



IEEE 1588 PTP Experiment for Wide Area i-PCGRID Workshop 2016

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Outline

- Motivation
- Project plan
- Current results, October 2015
 - Transfer results using two transports
 - Diagnostic efforts to determine cause of asymmetry
 - Long-term measurements
- Next steps

Motivation

- Need to back up critical infrastructure for time at **microsecond (μs) or better**
 - NTP over internet no better than \sim **1millisecond (ms)**
- Research use of public telecom networks to transfer time
 - Optical fibers excellent for two-way time transfer
 - Public network fibers are unidirectional
- Need a method that is commercially viable
 - PTP is a new standard for time transfer
 - Format cannot improve accuracy - requires access to physical signal

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History of Project

- CenturyLink provider agreed in principle to two-year experiment linking NIST Boulder and USNO AMC at Schriever AFB (Source of UTC from GPS)
- DHS issued RFI, December 2011
- One vendor, Symmetricom-Microsemi, gave a detailed plan
- Tri-lateral MOU written: DoC (NIST)-DHS-DoD (USNO)
- Three-way Cooperative Research and Development Agreement (CRADA) NIST with CenturyLink and Symmetricom-Microsemi signed in January 2013
- CRADA extended to January 2017

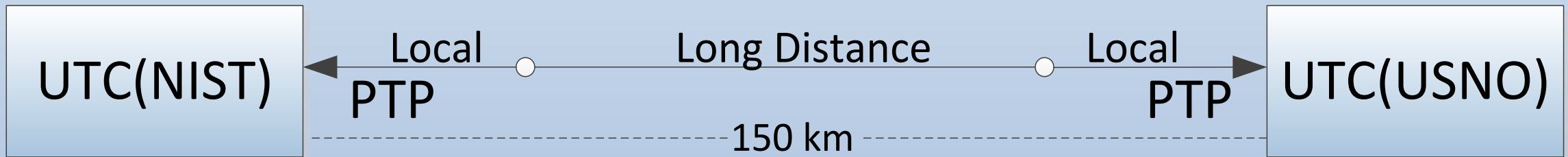
NIST-AMC Timing Experiment

Microsemi PTP + CenturyLink Circuit

- Microsemi provides PTP timing signals over Gigabit Ethernet
- CenturyLink provides two different circuits to carry the timing signals
 - STS over SONET with varied bandwidths on an OC-192
 - OTN on an ODU-0, within an ODU-2 transport

Time Transfer Experiment

- Two-way time transfer using neighboring unidirectional fibers
 - No time-awareness anywhere in network
 - No routers in path
 - No real traffic, though traffic noise can be added
- Measurements at NIST and AMC against UTC(NIST) and UTC(USNO)



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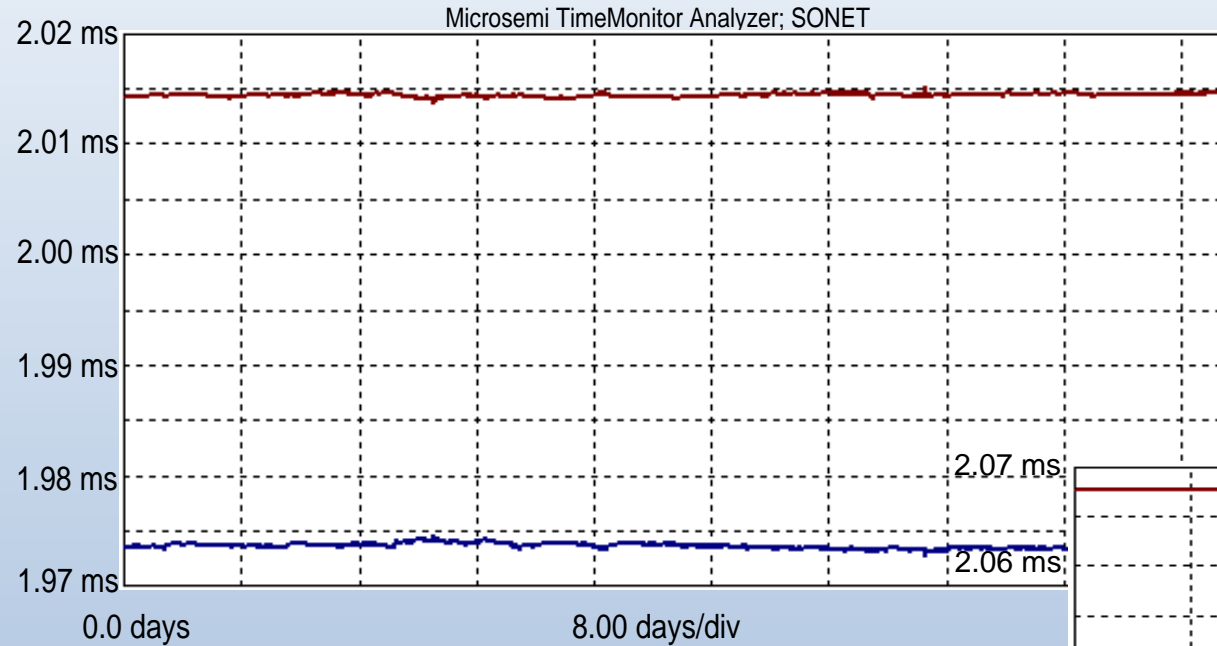
PTP Over SONET/OTN

