European Metrology Programme for Innovation and Research

Delivering Impact

Dissemination of accurate time and frequency over ground-based optical systems

A correct knowledge of time is vital to modern life. Without it, energy grids, financial systems, global positioning, transport, and the internet would fail. Currently, time is disseminated by radio signals or from orbital atomic clocks, which are prone to electromagnetic interference, space weather, or hostile acts. A more secure system is required to act as a backup or replacement for this essential service.

Europe's National Measurement Institutes working together

The European Metrology Programme for Innovation and Research (EMPIR) has been developed as part of Horizon 2020, the EU Framework Programme for Research and Innovation. EMPIR funding is drawn from 28 participating EURAMET member states to support collaborative research between Measurement Institutes, academia and industry both within and outside Europe to address key metrology challenges and ensure that measurement science meets the future.

Challenge

Almost all areas of modern life require an accurate knowledge of time, synchronised to a common time source. In Europe, time and frequency signals, and hence positioning information, are provided by radio signals or the European Space Agency's (ESA) Galileo network of 30 satellites orbiting 20 000 km above the Earth equipped with atomic clocks. These satellites can disseminate time with a 2-5 ns accuracy, but this requires high-quality receivers and competencies only available at dedicated agencies such as National Metrology Institutes (NMIs) and specialised laboratories.

Industry and academia generally rely on less highly-performing timing equipment, limiting the accuracy to 10 ns – 100 ns. Signals from satellites are relatively weak, vulnerable to electromagnetic interference, spoofing, or space weather, such as solar flares.

An attractive alternative is to disseminate time from the atomic clocks at European NMIs over more resilient ground-based networks.

The White Rabbit precision time protocol (WR-PTP) is an ethernet-based system capable of distributing time with sub-nanosecond accuracy over optical fibre.

Whilst WR-PTP had been demonstrated over dedicated fibre links, there was a need for improved scalable calibration techniques along with a demonstration of its accuracy and stability over the tens to thousands of kilometres required for terrestrial networks.

Solution

Building on the work of EURAMET projects NEAT-FT and TIMEFUNC, during the WRITE project a 2 x 50 km fibre-optic WR-PTP test bed was established between project partners VSL, the NMI of the Netherlands and Optical Positioning, Navigation and Timing (OPNT). In an ESA funded project these two partners also established a 260 km WR-PTP link between SMD, the Belgian NMI and European Space Agency's research facility, ESA-ESTEC. Both links ran for six months during which all components, from the fibre optics, filter set up, amplifiers, and switches were thoroughly characterised and improved. Along with scalable calibration techniques for WR-PTP optical fibre links, a redundancy solution was developed by OPNT, that allows the network to reconnect within a within a fraction of a second after a switch in the node is disconnected.

Initial results indicated that, as well as enhanced stability and resilience to disruption, WR-PTP distributed time and frequency signals down to 200 ps accuracy, one order-of-magnitude better performance than existing satellite-based atomic clock comparison methods.

Impact

The company OPNT, based in the Netherlands, is a leader in the use of WR-PTP for time and frequency dissemination, with the aim to *"relocate all current GPS-based services 'from the sky' to the telecommunication network"*.

As well as participation in the WRITE project, OPNT also worked with the Dutch organisation SURF, and developed a method to send WR-PTP over established telecommunication networks.

Results from this fed into the SuperGPS project funded by the Netherlands Organisation for Scientific Research (NWO) to demonstrate the feasibility of a hybrid optical-wireless sub-nano-second accuracy timing infrastructure as a basis for a terrestrial navigation system and various other applications in science and industry. The company has since introduced a 'voting system' to solve conflicts between different clocks within a network, along with Navigator software which can continually check the health and performance of WR-PTP network switches and can also provide updates to the system.

There is now a permanent WR-PTP link between VSL and ESA-ESTEC, and furthermore, thousands of kilometres of WR-PTP timing networks have been established in Italy, the Netherlands, France, and Sweden, demonstrating the stability, scalability and sub-nano second accuracy of this important backup to satellite based systems.

Not only will the WR-PTP allow countries that currently do not possess primary time standards easy access to accurate time and frequency signals but will also ensure Europe's resilience in this essential area.

Demonstrating an alternative to satellite-based time and frequency

The NEAT-FT and TIMEFUNC projects demonstrated that fibre optic frequency transfer could offer orders-of-magnitude better stability and accuracy than existing satellite-based atomic clocks, and provided traceable calibration techniques and uncertainty evaluations for WR-PTP time transfer over shared fibre-optic networks.

WRITE project built upon these results by establishing four WR-PTP testbeds in Italy, the Netherlands, France, and Sweden, linking the atomic clocks of National Measurement Institutes to European industries including space agencies and aerospace companies.

New instrumentation was developed providing state-of-the-art performance levels.

Project data was included as a 'High accuracy Option' in the IEEE 1588-2019 standard.

By demonstrating the maturity of WR-PTP systems in disseminating Coordinated Universal Time, below 200 ps with an unprecedented frequency stability, a validated alternative to satellite systems now exists in Europe. As well as providing redundancy to orbital systems, it allows industry and other sectors in countries without primary frequency standards access to accurate time and frequency signals available from the best clocks in Europe.

EMPIR EURAMET

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