Collaborative Clocks

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

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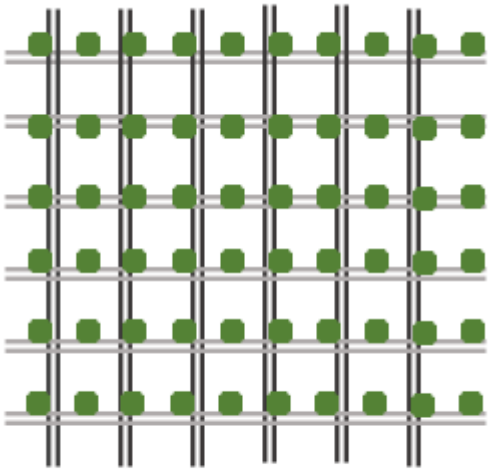
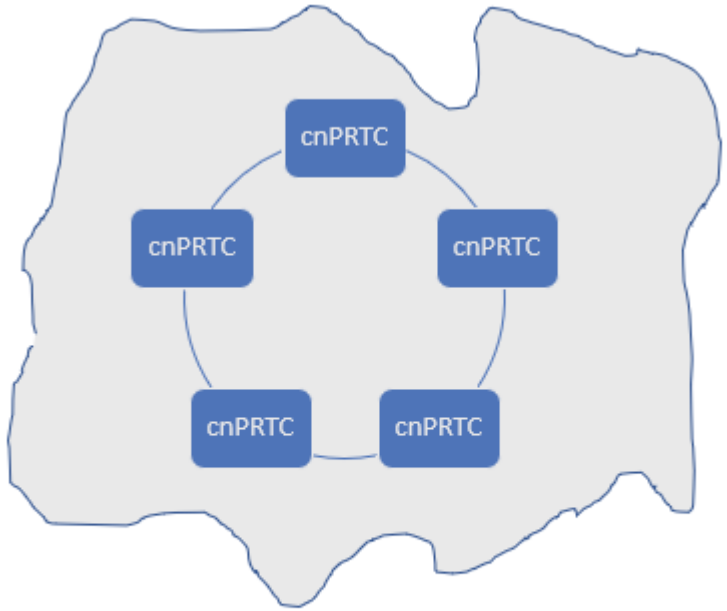
What are Collaborative Clocks?

- Share metrology data between neighbors
- Each node benefits from all the oscillators in the neighborhood
- Leverage high accuracy time and frequency transfer over fiber and radio



Smart City Collaborative Grid



National cnPRTC (Collaborative Clock) Example

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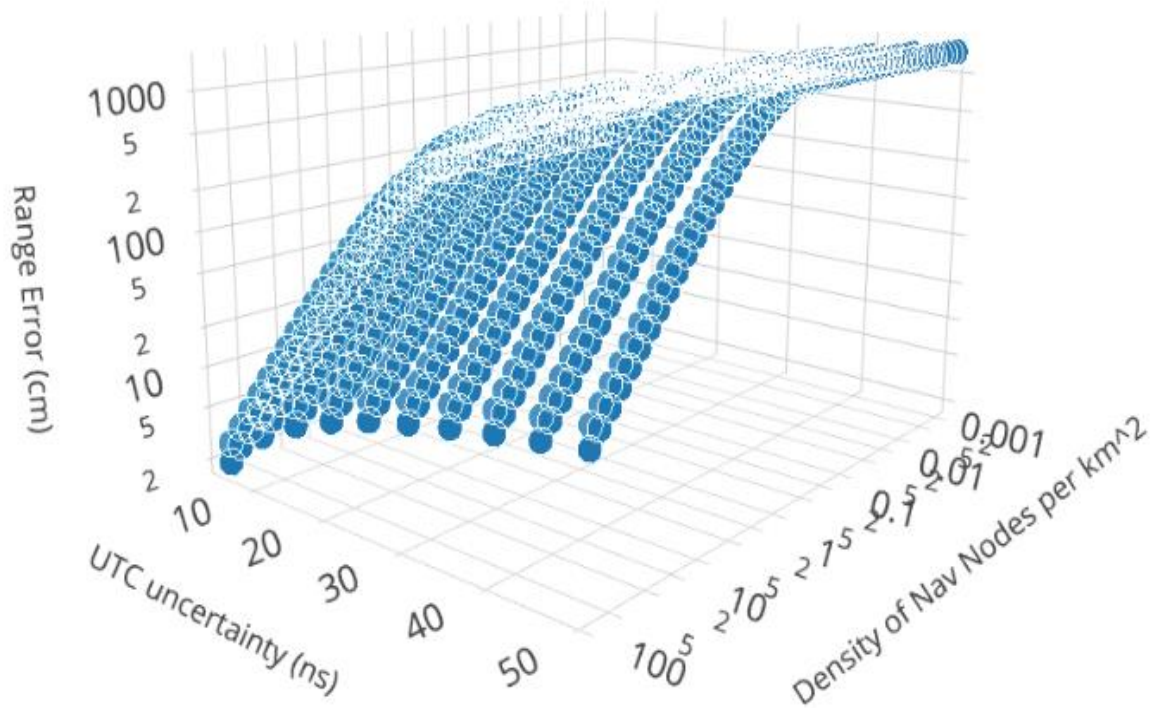
Smart City Positioning, Navigation and Timing (PNT) Performance Constraints

