Doctor Stratum: Or How I Learned to Stop Worrying and Love the Clock

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Intro

Ever had a server wake up thinking it's January 1st, 1970?

That's not just a bad hangover — it's a recipe for broken certificates, failed logins, and confused applications. In this talk, we'll explore how Linux keeps time, from NTP and chrony to stratums, time zones, and the infamous "watch problem." Whether you're syncing with GPS, hardening security, or just trying to keep your logs honest, you'll leave knowing how to make your systems tick like clockwork — all without needing 1.21 gigawatts.

About me

- Scientific Software Scientist by day
- Linux nerd by night
- User since 2003
- https://denner.co
- President of CIALUG

Why does time matter?

Security (TLS, Kerberos)

Logging

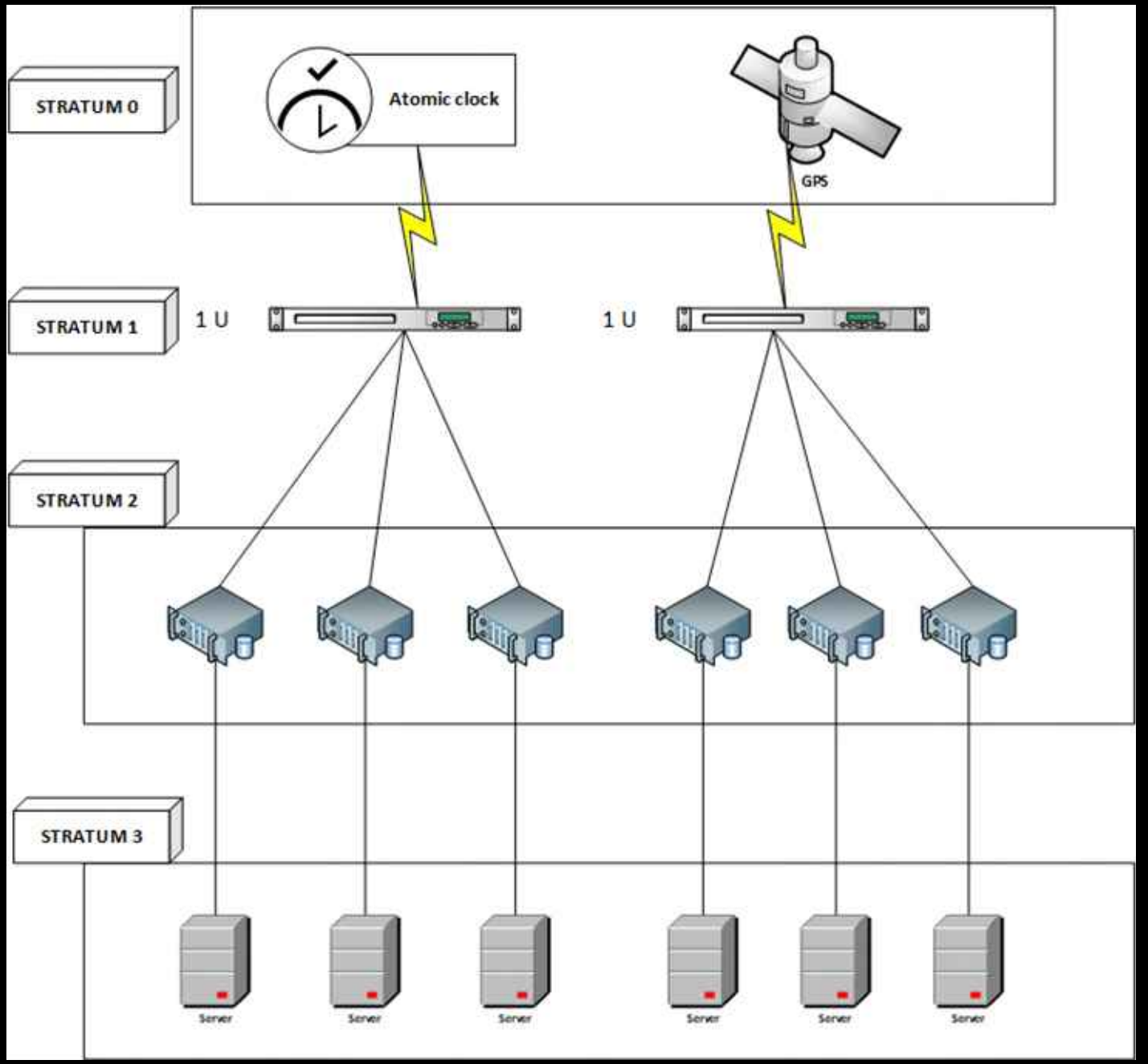
distributed systems

compliance.

