Calibration of “PTPv2 Golden Calibrator Pair” in a distributed timing network

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In a distributed system such as an electricity grid composed of substations, the synchronicity between substations to a common time standard is a crucial aspect of ensuring the reliable timing and the stability of the grid. The synchronicity within a substation comes in diverse formats used by the variety of substation equipment and each with their particularities. The timing accuracy reached within and between substations network depends on the synchronization technology used and the architecture of the distribution network. When the requirement for synchronization accuracy ranges from µs to ns level, the PTP-based timing network is widely used. Due to the tree-structured hierarchy of the PTP protocol, time can be delivered and synchronized among all PTP clocks in the network based on the master-slave structure. The local PTP clocks can distribute and disseminate the timing signal either through PTP messages or pulse signal standards.

There are a few methods up to now to link different time signal formats to a unified timing reference. The embedding of the exact time within a protocol like PTP makes it difficult to do a proper calibration at the ns level of such a device using present techniques. And relevant standards do not specify techniques and test methods for validating PTP time synchronization. From a metrological point of view, there is an urgent need to close the traceability gap between NMI references and the diverse timing formats used in the industry. By defining a unified time format and calibration methods, the accuracy of the timing in the PTP network can be made traceable and evaluated.

This paper describes a novel method for calibrating a pair of PTP clocks in a master-slave hierarchy as well as a method to subsequently calibrate other PTP devices. The method is based on two identical PTP devices, one configured as a PTP master clock and the other as a PTP slave clock, a calibration model that is compatible with both the IEEE Std. 1588-2008 and the IEEE Std. 1588-2019 protocols. In the calibration model, see Fig. 1, two reference planes are defined which correspond to the PTP timestamp and the PPS pulse. By taking the two reference planes into account separately, the internal latencies as well as uncertainties of the PTP clock pair will be defined in the calibration of the clock pair. As a result, both PTP and PPS ports can be unified into a common reference, and therefore the synchronization of the PTP clock pair can be calibrated at the ns level. As a next step, other PTP devices can be calibrated by taking the prior calibrated PTP clock pair as the “golden calibration pair”, hence all the timing ports and devices in the PTP network can be traceable to the same reference.[1]

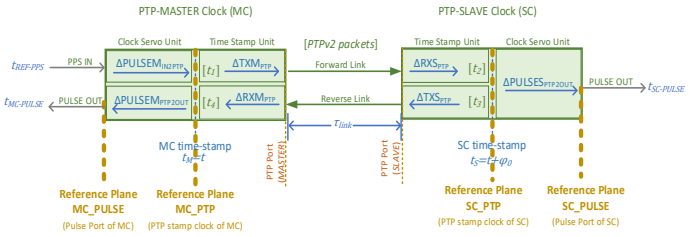

Fig. 1: PTP master-slave clock pair calibration model

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