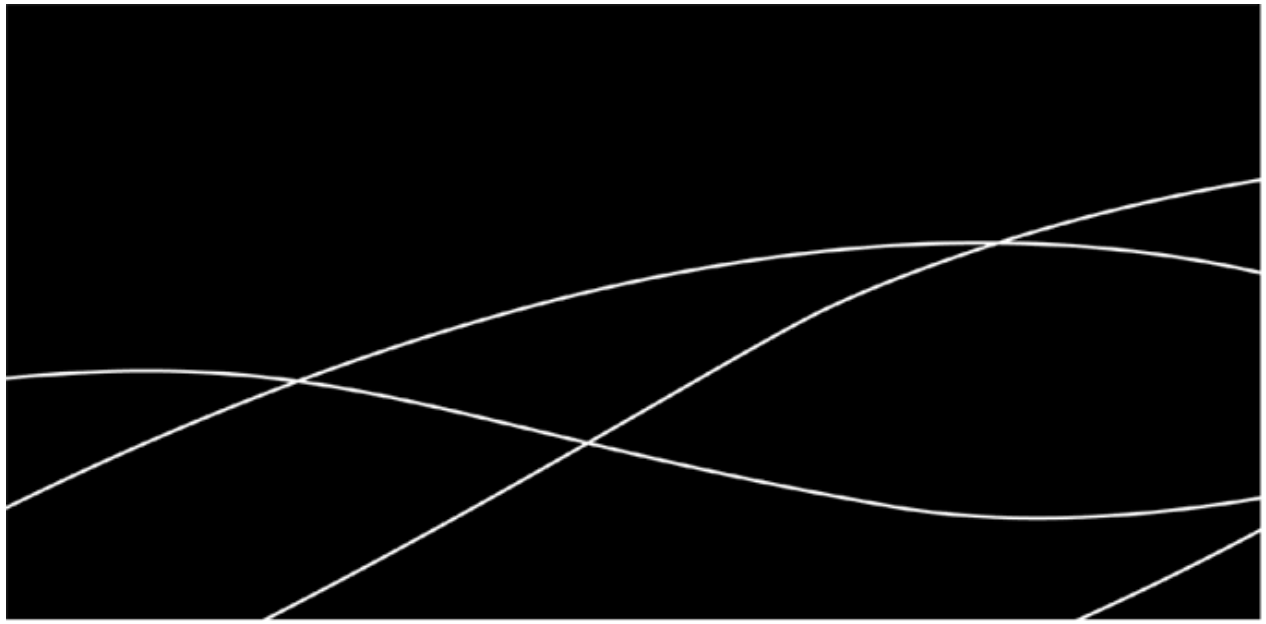
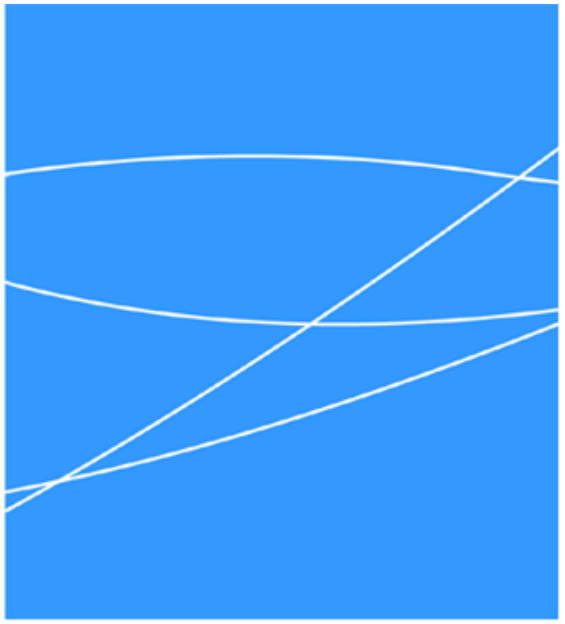
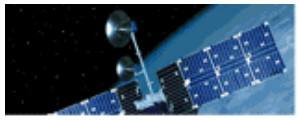
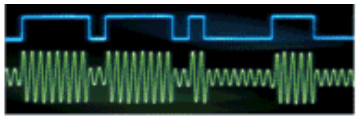







Timing Measurements in Packet Networks

ITSF November 2006

Lee Cosart

lcosart@symmetricom.com

Symmetricom

Presentation Outline

Symmetricom

- Measurement Setup
  - Measurement equipment configurations
  - Network configurations
- Performance Metrics
  - Phase (sequential)
  - Maximum Time Interval Error, MTIE
  - Time Deviation, TDEV
  - Phase statistics
- Measurements
  - Lab
  - Network

