioned here, OPNT is active on an international scale. With the knowledge and training material received in 15SIP04 TIMEFUNC, OPNT will further create impact both in the Netherlands and abroad.

With support of Tallgrass and OPNT and the training material developed in this project the optical fibre synchronisation by WR-PTP developed in JRP SIB02 NEAT-FT is ready to be taken-up by a larger group of end users, including: electrical power grid operators, telecom service providers, financial markets and scientific organisations collecting data from geographically spread locations like radio astronomy and particle detectors. For electrical power grids, synchronisation is essential for monitoring the balance between energy production and consumption. In case of unbalance, the grid will go down, causing severe social and economic damages. For telecom applications, more accurate synchronisation is essential to keep up with increasing consumer demands of data transfer capacity. This allows for improved or new services including high quality video conferencing, video and audio streaming on demand, on-line gaming, remote surgery, etc. These new services create both socially and economically positive impact. Financial markets benefit from synchronisation of all electronics transactions, because it makes the trading more transparent and avoid fraud. WR-PTP is an excellent tool for synchronising trading servers with a reliable source of UTC. Scientific organisations collecting data from geographically spread locations profit strongly from synchronising clocks at all locations, because it improves analysis of correlations between events on multiple locations and significantly reduces the computational power required for the correlating analysis.

Furthermore, in a follow-up collaboration between VSL and OPNT, a transnational time transfer link based on WR-PTP was implemented between Brussels (Belgium) and Noordwijk (Netherlands). This link was built as a demonstration project with the intention to use the results for future applications related to the synchronisation of ground stations for the Galileo satellite navigation system.

6 Contact details

VSL
Thijsseweg 11
2629 JA Delft
The Netherlands

Erik Dierikx
E-mail: edierikx@vsl.nl
Tel: +31 15 269 16 88