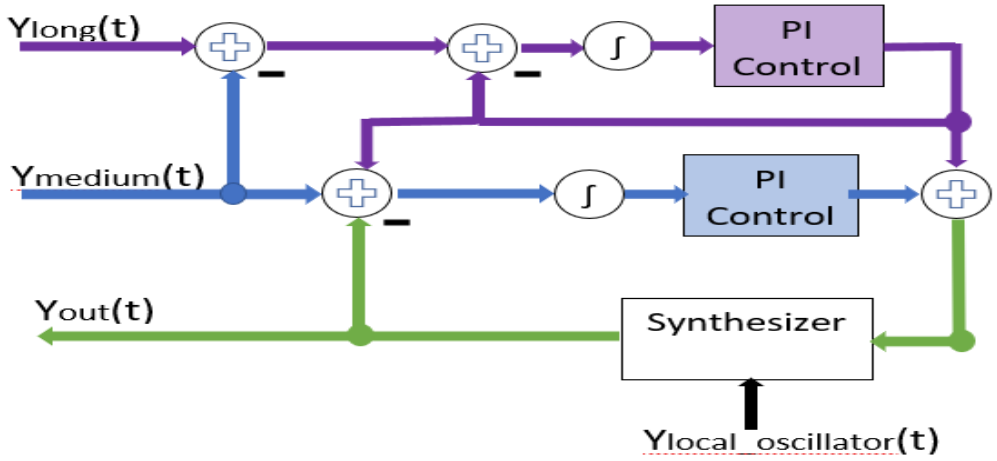


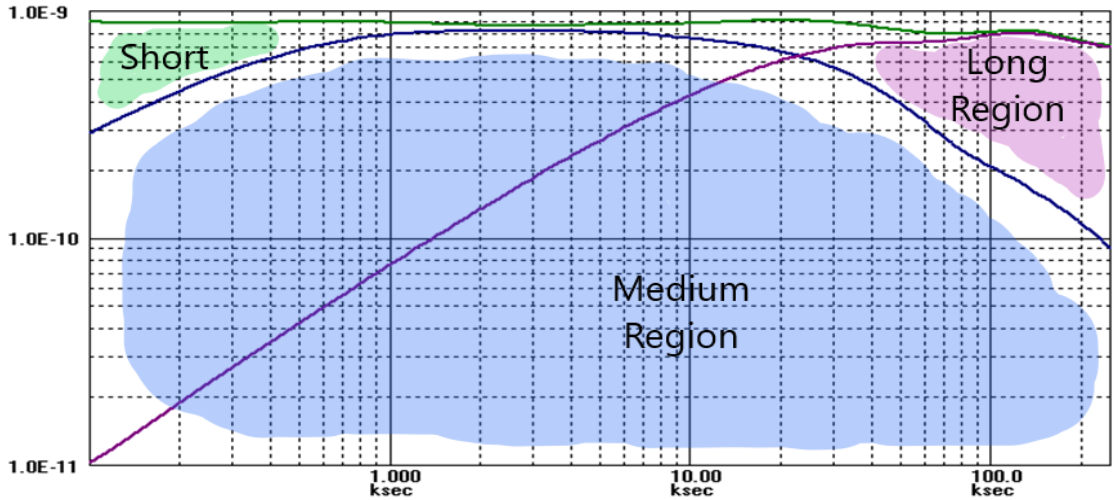
- **Surface shows position uncertainty**
- **2 direct parameters**
  - UTC uncertainty
  - Density of Nav Nodes
- **Contour function of spatial dependence of time**
- **Spatial dependence mitigated with collaborative clocks**
- **Shared clocks control cost**

