The NIST Fiber-based Time Service

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WSTS

Motivation

- Legal and regulatory requirements to use time stamps traceable to national standards
  - Distribution of electrical power
  - Commercial and financial transactions
- Increasing interference with GNSS signals
  - Intentional and accidental jamming
  - spoofing
- Executive Order 13905 (Feb. 12, 2020)
  - Provide a link to UTC that is independent of signals from GNSS and is traceable to national standards

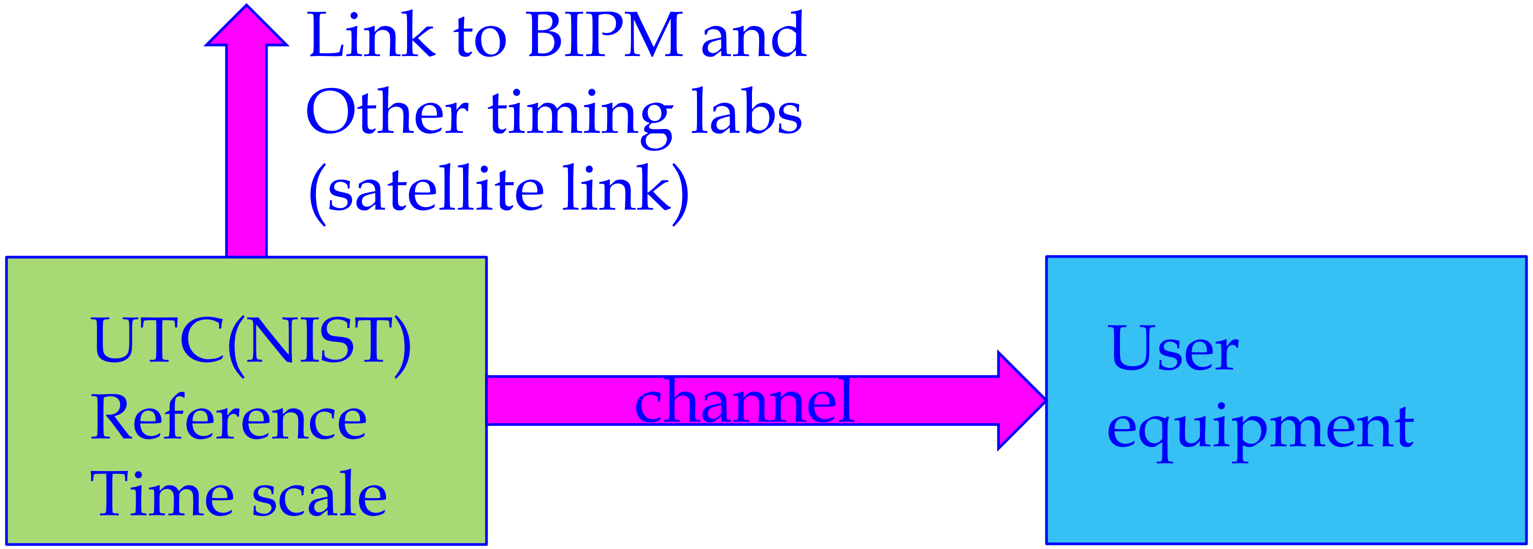
Cost Model

- Previous PNT services (LORAN, GPS, WWV, …) provided as "free" services
- Newer general public security enhancements are fee for service
- Is this the correct model for a general service?
- Important policy questions should not be decided by default

NIST Service

- NIST provides access to UTC(NIST) signals at facilities in Boulder, Colorado and Gaithersburg, Maryland. (Connection to reference time from radio station WWV in Fort Collins, Colorado also possible)
- NIST provides support and assistance for installing, maintaining and monitoring end-point hardware at NIST facilities
- User obtains and pays for channel circuit and hardware at remote end. (Not a public service)
- NIST and user share operational and maintenance activities.