- April 2014 - July 2014: studied SONET
- July 2014 – present: studying OTN
 - Better performance
 - Better for studying asymmetry
- PDV measurements made in two directions
 - GM at USNO AMC and PTP probe at NIST
 - Forward means USNO AMC to NIST
 - Reverse means NIST to USNO AMC
- PTP over SONET vs. PTP over OTN
 - **Asymmetry:** Both show large asymmetry of 40 μ s between forward and reverse directions
 - **Delay:** Both show \sim 2 ms delay over 150 km of fiber
 - **Jitter:** SONET: 200 ns; OTN: <4ns
 - **Wander:** SONET: Variations on order of 300 ns; OTN: Usually close to 0 ns, occasional excursions 10's of ns

PTP over SONET/OTN

~2 ms total delay, 40 μ s asymmetry

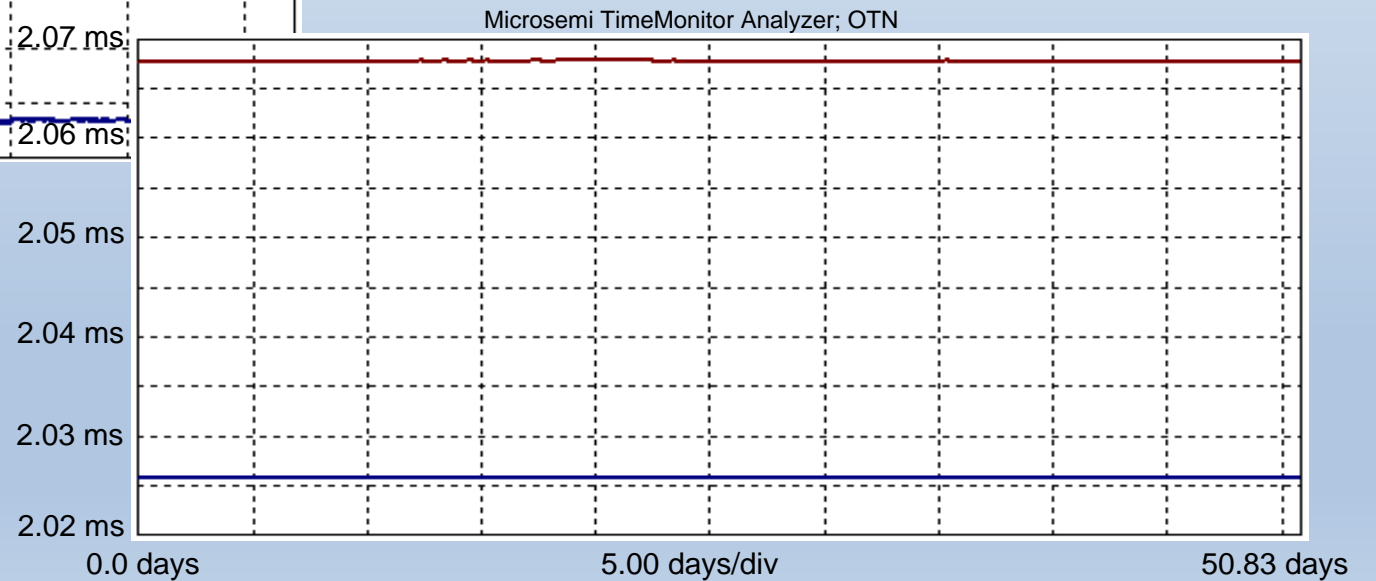
OC192 forward (blue) and reverse (red) packet delay



