                          RTP and Leap Seconds

Abstract

   This document discusses issues that arise when RTP sessions span
   Coordinated Universal Time (UTC) leap seconds. It updates RFC 3550
   by describing how RTP senders and receivers should behave in the
   presence of leap seconds.

Status of This Memo

   This is an Internet Standards Track document.

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   Internet Engineering Steering Group (IESG). Further information on
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1. Introduction

   In some media networking applications, RTP streams are referenced to
   a wall-clock time (absolute date and time). This is accomplished
   through use of the NTP timestamp field in the sender report (SR) to
   create a mapping between RTP timestamps and the wall clock. When a
   wall-clock reference is used, the playout time for RTP packets is
   referenced to the wall clock. Smooth and continuous media playout
   requires a smooth and continuous time base. The time base used by
   the wall clock may include leap seconds that are not rendered
   smoothly.

   This document updates RFC 3550 [1] by providing recommendations for
   smoothly rendering streamed media referenced to common wall clocks
   that do not have smooth or continuous behavior in the presence of
   leap seconds.

2. Terminology

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
   document are to be interpreted as described in RFC 2119 [2] and
   indicate requirement levels for compliant implementations.

3. Leap Seconds

   The world's scientific time standard is International Atomic Time
   (TAI), which is based on vibrations of cesium atoms in an atomic
   clock. The world's civil time is based on the rotation of the Earth.

In 1972, the civil time standard, Coordinated Universal Time (UTC), was redefined in terms of TAI and the concept of leap seconds was introduced to allow UTC to remain synchronized with the rotation of the Earth.

Leap seconds are scheduled by the International Earth Rotation and Reference Systems Service. Leap seconds may be scheduled at the last day of any month but are preferentially scheduled for December and June and secondarily March and September [6]. Because Earth's rotation is unpredictable, leap seconds are typically not scheduled more than six months in advance.

Leap seconds do not respect local time and always occur at the end of the UTC day. Leap seconds can be scheduled to either add or remove a second from the day. A leap second that adds an extra second is known as a positive leap second. A leap second that skips a second is known as a negative leap second.

Since their introduction in 1972, all leap seconds have been scheduled in June or December, and they have all been positive.

NOTE: The ITU is studying a proposal that could eventually eliminate leap seconds from UTC. As of January 2012, this proposal is expected to be decided no earlier than 2015 [7].

3.1. UTC Behavior during a Positive Leap Second

UTC clocks feature a 61st second at the end of the day when a positive leap second is scheduled. The leap second is designated "23h 59m 60s".

3.2. NTP Behavior during a Positive Leap Second

Under NTP [8], a leap second is inserted at the beginning of the last second of the day. This results in the clock freezing or slowing for one second immediately prior to the last second of the affected day. This results in the last second of the day having a real-time duration of two seconds. Timestamp accuracy is compromised during this period because the clock's rate is not well defined.

3.3. POSIX Behavior during a Positive Leap Second

The POSIX (Portable Operating System Interface) standard [3] requires that leap seconds be omitted from reported time. All days are defined as having 86,400 seconds, but the timebase is defined to be UTC, a leap-second-bearing reference. Implementors of POSIX systems are offered considerable latitude by the standard as to how to map POSIX time to UTC.

In many systems, leap seconds are accommodated by repeating the last
second of the day. A timestamp within the last second of the day is
therefore ambiguous in that it can refer to a moment in time in
either of the last two seconds of a day containing a leap second.

Other systems use the same technique used by NTP, freezing or slowing
for one second immediately prior to the last second of the affected
day.

In some cases, leap seconds are accommodated by warping time [5] [4];
that is, the length of the second in the vicinity of a leap second is
slightly altered.

3.4. Example of Leap-Second Behaviors

Table 1 illustrates the positive leap second that occurred June 30,
2012 when the offset between TAI and UTC changed from 34 to 35
seconds. The first column shows RTP timestamps for an 8 kHz audio
stream. The second column shows the TAI reference. The following
columns show behavior for the leap-second-bearing wall clocks
described above. Time values are shown at half-second intervals.

RTP	TAI	UTC	POSIX	NTP
8000	00:00:32.500	23:59:58.500	23:59:58.500	23:59:58.500
12000	00:00:33.000	23:59:59.000	23:59:59.000	23:59:59.000
16000	00:00:33.500	23:59:59.500	23:59:59.500	23:59:59.500
20000	00:00:34.000	23:59:60.000	23:59:59.000	00:00:00.000
24000	00:00:34.500	23:59:60.500	23:59:59.500	00:00:00.000
28000	00:00:35.000	00:00:00.000	00:00:00.000	00:00:00.000
32000	00:00:35.500	00:00:00.500	00:00:00.500	00:00:00.500

Table 1: Positive Leap-Second Behavior

NOTE: Some NTP implementations do not entirely freeze the clock while
the leap second is inserted. Successive calls to retrieve system
time return infinitesimally larger (e.g., 1 microsecond or 1
nanosecond larger) time values. This behavior is designed to satisfy
assumptions applications may make that time increases monotonically.
This behavior occurs in the least-significant bits of the time value
and so is not typically visible in the human-readable format shown in
the table.

NOTE: POSIX implementations vary. The implementation shown here
repeats the last second of the affected day. Other implementations
mirror NTP behavior or alter the length of a second in the vicinity
of the leap second.

