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White rabbit: a deterministic time transfer and frequency dissemination technology for distributed systems

J. Díaz [(1)], E. Ros* [(1)], and R. Rodríguez -Gómez[(2)]
(1) Computer Architecture and Technology Department. University of Granada, e-mail: {jda, eros}@ugr.es
(2) Seven Solutions S.L., e-mail: rrodriguez@sevensols.com

Latest developments on the field of radio-communications and astrophysics rely on the development of distributed systems as a way to better sensing and optimize the utilization of the electromagnetic spectrum. From modern radio-telescopes like the Square Kilometer Array (SKA) or the Cherenkov Telescope Array (CTA), to distributed radars and communication systems, all of them require a common and highly stable frequency reference in all the antennas. This is needed to guarantee that the radio signal is sampled or emitted in a coherent way despite the location. Furthermore, all of them need a proper Pulse-Per-Second (PPS) signal. This signal is used as synchronization mechanism, key for signal timestamping as well as a mechanism to control the phase of the signal distributed at each antenna of the system. This allows the distributed instrumentation (arrays of antennas) to work as a single system, with a global time and frequency reference.

In this contribution we describe an outstanding technology called White Rabbit [1] able to distribute time with accuracy better than one nanosecond and disseminate frequency with stability better than 10 picoseconds. For this goal the approach uses optical fibers and standard Ethernet links, inhering all the capabilities of this well-known network technology. The high specifications are obtained by the combination and improvement of different technologies such as Precision Time Protocol (IEEE-1588v2) used for synchronization and the utilization of the L1 syntonization mechanism (inspired from the SyncE protocol) as a physical way to provide frequency to all the nodes using just standard Ethernet links. The recipe also integrates a high accurate mechanism for the measurement of the clock phase by means of the digital DDMTD. The final result is a high performance solution, known as White-Rabbit, that is able to distribute time and frequency together with generic Ethernet data packet without performance penalty and propagate these time & frequency signals (within Ethernet packets) tens of kilometers to thousands of devices. The solution, born at CERN in the field of High Energy Physics instrumentation, is progressively being incorporated on many applications especially on the industry for science but also on telecommunication applications. There are results showing their scalability to more than 20 hops [2] or distances of more than 1000 Kms with outstanding performances. There are also implementations to cope with the dependability of the technology to avoid single point of failure. This is addressed by including redundant network topologies with zero-time recovery based on switchover mechanism [3]. Moreover, latest implementations are improved increasing its interoperability, existing devices capable to provide White-Rabbit as well as other protocols as IRIG-B, PTPv2 or NTP on the same platform.

In this contribution we prove a brief description of the base of the technology as well as the current state of the art on the existing implementations. We present as reference the use case for the SKA Telecope where White-Rabbit technology will be used as PPS distribution mechanism. Finally, we will provide some hints on the latest results to improve the stability of the distributed clock signal, reaching results in the range of a few ps. This opens the door to new applications on the field of radio-communications and astrophysics based on the capability of using Digital Direct Synthesis techniques as a vehicle to disseminate phase and frequency on distributed applications through standard Ethernet links.

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