← SONET

OTN fwd (blue) and rev (red) PDV

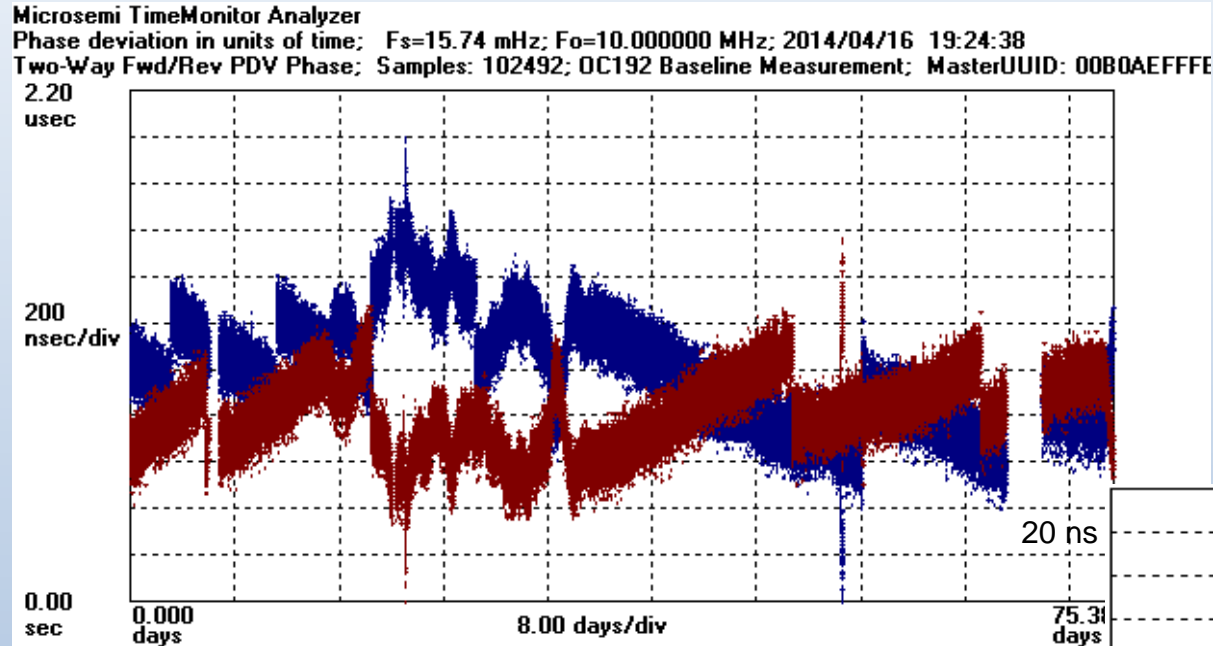
OTN →



PTP over SONET/OTN

SONET: a few μs p-p; OTN: a few ns p-p

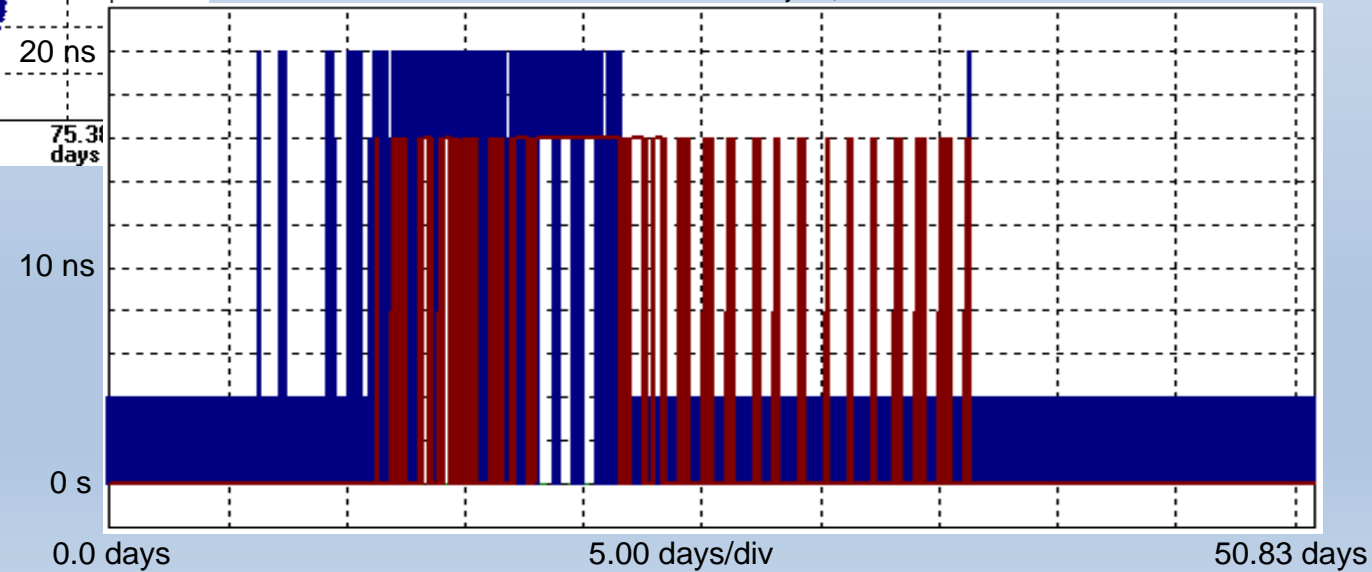
OC192 forward (blue) and reverse (red) packet delay