Configurations



Channels:
"dark" fiber
Unique λ
OTN
Satellite link

User equipment:
Simple Receiver
Rubidium
Cesium
Clock ensemble

System Design Trade Space

- Characteristics of channel and end-point hardware should complement each other
  - Must be designed together based on requirements
- Combination better than either by itself
  - In short term, end-point clock more stable than remote reference seen through the channel
    - Errors and time-steps in channel easy to identify
  - Remote reference more stable in longer term
    - Stochastic fluctuations are bounded in the long term
    - Remote reference linked to national/international standards
  - Validating Long-term accuracy
    - Re-calibration will be needed in long term
    - National laboratories re-calibrated every few years

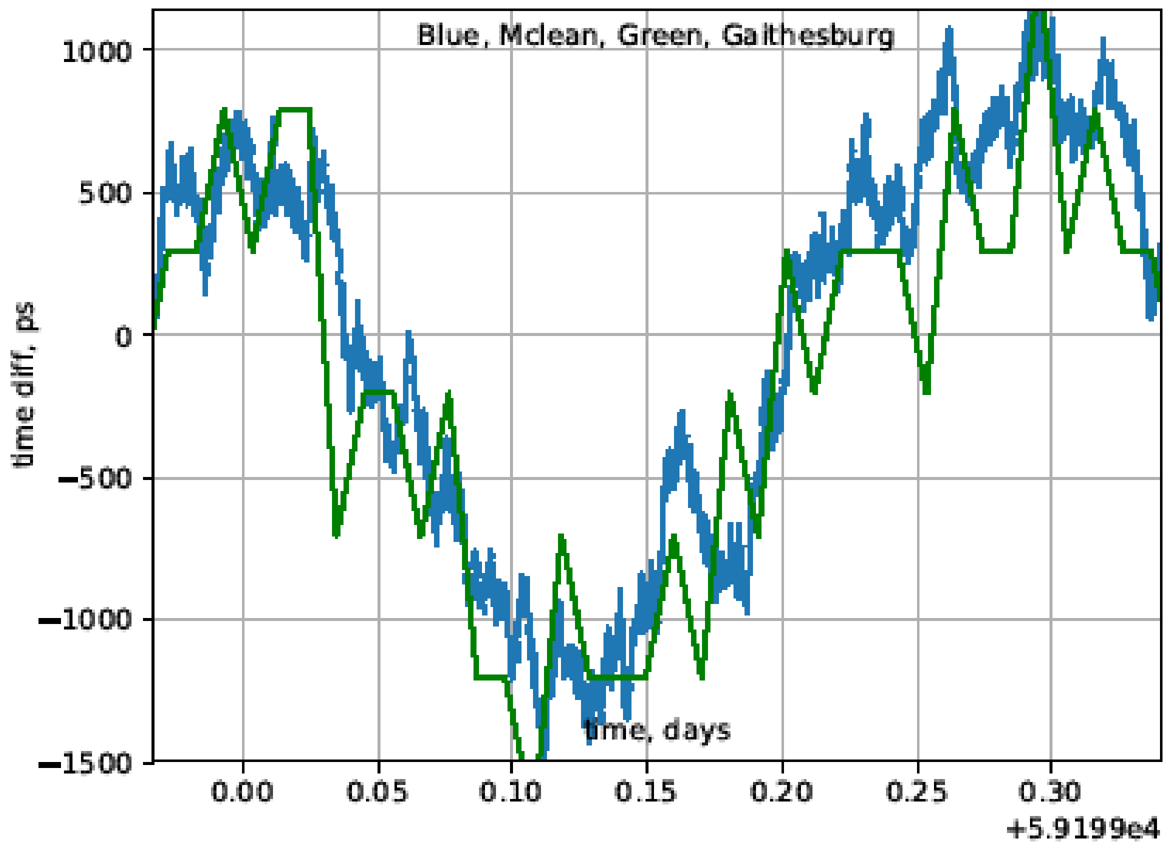
Possible solutions

- Lowest recurring cost
  - Optical Transport network (OTN)
  - Rubidium/cesium clocks at user end
  - Sophisticated analysis at user end to mitigate network weakness
    - "lucky packet" method
    - "huff-n-puff" filter
  - Periodic delay calibration (every year?)
- Simplest user equipment
  - Dark fiber + white rabbit format
- Some residual GNSS dependence
  - Channel accuracy less important

Preliminary Results - 1

- Two white-rabbit links between Gaithersburg, Maryland and McLean, Virginia
  - Collaboration with OPNT
  - Links have independent end-point clocks and white-rabbit hardware
  - Links share common “dark” fiber

