Teaching Penguins to Tell Time

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Agenda

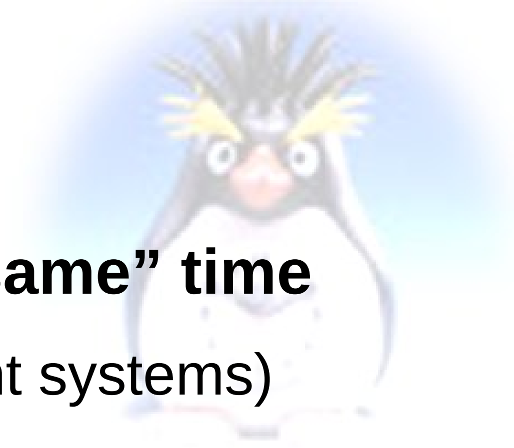
- **Why do we care?**
- **Hardware Clocks**
- **Time zones and UTC**
- **Network Time Protocol**
- **NTP and Linux on z/VM**

Why care about correct time?

- **For isolated systems correct time is convenient**
  - Time stamps on files
  - Reliable backup and restore
  - Applications that can pick up system date and time

```
MSG FROM: [illegible]     --DKIBMVM2 TO: NLX3951 --UITVM1           06/04/97 20:55:45
To:    Rob van der Heij
From: [illegible]                                                     at DKIBMVM2

Hi, Rob.

Next time anyone IPLs DKIBMVM2, could they also set the clock.  It is
now five minutes fast.  That means that I rush down to the train and
stand there waiting :-)

VM1 is about a couple of minutes fast.

    [illegible]                                              [illegible]
```


Why care about correct time ?



- **Distributed applications require the “same” time**
  - File sharing (e.g. edit and make on different systems)
  - Security (e.g. Kerberos tokens)
  - Convenient for debugging and tracking
- **Most systems get the time from someone else**
  - No infinite accuracy possible
  - Required quality of clock depends on application

Who has the correct time?

- **Universal Time 1 (UT1)**
  - Computed from astronomical observations
  - Speeds up and slows down with earth rotation
- **International Atomic Time (TAI)**
  - Based on Cesium-133 radiation
- **Coordinated Universal Time (UTC)**
  - Derived from TAI
  - Adjusted to UT1 with occasional leap seconds

Daytime Protocol

- **Public Internet Service**
  - Provided by several organizations (e.g. NIST)
- **Documented in RFC 867**
  - Query to UDP or TCP port 13
  - Format of response is different per server

```
pipe tcpclient 192.43.244.18 13 linger 1 | deblock linend 0a | xlate a2e | cons
53108 04-04-13 10:08:46 50 0 0 432.8 UTC(NIST) *
```

Julian Day

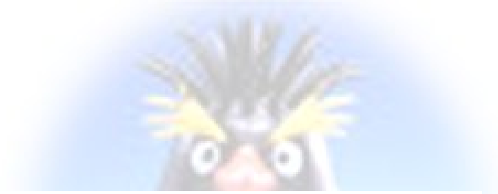
DST

Network delay

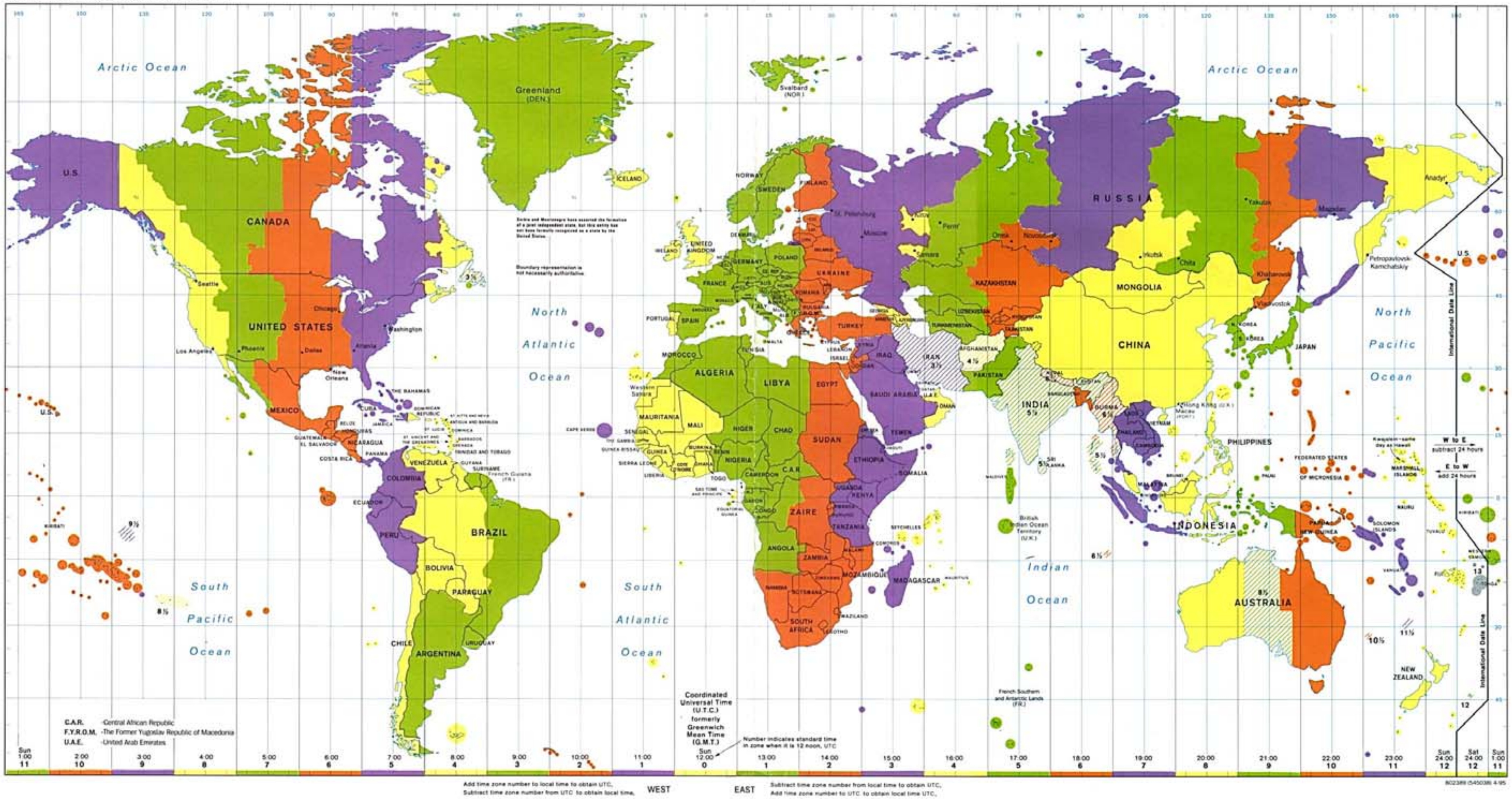
Clock Health (error < 5 s)

