National time scale generation and distributions

Outline
1. NIMT time keeping and timescale generations
2. GNSS time transfers
3. NIMT time disseminations
4. Future plans
5. Conclusions

National positioning and timing infrastructure
- GNSS CORS
- Precise positioning services
- GNSS timing station by NIMT
- Timing services

NIMT time and frequency laboratory
- Realise and disseminate the SI second; UTC(NIMT)
- Contribute to the BIPM atomic time scales; International Atomic Time (TAI)
- Distributions to the public are through:
  - Calibration services: frequency standards i.e. caesium and rubidium clocks
  - Internet time services: network time protocol (NTP) and precise time protocol (PTP)
  - Fiber links: white rabbit
  - GNSS national permanent ground network: observations and correction message
- Future research works on next generation of atomic clocks based on ytterbium (Yb+) ion trap

https://www.bipm.org/en/si-base-units/second

1 s = \frac{\Delta v_{Cs}}{9 192 631 770}

1 Hz = \frac{\Delta v_{Cs}}{9 192 631 770}

1 second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom

https://www.bipm.org/en/si-base-units/second

Thayathip Thongtan
United Nations/Philippines Workshop on the Applications of Global Navigation Satellite Systems
25 April 2024, Manila, Philippines
1. NIMT time keeping

International time keeping scheme

UTC - UTC(k) is published in BIPM circular T

- BIPM
  - Free atomic time (EAL)
  - International Atomic Time (TAI)
  - Coordinated Universal Time (UTC)

- Time link

- National timing institutes
  - ~450 atomic clocks
  - ~85 laboratories
  - UTC(k)

- Time link

- UTC - UTC(k)
  - NIMT
  - UTC(NIMT)

- Steering
  - ∑

- UT1-UTC < 0.9 s
  - Leap second

- IERS
  - UT1

- Σ

- Caesium frequency standard
- Hydrogen maser

- ~10 Primary frequency standards (PFS)

- IERS

- Σ

- UT1 - UTC < 0.9 s
  - Leap second

- TAI – UTC = 37 second
  - (31 December 2016)

- 22nd CCTF meeting – hot issues are on:
  - leap second in UTC,
  - roadmap towards redefinitions,
  - promotions of UTC and GNSS,
  - international time keeping

BIPM International Bureau of Weights and Measures
IERS International Earth Rotation Services
NIMT National Institute of Metrology Thailand
1. NIMT time keeping

**International time keeping scheme**

- **BIPM**
  - Free atomic time (EAL)
  - International Atomic Time (TAI)
  - Coordinated Universal Time (UTC)

- **IERS**
  - UT1

- **NIMT**
  - UTC(NIMT)

**NIMT contribution laboratories equipment:**
- Two-way time and frequency transfer is via communication satellites
- **GNSS equipment**

UTC - UTC(k) is published in BIPM circular T

Geographical distribution of the laboratories that contribute to TAI and time transfer equipment (2023)

**National timing institutes**
- ~450 atomic clocks
- ~85 laboratories
- UTC(k)

- ~10 Primary frequency standards (PFS)

**TAI contribution laboratories equipment:**
- Two-way time and frequency transfer is via communication satellites
- **GNSS equipment**

1. NIMT time keeping

National time keeping scheme

- Caesium frequency standard 5071A option 001
  - Cs2
- Caesium frequency standard 5071A option 001
  - Cs3
- Caesium frequency standard 5071A option 001
  - Cs4
- Active hydrogen maser
  - CH1 - 95
  - HM

UTC(NIMT) 1 pps

Time interval counter

1 pps 5 MHz

Microphase stepper

HROG - 5

1 pps

Frequency distribution amplifier TSC4036B

UTC(NIMT) 10 MHz

Pulse distribution 6602

1 pps

Switch

1 pps 10 MHz

Clock data

UTC - UTC(k) is published in BIPM circular T

Measured clock data: nimt2401.clk

Cs2 – Cs3 = 14150.7 ns
Cs2 – Cs4 = 35919.8 ns
Cs2 – HM = 35919.8 ns

2. GNSS time transfers

One way GNSS measurements

\[ P = c \left( t_{\text{rec}} - t_{\text{sat}} \right) + c(dt - dT) \]

\[ = \rho + c(dt - dT) \]

\( P \) = pseudorange measurement (meter)
\( \rho \) = true range (meter)
\( c \) = speed of light (meter/second)
\( dt - dT \) = receiver clock offset (second)

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#### Example

<table>
<thead>
<tr>
<th>Channel</th>
<th>Transmitted time (second)</th>
<th>Received time (second)</th>
<th>Travel time (ms)</th>
<th>Pseudorange (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>500</td>
<td>500.067</td>
<td>67</td>
<td>20,100</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
<td>500.068</td>
<td>68</td>
<td>20,400</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>500.077</td>
<td>77</td>
<td>23,100</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>500.095</td>
<td>95</td>
<td>28,500</td>
</tr>
</tbody>
</table>
2. GNSS time transfers

GNSS common – view measurements

• Two or more receivers observe a single physical source at the same time
• Each receiver measures the arrival time of the signal from the source with respect to its local clock

\[ T_1 = t_{rec_1} - \text{GPST} \quad \ldots \ldots \quad (1) \]
\[ T_2 = t_{rec_2} - \text{GPST} \quad \ldots \ldots \quad (2) \]

\[ T_1 - T_2 = \text{time differences between two time scales (from two different clocks)} \]
2. GNSS time transfers

