Power Matters.

Microsemi

A Man With One Watch Knows What Time It Is

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Problem Statement Too Many Clocks (or not enough good ones)

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

- Lee Segall

Does anyone really know what time it is?

Ye Olde Two Way Time Transfer

At 13.00 exactly, **the ball falls**, and so provides a signal to anyone who happens to be looking.

the first stroke of the hour bell should register the time, correct to within one second per day, and furthermore that it **should telegraph** its performance twice a day to Greenwich Observatory, where a record would be kept."

Errors are normally fixed by adding and removing old coins in the pendulum to adjust the rate at which it swings.

http://time.com/4010170/big-ben-running-slow/

Some Observations

Ye Olde Two Way Time Transfer

1. Goal Both Clocks should always Agree
2. Royal Observatory is always right (always drops the ball at the right time).
3. Big Ben has no influence on time beyond a day it just follows.

Some Potential Problems

Ye Olde Two Way Time Transfer

1. Ball drops at the wrong time
2. Write down wrong timestamp
3. Too foggy to see ball (jamming)
4. Someone messes with the telegraph (spoofing)
5. Big Ben degrades

At 156, Big Ben is allowed some tantrums. A spokesperson was sympathetic to the clock's missteps, acknowledging Ben "Does have a little fit every now and then," but asking people to "Imagine running your car for 24 hours a day, 365 days a year for the last 156 years /http://time.com/4010170/big-ben-running-slow/

Solution: The More the Merrier

Ye Olde Two Way Time Transfer

1. More Royal Observatories
2. More Balls
3. More Telegraphs

BUT ….

What if they disagree?

Learning From The Past …

The problem of coordinating a distributed network of clocks is not new…

The well known Network Timing Protocol started from:

(1981 RFC 778 DCNET Internet Clock Service D.L. Mills, COMSAT Laboratories 18 April 1981)

8 Years Later the issue of clock agreement was formally addressed:

In 1989, NTPv2 was published. The design of NTP was criticized for lacking formal correctness principles by the DTSS community. Their alternative design included Marzullo's algorithm, a modified version of which was promptly added to NTP.

https://en.wikipedia.org/wiki/Network_Time_Protocol

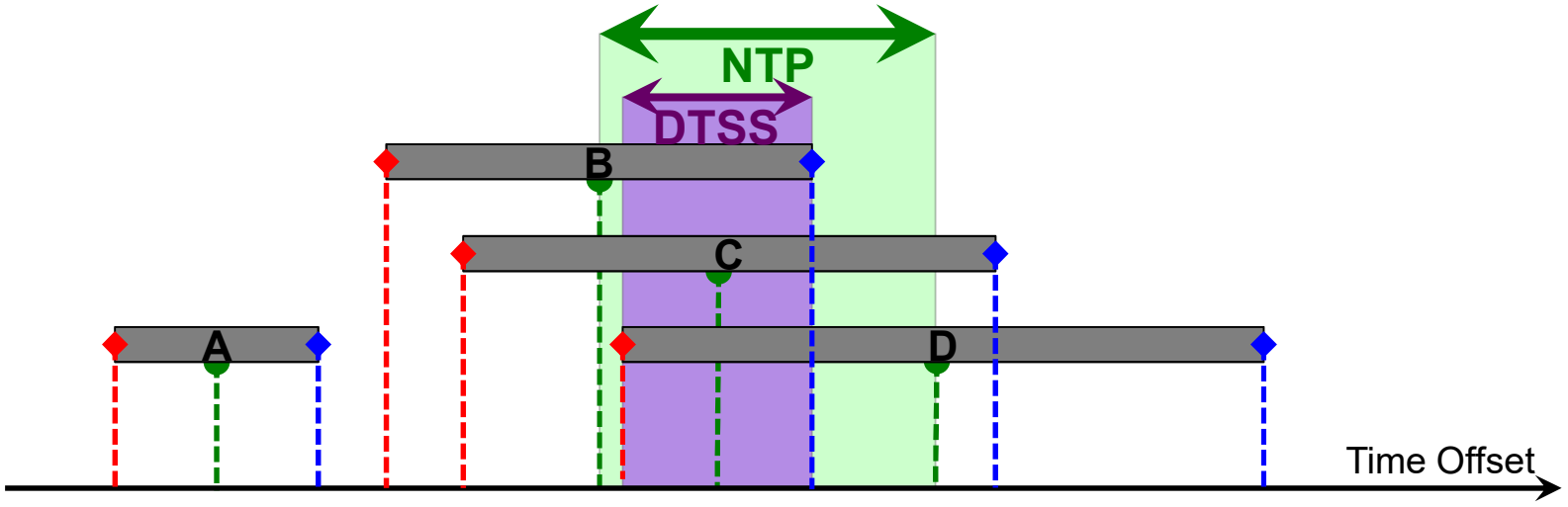
"Those who cannot remember the past are condemned to repeat it it." George Santayana

DTSS intersection algorithm (NTP)

The intersection algorithm is an agreement algorithm used to select sources for estimating accurate time from a number of noisy time sources, it forms part of the modern **Network Time Protocol (NTP)**.
It is a modified form of Marzullo's algorithm.