Leap seconds

Time Zones



Standard Time Zones of the World



Time zones and UTC

- **Linux system clock is in UTC**
  - Number of seconds since 1970
- **Local time computed from System Time**
  - GNU C Runtime Library routines
  - Defined by zone info in /etc/localtime
    - Offset to UTC
    - Beginning and end of DST

Quality of Clocks

- **System clock is at best approximation of UTC**
  – Delay, jitter, offset, drift
- **High quality time keeping is expensive**
  – Trade-off between various type of error
- **Quartz controlled clocks**
  – Typical frequency offset in the range of 10’s PPM
  – Variation of several PPM due to temperature changes
  – When not corrected, may add up to seconds per day

1 ppm ~ 30 s / yr

The Ideal Broken Clock

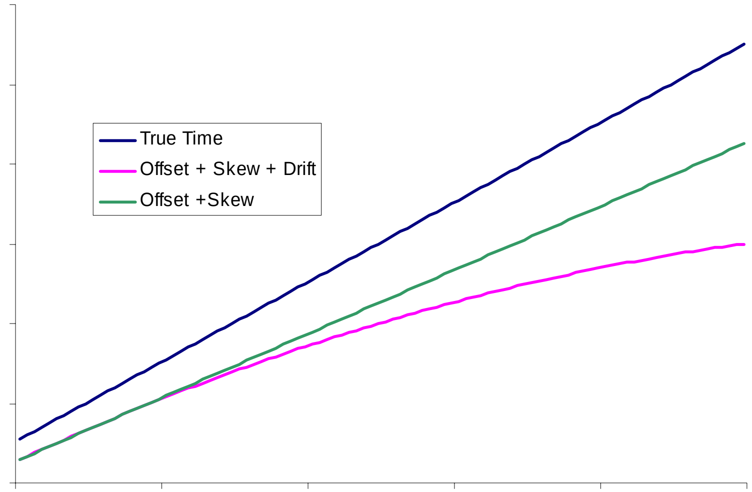
Clock differs from true time

Constant base offset

Different frequency (skew)

Drift due to aging

Jitter

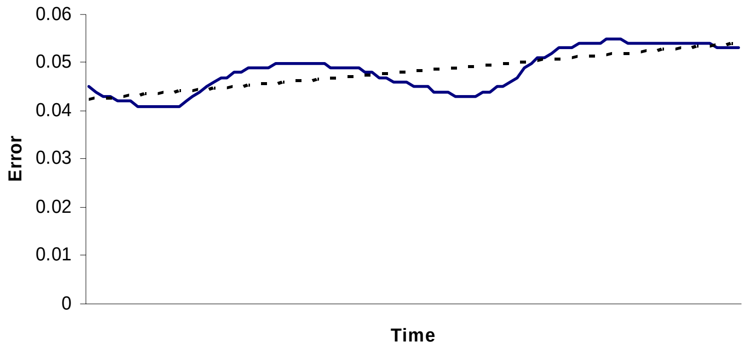


PC Clock

- **Real Time Clock with battery backup**
  - Keeps time while PC powered off
  - Cheap and not very accurate
    (e.g. several seconds per day off)
  - Low precision (one second)
    - Not suitable for system timing

PC Clock

- **Software Clock in Linux**
  - Initialized from the RTC during boot process
  - Incremented by timer interrupts
  - High resolution based on CPU clock frequency
    - Exploits CPU cycle counter
  - Can be adjusted through NTP
  - Used to compensate RTC drift
    - Be careful with adjusting RTC



PC Clock

- **Software Clock in Windows**
  - Initialized from RTC during boot
  - Incremented by timer interrupts
  - Corrected frequently using RTC
  - RTC and Software Clock in local time rather than UTC
    - Complications with DST