← SONET

OTN fwd (blue) and rev (red) PDV

Microsemi TimeMonitor Analyzer; OTN



OTN →

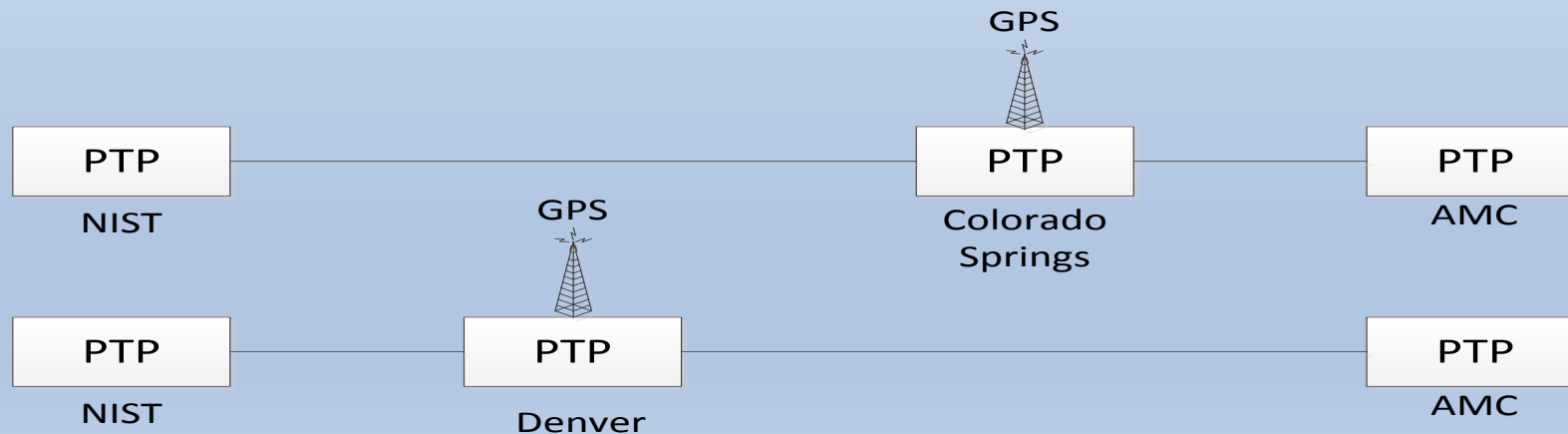
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Asymmetry Investigation

Placed Microsemi PTP Equipment in CenturyLink Offices

- Placed two PTP+GPS devices, TP5000, same model as what is at NIST and USNO AMC now
- Placed TP5000s at Denver and Colorado Springs offices
- Allow for direct two-way time transfer in three sections
 - Between NIST, Boulder and Denver
 - Between Denver and Colorado Springs
 - Between Colorado Springs and USNO AMC, Schriever AFB



Results from “Asymmetry” Experiment

- Isolated sources of 40 microsecond asymmetry
 - Latency divided approximately equally between NIST-D, D-CS, CS-AMC
 - 75% of the asymmetry is accounted for by the Denver-Colorado Springs link