Licensing

NTP fundamentals

- UTC vs TAI
- Leep Seconds
- Stratums
- 3 watch problem


STRATUM 0
Atomic clock
GPS
STRATUM 1
1 U
1 U
STRATUM 2
STRATUM 3
Server
Server
Server
Server
Server
Server

NTP fundamentals

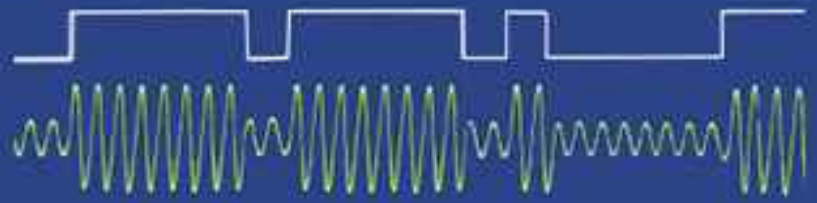
- UTC vs TAI
- Leep Seconds
- Stratums
- 3 watch problem

Segal's Law

A man with a watch knows what time it is. A man with two watches is never sure.

Time Sources

- Public
- Private
- Why need to trust
- Local
- Where to get your time?

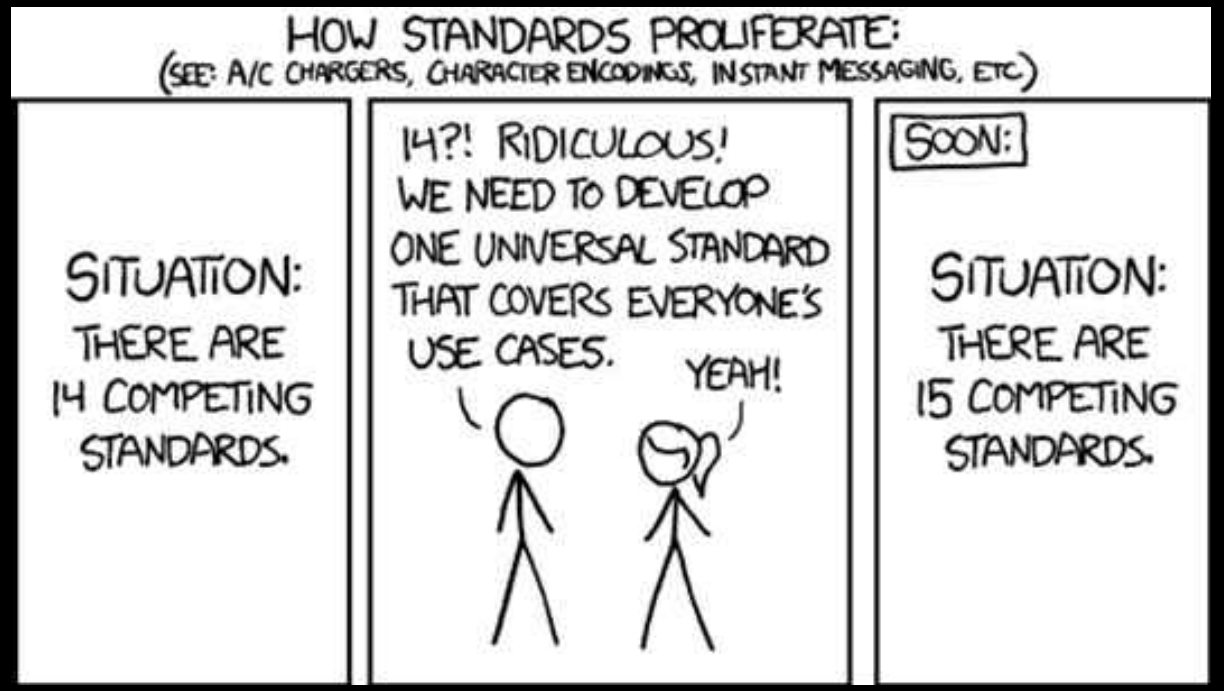


Information
GNSS Status
NTP Status
System Management
NTP Management
Ethernet Management