Dual Boot PC

- Linux must be aware RTC is in local time

zSeries Clock

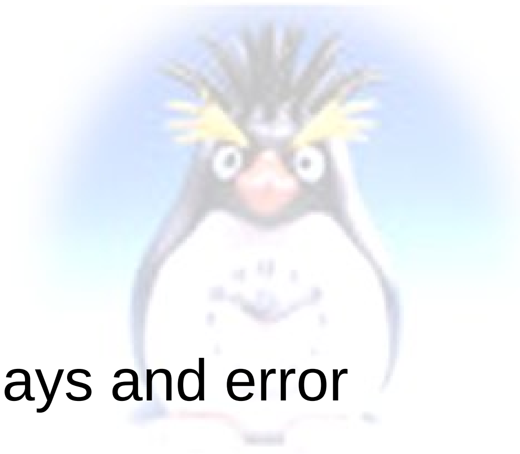
- **Hardware Time-of-Day (TOD) Clock**
  - Reasonable stable and high precision
  - Very cheap to read (STCK instruction in SIE)
  - Frequently set manually by Operator at IPL
    - Not synchronized to official time

- **Linux Software Clock**
  - Initially based on the TOD Clock
  - Even with a stable clock – wrong all day
  - Attractive to synchronize with external source

Network Time Protocol

- **Framework to synchronize clocks**
  - Defined in RFC 1305 (v3) and RFC 2030 (v4)
  - Format allows for very high precision
  - Formalizes quality of time reference
    - Stratum: Number of hops to a primary reference
    - Precision: Accuracy of the clock
  - Implementations available for many platforms
  - Many high quality public time servers

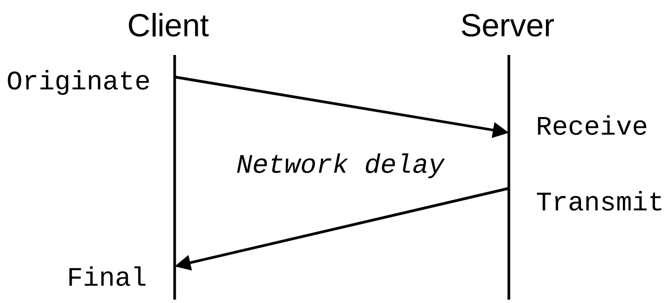
Network Time Protocol



UDP Packet to port 123

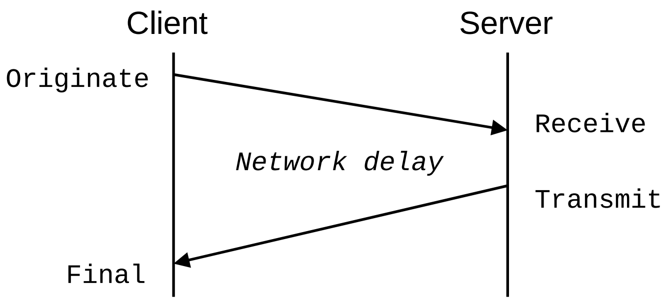
- Contains several timestamps to compute delays and error
- Timestamps in 32 + 32 bits (0.2 ns resolution)

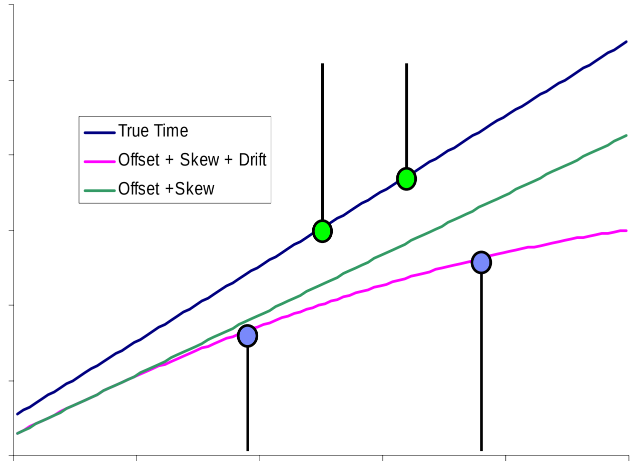
- Allows client to compute the error
- Network delay is assumed to be symmetrical and constant



Network Time Protocol

- **Using the timestamps**
  - Estimate the correct time
  - Compute the maximum error
- **A proper model for the delay**
  - Interpolate time for high precision
  - Extrapolate for long term measurement





NTP on Linux

- **Provisions in the kernel to adjust time**
- **The ntpd daemon and additional binaries**
  - SuSE xntp package
  - Red Hat ntp package
  - Download from www.ntp.org
- **Client configuration is trivial**
  - Single entry in /etc/ntpd.conf to list the time server
  - Finding the right server is harder

Starting ntpd

- **Special adaptation mode**
  - Runs for approximately 15 minutes
  - Exchanges messages with server to adapt oscillator
  - Clock is “stepped” to approach the obtained time
  - An excessive time difference causes ntpd to panic
  - Frequency in ntp.drift maintained