Measurement Setup

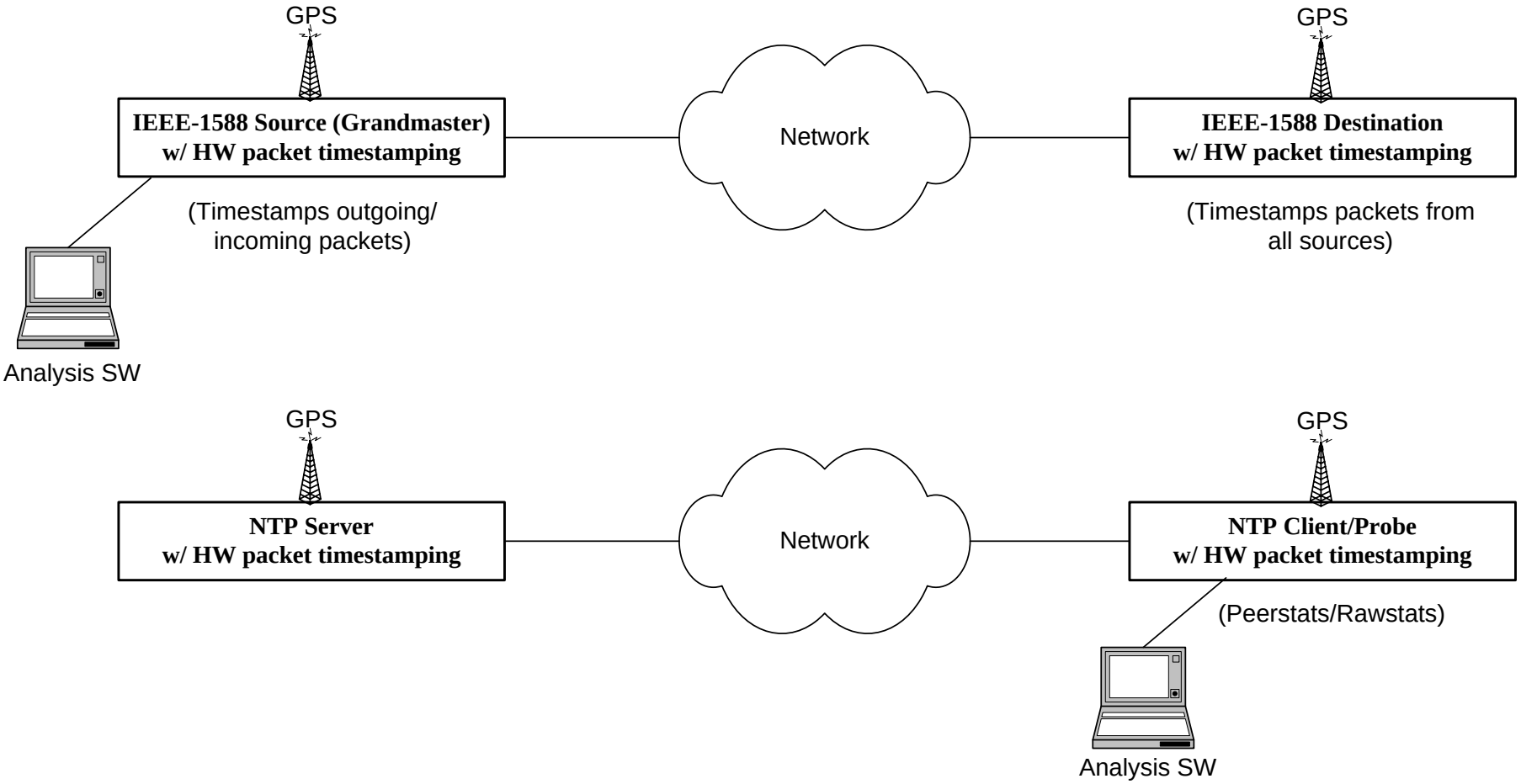
Symmetricom

- Measurement equipment with precision IEEE-1588 or NTP hardware time-stamping
- GPS time-of-day reference in each unit
  - Required for sub-microsecond end-to-end analysis
  - Log-files of the time-stamp data is post-processed
- Network configurations
  - Basic: crossover cable, hub, switch
  - Baseline: switch, router, multi-hop with no traffic
  - Traffic: load based upon G.8261 “data” profile
  - Production Network with Live Traffic

Packet Measurement Example Configurations

Example Measurement Equipment Configurations

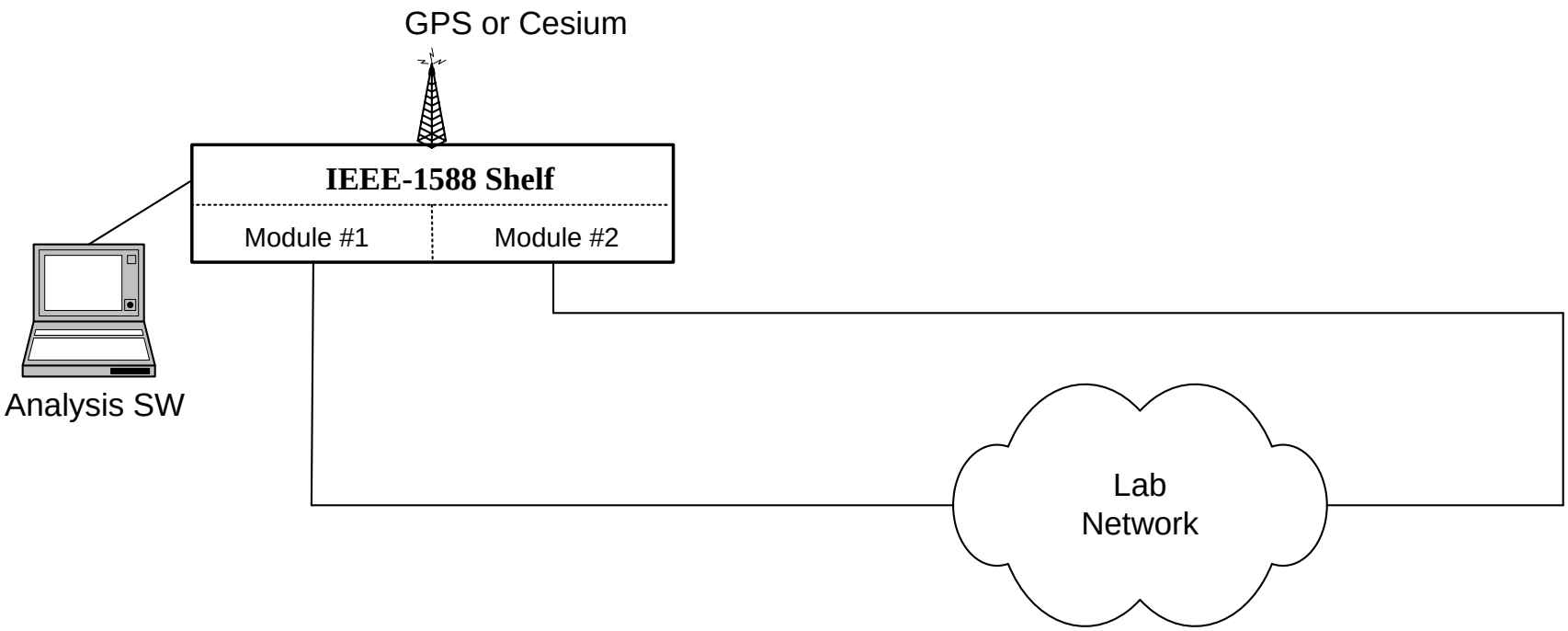
Need (1) PRC TOD reference (2) Precision Packet TimeStamping (3) Analysis SW