Information

System	
Product Name	**FC-NTP-MINI**
Firmware Version	2.0.1
Runtime	54 Day 21:03:29
Current Time (UTC)	2025/09/09 05:15:05
Management Ethernet Port	
Address Type	Static IP
IP Address	10.0.0.2
Subnet Mask	255.255.255.0
Default Gateway	10.0.0.1
MAC Address	D8:B0:4C:FF:0D:F5

How do we keep time in linux?



[xkcd: Standards]

Systemd-timesyncd

- SNTPD “Simple” client built on system
- Default on Debian, Ubuntu*, Arch
- Client only
- Lightweight
- Auto fallback
- Network aware
- Boot time correction
- “Good enough”

```
systemctl status systemd-timesyncd
```

```
● systemd-timesyncd.service - Network Time Synchronization
   Loaded: loaded (/lib/systemd/system/systemd-timesyncd.service; ena
   Active: active (running) since Fri 2018-02-23 08:55:46 UTC; 10s ag
     Docs: man:systemd-timesyncd.service(8)
 Main PID: 3744 (systemd-timesyn)
   Status: "Synchronized to time server 91.189.89.198:123 (ntp.ubuntu
    Tasks: 2 (limit: 4915)
   CGroup: /system.slice/systemd-timesyncd.service
           └─3744 /lib/systemd/systemd-timesyncd

Feb 23 08:55:46 bionic-test systemd[1]: Starting Network Time Synchro
Feb 23 08:55:46 bionic-test systemd[1]: Started Network Time Synchron
Feb 23 08:55:46 bionic-test systemd-timesyncd[3744]: Synchronized to
```

NTPD

- 1985 NTP protocol Dr David Mills
- 1990-2000 Ntpd was the standard
- 2010 A shift to chrony

```
sudo apt install ntp
```

```
$ ntpq -p
```

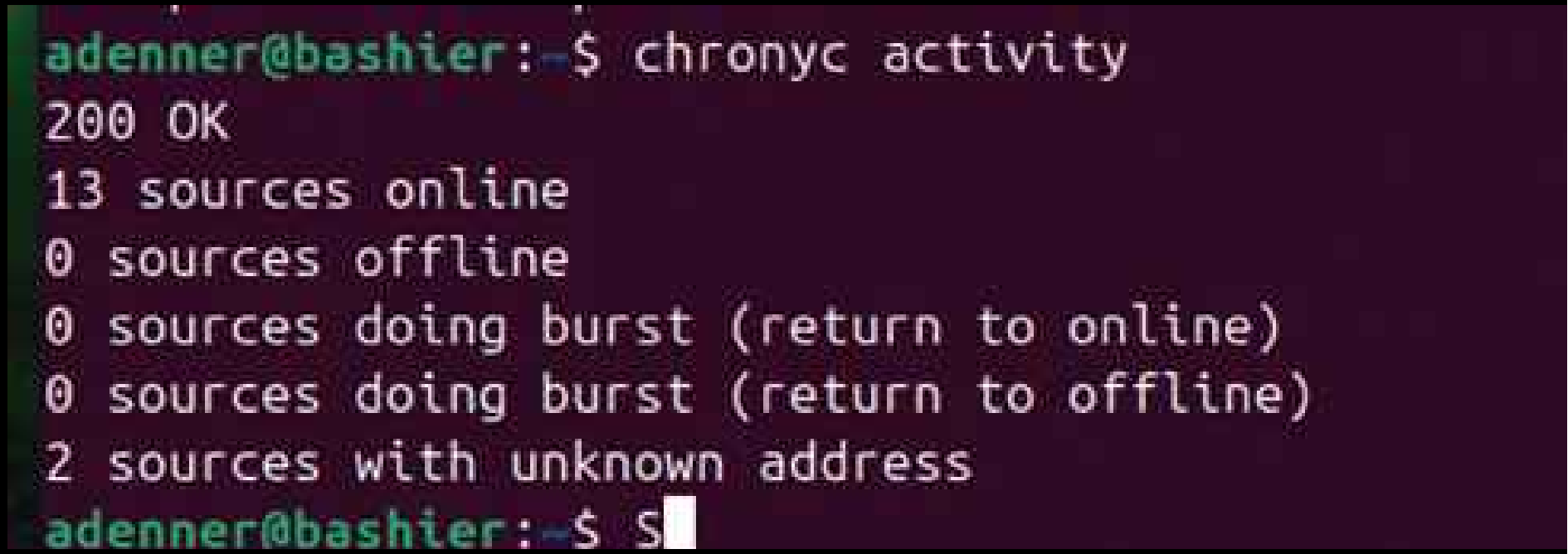
- Now:
  - Ntpd is still maintained and alive but slow development
  - Legacy and enterprise
  - Most use chrony and systemd-timesyncd