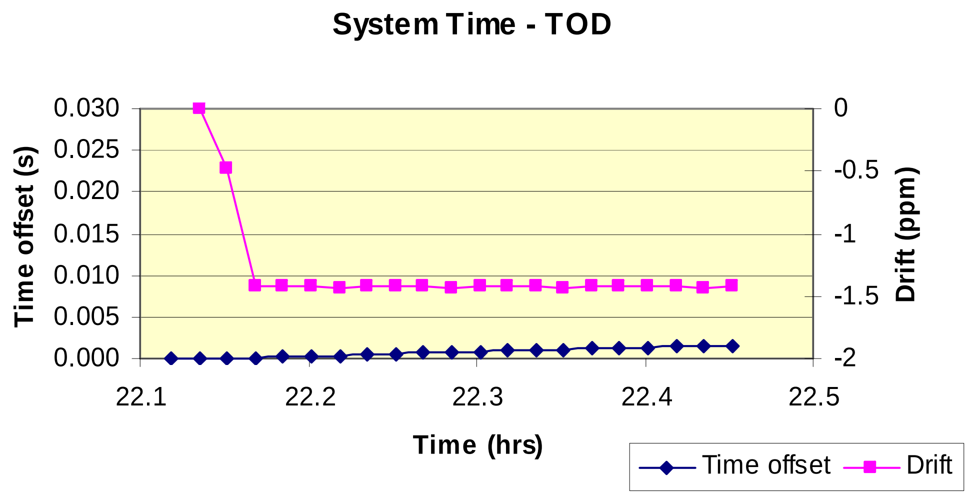
```
Apr  4 12:32:07 box ntpd: ntpd startup succeeded
Apr  4 12:32:07 box ntpd[712]: ntpd 4.1.1c-rc1@1.836 Thu Feb 13 12:17:19 EST 2003 (1)
Apr  4 12:32:11 box ntpd[712]: precision = 9 usec
Apr  4 12:32:11 box ntpd[712]: kernel time discipline status 0040
Apr  4 12:40:46 box ntpd[712]: time set 311.058971 s
Apr  4 12:40:46 box ntpd[712]: synchronisation lost
```

Example of NTP setting the clock

- **Initial frequency offset during adaptation mode**
  - Taken from drift measured during earlier runs
  - Assumes clock is set by hwclock
  - For Linux on zSeries this does not hold

SuSE boot.clock broken when hardware clock not set UTC

```
cat /etc/sysconfig/clock
#
# Set to "-u" if your system clock is set to
UTC, and to "--localtime"
# if your clock runs that way.
#
HWCLOCK="-u"
```



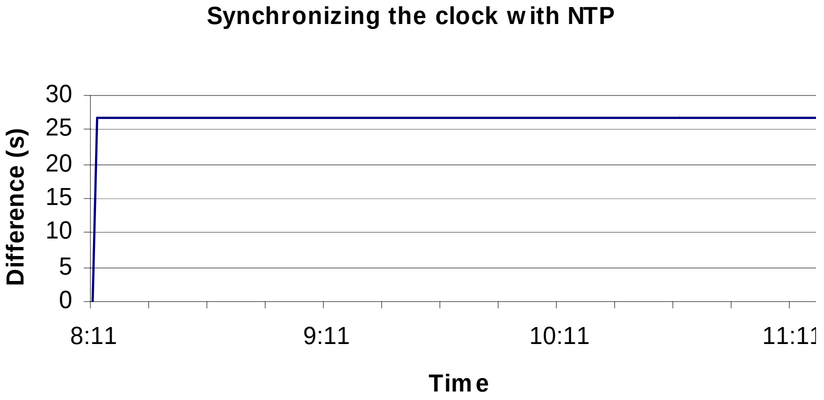
Running ntpdate

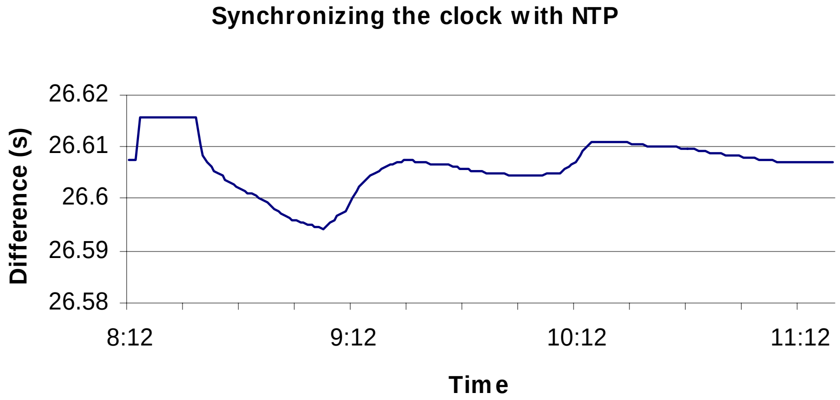
- **Correct time only available after adaptation mode**
  - Not attractive for workstations
  - May be confusing for other daemons started
- **SuSE runs ntpdate once during startup**
  - Obtains an estimate for current time from one server
  - Time difference probably small enough to avoid stepping

```
Apr 14 10:12:18 linux390 ntpdate[9876]: step time server 9.61.40.85 offset 26.607496 sec
Apr 14 10:12:18 linux390 ntpd[9879]: ntpd 4.1.1@1.786 Mon Sep 29 06:44:00 UTC 2003 (1)
Apr 14 10:12:18 linux390 ntpd[9879]: precision = 22 usec
Apr 14 10:12:18 linux390 ntpd[9879]: kernel time discipline status 0040
```


Running ntpdate

- **Difference between Linux clock and TOD clock**
  - Initial clock stepping via ntpdate
    - Can be disabled with `XNTPD_INITIAL_NTPDATE` setting in `/etc/sysconfig/xntp`
  - Subsequent tuning of oscillator





