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Discontinuities in Coordinated Universal Time: advantages and perspectives

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Extended Abstract

Coordinated Universal Time, UTC, is the international reference time scale computed at the BIPM on the basis of data from atomic clocks maintained in about 80 Time laboratories in the world. It is kept in agreement with the time scale defined by the Earth rotational angle, UT1, by adding or removing an exact integer second in UTC as needed, so that the magnitude of the difference UT1-UTC is maintained not greater than 0.9 s [1, 2, 3]. These additional seconds are called "leap seconds". This method of steering UTC to UT1 was started in 1972 with the goal of maintaining UTC, which defines civil time, linked to the rotation of the Earth. This link was useful for celestial navigation and for other astronomical applications, since it made possible the use of UTC as a low-accuracy approximation to UT1. Measurements and predictions of the difference UT1-UTC, with a resolution of ten microseconds, are published by the International Earth Rotation and Reference Service [4].

Many new uses for time and frequency data have been developed since 1972, and these applications are not compatible with the discontinuities in time interval and in frequency that occur when a leap second event occurs. Possible changes to the realization of UTC have been discussed since 1999. The standard realization of a positive leap second [3] is obtained by adding an additional second on the agreed day at 23h 59m 59 s; the leap second is labelled as 23h 59m 60s. (Negative leap seconds have never been used and are unlikely to be necessary for the foreseeable future.) Many systems, especially those that represent time as the number of seconds (and fractions of a second) that have elapsed since some epoch, cannot represent this additional second. Computer networks, global navigation satellite systems such as GPS or Galileo, and most digital applications are examples of systems with this problem. Each one of these groups has implemented a private, non-standard strategy to address the problem of the discontinuities of leap seconds. Thus, we have the Google frequency smear, which amortizes the leap second as a frequency change over the leap-second day, the Microsoft methods, which either ignores the leap second completely or amortizes it by a frequency adjustment over the last second of the day, the method of several commercial devices, which insert the leap second as the first second of the new day (rather than the last second of the old one), the POSIX computer system, which effectively defines a new discontinuous time scale at every leap second, the various Linux distributions, which support multiple realizations of the leap second, so that systems running identical versions of the operating system can disagree about the time in the vicinity of a leap second, and finally the NTP version, which realizes the leap second by repeating 23:59:59 a second time. A large number of users ignore UTC completely and just use a continuous time scale as GPS system time because their applications require uniform frequency and time intervals. Examples include distribution of electrical power and communications systems that depend on time-division multiplexing, since both of these systems depend on a uniform frequency and a constant value for time interval.

The number of applications that are affected by the current realization of UTC that includes leap seconds is likely to increase significantly as more and more systems are based on digital realizations of frequency and time interval. The diversity in *ad-hoc* solutions is likely to increase in the future as requirements for stable times and time intervals increase, and is affecting the fundamental purpose of UTC, which was to provide a universal time scale that could support many diverse applications.

The presentation will review all these cases and delineate the possible way forward.

References

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[4] Bulletin A, published at https://ww.iers.org