Output

```
     remote           refid      st t when poll reach   delay   offset  jitter
==============================================================================
 0.ubuntu.pool.n .POOL.          16 p    -   64    0    0.000    0.000   0.000
 1.ubuntu.pool.n .POOL.          16 p    -   64    0    0.000    0.000   0.000
 2.ubuntu.pool.n .POOL.          16 p    -   64    0    0.000    0.000   0.000
 3.ubuntu.pool.n .POOL.          16 p    -   64    0    0.000    0.000   0.000
 ntp.ubuntu.com  .POOL.          16 p    -   64    0    0.000    0.000   0.000
+t1.time.bf1.yah 129.6.15.28      2 u   16   64    1   61.766  -20.068   1.964
+puppet.kenyonra 80.72.67.48      3 u   16   64    1    2.622  -18.407   2.407
*ntp3.your.org   .GPS.           1 u   15   64    1   50.303  -17.499   2.708
+time.cloudflare 10.4.1.175       3 u   15   64    1    1.488  -18.295   2.670
+mis.wci.com     216.218.254.202  2 u   15   64    1   21.527  -18.377   2.414
+ipv4.ntp1.rbaum 69.89.207.99     2 u   12   64    1   49.741  -17.897   3.417
+time.cloudflare 10.4.1.175       3 u   15   64    1    1.039  -16.692   3.378
+108.61.73.243   129.6.15.29      2 u   14   64    1   70.060  -16.993   3.363
+ny-time.gofile. 129.6.15.28      2 u   21   64    1   75.349  -18.333   2.763
 golem.canonical 17.253.34.123    2 u   28   64    1  134.482  -21.655   0.000
 ntp3.junkemailf 216.218.254.202  2 u   19   64    1    2.632  -16.330   4.387
 clock.xmission. .XMIS.           1 u   18   64    1   24.927  -16.712   3.415
 alphyn.canonica 142.3.100.2      2 u   26   64    1   73.612  -19.371   0.000
 strongbad.voice 192.5.41.209     2 u   17   64    1   70.766  -18.159   3.481
 chilipepper.can 17.253.34.123    2 u   25   64    1  134.982  -19.848   0.000
 pugot.canonical 145.238.203.14   2 u   28   64    1  135.694  -21.075   0.000
```

Chrony

- Fast & acurate
- Offline support
- Power Efficent
- Security
- Flexible
- Monitoring tools



```
adenner@bashier: $ sudo systemctl restart chronyd
adenner@bashier: $ chronyc tracking
Reference ID    : 0A000002 (10.0.0.2)
Stratum         : 2
Ref time (UTC)  : Tue Sep 09 04:06:16 2025
System time     : 0.000000002 seconds slow of NTP time
Last offset     : +0.000061365 seconds
RMS offset      : 0.000061365 seconds
Frequency       : 30.191 ppm slow
Residual freq   : +49.448 ppm
Skew            : 19.832 ppm
Root delay      : 0.003686088 seconds
Root dispersion : 0.001116364 seconds
Update interval : 1.4 seconds
Leap status     : Normal
```