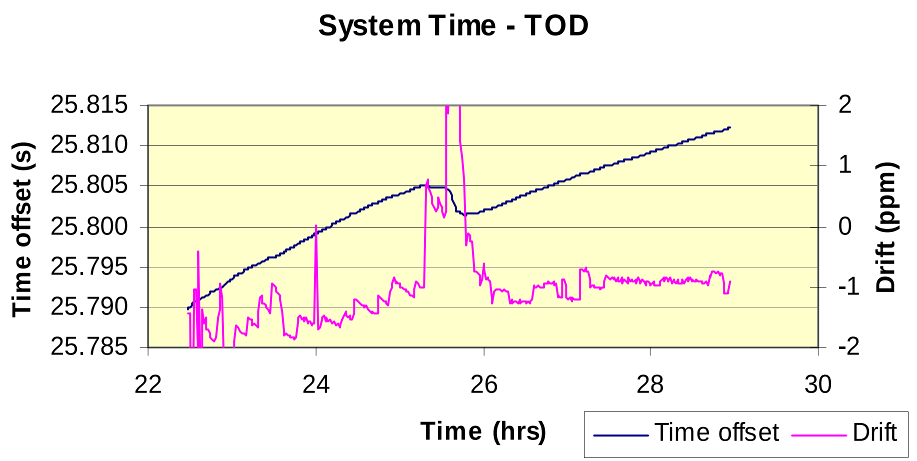
Running ntpd

- **Normal mode**
  - Continuous exchange of messages with servers
  - Delays compared to compute frequency errors
  - Message rate lowered over time to reduce network load

```
linuxgw:~ # ntpq -p -n
     remote           refid      st t when poll reach   delay   offset  jitter
==============================================================================
 127.127.1.0     127.127.1.0     10 l    6   64  377    0.000    0.000   0.015
+9.61.40.85      9.61.37.158      2 u   12 1024  377   15.585    1.132 100.497
+9.1.24.204      9.41.0.213       2 u   17 1024  377  104.729    0.079 313.260
*9.41.0.213      .GPS.            1 u  924 1024  377   57.036    0.898   0.185
-9.154.60.2      .hopf.           1 u 1002 1024  377   99.453    8.494   3.280
```

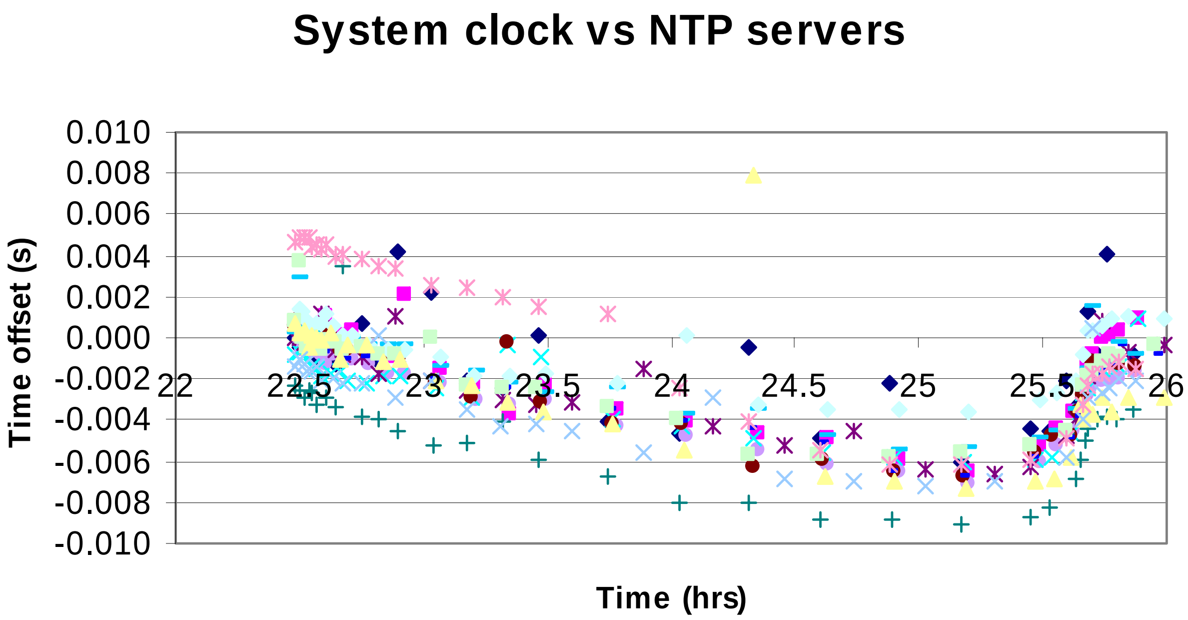
Example of NTP adjusting the clock

- **Over time NTP will tweak frequency to get system clock close to observed true time**
- **You can not have it all**
  - Stable clock with little jitter
  - Clock that follows true time

