A Brief History of Time (Synchronisation)

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THE MAN WHO CANNOT SUMMARIZE

IT ALL STARTED 4.53 BILLION YEARS AGO DURING THE HADEAN EON.

I HOPE YOU DON'T MIND IF I SKIP OVER THE PART WHERE THE EARTH FORMED BY ACCRETION FROM THE SOLAR NEBULA.

...AND THAT FORMED WHAT WE CALL THE MOON.

HOURS LATER

MAYBE I'LL JUST ASK SOMEONE ELSE WHAT TIME IT IS.
History
Clocks
Synchronisation
Master Clocks

- Pulse on the hour jump-syncs
- GrandMaster per city
- Master per site
- SubMaster per building
PPS

- The ultimate timing reference
- One pulse, on the second
  - Most gear offers negative delays
- Cable delay compensation
IRIG B

- Inter-Range Instrumentation Group
  - i.e. rockets, missiles
- 1 kHz signal
- Time, Day of year
10Mhz / 5Mhz

- Lab frequency references
- Usually sine wave, sometimes square
- 10Mhz current standard, 5Mhz old
“Time Code”

- SMTPE – Audio time code
- VITC – Video time code
- Used in audio, video, film production
- Accurate to sub-frame
- Bi-Phase & Tach for speed
Word Clock

- Digital audio synchronisation
- AES “Black Burst”
  - Standard AES signal, just all-zeros
NTP
Network Time Protocol

- v1 RFC958 – September 1985
- Capable of <100ns lock within a LAN
- <1ms long-term over internet
- Many high-quality public servers
An aside...
NTP Strata

• Stratum 0 – Master clock
• Stratum 1 – Directly connected to master
• Stratum 2 – Slaved to a Stratum 1
• Stratum 3 – Slaved to a Stratum 2
• ...
• Stratum 16 – Slaved to a Stratum 15
## Telco Strata

<table>
<thead>
<tr>
<th>Stratum</th>
<th>OR</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PRC</td>
<td>$10^{-11}$</td>
</tr>
<tr>
<td>2</td>
<td>SC</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>3</td>
<td>SC</td>
<td>$10^{-8}$</td>
</tr>
<tr>
<td></td>
<td>SEC</td>
<td>$5 \times 10^{-6}$</td>
</tr>
</tbody>
</table>
PTP
Precision Time Protocol

- “Replacement” for NTP
- v1 (2002) multicast LAN only
- v2 (2008) routable, only slightly better then NTP, incompatible with v1
- No serious deployment outside labs
Managing Time
Systems
Why have accurate time?

- Users complain if >10 min
- Kerberos refuses if > 5 min
- Users actually complain if > 0 min
  - “Why did this e-mail take so long”
  - “Why am I getting e-mail from the future”
- Log analysis sucks if out
  - “Out” can mean <30ms for big logs
Time Standards

• GMT – Greenwich Mean Time
• UTC – Civil standard
  • UT0 – Astronomical Time
  • UT1 – Mean Solar Time
    • UT1R – Smoothed out tides
  • UT2 – Smoothed out seasons
    • UT2R – Smoothed out tides & seasons
• TAI – Atomic time, UTC with no leap seconds
Time Zone Databases

- “tz Database” – The canonical Database
- Used by just about everybody
  - Except Microsoft
- Keep updated
  - DST changes multiple times per year
Daylight Savings

- Usually 1 hour “forward” in summer
- Lord Howe Island uses 30m
- 20m and 2h have been used
Silly Time Zones

- AU – Adelaide – UTC+9:30
- AU – Eucla – UTC+8:45
- SI – Singapore – UTC+7:20 (Historic, pre 1941)
- IR – Dublin – UTC-0:25 (Historic, pre Oct 1916)
- LR – Liberia – UTC-0:44 (Historic, pre 1972)
- LR – Liberia – UTC-0:43:08 (Historic, pre 1919)
Large Scale Distributed Timing
Local Masters

- Two or three *physical* hosts with good clocks
- Synced off:
  - Nearby Stratum 1/2 NTP (3-5 *no more*)
  - GPS
  - Caesium / Rubidium & GPS/NTP
- Consider NTP appliances
Distribution

- If > 1000 clients then distribution may be needed
- Or with older NTP appliances, > 50
- Physical hosts
- Sync with 3-5 masters *no more*
Slaves

• Sync to masters or distribution as appropriate

• 3-5 masters *no more*
NTP “Local”

- Most default NTP configs set up a local clock
- Disable on everything that’s not a master
Virtual Machines

- Virtual guests are never timing masters
- Lucky to get <5s skew over 24h
Managing Time

Applications
Time Zones

- Use the OS’ zone database
- Store everything as UTC + offset
- Store everything as local + zone
Daylight Savings

- For embedded developers *only*
- Everyone else use tz DB
- 0-2h offset, by minute or 15m
- Direction
- Day starts, day stops
- As date & day of week of month
- Hour starts, hour stops
- Remember start day > stop day in south
Leap Seconds

- Not every minute has 60 seconds
- Some have 61
- Unless you’re doing a lab experiment

IGNORE
Questions?

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