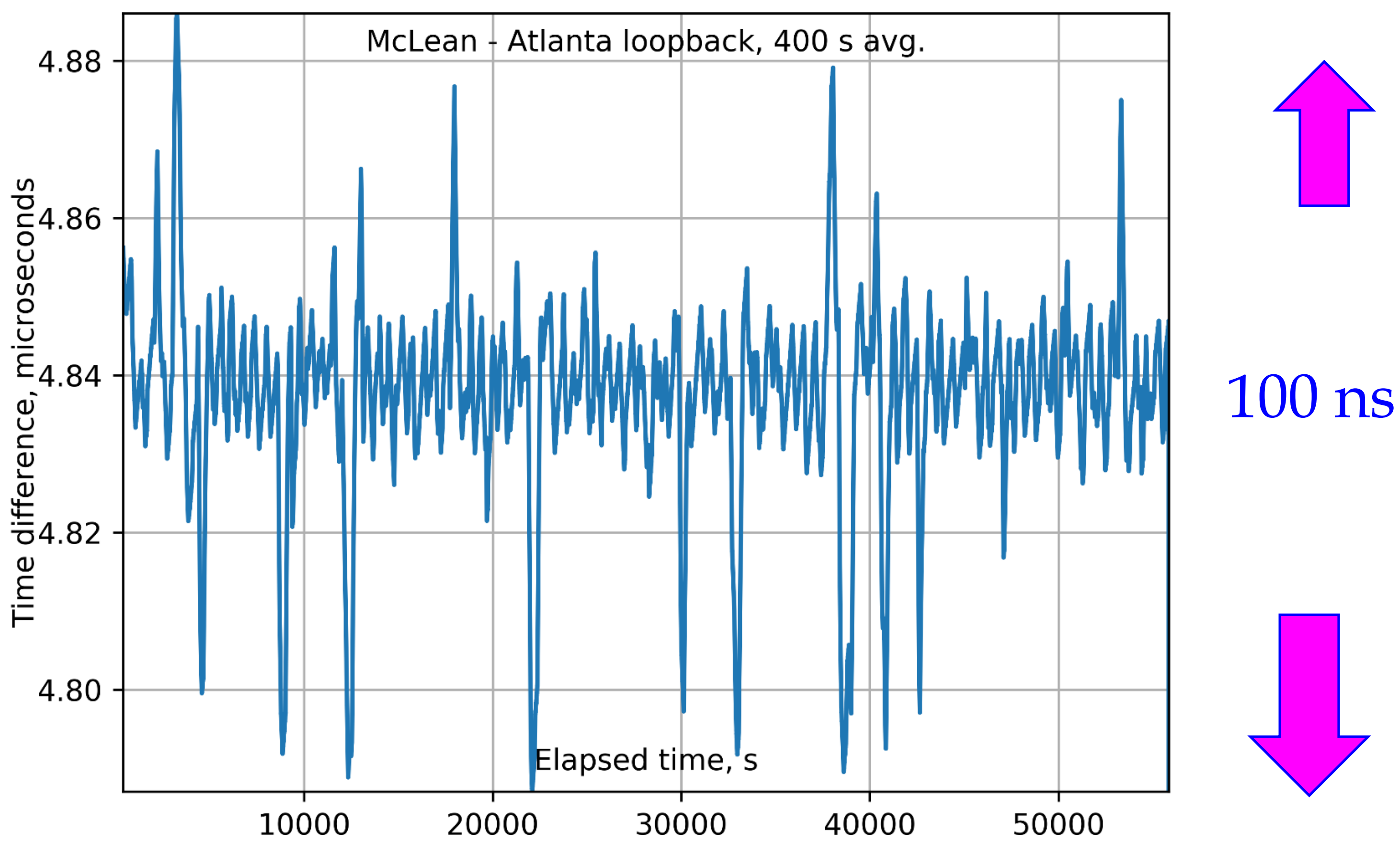
Data comparison



Preliminary Results - 2

- OTN Link from McLean, Virginia to Atlanta, Georgia (~1300 km) and return
  - operated by OPNT/NIST collaboration
  - Time signal sent from McLean to Atlanta and echoed back to McLean
  - Time difference measured at McLean between original signal and echo return
- Results:
  - Stability better than 100 ns (p-p), 400 s avg.
  - Accuracy about 5 μs

McLean-Atlanta loopback



Portable GPS calibrator

Calibration Results: all 1 σ

- Calibration when originally installed
  - 682 ns ± 25 ns
- Calibration following power failure
  - About 2 years later
  - 660 ns ± 30 ns
- Calibration during system upgrade
  - About 1 year after previous
  - 675 ns ± 30 ns

Current Status

- Equinix has installed circuits to NIST facilities in Boulder and Gaithersburg
  - Preliminary tests of dedicated-λ transport
- Hoptroff has installed a circuit from the NIST time scale in Boulder
  - Preliminary tests of OTN transport

Thank you