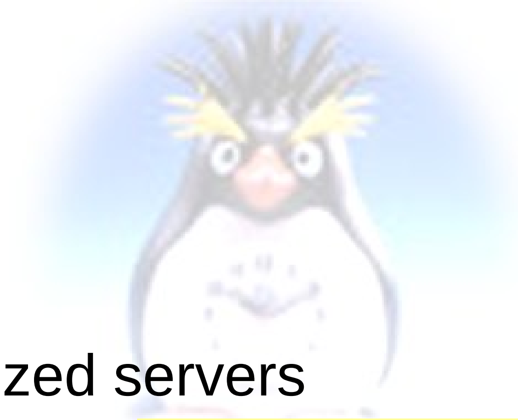


Example of NTP adjusting the clock

- **Jump in time appears to be consistent**
  - Most likely something in the network that changed delay
  - Could be related to system load



Synchronizing Linux with NTP



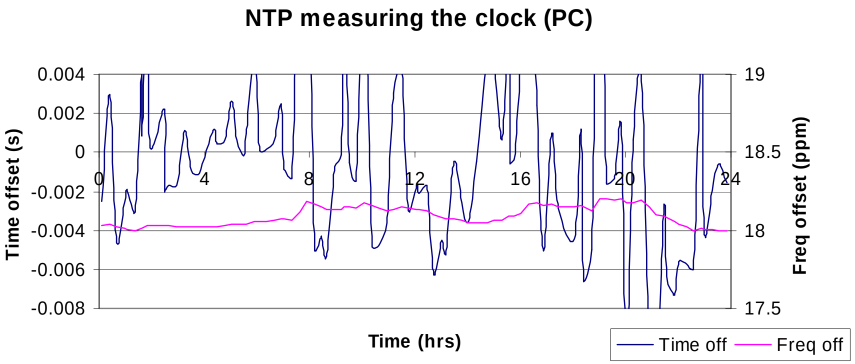
- **NTP works for Linux on zSeries too**
  - Keeps Linux clock close to other synchronized servers
- **Running ntpd is not for free**
  - CPU cost for idle server may increase with 50%
  - May increase memory footprint with 50%
  - Will depend on the number of time servers polled
  - Do your requirements justify the cost?

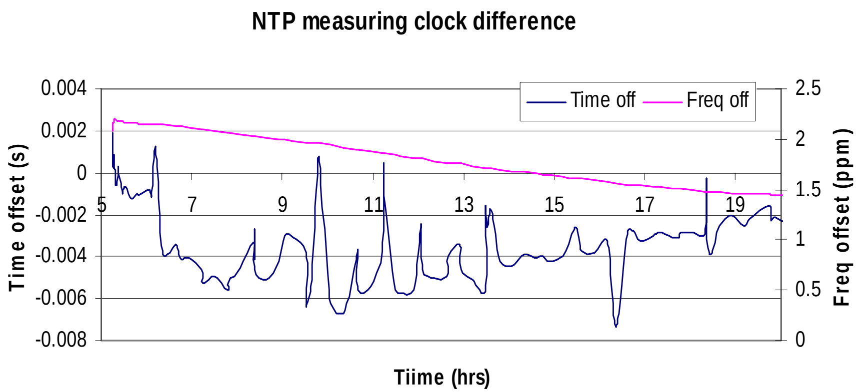
Experiment on z990
Idle: 4.1 ms/min
With ntpd 6.2 ms/min

Experiment:
Idle server 2270 pages
With ntpd 3385 pages

So how close do we get?

- **NTP keeps its own statistics**
  – The loopstats is only what NTP believes
- **How do we know what is true?**
  – The zSeries TOD wrong? Is this bad?
  – NTP getting the time wrong ?

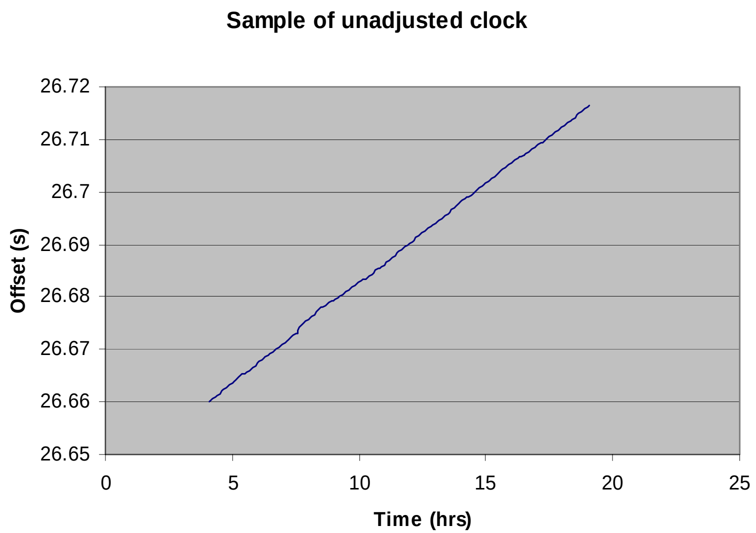




So how close do we get?

