SGNOG7 @One Farrer Hotel & Spa

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Computer System Time and Network Time Synchronization

How To Handle Leap Seconds

July 12th, 2019

Junko Nozaki

Seiko Solutions Inc.

Seiko as Time Solution Provider

The origin of Seiko as time solution provider dates back to 1881 when K. Hattori started a clock shop.
We have more than 130 years of history providing precise time solution with cutting edge products such as clock, watch and electronic.

Company	SEIKO SOLUTIONS INC.
Established	December 13, 2012
Business Starting Date	April 1, 2013
Location	1-8 Nakase, Mihama-ku, Chiba City
Capital	500 million yen
Stockholder	100% by Seiko Holdings Corporation
Employee	Approx. 700
CEO	President Mr. Jun Sekine

Head Office in Japan

Accurate time and frequency are the foundation of information and communications, as well as the foundation of academic, industrial, and safe social life.

Tetsuya Ido
Director of NICT Space-Time Standards Laboratory
(NICT: Japan **N**ational Institute of **I**nformation and **C**ommunications **T**echnology)

正確な時刻と周波数は、情報通信の基盤であるとともに、学術、産業、安心安全な社会生活の基盤です。
http://www2.nict.go.jp/sts/lab/index.html

What is Computer Time ?

Question :

What is the definition of time to computers?

We start from this point???

Yes, we need some abstraction to explore!

(POSIX.1 A.4.16, ITU-T G.810, IEEE1588-2008 etc.)

Answer :

A continuously and truly monotonically increasing value

that does not jump or regress.

What is Computer Time?

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It is measured by the elapsed time from Epoch

Epoch

- Starting point to measure the elapsed time
- 12:00:00 am of January 1st, 1970 in UTC

Elapsed time

- SI second is used to measure elapsed time from Epoch

SI second

- Physical quantity determined by a certain change time of cesium atom

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In fact, computers (i.e. OS) do NOT comprehend any calendar as we do.

Q: What is a calendar?

A: Something we use like "12th of July, 2019."

Q: What calendar are we currently using?

A: Gregorian Calendar.

What is Computer Time?

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But my computer tells me the correct date and time.

```
root@ubuntu:~$ date
Fri Jul 12 10:45:44 SGT 2019
```

It seems it understands our calendar. Doesn't it?

Answer:

It is because of the smart one (tz database) who translates computer time to the calendar we are familiar with.

What is Computer Time?

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OS recognizes the time as

```
root@ubuntu:~$ date +%s
1562899544
```

Which tells us

Friday 12th of July, 2019 10:45:44 SGT

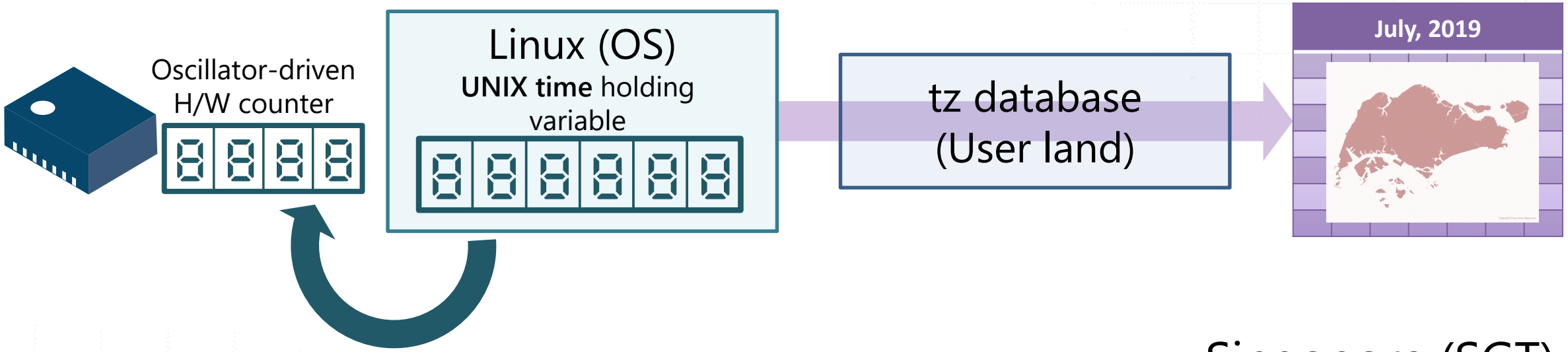
= 1562899544 (s)

(1,562,899,544 seconds have been passed since 1st of January, 1970 12:00:00 am (UTC))

We call this UNIX time (POSIX time) as it is the elapsed time from Epoch.