GNSS common – view measurements

Satellite time scale
GPST

UTC-GNSS Time

Nanosseconds

Modified Julian Date

Receiver 1

Clock $T_1$

$trec_1$

Receiver 2

Clock $T_2$

$trec_2$

https://webtai.bipm.org/database/canvas_gnss.html?scale=gnss&mjd1=55559&mjd2=60399
2. GNSS time transfers

**GNSS common – view measurements and common-clocks**

- Satellite time scale: GPST

**CGGTTS**
- `raw_gnss_data/`
  - `xxxxyymm.gnss` are the GPS CA raw data
  - `xxxxyymm.p3` are the GPS P1/P2 (ionosphere-free combination, P3)
- `corrected_gnss_data/`
  - `xxxxyymm.gnss-cor` are the GPS CA corrected data
  - `xxxxyymm.p3-cor` are the GPS P1/P2 (ionosphere-free combination, P3)

**PPP**
- `/ppp/xxxxyymm.gpi` contain monthly PPP solution

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**Satellite time scale**

**GPST**

**Receivers**

- **Receiver 1**
  - MTTI
  - Mesit GTR55
  - trec\_1
  - NOV850
  - NONE

- **Receiver 2**
  - MTME
  - Mesit GTR55
  - trec\_2
  - NOV850
  - NONE

- **Receiver 3**
  - MTTN
  - PolaRx5TR
  - trec\_3
  - SEPCHOKE\_B3E6\_SPKE

- **Receiver 4**
  - xxxx
  - Receiver to be calibrated
  - trec\_4

**Clocks**

- UTC(NIMT)

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2. GNSS time transfers

GNSS all – in – view measurements comparisons at NIMT

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2. GNSS time transfers

GNSS all-in-view measurements comparisons between PTB and NIMT
- Shows UTC(NIMT) – UTC(PTB)
- Two PPP results files based on GPS observations
- August 2023 from MJD 60152 – 60185 (40 days)

https://webtai.bipm.org/ftp/pub/tai/timelinks/lkc/2308/nimtptb/lnk/
2. GNSS time transfers

GNSS all – in – view measurements comparisons between PTB and NIMT
- Shows UTC(NIMT – UTC(PTB)
- Two dual frequency, all-in-view GPS observations
- August 2023 from MJD 60152 – 60185 (40 days)

https://webtai.bipm.org/ftp/pub/tai/timelinks/lkc/2308/nimtptb/lnk/
3. NIMT time disseminations

Time and frequency calibration services

- Internet time services for time synchronisation for computers.
  - IP dedicated for NTP servers are:
    time1.nimt.or.th
    time2.nimt.or.th
    time3.nimt.or.th
    time4.nimt.or.th
    time5.nimt.or.th
- Precise time protocol are installed
- White rabbit project

<table>
<thead>
<tr>
<th>Measurand</th>
<th>Method</th>
<th>Range</th>
<th>CMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>General frequency source</td>
<td>Direct measurement</td>
<td>1 Hz – 1 kHz</td>
<td>3.6 x 10^{-9}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;1 kHz – 10 kHz</td>
<td>1.2 x 10^{-10}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;10 kHz – 255 MHz</td>
<td>8.6 x 10^{-12}</td>
</tr>
<tr>
<td>Local frequency standard</td>
<td>Phase measurement</td>
<td>5 MHz and 10 MHz</td>
<td>1.0 x 10^{-13}</td>
</tr>
<tr>
<td>Time interval source</td>
<td>Direct measurement</td>
<td>100 ns – 10000 s</td>
<td>2 ns</td>
</tr>
<tr>
<td>Remote frequency standard</td>
<td>GPS common-view</td>
<td>5 MHz and 10 MHz</td>
<td>2.1 x 10^{-13}</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Digital time services</th>
<th>Accuracy level (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTP farm</td>
<td>10^{-3}</td>
</tr>
<tr>
<td>PTP</td>
<td>10^{-6}</td>
</tr>
<tr>
<td>White rabbit</td>
<td>10^{-9}</td>
</tr>
</tbody>
</table>

Internet time information dissemination

- Internet time services for time synchronisation for computers.
3. NIMT time disseminations

**GNSS time dissemination:** GNSS national permanent ground network
- Positioning and timing references
- MTTH and MTTI receivers
- RINEX and RTCM format

**Services**
- RTK NRTK positioning services
- GNSS observation data
- Online processing

**Applications**
- Reference frame determinations
- Precise time information
- Surveying and mapping
- Cadastral survey
- Precision agriculture
4. Future plans

**GNSS receiver calibrations:**
- Positioning: geodetic, survey, low-cost
- Timing: timing receiver
- Velocity: speed and INS systems
- Collaborations amongst organisation working under national positioning and timing infrastructure and national quality infrastructures

**Capacity buildings:** upskills and reskils

**ISO documents for GNSS: receiver, NRTK and data centre**
- ISO 24245:2023 Space systems — GNSS receiver class codes
- ISO 17123-8:2015 measurement systems in real-time kinematic (RTK)
- ISO 24246:2022 Requirements for global navigation satellite system (GNSS) positioning augmentation centres
- ISO/TS 21176:2020 Cooperative intelligent transport systems (C-ITS) Position, velocity and time functionality in the ITS station
5. Conclusions

- NIMT maintains official time scale link to UTC using GNSS measurements for time comparisons and provide time information for Thailand; also called UTC(NIMT)
- Time comparisons based on GNSS common-view, all-in-view and precise point positioning determinations for multi-GNSS constellations and multi-frequencies
- Disseminations are through internet time protocol and calibration services
- Future plans are on national quality infrastructure and capacity building to ensure trusted PNT quality scheme through collaborations

Thank you very much for your kind attentions