Spatial Correlation: Lee SI. (2017) Correlation and Spatial Autocorrelation. In: Shekhar S., Xiong H., Zhou X. (eds) Encyclopedia of GIS. Springer, Cham. https://doi.org/10.1007/978-3-319-17885-1_1524

Three Region Ensemble Processing

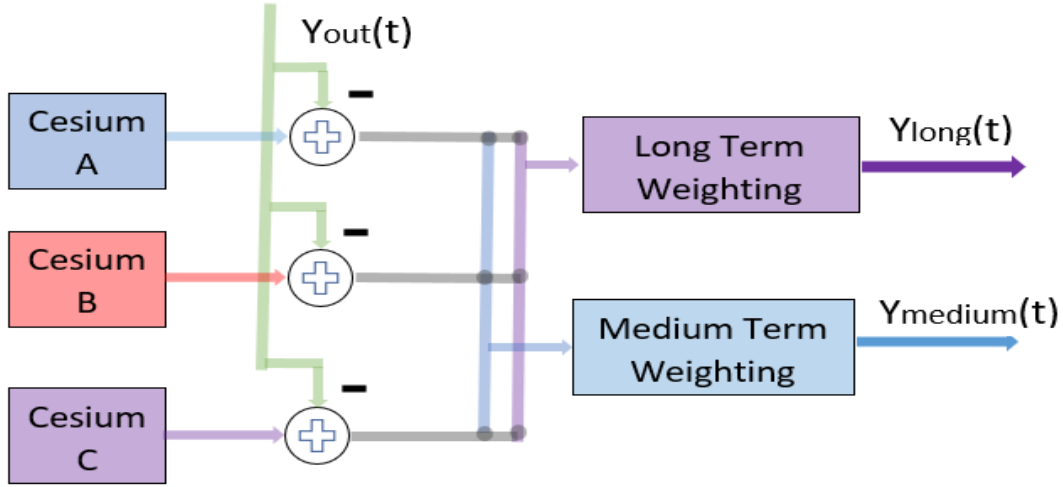
- Local oscillator(s) support short term. Ensure reliability
- Medium term remote oscillator contributes
- Typically, white noise region
- Long-term contribution depends on noise floor

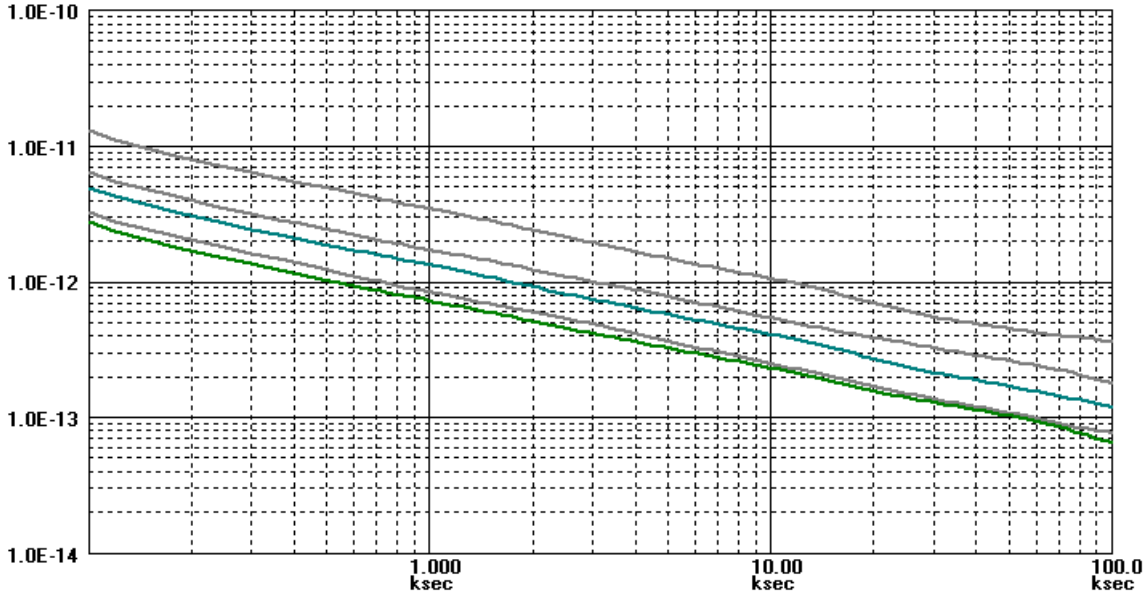




Collaborative Clock Ensemble Extension

- Extension supports remote oscillator ensembling
- Cesium clocks used in this example
- Octave Noise shows ensemble not average
- Green ensemble superior to Blue Average
- Optimal weights different for long and medium