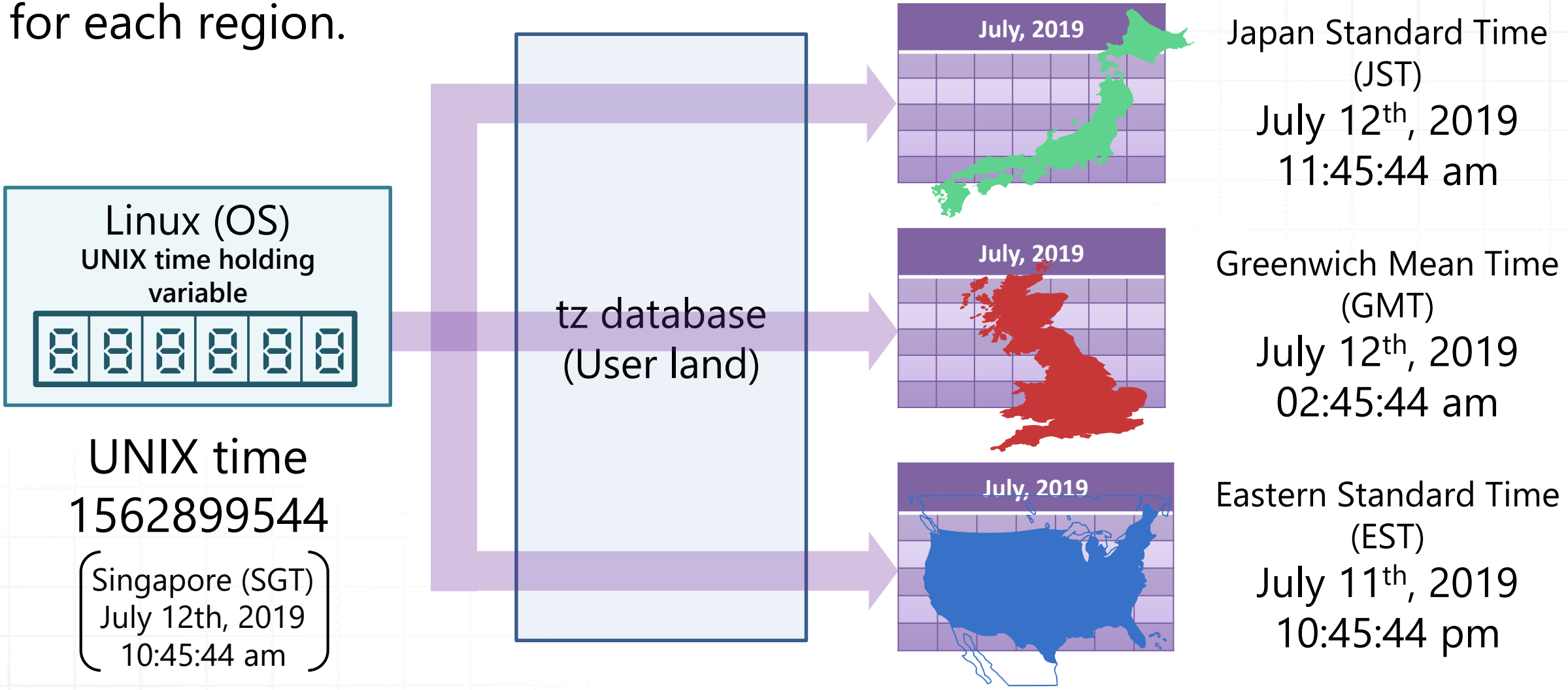
TZ Database (1)

- Most OS from UNIX family understand calendar via tz database.
- It translates UNIX time to calendar time.



