Issues and Challenges Facing Traceable Accurate Time Delivery

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ITSF, Prague, November 1st 2016 – Session 2

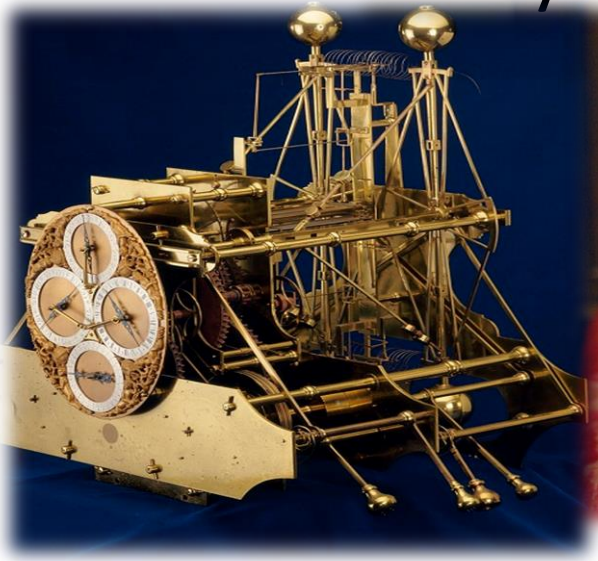
Where does time come from

- A brief history of time
  - Ancient Babylonians gave us the Sundial

  - Recently updated

Increasing precision

- A brief history of time (before Optical clocks)



Harrison's H1

Harrison's H5

Caesium Fountain

Courtesy of NPL

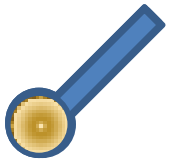
Is time the same everywhere?

- Equation of Time and Longitude
  - London to Bristol 10 minutes 21 seconds (2.6^{o} west of Greenwich)

http://www.bristolpost.co.uk/city-really-times/story-19967798-detail/story.html

Time Definitions

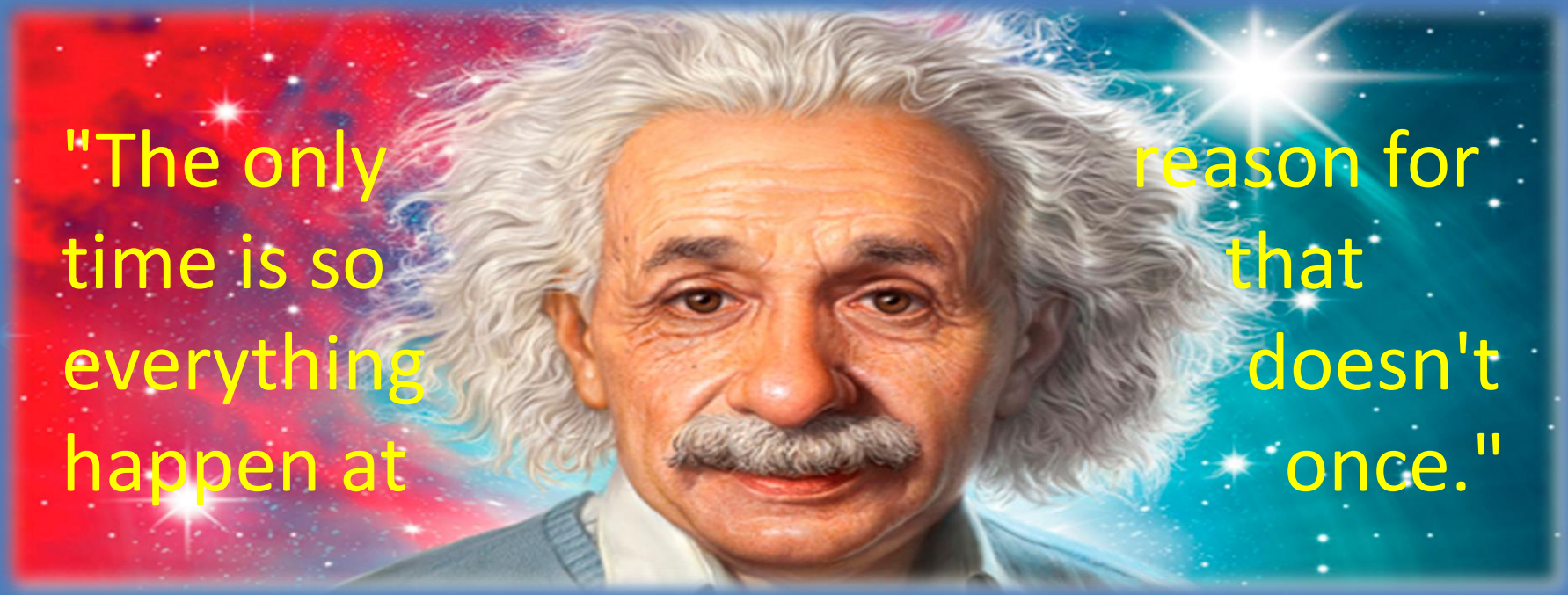
- Apparent solar time – Day approximately 24 hours
- Sidereal time – Star observation – Day approx. 23:56:04
- Mean Solar time – Solar time corrected for seasons
- Greenwich Meantime (GMT - 1884)
  - Observation of stars crossing meridian
  - Renamed Universal Time (UT – 1928) multiple versions
    - UT0 – Observation of diurnal movement of stars
    - UT1 - Observation of Quasars and Moon laser ranging. UT1 is the same everywhere on Earth
    - UT1R – As UT1 filters out permutations due to e.g. tides
    - UT2 – Another smoothed UT1 rarely used now.
- Coordinated Universal Time (UTC – 1960)
  - Atomic timescale. Based on SI seconds 86399 – 86401 seconds per day (usually 86400). Leap seconds keep UTC within 0.9 seconds of UT1
  - Maintained by the International Bureau of Weights and Measures (Bureau international des poids et mesures) – BIPM
  - defined by ITU-R TF.460-6



