White Rabbit Digital Time Scale

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A growing number of applications make use of White Rabbit (WR) for network synchronization[1]. These include emerging technologies such as the quantum Internet[2] and terrestrial networked positioning systems[3], which exploit the sub-nanosecond time synchronization between distant nodes enabled by WR. Because such applications are often developed to increase the integrity and resilience of existing communication and positioning, navigation and timing technologies, it is imperative that the underlying WR synchronization network be reliable and fail-safe.

In its current implementation, all the nodes in a WR network are essentially phase-locked to one reference clock, which represents a single point of failure. To mitigate this issue, methods have been developed to switch over from the primary WR time source to a secondary (back-up) WR time source elsewhere in the network[4]. However, even high-performance atomic clocks tend to drift apart by nanoseconds per day, such that failover to a back-up atomic clock will inevitably lead to a network time jump of several nanoseconds or more, potentially disrupting the services that make use of the sub-nanosecond WR network synchronization. In addition, the time sources in standby mode do not contribute to the network time stability during nominal operating conditions, which implies suboptimal use of resources.

Here we report an approach that addresses both issues as follows. First, we modify the software of the WR switch so that it can measure time offsets from multiple WR grandmaster switches, and thereby the time differences between their reference clocks. The digital time differences are processed by an algorithm that estimates the individual reference clock phases with respect to a time scale, with the time scale stability approaching the combined stability of the reference clocks at all averaging times[5]. The time scale – a purely digital construct – can subsequently be realized at output ports of the WR grandmaster switches by digitally correcting the time stamps, derived from the reference clock, for the estimated clock offsets. In this way, a WR network is achieved with redundant WR grandmaster switches that have two types of WR ports: a first set of ports whose time mirrors that of the free-running clocks and is used for clock comparisons (the 'time measurement network'), and a second set of ports whose time stamps are steered (with picosecond resolution) to the common digital time scale (the 'time production' network; note that a similar architecture was proposed independently in the context of mobile networks[6]). Thus, the time production network ports represent redundant WR time sources that are aligned with the time scale to within a fraction of a nanosecond, while taking advantage of the combined stability of all reference clocks.

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