TZ Database (2)

TZ database, as its primary job, translates UNIX time into standard time for each region.



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TZ Database can handle Daylight Saving Time correctly.

UNIX time	EST
1520751598	Sun Feb 11, 2018 01:59:58 am (EST)
1520751599	Sun Feb 11, 2018 01:59:59 am (EST)
1520751600	Sun Feb 11, 2018 03:00:00 am (EDT)
1520751601	Sun Feb 11, 2018 03:00:01 am (EDT)
:	:

:	:
1541311198	Sun Nov 4, 2018 01:59:58 am (EDT)
1541311199	Sun Nov 4, 2018 01:59:59 am (EDT)
1541311200	Sun Nov 4, 2018 01:00:00 am (EST)
1541311201	Sun Nov 4, 2018 01:00:01 am (EST)
:	:

UNIX time retains continuity without a jump!

Leap Second and UNIX time

Question:

Isn’t Leap Second the same as Daylight Saving Time?

Answer:

TZ database doesn’t deal with leap second.

Leap second is directly handled by OS.

So, it DOES have an impact on UNIX time continuity.

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Question:

Calculate below as UNIX time

July 1, 12:00:00 am UTC 1972

Answer : 78796800

- 1970 is not a leap year ⇒ 31536000 s
  (86400 s x 365 d)
- 1971 is not a leap year ⇒ 31536000 s
- 1st of January to 1st of July in 1972 ⇒ 15724800 s
  (86400 s x (31 d x 3 m+30 d x 2 + 29 d))
- 31536000×2＋15724800 ＝ 78796800

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June 30,1972 was the first day with a leap second

UNIX time	UTC
78796798	Fri Jun 30, 1972 11:59:58 pm
78796799	Fri Jun 30, 1972 11:59:59 pm
????	Fri Jun 30, 1972 11:59:60 pm
78796800	Fri Jul 1, 1972 12:00:00 am
78796801	Fri Jul 1, 1972 12:00:01 am

What should we do when there is no appropriate integer to put in “????” ?

A) Repeat “78796799”
B) Adjust by changing the rate of increase in value beforehand

However A) cannot retain time continuity.

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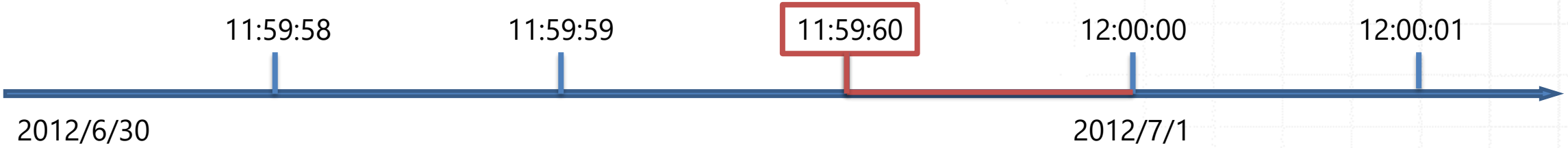
Key Features of leap second

- Cannot avoid since our daily life is based on UTC
- Go into effect irregularly
  - Future implementation date is unknown
  - Out of scope of UNIX time calculation
- Contrary to the definition of computer time continuity
  - Discontinuity directly affects time difference calculation
  - Unprepared computer programs get affected

Pre-testing is important for leap second handling!

What Happened with the Extra Second in 2012

A leap second “11:59:60” inserted between “11:59:59” on June 30 and “12:00:00” on July 1 in UTC



What happened?

- A glitch in the Linux kernel caused problems for various services, such as Reddit, Mozilla, Yelp, Foursquare, LinkedIn and etc.
- Passengers of Qantas and Virgin Australia were required manual check-ins causing flights delays.

Even the latest kernel versions couldn’t prevent system failure.