Packet Measurement Example Configurations

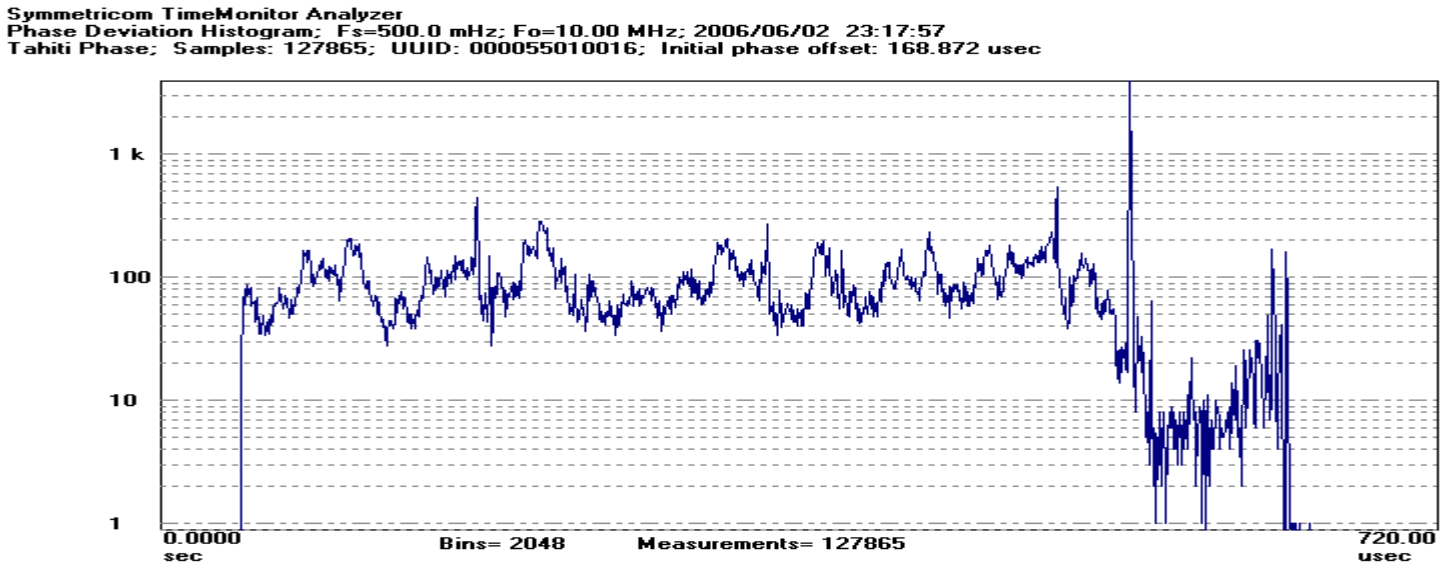
Symmetricom

Alternate Measurement Equipment Configuration for Lab

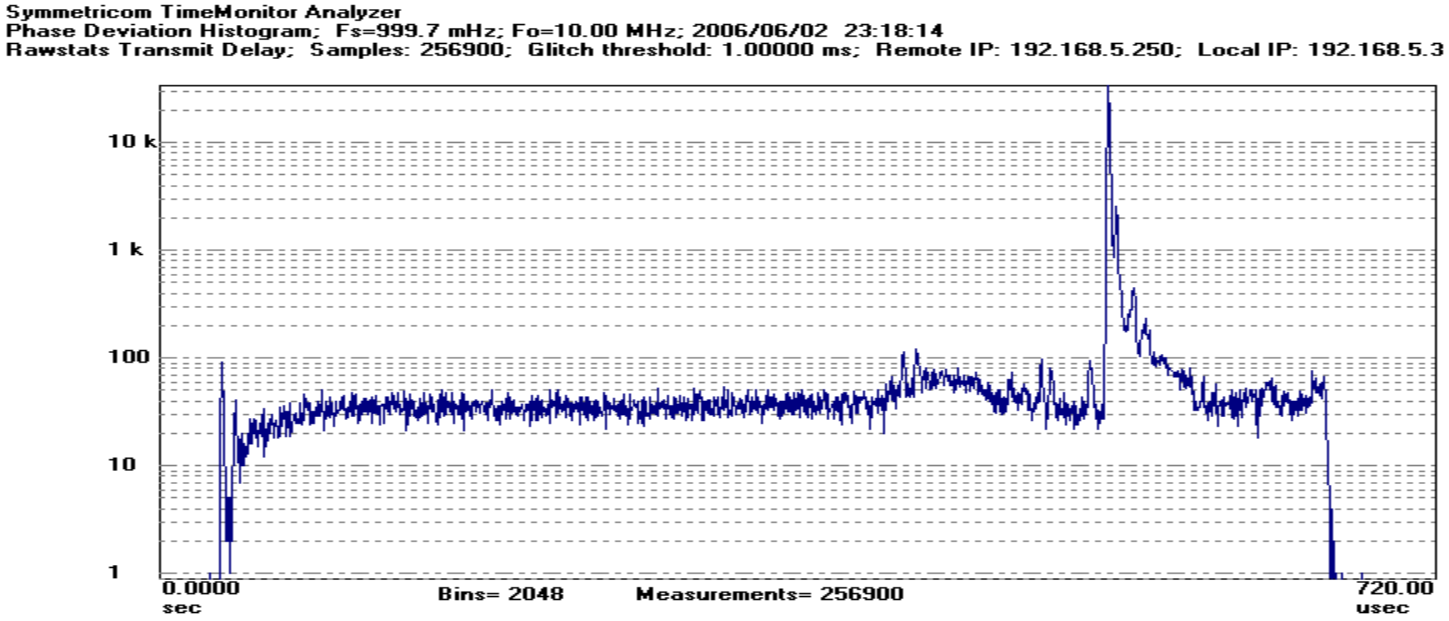


IEEE 1588 vs. NTP Packet Measurement Tools: Example 1

Symmetricom



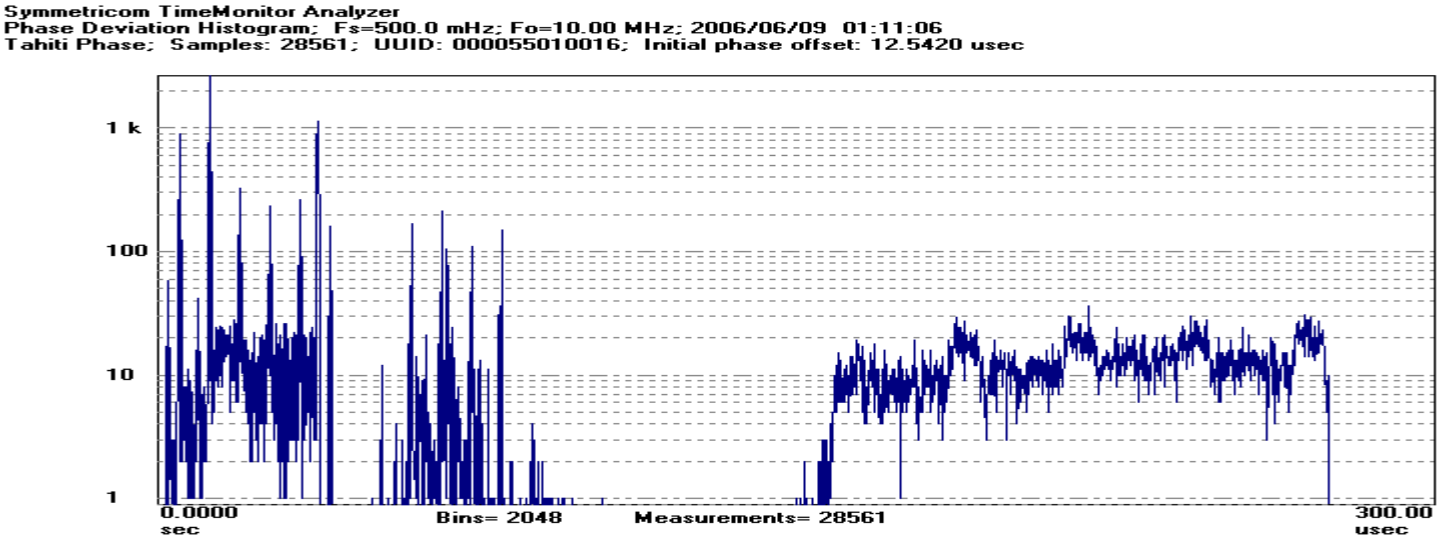
IEEE 1588



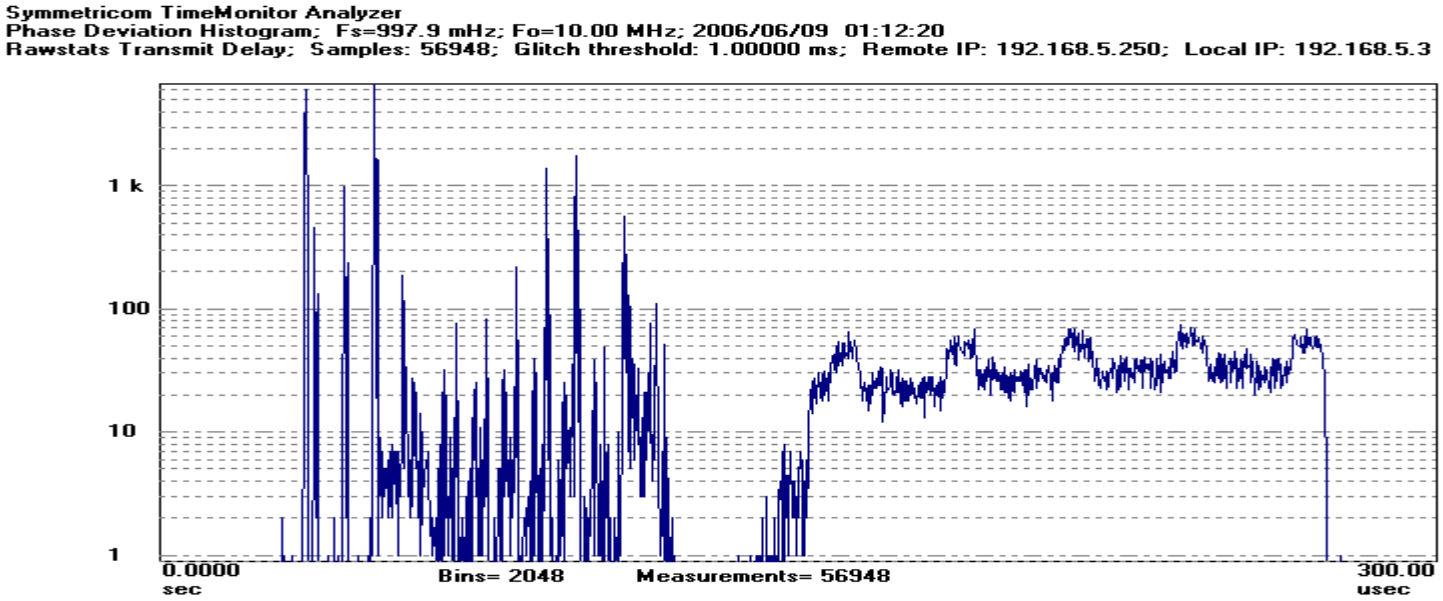
NTP

IEEE 1588 vs. NTP Packet Measurement Tools: Example 2

Symmetricom



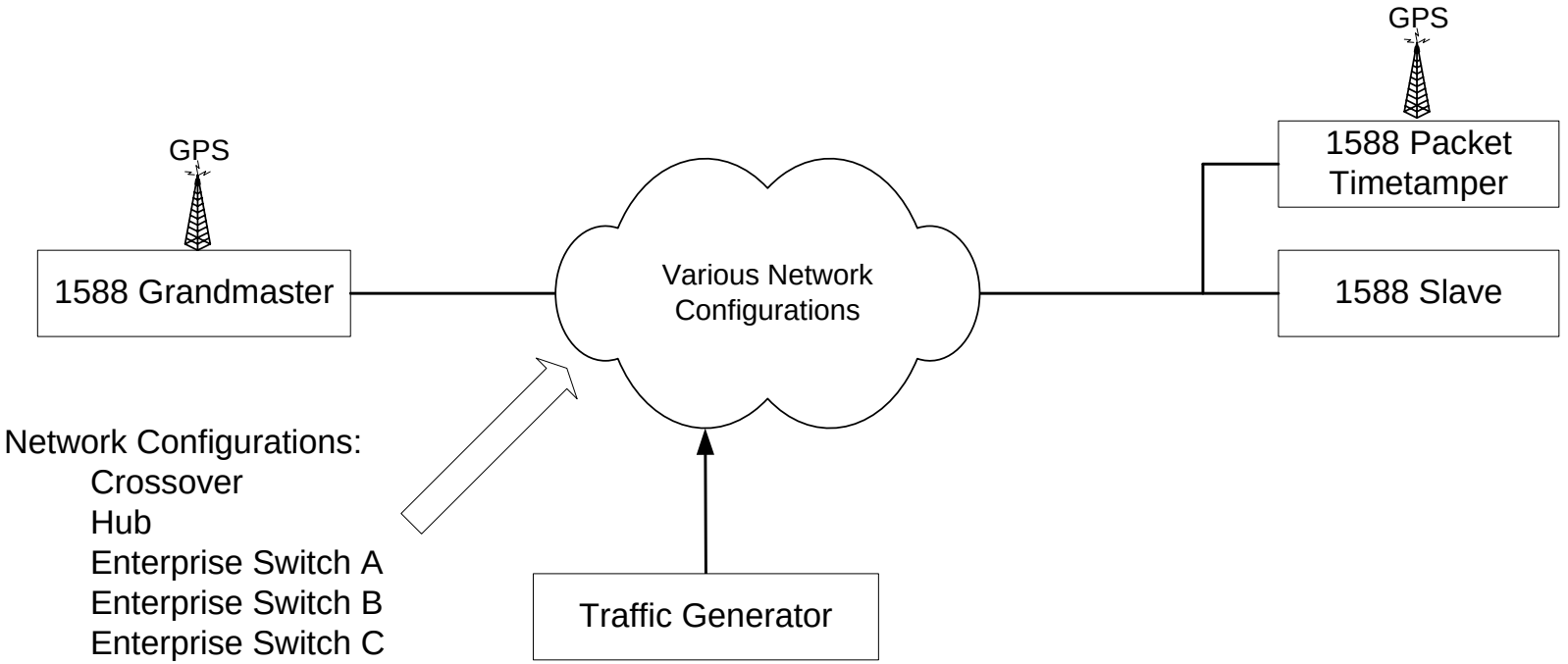
