Redundant Distributed Timescale Traceable to UTC(SP)

Sven-Christian Ebenhag, Per Olof Hedekvist, Per Jarlemark, RISE Research Institutes of Sweden, Boras, Sweden
Ragnar Sundblad, Netnod Internet Exchange, Stockholm, Sweden

ABSTRACT

The Swedish Post and Telecom Authority (PTS), the supervisory authority for digital infrastructure and digital services in Sweden, identified that telecom networks of today are heavily dependent on time and frequency for correct operation. PTS decided to strengthen the national time and frequency availability by ordering and financing a general national service. As a result, a time dissemination system was designed and implemented, in a cooperation between RISE Research Institute of Sweden and Netnod. RISE is designated national metrology institute (NMI) of Sweden, and Netnod operates various Internet services including NTP server systems.

SYSTEM OVERVIEW

The system is designed to be robust, resilient and able to operate also when other infrastructure is unavailable. These criteria are met by implementing a geographically distributed system using redundancy in each node and by providing an accurate holdover for a long time i.e. 30 days or more. The system comprises five production time nodes, where each time node generates two cesium clock-based timescales realized by a high-resolution phase and frequency offset generator (HROG), steered by an algorithm using an ensemble of clocks. The timescales are disseminated using NTP, PTP on dark fibers or alien wavelengths, and using 1 PPS, 5 MHz, 10 MHz, and 2048 kHz, see Fig. 1. For time comparisons between the nodes and the national timescale UTC(SP), a fiber-based network as well as GNSS common view are implemented.

ROBUSTNESS

The time nodes are geographically distributed and placed in major cities (Fig. 2), to be able to provide time in a region would it get isolated from the other regions. For physical security and resilience, the nodes are placed in secure and physically strong facilities with uninterruptible power supply such as battery UPS units and diesel generators. All time keeping components of a node; such as the cesium clocks, micro-steppers and PTP equipment (Fig. 3); have a dedicated 24 VDC battery with a capacity of about 3 days beyond the other backup power facilities (Fig. 4).

NTP SERVERS

Each time node has two NTP servers for distribution of time over public Internet (Fig. 5). The servers are implemented in FPGA, each with 4 x 10 Gb/s Ethernet interfaces and support full wire speed NTP traffic on all ports, IPv4 and IPv6. The resolution of the NTP servers timestamping is 15 ns, and the accuracy is well within ± 100 ns. The NTP servers handle two clock inputs, each consisting of a 1 PPS and a 10 MHz signal, connected to the two timescales of the node and falls over to the second clock input if the primary fails. The 1 PPS and 10 MHz outputs are connected to time interval counters for monitoring of the internal phase accuracy.

PTP DISTRIBUTION

The PTP signal, carried on 1 Gb/s synchronous Ethernet, is delivered through dark fiber or in some cases using optical alien wavelength. The service is implemented using commercially available PTP grand masters connected to both node timescales, with failover. Phase accuracy is monitored with time interval counters.

CALIBRATION

Calibration is performed by the national metrological institute RISE biennially using a portable time calibration system designed by RISE.
The main components of the calibration system is an outdoor unit with a high performance GNSS receiver, an indoor unit with time interval counters and two White Rabbit connections, one in each direction to connect the outdoor and the indoor unit (Fig. 6). Two optical fibers are required between the units for the White Rabbit connections.
The resulting calibration value is a phase offset, which is stored in node itself and is accounted for when calculations for steering of the time scales are performed.