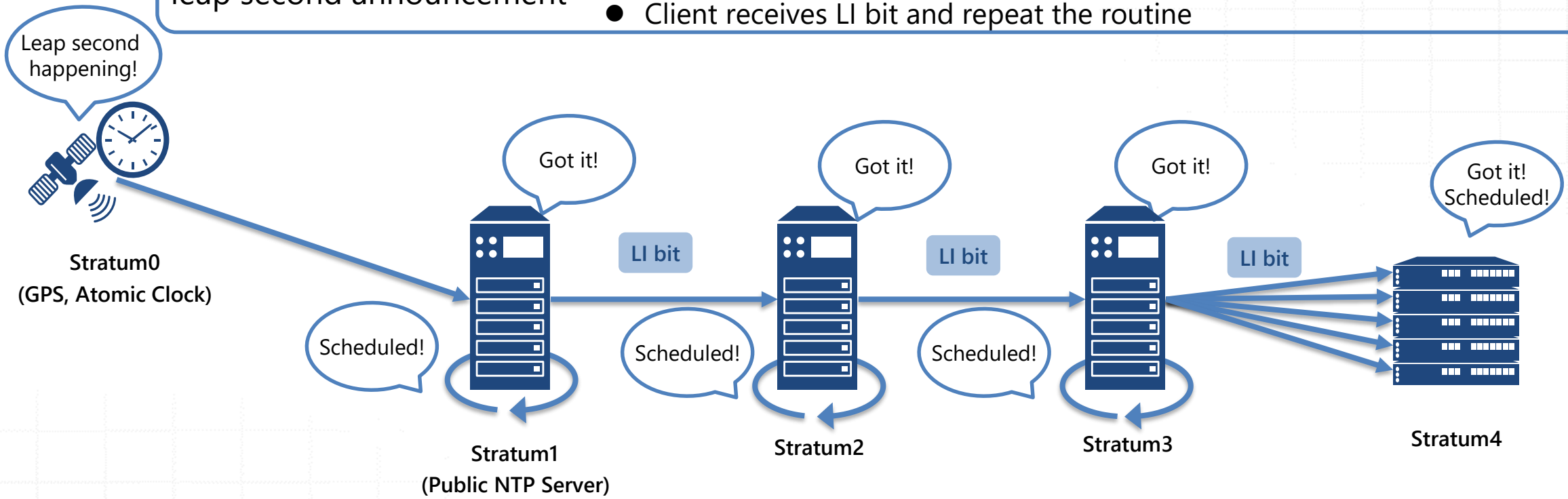
https://en.wikipedia.org/wiki/Leap_second / https://www.wired.com/2012/07/leap-second-glitch-explained/ / https://www.theregister.co.uk/2015/01/09/leap_second_bug_linux_hysteria/

How to Handle Leap Second without Time Server (Linux System)

NTP daemon : transfers leap second announcement / Linux OS : handles leap second

When NTP daemon detects leap second announcement

- Schedules Linux OS to handle it on designated moment
- Passes the announcement on to its clients as "**Leap Indicator (LI bit)**"
- Client receives LI bit and repeat the routine



What's the problem?

- Repeating / skipping time may cause system failure
- Requires **all the computers in the system to support LI bit** to realize time synchronization of the whole system