IEEE 1588



NTP

Lab Network Configurations

Example Lab Network Configurations

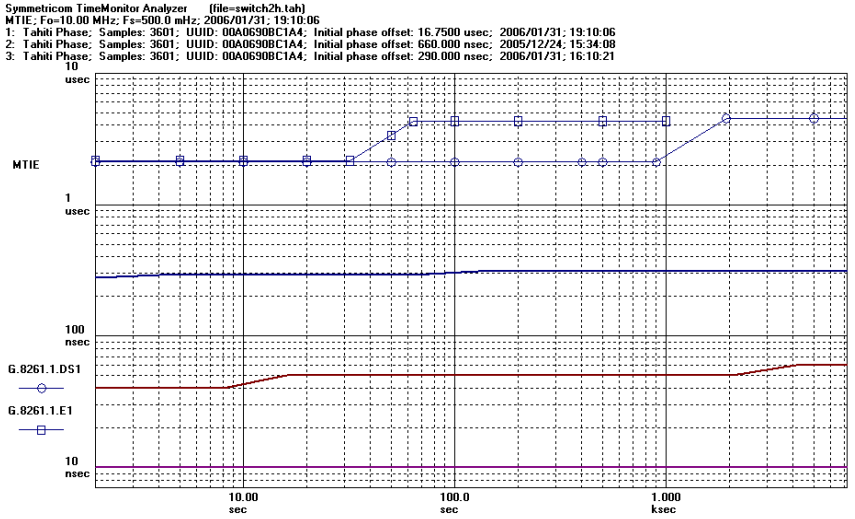


Network Configurations:

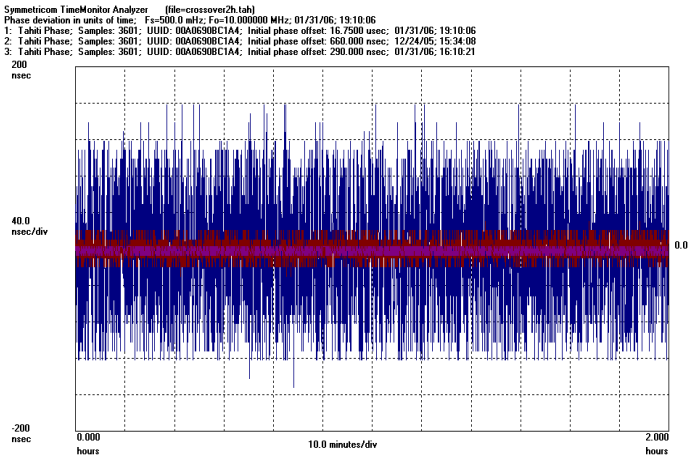
- Crossover
- Hub
- Enterprise Switch A
- Enterprise Switch B
- Enterprise Switch C
- Enterprise Switch D
- Multilayer Switch E
- Wirespeed router M
- Router X
- Router Y
- Multi-Hop: SwA/RtX/SwB
- Multi-Hop: SwA/RtM/SwB
- Multi-Hop: SwA/RtX/RtX/SwB