4. Receiver Behavior during a Leap Second

Timestamps generated during a leap second may be ambiguous or
interpreted differently by a sender and receiver or interpreted
differently by different receivers.

Without prior knowledge of the leap-second schedule, NTP servers and
clients may become offset by exactly one second with respect to their
UTC reference. This potential discrepancy begins when a leap second
occurs and ends when all participants receive a time update from a
server or peer. Depending on the system implementation, the offset
can last anywhere from a few seconds to a few days. A long-lived
discrepancy can be particularly disruptive to operation of NTP-
referenced RTP streams.

These discrepancies, depending on direction, may cause receivers to
think they are receiving RTP packets after they should be played or
to attempt to buffer received data an additional second before
playing it. Either situation can cause an interruption in playback.
Some receivers may automatically recognize an unexpected offset and
resynchronize to the stream to accommodate it. Once the offset is
resolved, such receivers may need to resynchronize again.

5. Recommendations

Senders and receivers that are not referenced to a wall clock are not
affected by issues associated with leap seconds, and no special
accommodation is required.

RTP implementation using a wall-clock reference is simplified by
using a clock with a timescale that does not include leap seconds.
IEEE 1588 [9], GPS [10], and other systems that use a TAI [11]
reference do not include leap seconds. NTP time, operating system
clocks, and other systems using a UTC reference include leap seconds.

Note that some TAI-based systems such as IEEE 1588 and GPS, in
addition to the TAI reference clock, deliver TAI to UTC mapping
information. By combining the delivered TAI reference clock and the
mapping information, some receivers of these systems are able to
synthesize a leap-second-bearing UTC reference clock. For the
purposes of this document, it is important to recognize that it is
the timescale used, not the delivery mechanism that determines
whether a reference clock is leap-second bearing.

Reference clock type	Examples	Accommodation
None	Self clocking	None needed
Non-leap-second-bearing	IEEE 1588, GPS, TAI	None needed
Leap-second-bearing	NTP	Recommended

Table 2: Recommendations Summary

All participants generating or consuming timestamps associated with a leap-second-bearing reference MUST recognize leap seconds and SHOULD have a working communications channel to receive notifications of leap-second scheduling. A working communication channel includes a protocol means of notifying clocks of an impending leap second such as the Leap Indicator in the NTP header [8] and also a means for top-tier clocks to receive leap-second schedule information published by the International Earth Rotation and Reference Systems Service [12].

Such a communications channel may not be available on all networks. For security or other reasons, leap-second schedules may be configured manually for some networks or clocks. When a device does not reliably receive leap-second scheduling information, failures as described in Section 4 may occur.

Because of the timestamp ambiguity that positive leap seconds can introduce and the inconsistent manner in which different systems accommodate positive leap seconds, generating or using NTP timestamps during the entire last second of a day on which a positive leap second has been scheduled SHOULD be avoided. Note that the period to be avoided has a real-time duration of two seconds. In the Table 1 example, the region to be avoided is indicated by RTP timestamps 12000 through 28000

Negative leap seconds do not introduce timestamp ambiguity or other complications. No special treatment is needed to avoid ambiguity with respect to RTP timestamps in the presence of a negative leap second.

POSIX clocks that use a warping technique to accommodate leap seconds (e.g., [4] [5]) are not a good choice for an interoperable timestamp reference and SHOULD not be used to timestamp RTP streams.

5.1. Sender Reports

In order to avoid generating or using NTP timestamps during positive leap seconds, RTP senders and receivers need to avoid sending or using sender reports to synchronize their clocks in the vicinity of a

leap second and instead rely on their internal clocks to maintain
synchronization until the leap second has passed.

RTP Senders using a leap-second-bearing reference for timestamps
SHOULD NOT generate sender reports containing an originating NTP
timestamp in the vicinity of a positive leap second. To maintain a
consistent RTCP schedule and avoid the risk of unintentional
timeouts, such senders MAY send receiver reports in place of sender
reports in the vicinity of the leap second.

For the purpose of suspending sender reports in the vicinity of a
leap second, senders MAY assume that a positive leap second occurs at
the end of the last day of every month.

Receivers consuming leap-second-bearing timestamps SHOULD ignore
timestamps in any sender reports generated in the vicinity of a
positive leap second.

For the purpose of ignoring sender reports in the vicinity of a leap
second, receivers MAY assume that a positive leap second occurs at
the end of the last day of every month.

5.2. RTP Packet Playout

Receivers consuming leap-second-bearing timestamps SHOULD take both
positive and negative leap seconds in the reference into account to
determine the playout time based on RTP timestamps for data in RTP
packets.

6. Security Considerations

RTP streams using a wall-clock reference as discussed here present an
additional attack vector compared to self-clocking streams.
Manipulation of the wall clock at either the sender or receiver can
potentially disrupt streaming.

For an RTP stream operating to a leap-second-bearing reference to
operate reliably across a leap second, the sender and receiver must
both be aware of the leap second. It is possible to disrupt a stream
by blocking or delaying leap second notification to one of the
participants. Streaming can be similarly affected if one of the
participants can be tricked into believing a leap second has been
scheduled where there is not one. These vulnerabilities are present
in RFC 3550 [1] and these new recommendations neither heighten nor
diminish them. Integrity of the leap-second schedule is the
responsibility of the operating system and time distribution
mechanism, both of which are outside the scope of RFC 3550 [1] and
these recommendations.

7. Acknowledgements

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8. References

8.1. Normative References

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