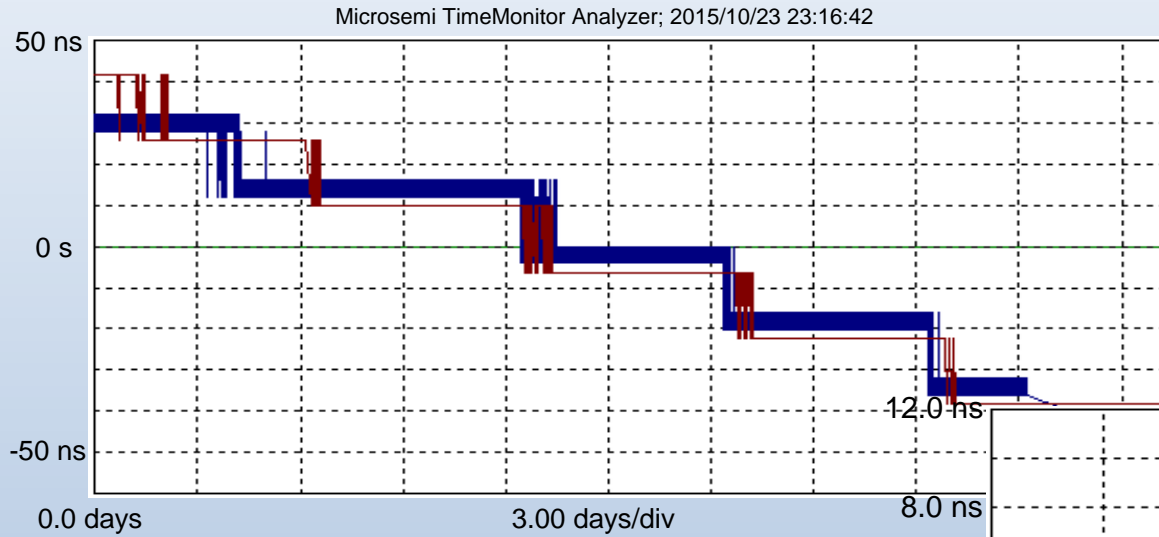
	AMC to NIST delay	NIST to AMC delay	Asymmetry
Direct circuit	2025 μ s	2066 μ s	40.5 μ s
Circuit broken in Colorado Springs	2270 μ s	2300 μ s	30.2 μ s
Circuit broken in Denver	2232 μ s	2278 μ s	46.5 μ s

- Two important points
 - When circuits are rebuilt, latency and asymmetry change (see table above)
 - **Asymmetry is static and can be calibrated out as long as the circuit stays up** (several measurements of two to three months or more have shown this to be the case)

Outline

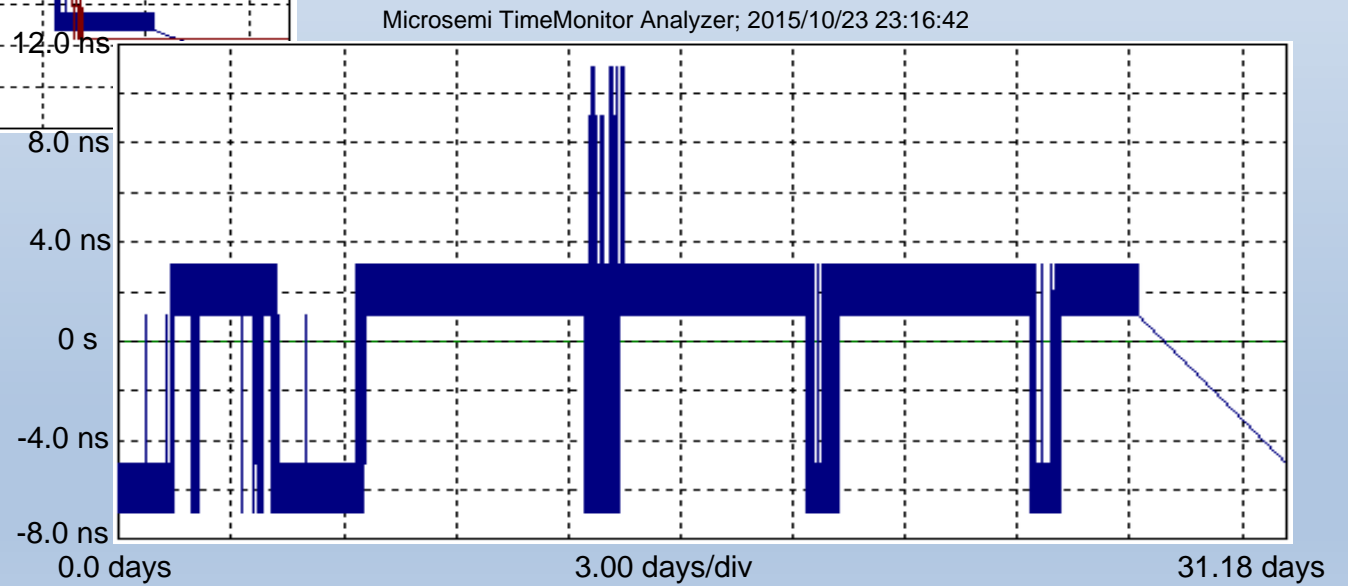
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Forward/Reverse Latency Variations Cancel Out