UTC

- The BIPM in France maintains the international unit for time (the SI second) by averaging data around 60 timing laboratories around the world to generate the UTC time scale.
- BIPM distributes UTC on paper, through a monthly publication called the Circular-T
- Other laboratories maintain physical real-time versions of UTC that are constantly steered to agree as closely as possible to the “official” UTC.

Time – Do you trust your source



Source trust & distribution

- Traceable to UTC
  - UTC is a paper clock defined by ITU-R TF.460-6
  - But for realisable time accuracies we can cope with the delay in determining what it was
- $Accuracy \propto \frac{1}{Complexity\ of\ delivery}$
  - $< 1us$ is achievable with:-
    - Ethernet networks (No Routers)
    - IP networks with Hardware in routers support for PTP
    - Both need Synchronous Ethernet

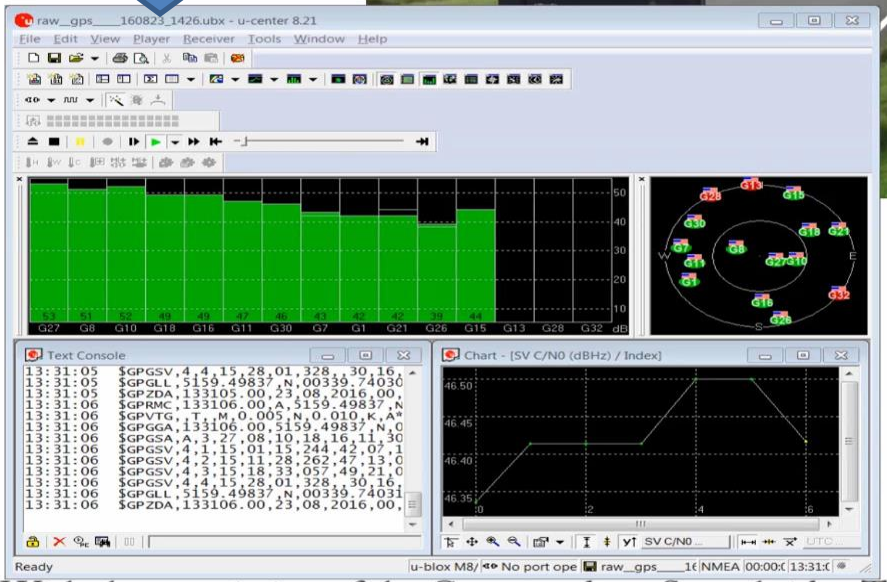
Practical Time Sources

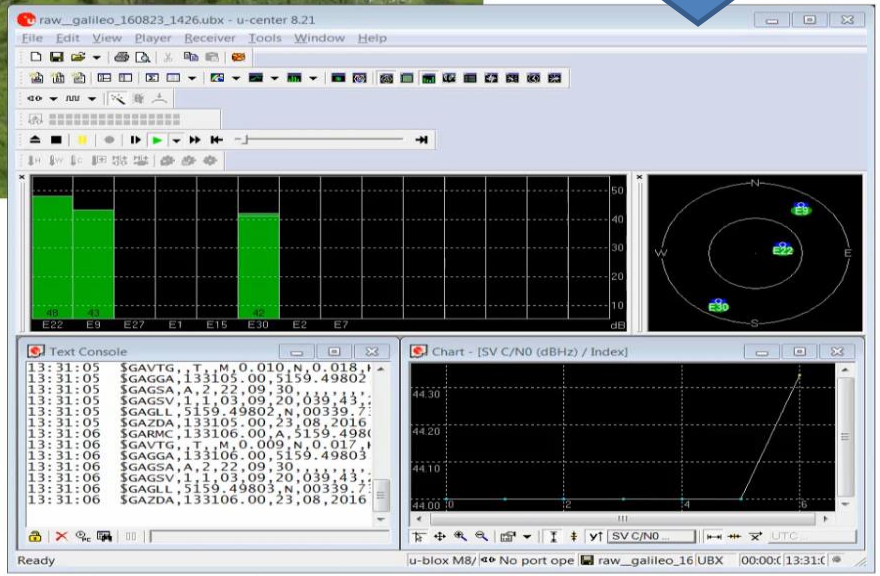
- Direct connection to National Standard
  - Expensive & distance limited
- Local proxy
  - Provided holdover in event of loss of primary clock(s)
- Galileo / GPS / GLONASS
  - Not always possible or available

Jamming Drive-past

GPS

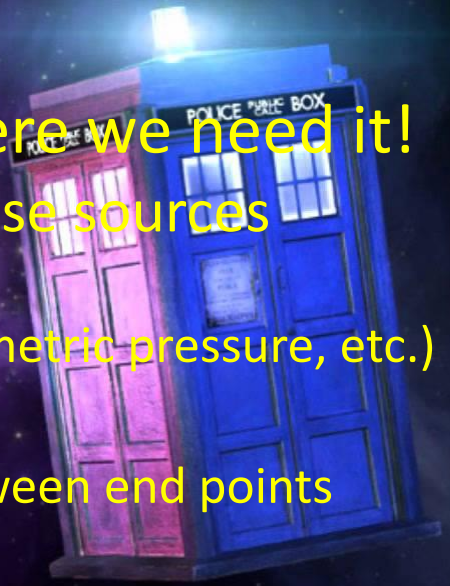
Galileo





With the permission of the Commandant, Sennybridge Training Area.

Time Transport



- The time source is never where we need it!
  - Transport introduces new noise sources
    - Dispersion effects
    - Variability (Temperature, Barometric pressure, etc.)
  - Best method
    - Precisely known distances between end points
    - Optical line of sight
    - In a vacuum.
  - GNSS achieves much of this
    - But has problems once it hits the atmosphere