- **Sample of a 9672 TOD clock**
  - NTP adjusted system time versus hardware TOD clock
    - Numbers as good as NTP can get
    - Not representative for all CPUs
  - In this case
    TOD clock is 4 ms/hr too slow

    100 ms / day ~ 1 ppm



Cheap way to set the clock

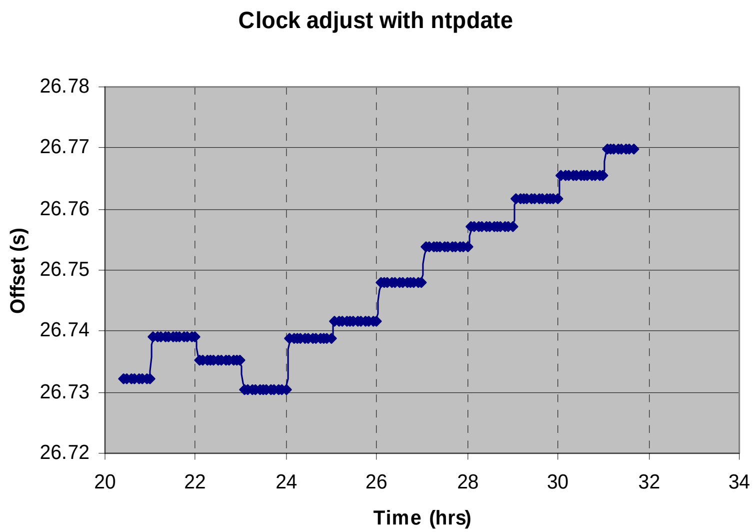
- **Reduce cost by setting the clock once**
  - Compensates for inaccurate set VM clock
  - Drift of zSeries TOD clock probably seconds per month
  - Run ntpdate once during boot process
    - Standard code (use ntpd –q rather than ntpdate)
    - May need the –g and –x options for large adjustments
    - It does not compensate for drift

Cheap way to set the clock

- **Set the virtual machine TOD offset**
  - Can be done in PROFILE EXEC before boot
  - Isolates Linux from the details of the hardware clock
  - No adaptation phase needed, no sudden clock shift
  - With SET VTOD the TOD clock offset can be set equal to the offset of another virtual machine
    - Linux servers with identical clock
    - Clock could be read completely in user space

Cheap way to set the clock

- **Run ntpdate occasionally cron**
  - Not recommended by everyone
  - It does not compensate for drift but jumps the clock
  - May even step your clock back
- **Doing so affects global time**
  - Simultaneous requests will overload the NTP servers
  - Will be removed in the future
    - Instead use ntpd –q –x

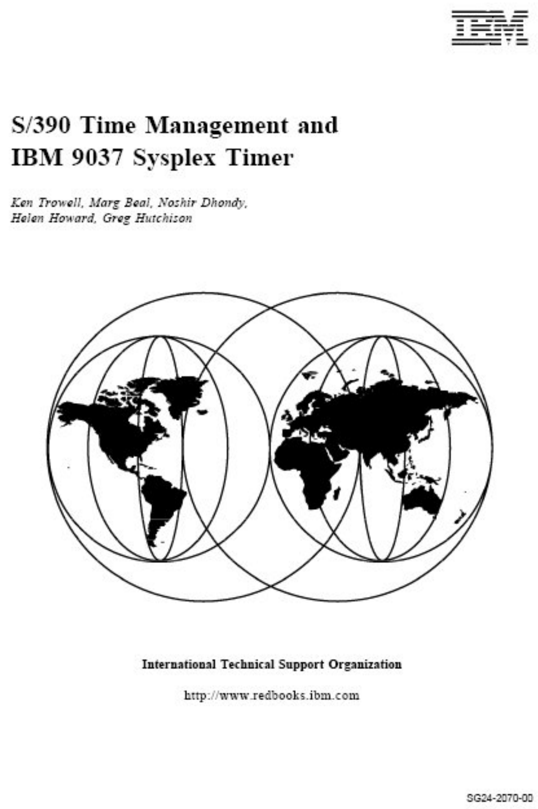


Using External Time Reference

- **IBM 9037-2**
  - Used to synchronized TOD clocks over multiple CECs in parallel sysplex
  - Can also use external reference to synchronize the clock
    - Dial-up to ACTS
    - RF receiver providing timestamp and PPS signal
  - z/VM has no explicit support for ETR but can benefit from a TOD clock kept exact

1000 Linux guests not running ntpd pays for a 9037-2

IBM 9037 Redbook


S/390 Time Management and
IBM 9037 Sysplex Timer

Ken Trowell, Marg Beal, Noshir Dhondy,
Helen Howard, Greg Hutchison

International Technical Support Organization

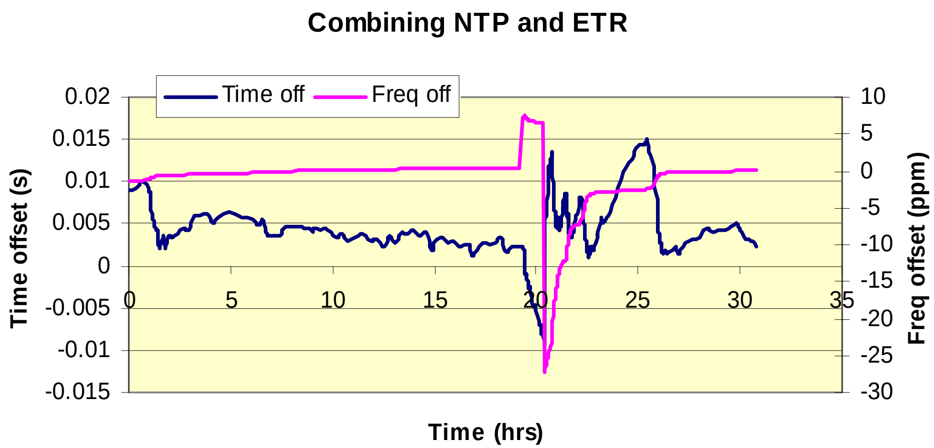
http://www.redbooks.ibm.com

SG24-2070-00

- **ITSO Redbook SG24-2070 S/390 Time Management and IBM 9037 Sysplex Timer**
  - z/OS configuration
  - ETR configuration setup