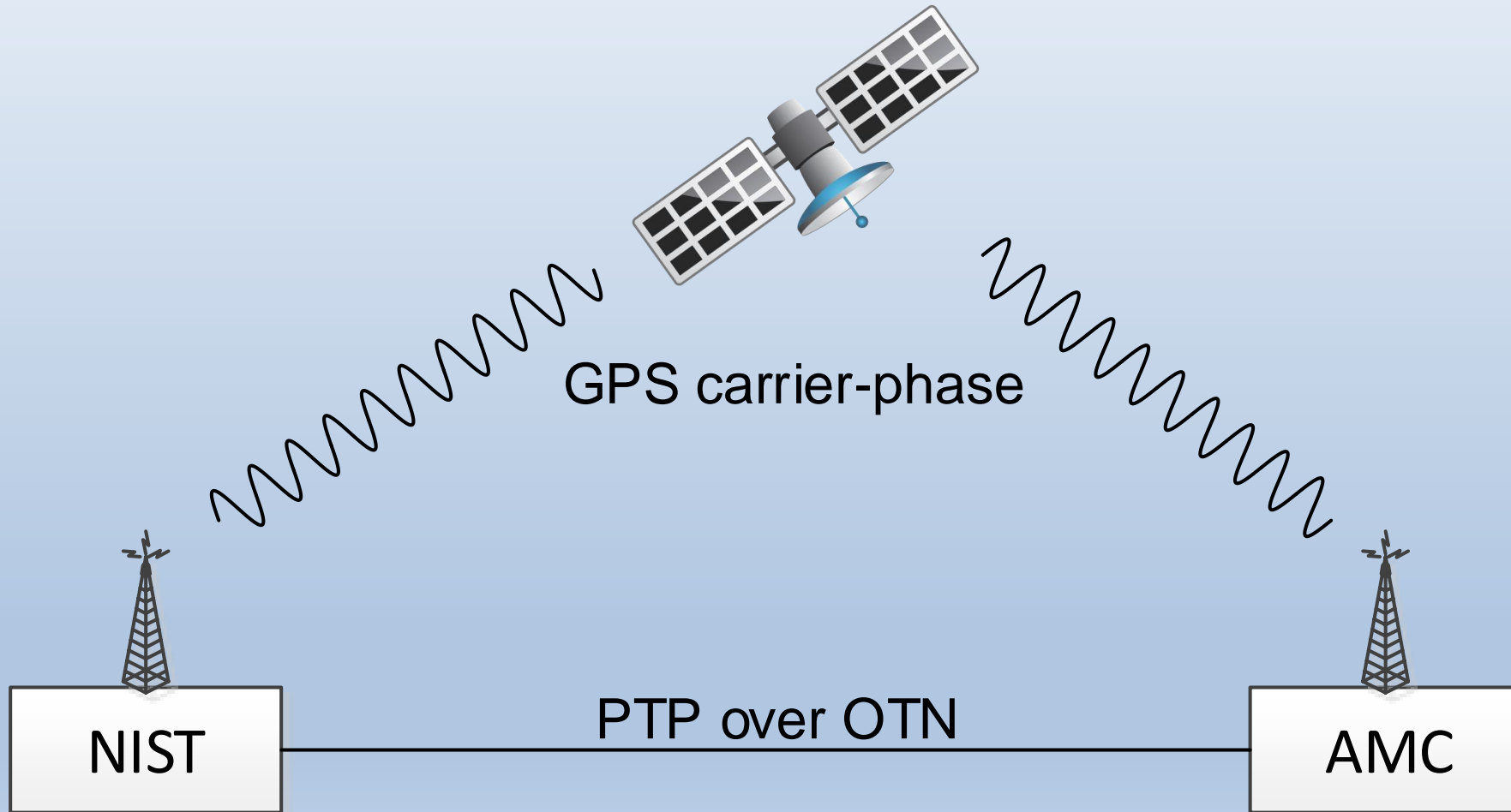


← One-Way Measurements

Two-Way Time-Transfer →

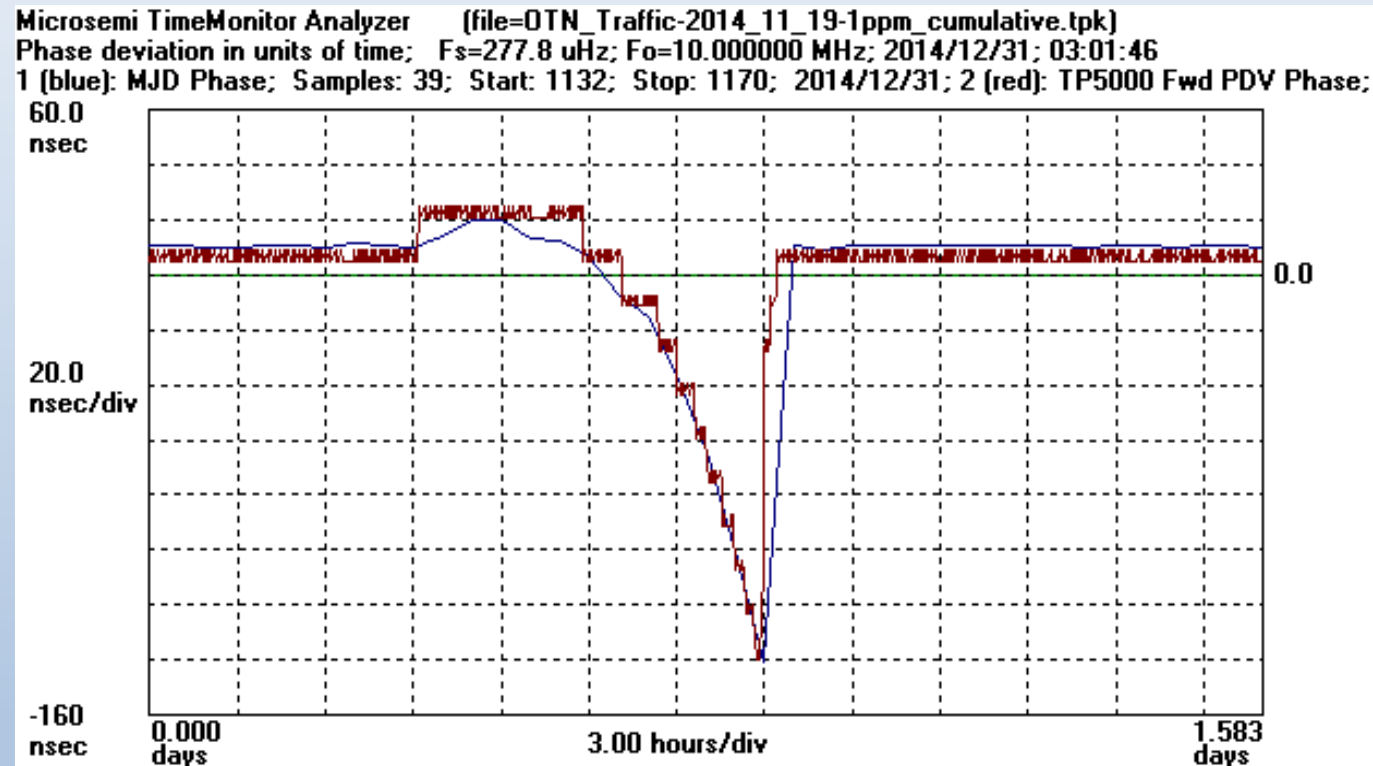


PTP fiber vs. GPS Carrier Phase



PTP fiber vs. GPS Carrier Phase

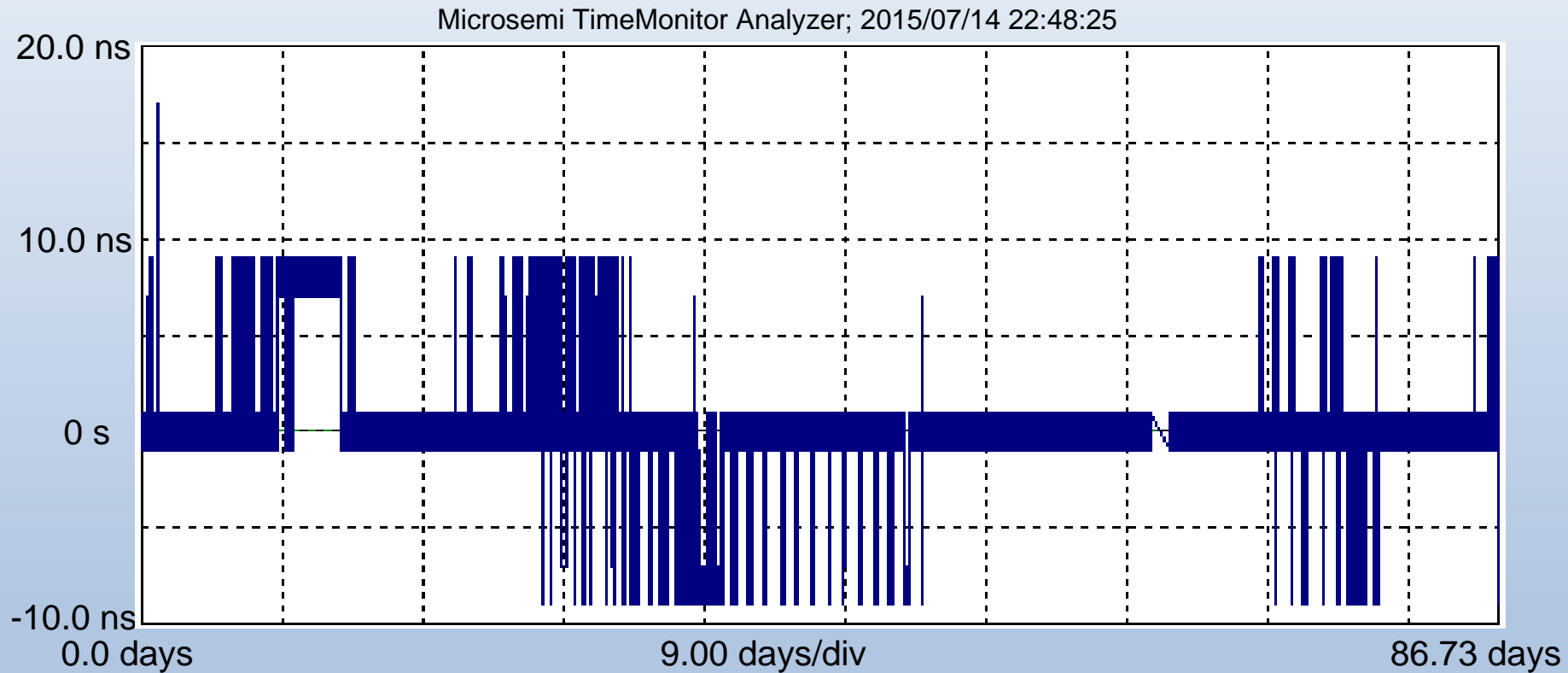
PTP (blue) and GPS carrier-phase (red) measurements during a failure of timing distribution equipment at one of the UTC sites



The two measurements match well with the 180 ns excursion occurring over the 12-hour period of timing distribution equipment failure at one of the UTC sites. The PTP timestamp resolution can be seen in the 4 nanosecond quantization and 16 nanosecond steps.

Long-term PTP fiber measurement

Two-way offset calculation on 87-day measurement shows 26 ns peak-to-peak over the entire run



These results support the possibility that this method could provide time holdover below 100 ns indefinitely

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Next Steps

- Looking to extend experiment to ultra-long range equipment in a network extending over 1000s of kilometers
- Results of experiment are being published
- ATIS sync standards committee (COAST-SYNC) has a project for GPS backup
 - This experiment to show capabilities across one commercial carrier
 - Consider extending this experiment to other geographic areas or using other carriers

Thank You for Your Attention

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