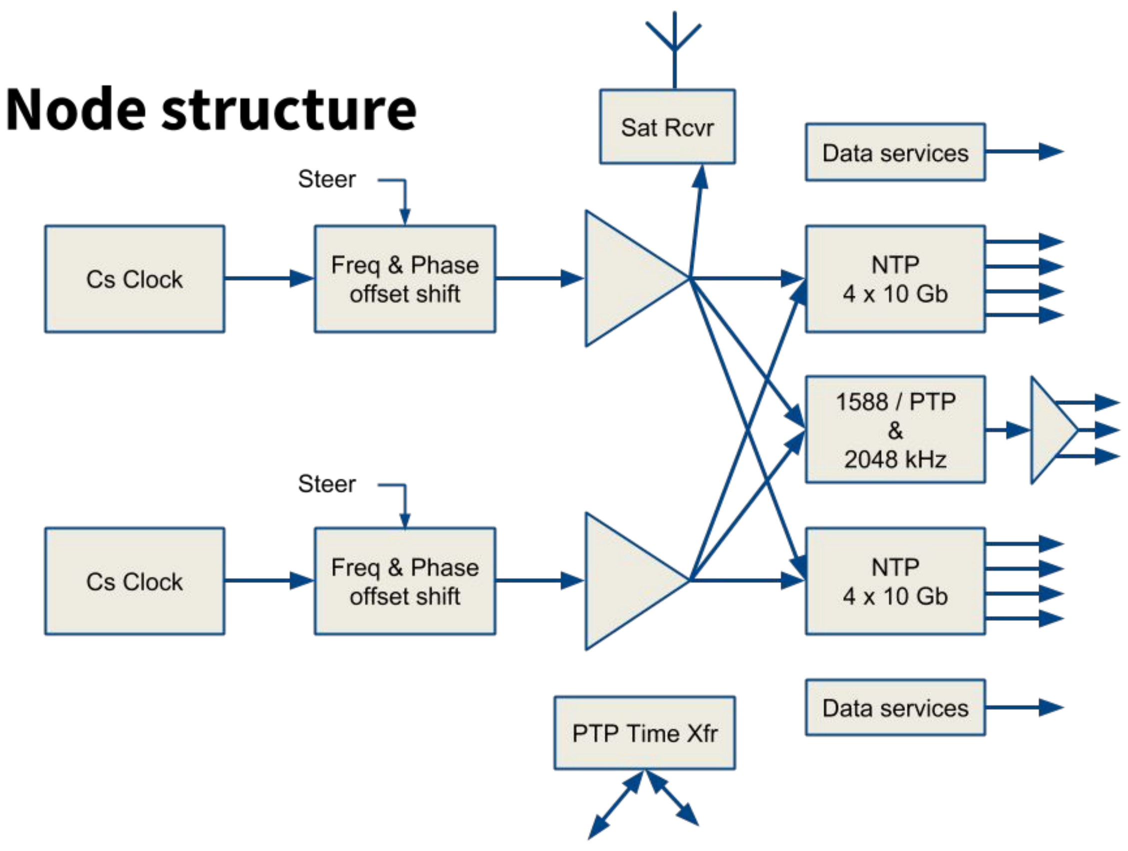

Figure 1. Each time node generates two cesium clock-based timescales realized by a high-resolution frequency and phase offset generator (HROG). The timescales are disseminated using NTP, PTP on dark fibers or alien wavelengths, and using 1 PPS, 5MHz, 10 MHz, and 2048 kHz.

Figure 2. The time nodes are geographically distributed and placed in major cities, to be able to provide time if a region would get isolated. For physical security and resilience, the nodes are placed in secure and physically strong facilities.

Figure 3. A time node, with cesium clocks (red displays), phase and frequency steppers (blue-white displays), distribution amplifiers, multi-channel time interval counters for monitoring, GNSS receiver, PTP grandmasters, and computers. The taller computers close to the top are the NTP servers.

Figure 4. The time node sites have uninterruptible power supply such as battery UPS units and diesel generators. In addition, the time keeping equipment in the node has 24 VDC battery for another three days.

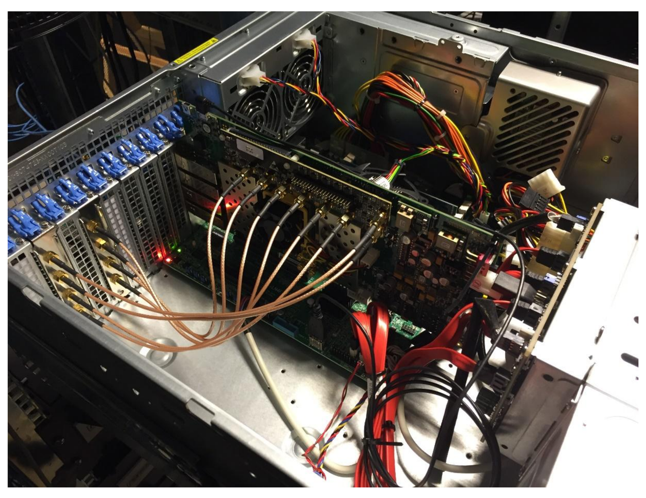

Figure 5. The NTP servers are implemented in FPGA, each with 4 x 10 Gb/s Ethernet interfaces, and are able to handle full wire speed NTP traffic on all ports, IPv4 and IPv6

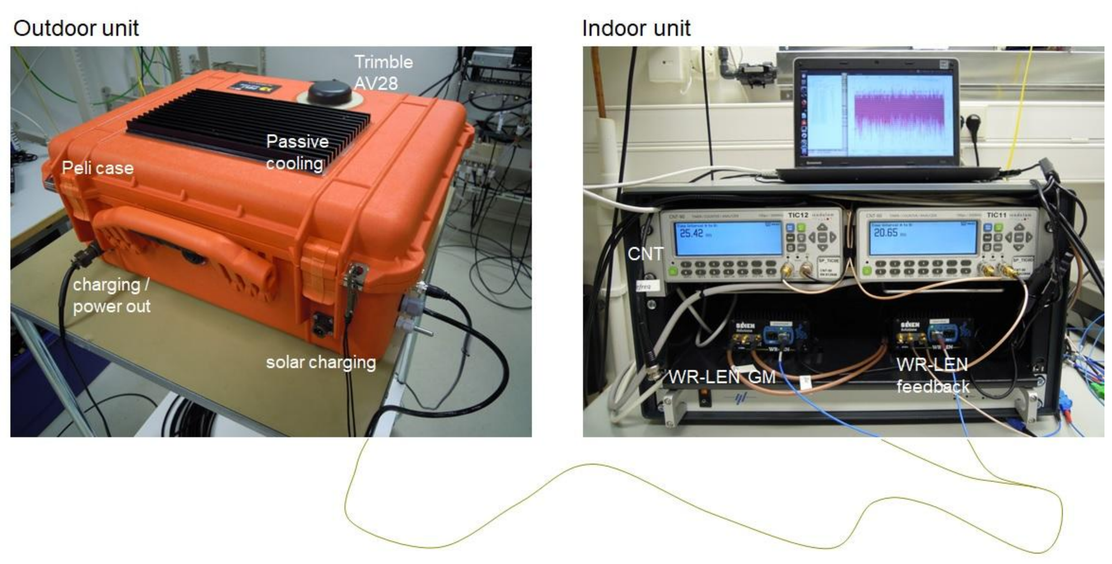

Figure 6. Portable calibration equipment. Outdoor parts housing in a Pelican™ case using passive cooling and solar charging as well as an GNSS antenna. The indoor equipment is constructed of time interval counters, White Rabbit equipment for time transfer and a computer for data collection.

CONCLUSION

A distributed, nationwide, robust, time dissemination system has been implemented and in operation for over three years. The system works as a primary time source for some applications and as a backup for others. At the time nodes the time scales are traceable to UTC(SP), and with calibrated time links traceability can be achieved also in the consuming equipment.

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