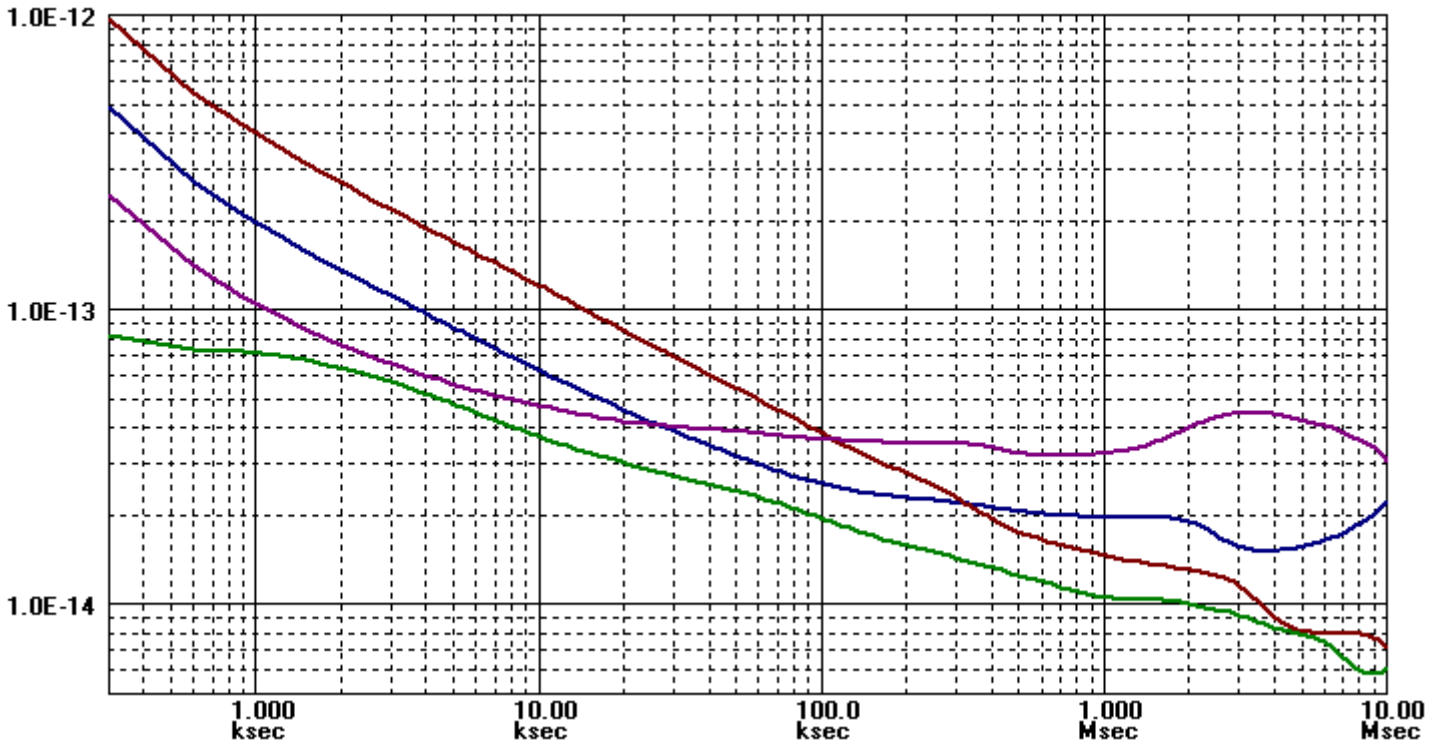




Collaborative Clock In Action

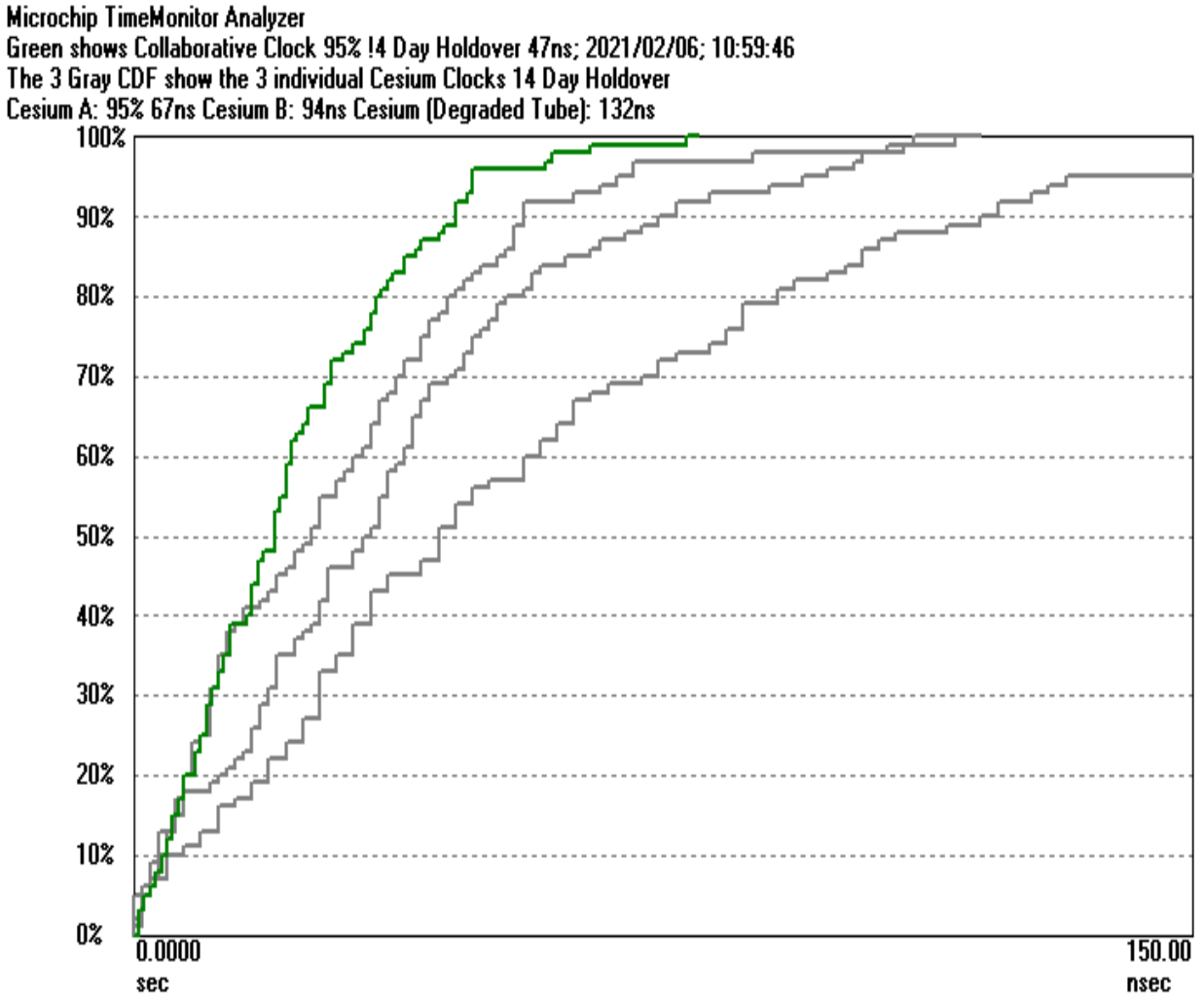
- **Cesium A typical Cesium clock (blue)**
- **Cesium B (red) 2x better long term**
- **Cesium B 2x worse in medium term**
- **Cesium C (magenta) just the opposite**
- **Collaborative clock (green) superior to all**

Cesium Ensemble Octave Noise Use Case		
Cesium ID	White Noise	Flicker Noise
A	8.50E-12	2.00E-14
B	1.70E-11	1.00E-14
C	4.25E-12	4.00E-14



Collaborative Clock Extends Holdover

- **ePRTC requirement 100ns over 2 weeks**
- **100 holdover trails simulated over 2 years**
- **Individual clocks**
  - Clock A: 67ns
  - Clock B: 94ns
  - Clock C: 132ns (Degraded past Spec)
- **Collaborative clock (green) 47ns (2x Specification)**
- **Consistent performance all 3 sites**



Collaborative Clocks Summary

- Generate multiple timescales at each location
- Timescale superior stability and coherency.
- Centimeter level PNT achievable in applications like smart cities.
- Coherent network PRTC achieve both better coherency and extended holdover
- Sharing of oscillators cost effective approach to clock ensembling
- Spatial diversity of oscillators reducing common environmental effects

Thank you

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