Using External Time Reference

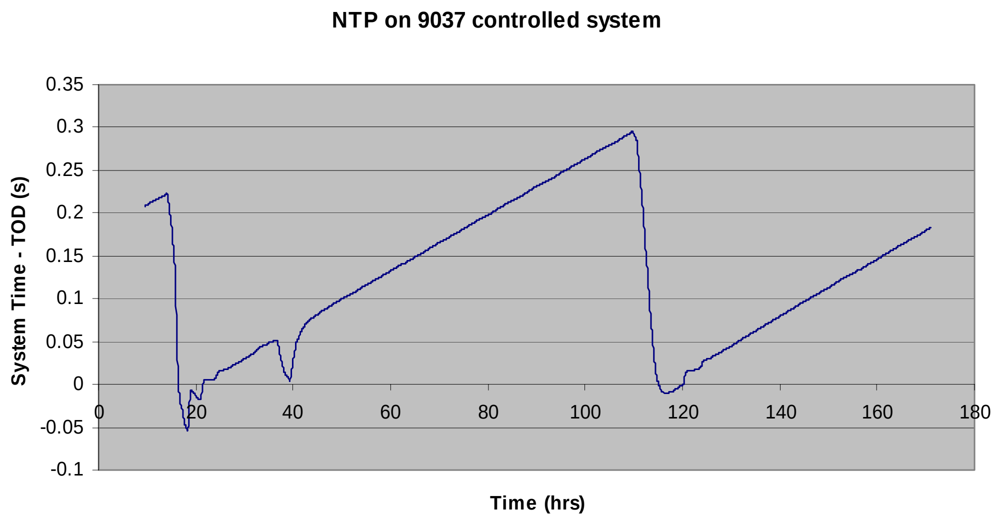
- **Use either ETR or NTP**
  - 9037 is not very subtle
  - NTP algorithms are not tuned for ETR clock steering
- **Combining NTP with ETR results in poor quality**
  - Increased swings
  - Correction overshoot
  - No improved long term stability



Using External Time Reference

- **Another example of clock quality**
  - System time driven by NTP (with 15 time servers)
  - zSeries hardware TOD clock (steered by 9037)

  - Stable drift: ~ -1 ppm
  - Correction: ~ 10 ppm

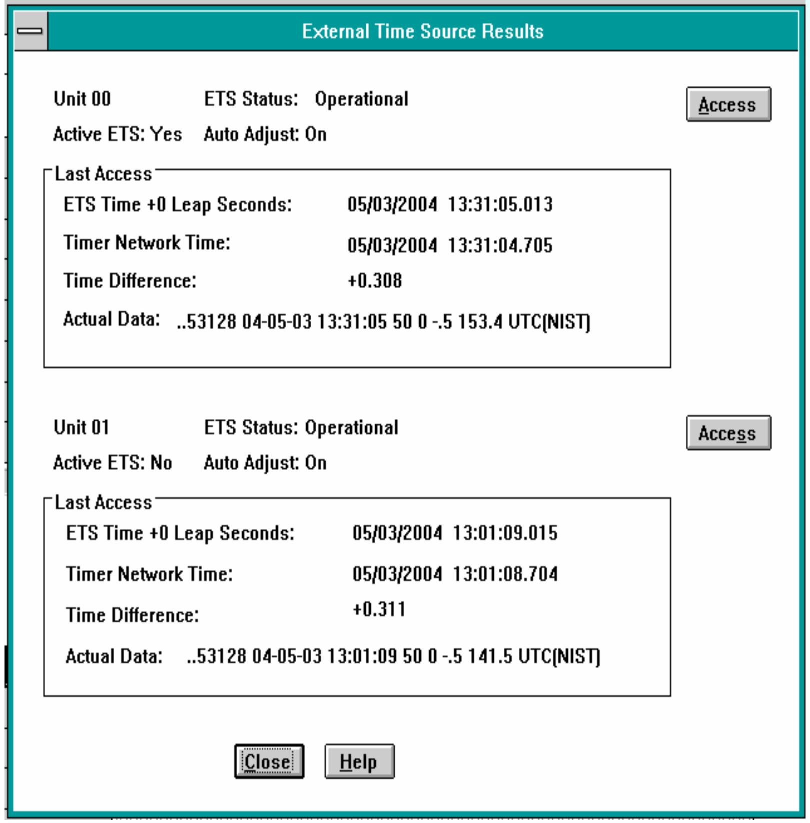


Using External Time Reference

- **Verified NTP measurements with 9037 status**
  - Jumps in the curve match the ETR dial-up times
  - Difference reported by ETR matches the measurement very well

    300 mS in 4 days

    ~ 1 ppm



Conclusion

- **NTP with Linux on z/VM is no silver bullet**
  – Expensive to run, algorithms do not fit completely
- **If you can afford some drift**
  – Set the clock once during boot with ntpd -q or SET VTOD
- **When clock stepping back is acceptable**
  – Compensate drift by running ntpd –q via cron
- **When more accurate time is necessary**
  – Run ntpd as daemon to enable kernel time discipline
  – Check the hwclock issues in the boot scripts
  – Carefully select the time servers to use as reference