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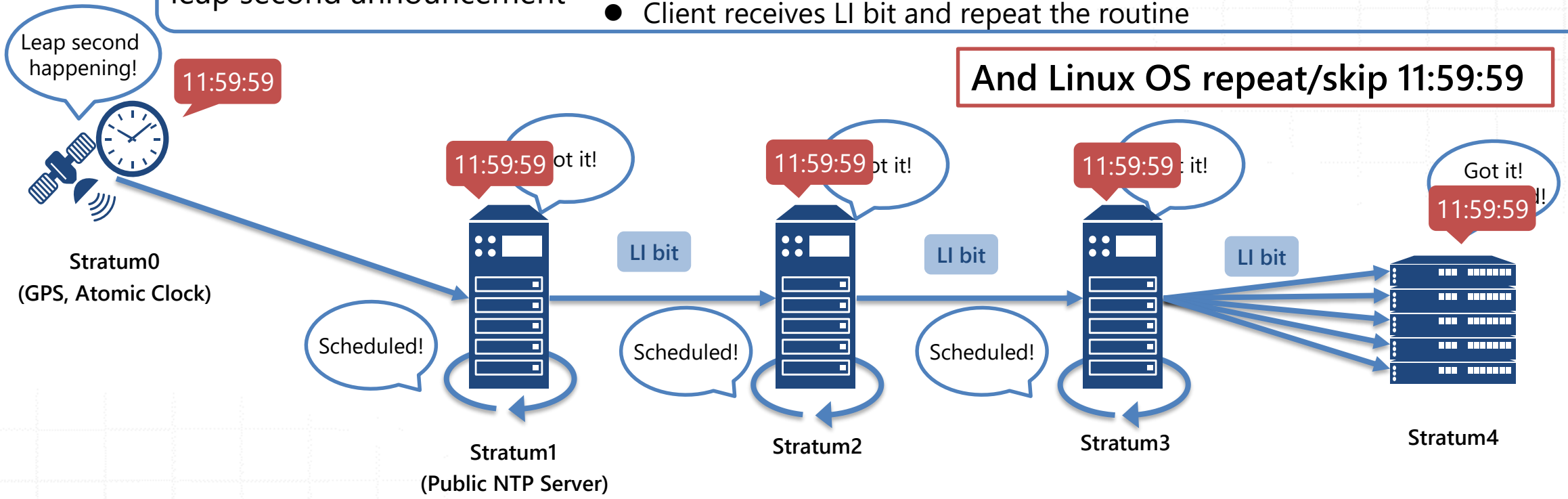
And Linux OS repeat/skip 11:59:59



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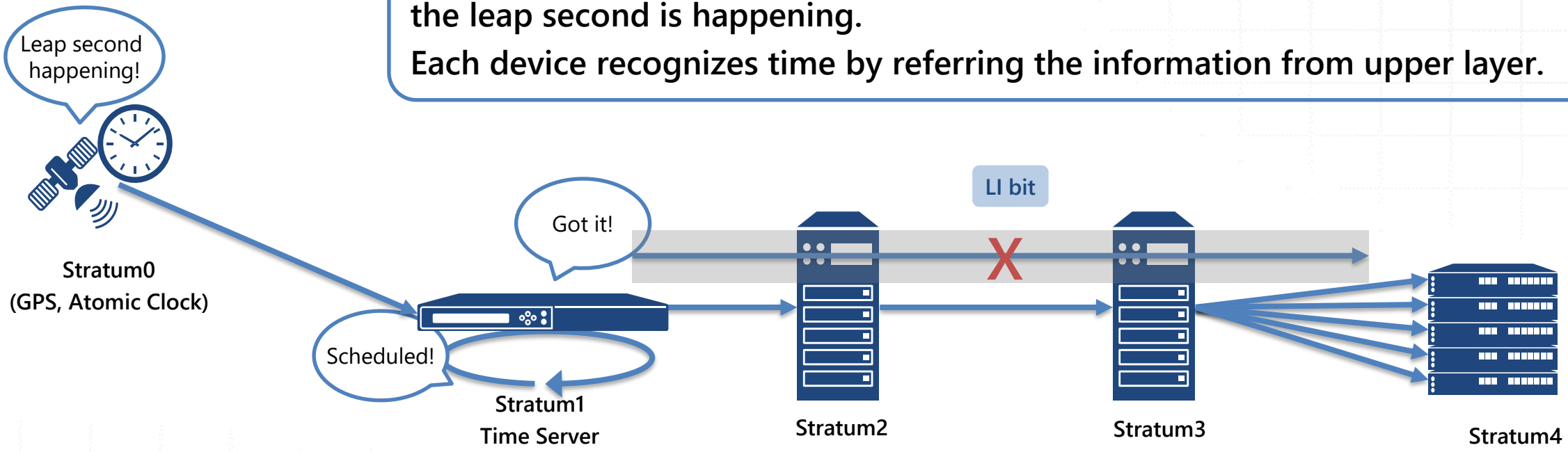
How to Handle Leap Second with Time Server

With Time Server as your own Stratum1 server, leap second handling is complete within it.

The LI bit is not advertised to lower NTP clients, so only the time server knows the leap second is happening.