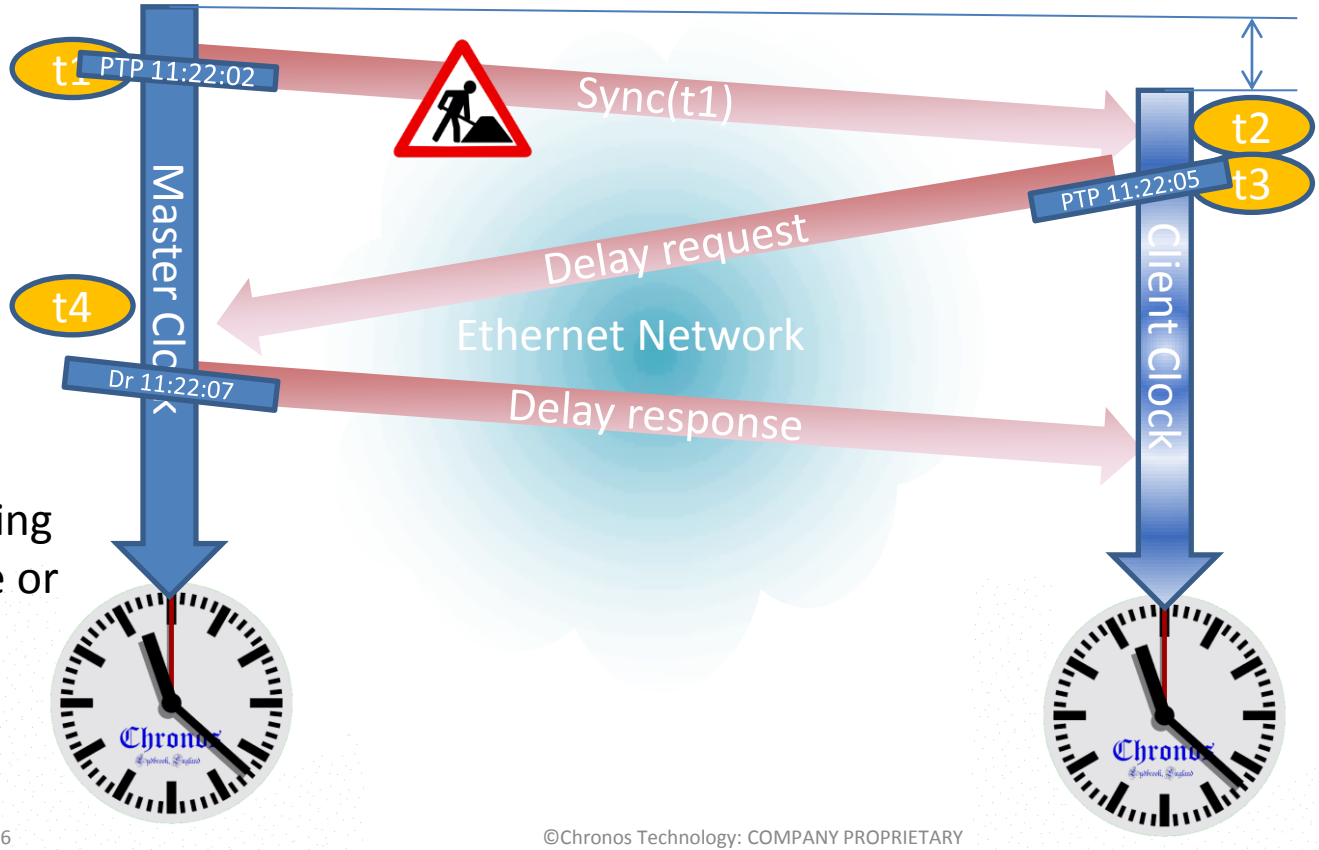
Time Transport (1)

- Terrestrial options
  - Mainly limited to Fibre and Radio
    - Radio suffers usual atmospheric effects
      - But can economically get us to 100's ns region
    - Fibre is dispersive and difficult to obtain
      - Can get us to sub nanosecond on dedicated fibre
      - Can get us to sub micro-second on Ethernet over fibre/WDM
    - Both introduce electronics (more noise)
      - And even worse – Non deterministic packet arrival times!

Data Network types

- Point to Point
  - Dedicated fibre – Expensive
- Circuit Switched
  - SDH(SONET) – Good timing performance (frequency) – Legacy
  - OTN – Relatively poor timing performance - Current
- Packet Switched
  - Ethernet – SyncE similar to SDH for frequency – Layer 1
  - Ethernet – PTP at Layer 2. Large variable asymmetry
- Packet Routed
  - IP – NTP – Huge variable asymmetry and re-routing delays

Problem – ΔAsymmetric Delay



Fixed Asymmetry offset

$t2 = t1 + tpd \pm \Delta pd + ClientOffset$

PTP Time transfer. Not showing Announce or follow up messages

Questions you must answer

- How accurately do you need to know the time
- Where do you need to know the time
- What availability do you need
  - Performance
  - Availability
  - Cost

To reach a solution

Source(s)	Transport	Client application
Which Timescale	Delay	Required Accuracy
Location	Delay Asymmetry	Location
Trust	Delay Variation	Required Availability
Duplication	Availability/Reliability	Holdover
Accuracy	Multiple routes	How many sources
	Network type	Quality estimation
		Source selection
Auditing/Calibration	Monitoring	Calibration/Traceability
Cost (Low as shared)	Cost	Cost

Thankyou

http://www.chronos.co.uk/
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