^* Current
^? No response (yet)
^_ online but not selected

```
MS Name/IP address         Stratum Poll Reach LastRx Last sample
===============================================================================
^* 10.0.0.2                      1   6    17    35   +115us[ +176us] +/- 1854us
^? time-e-b.nist.gov             0   7     0     -     +0ns[   +0ns] +/-    0ns
^- india.colorado.edu            1   6    17    34  -2072us[-2072us] +/-   16ms
^- prod-ntp-5.ntp4.ps5.cano>     2   6    17    35  -1535us[-1535us] +/-   51ms
^- prod-ntp-3.ntp1.ps5.cano>     2   6    17    34   -527us[ -527us] +/-   50ms
^- prod-ntp-4.ntp4.ps5.cano>     2   6    17    36   -500us[ -439us] +/-   52ms
^- alphyn.canonical.com          2   6    17    34   -320us[ -320us] +/-   41ms
^- vps3.drown.org                2   6    17    35  -1163us[-1102us] +/-   19ms
^- 66.42.71.197.vultruserco>     2   6    17    35   +476us[ +537us] +/-   44ms
^? 2600:1f13:2c1:2e00::be00>     0   7     0     -     +0ns[   +0ns] +/-    0ns
^? 240b:4004:108:200:8314:1>     0   7     0     -     +0ns[   +0ns] +/-    0ns
^? 2605:6400:488d:e1b2:84ba>     0   7     0     -     +0ns[   +0ns] +/-    0ns
^? vps-d455c3c7.vps.ovh.us       0   7     0     -     +0ns[   +0ns] +/-    0ns
```

Chrony and broadcast ntp

- Nope... multicast does exist... my cool hardware wasn’t smart enough...
- I forgot what ip address I was using (er ok I didn’t but lets just say...)
- What do I do to listen for the broadcasted time to set...

Searching for time

sudo tcpdump -i <interface> port 123 -vv

```
          Originator - Receive Timestamp:  0.000000000
          Originator - Transmit Timestamp: 3966379399.441999999 (2025-09-09T04:03:19Z)
23:03:19.486323 IP (tos 0x0, ttl 64, id 52152, offset 0, flags [DF], proto UDP (17), length 76)
    bashier.57949 > india.colorado.edu.ntp: [bad udp cksum 0x177a -> 0x6643!] NTPv4, Client, length 4
        Leap indicator:  (0), Stratum 0 (unspecified), poll 6 (64s), precision 32
        Root Delay: 0.000000, Root dispersion: 0.000000, Reference-ID: (unspec)
          Reference Timestamp:  0.000000000
          Originator Timestamp: 0.000000000
          Receive Timestamp:    0.000000000
          Transmit Timestamp:   2516140875.784085516 (1979-09-26T00:01:15Z)
            Originator - Receive Timestamp:  0.000000000
            Originator - Transmit Timestamp: 2516140875.784085516 (1979-09-26T00:01:15Z)
23:03:19.547603 IP (tos 0x40, ttl 47, id 15345, offset 0, flags [none], proto UDP (17), length 76)
    india.colorado.edu.ntp > bashier.57949: [udp sum ok] NTPv3, Server, length 48
        Leap indicator:  (0), Stratum 1 (primary reference), poll 13 (8192s), precision -29
        Root Delay: 0.000244, Root dispersion: 0.000488, Reference-ID: NIST
          Reference Timestamp:  3966379392.000000000 (2025-09-09T04:03:12Z)
          Originator Timestamp: 2516140875.784085516 (1979-09-26T00:01:15Z)
          Receive Timestamp:    3966379399.506107318 (2025-09-09T04:03:19Z)
          Transmit Timestamp:   3966379399.506109434 (2025-09-09T04:03:19Z)
            Originator - Receive Timestamp:  +1450238523.722021802
            Originator - Transmit Timestamp: +1450238523.722023918
23:03:19.565727 IP (tos 0x0, ttl 255, id 1779, offset 0, flags [none], proto UDP (17), length 76)
    10.0.0.2.ntp > 255.255.255.255.ntp: [udp sum ok] NTPv4, Broadcast, length 48
        Leap indicator:  (0), Stratum 1 (primary reference), poll 0 (1s), precision -18
        Root Delay: 0.000000, Root dispersion: 0.000000, Reference-ID: PPS^@
          Reference Timestamp:  3966379399.000000000 (2025-09-09T04:03:19Z)
          Originator Timestamp: 0.000000000
          Receive Timestamp:    0.000000000
          Transmit Timestamp:   3966379399.501999999 (2025-09-09T04:03:19Z)
            Originator - Receive Timestamp:  0.000000000
            Originator - Transmit Timestamp: 3966379399.501999999 (2025-09-09T04:03:19Z)
^C
264 packets captured
264 packets received by filter
0 packets dropped by kernel
```