- Multi-Hop: SwA/RtX/RtY/SwB

Performance Metrics

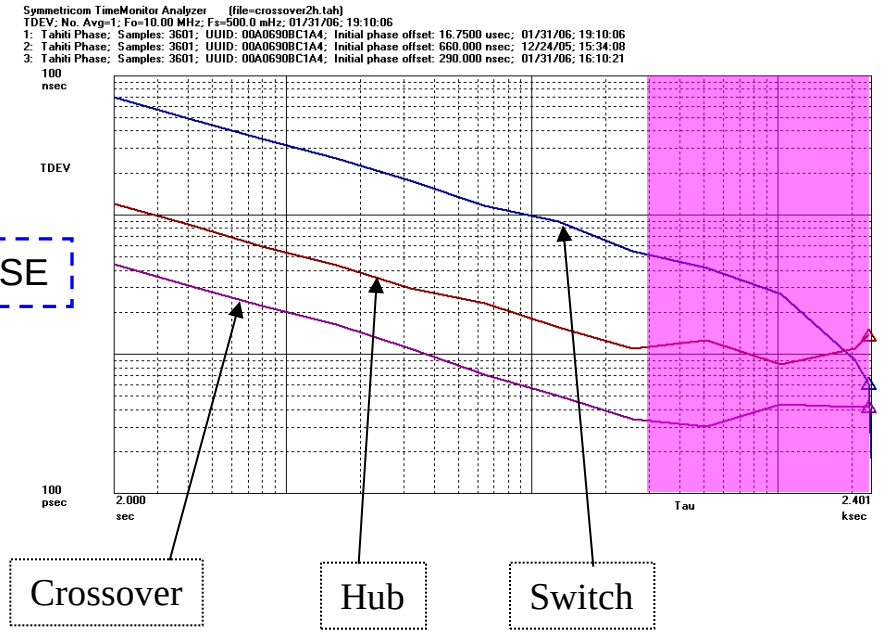
- Phase, TIE (Time Interval Error)
  - Basis for all PM data sets
- Maximum Time Interval Error
  - MTIE, PM definition defined in G.8261 (G.pactiming)
- Time Deviation, TDEV



MTIE



PHASE



TDEV

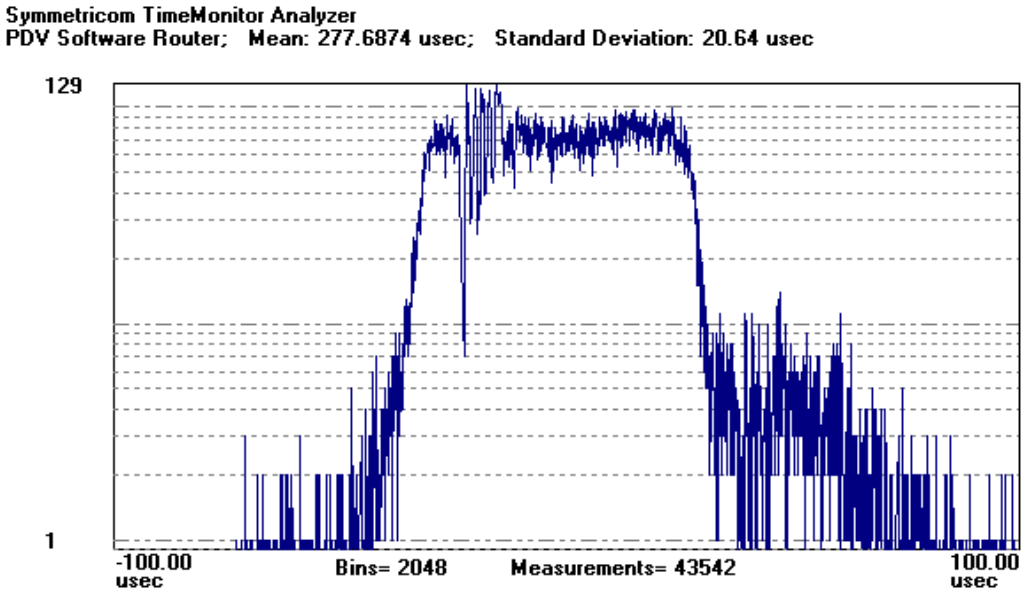
Crossover

Hub

Switch

Performance Metrics

- Standard Deviation (PDV)
- Mean (Latency)
- Maximum Peak Deviation (PDV)