While **Marzullo's algorithm will return the smallest interval consistent with the largest number of sources**, the returned interval does not necessarily include the center point (calculated offset) of all the sources in the intersection.

The Intersection algorithm returns an interval that includes that returned by Marzullo's algorithm but may be larger since it will include the center points. This larger interval allows using additional statistical data to select a point within the interval, reducing the jitter in repeated execution.



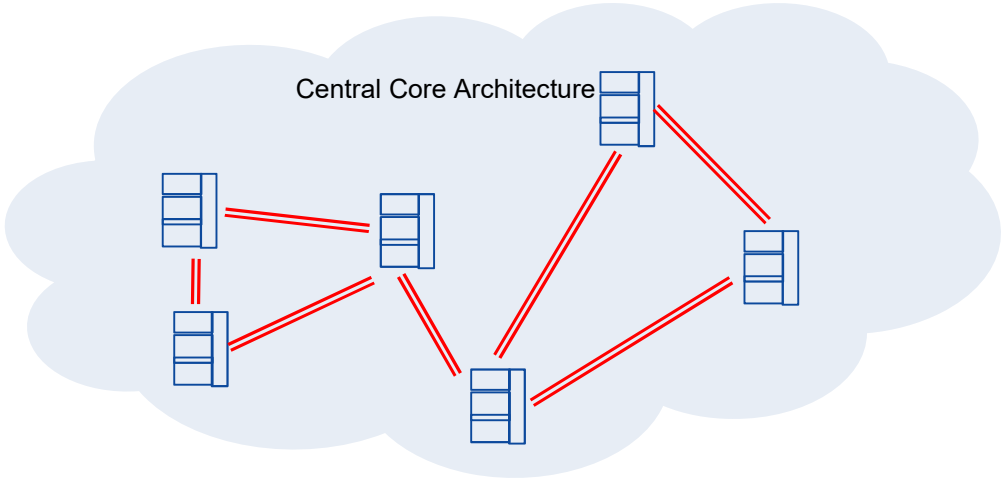
Slide from MARZULLO 's agreement algorithm
*& DTSS intersection algorithm **in Golang** Romain Jacotin 2014*

Challenge

So the challenge is how to juggle the collection of Royal Observatories. Big Bens, Balls, Telegraphs etc. …

Into a cost effective coordinate set of clocks support a coherent time service

Coherent Network PRTC Overview

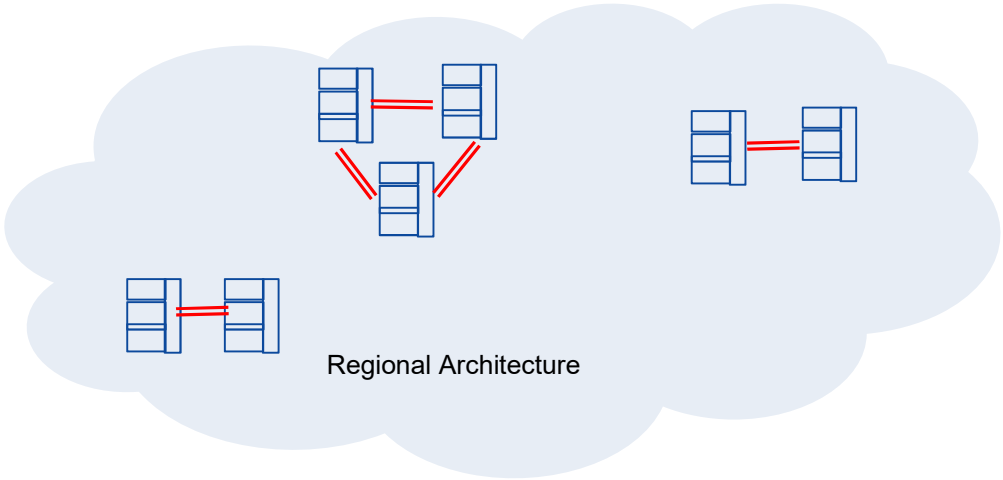


cPRTC is a cluster of PRTC that support the following primary objectives:

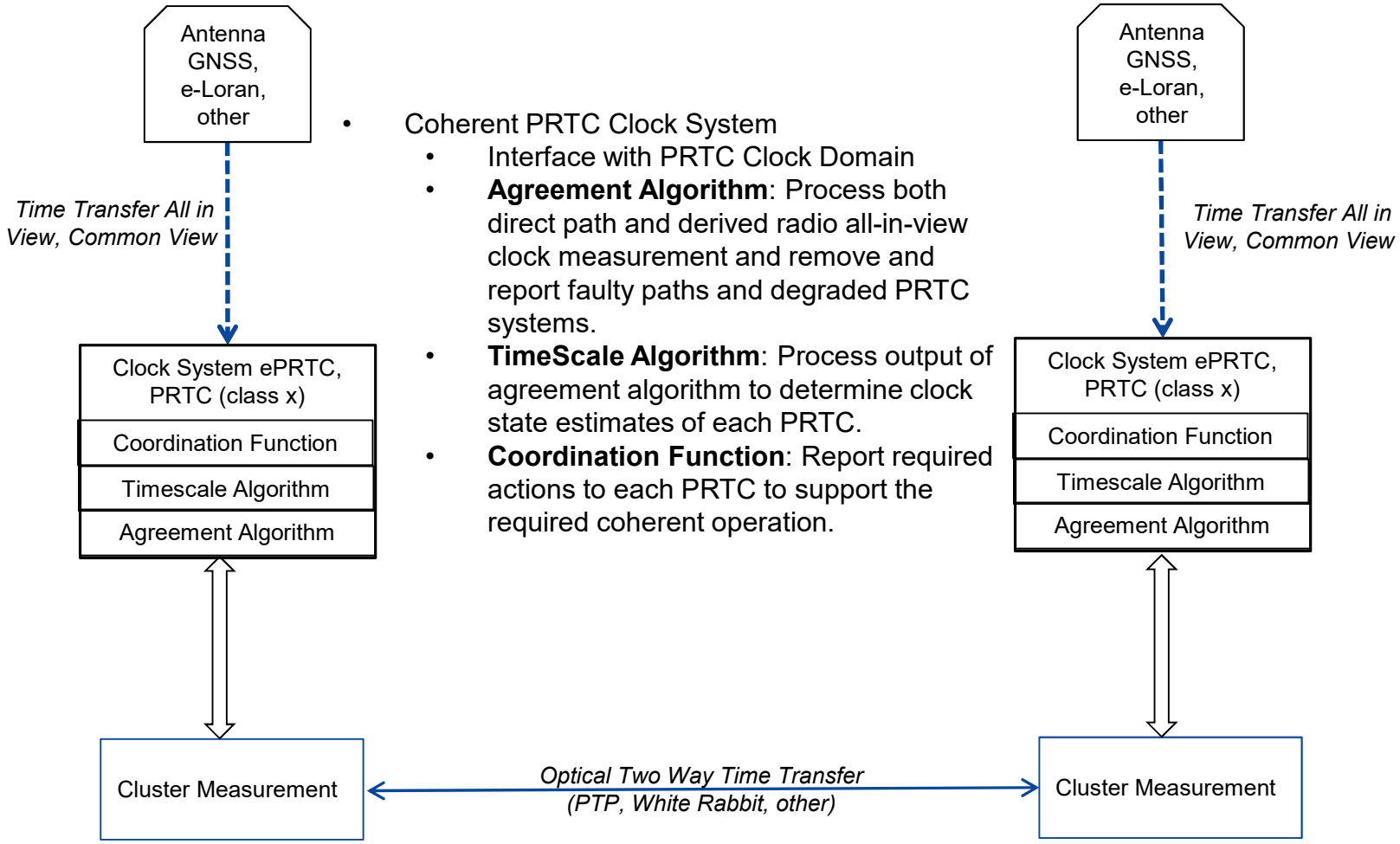
- Reliability: Immune from local jamming or outages

- Autonomy: Atomic Ensemble Sustained Timescale GNSS connect non-critical.

- Coherency: Error budget (e.g.) 30ns coordination assures overall PRTC budget



Coherent PRTC Functional Architecture



- Coherent PRTC Clock System
  - Interface with PRTC Clock Domain
  - **Agreement Algorithm**: Process both direct path and derived radio all-in-view clock measurement and remove and report faulty paths and degraded PRTC systems.
  - **TimeScale Algorithm**: Process output of agreement algorithm to determine clock state estimates of each PRTC.
  - **Coordination Function**: Report required actions to each PRTC to support the required coherent operation.

Summary

• The “man with two watches” can know what time it is.

• Agreement algorithms are core to ensuring distributed clocks will deliver required performance.

•We need to sensibly use all resources (PTP and GPS and Sync E and ….) not (PTP vs. GPS vs …)

•Coherent PRTC work effort started in ITU Q13 needs to move to completion