Feature	Chrony	ntpd
Accuracy	More accurate, especially on systems with variable network latency or intermittent connectivity	Good, but less adaptive
Startup Sync	Syncs time **quickly** at boot, even before network is fully stable	Slower to sync at startup
Offline Handling	Can track time even when offline and correct drift later	Less effective offline
Power Efficiency	Designed for laptops and mobile devices (handles suspend/resume well)	Not optimized for power-saving scenarios
Configuration Simplicity	Easier to configure and manage	More complex and legacy-style config
Security	Supports **NTS (Network Time Security)** for encrypted NTP	Limited or no NTS support
Active Development	Actively maintained and modern	Legacy software, slower updates
Broadcast/Multicast Support	Limited or disabled in some builds	More mature support (but less used today)

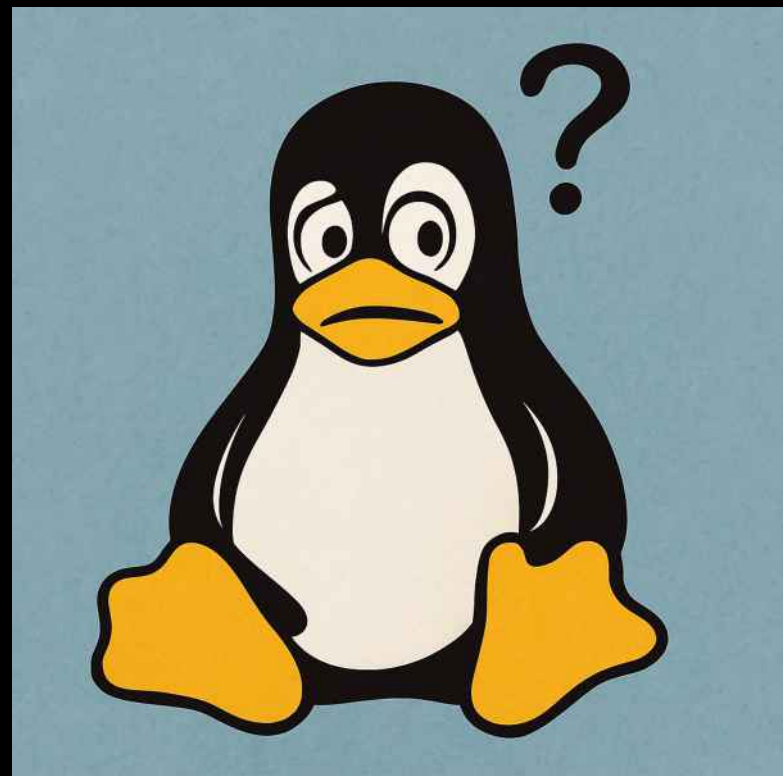
Timezones

- timedatectl status
- timedatectl list-timezones
- sudo timedatectl set-timezone America/Chicago
- ls -l /etc/localtime
- zdump -v /etc/localtime | head -n 10

People assume that time is a strict progression of cause to effect, but actually from a non-linear, non-subjective viewpoint, it's more like a big ball of wibbly wobbly, timey-wimey stuff.
--The Doctor

Time Zones-Time is hard (easy edition)

- A day is always 24 hours?
- Febuary is always 28 days
- UTC offset can be -12 to +12
- One offset = one time zone
- Time zones never change
- All countries have one time zone
- DST rules are consistent
- Leap Seconds are predictable
- All time zones are whole hours



Time Zones-Time is hard (hard edition)

- Some minutes can have 61 seconds
- Leap second smearing
- Some days never happened
- Excel Treats 1900 as a leap year
- Year 2038 – Today’s Y2k
- Year 2100 is not a leap year
- Negative leap seconds
- 24:00 timestamps are ok
- Bombay time historically weird

UTC-12 (AoE)

- No permanent residents
- ETC/GMT+12
- Latest-on-Earth
- Good edge test

UTC+14

- Kiribati
  - + 33 atolls over 3.5 million sq km in pacific
  - + Technically 26 hours ahead of utc-12

Questions?