Each device recognizes time by referring the information from upper layer.



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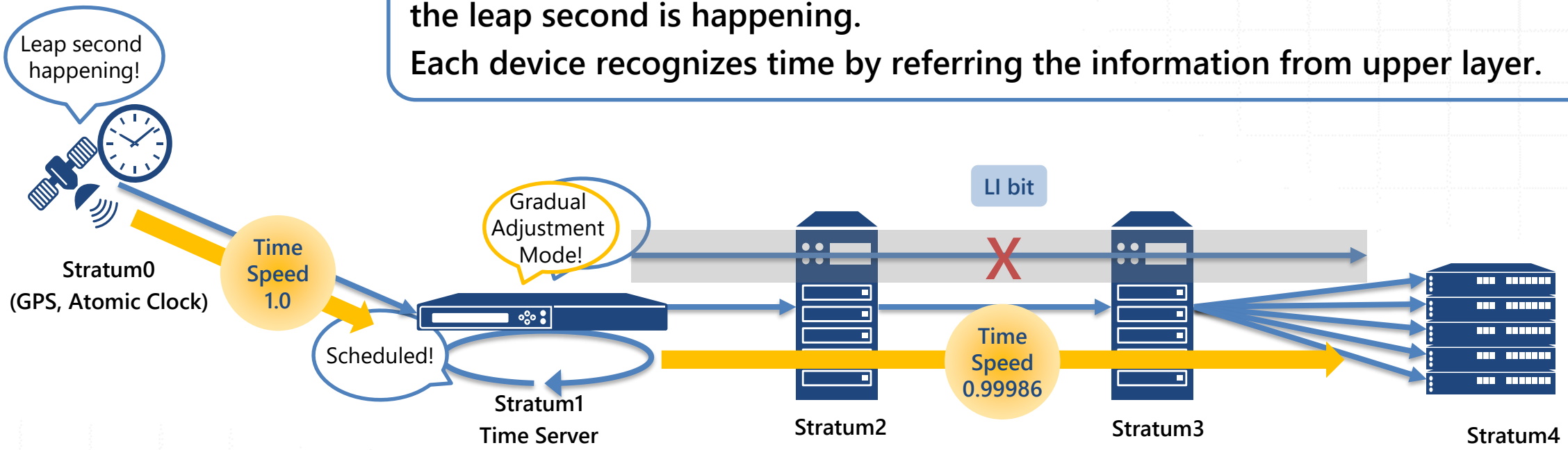


Time Server with "**Gradual Adjustment Mode**" is recommended in the following situations.

- The system needs to hold time continuity (no jumping and repeating)
- The system includes devices which doesn't support Leap second indicator

Set to Gradual Adjustment Mode, divided leap second starts to be inserted 2 hours before it really occurs.

Case Study : Tokyo Stock Exchange, Inc,

Tokyo Stock Exchange conducted a pre-test to confirm system stability throughout the upcoming leap second of July, 2015.