Statistics

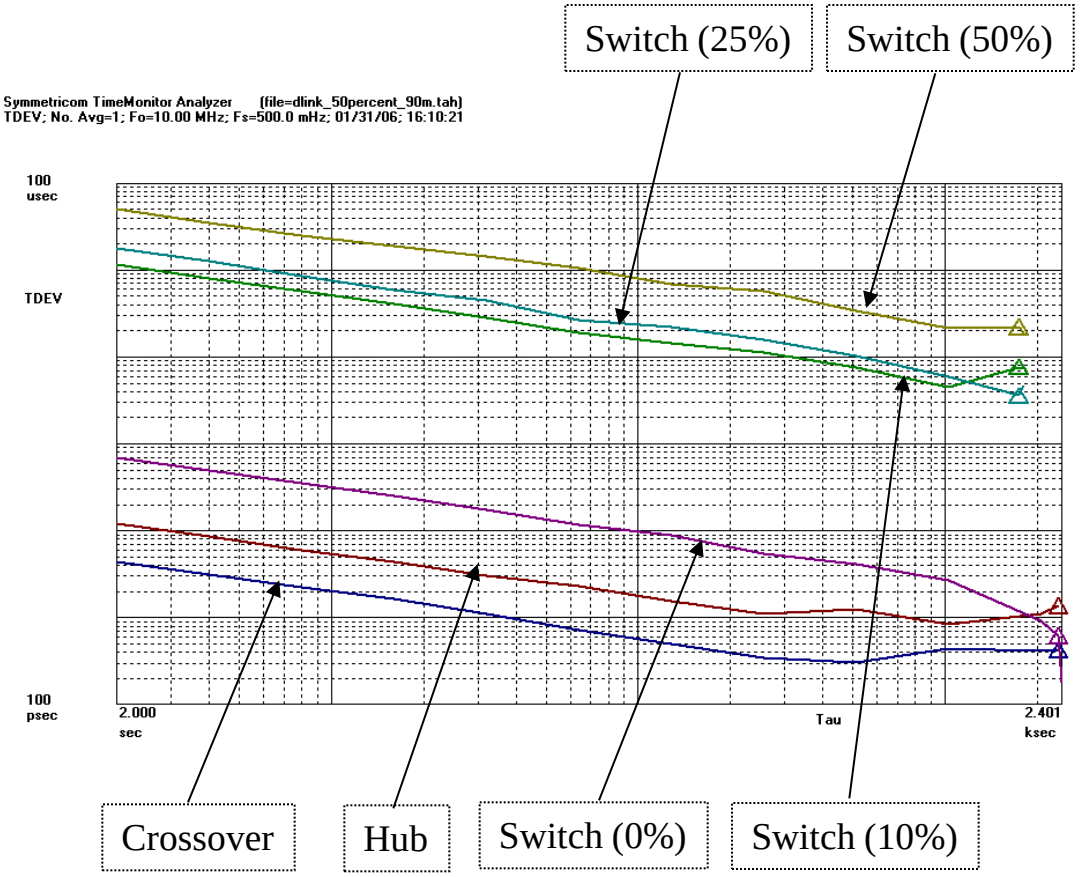
Crossover cable:
Mean: 287.2818 nsec
Peak to Peak: 10.01 nsec
Standard Deviation: 4.450 nsec

Hub:
Mean: 659.7955 nsec
Peak to Peak: 60.01 nsec
Standard Deviation: 12.13 nsec

Switch:
Mean: 16.75112 µsec
Peak to Peak: 310.0 nsec
Standard Deviation: 70.10 nsec

Router:
Mean: 277.6874 µsec
Peak to Peak: 212.5 µsec
Standard Deviation: 20.64 µsec

Performance As a Function of Load



Statistics

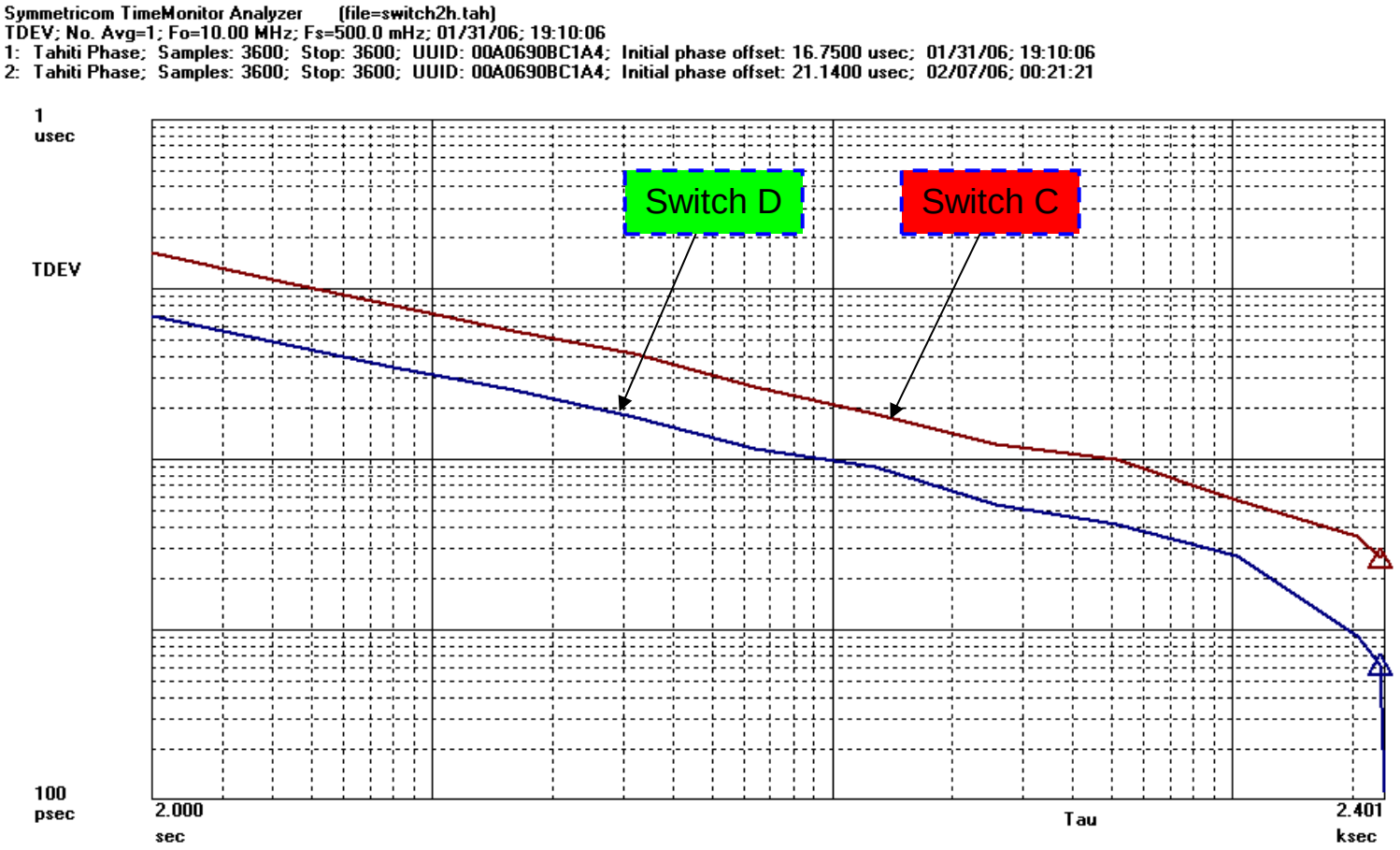
No traffic:
Mean: 16.75112 µsec
Peak to Peak: 310.0 nsec
Standard Deviation: 70.10 nsec