TSE Market Center

What were done for handling

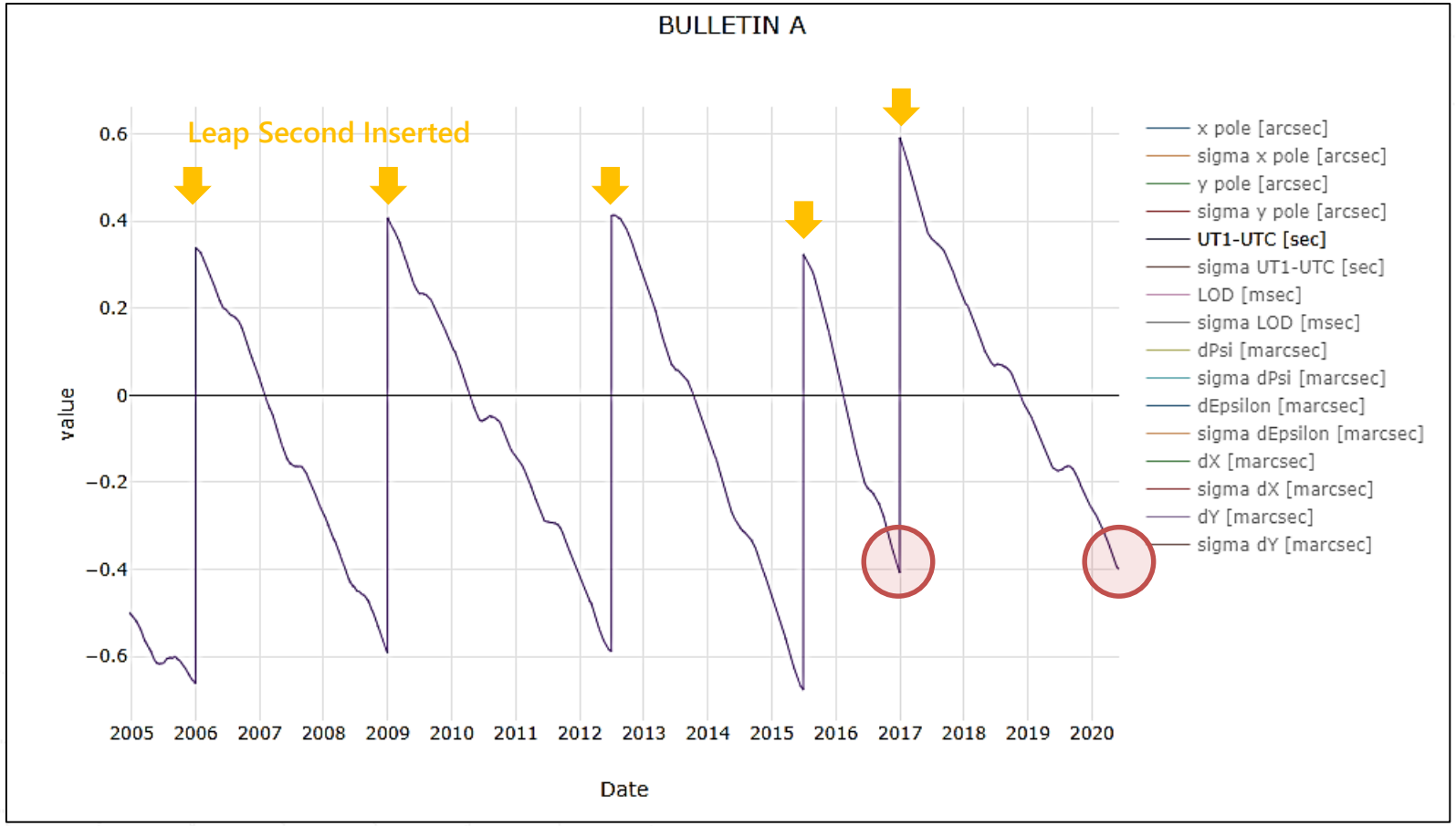
- **Prepared the environment with simulated leap second** occurring once a day with private NTP server.
- Checked that any failure caused by leap second would not occur in the on-premise environment.
- **The verification process took six months** to complete the detailed test items.

Tokyo Stock Exchange also notified relevant parties of the points of concern in advance.

> The Tokyo Stock Exchange, which starts trading at 9 AM, will insert dispersed 1 second in 2 hours from 7 AM (7200 seconds) to avoid the sudden insertion of the whole 1 second. In March, the TSE notified relevant companies of a note of caution, as orders are flowing in 1/1000 second increments, although it is not expected to have a major impact on the market.
>
> **-Nihon Keizai Shimbun (Nikkei), May 9, 2015**

Leap Second Prediction

Leap second is inserted when time gap reaches certain level.



July, 2019
No occurrence

January, 2020
IERS time gap prediction
: about-0.3 second
There will be no insertions
(Announced on July 4th)

July, 2020
IERS Time gap prediction
: same level as the previous leap second of January 2017
Most probable?!

IERS, "Earth orientation data",
https://www.iers.org/IERS/EN/DataProducts/EarthOrientationData/eop.html

Summary

- We cannot avoid leap second since our business and daily life is based on UTC
- Leap second may affect unprepared computer programs causing serious system failure
- Pre-testing is essential to secure system stability

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