10% BW Utilization:
Mean: 17.93500 µsec
Peak to Peak: 121.4 µsec
Standard Deviation: 11.53 µsec

25% BW Utilization:
Mean: 19.62525 µsec
Peak to Peak: 122.6 µsec
Standard Deviation: 17.61 µsec

50% BW Utilization:
Mean: 47.99551 µsec
Peak to Peak: 122.8 µsec
Standard Deviation: 50.90 µsec

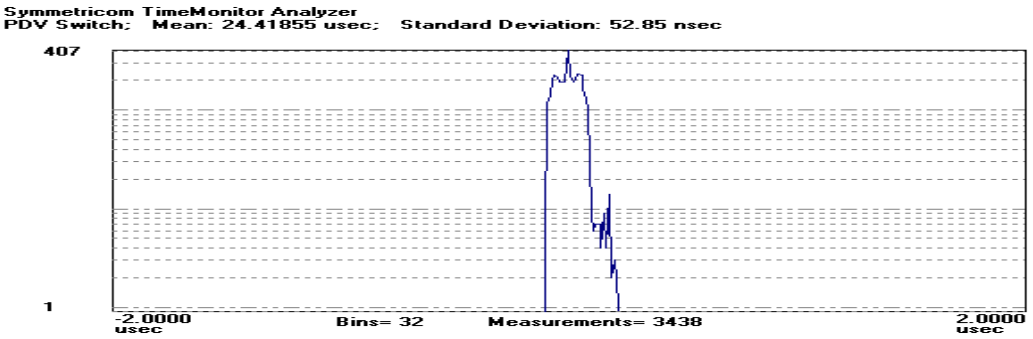
Not All Devices are *Equal*

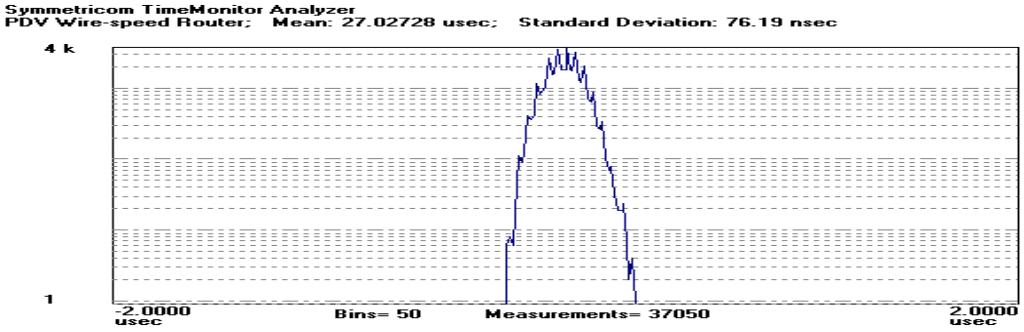


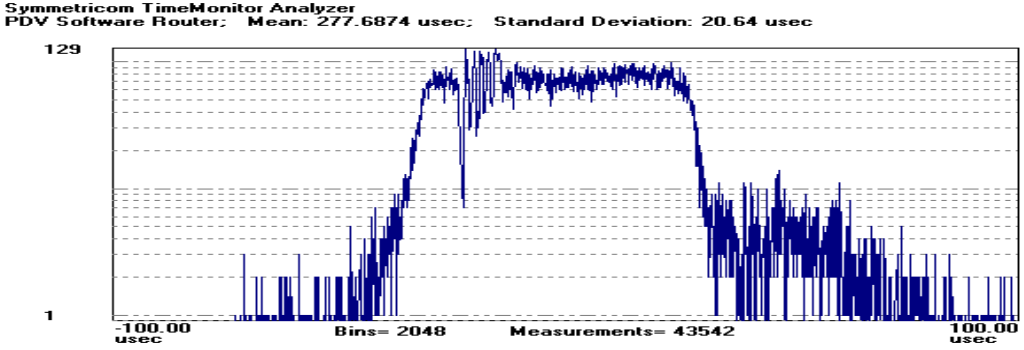
Not All Devices are *Equal*

Symmetricom

Switch vs. Multilayer switch vs. Router







Statistics

Switch:

Mean: 24.41855 µsec

Peak to Peak: 334.8 nsec

Standard Deviation: 52.85 nsec

Multilayer Switch:

Mean: 27.02728 µsec

Peak to Peak: 576.0 nsec

Standard Deviation: 76.19 nsec

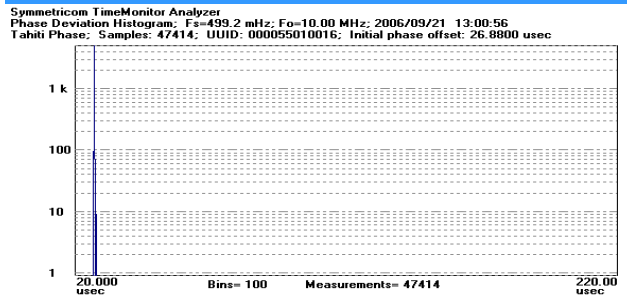
Router:

Mean: 277.6874 µsec

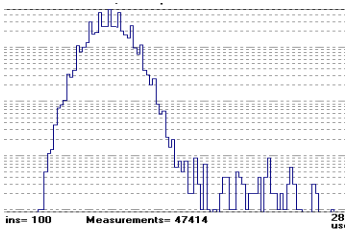
Peak to Peak: 212.5 µsec

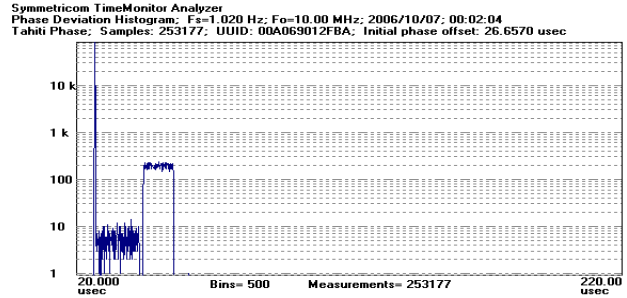
Standard Deviation: 20.64 µsec

Multilayer Switch with Traffic

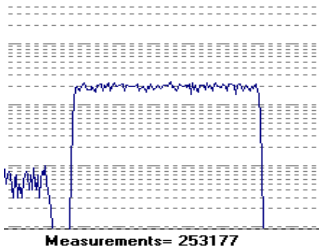


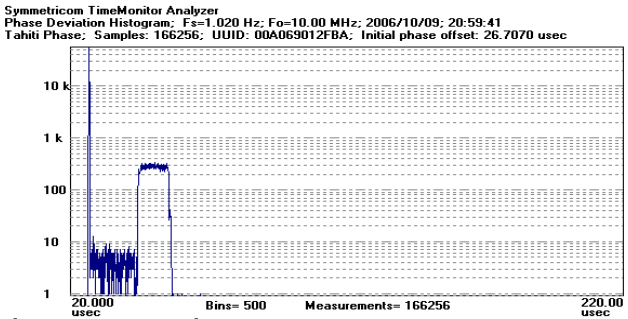
5%



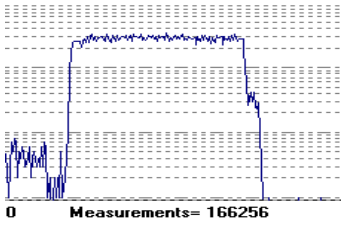


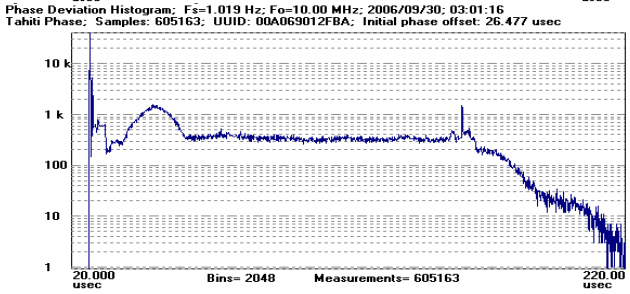
10%





20%





50%

Zooms

No traffic:
Mean: 26.9586 µsec
Peak to Peak: 620.4 nsec
Standard Deviation: 73.20 nsec

5% BW Utilization:
Mean: 26.9462 µsec
Peak to Peak: 1.209 µsec
Standard Deviation: 79.12 nsec

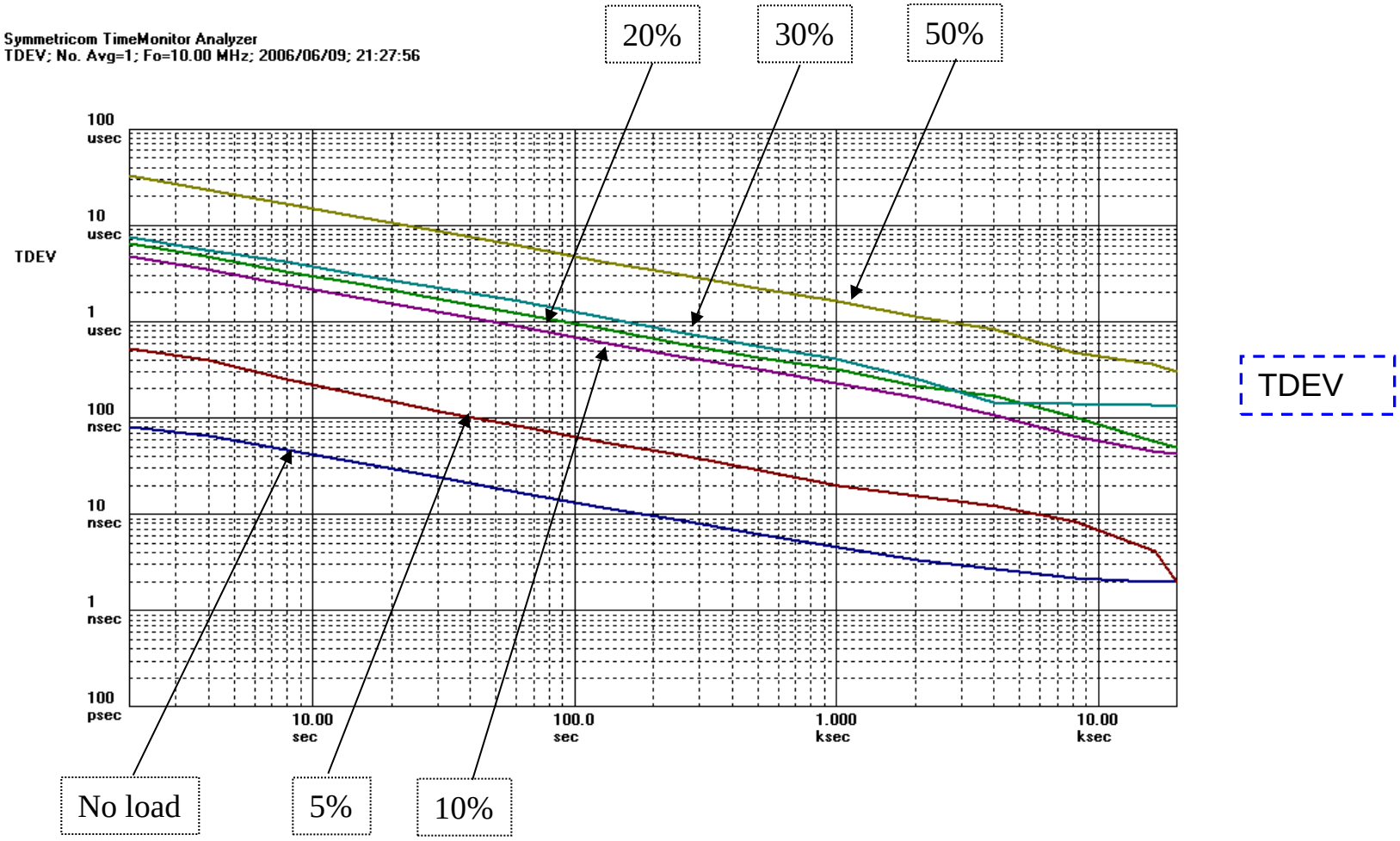
10% BW Utilization:
Mean: 28.9450 µsec
Peak to Peak: 34.77 µsec
Standard Deviation: 7.008 µsec

20% BW Utilization:
Mean: 31.2810 µsec
Peak to Peak: 40.41 µsec
Standard Deviation: 9.426 µsec

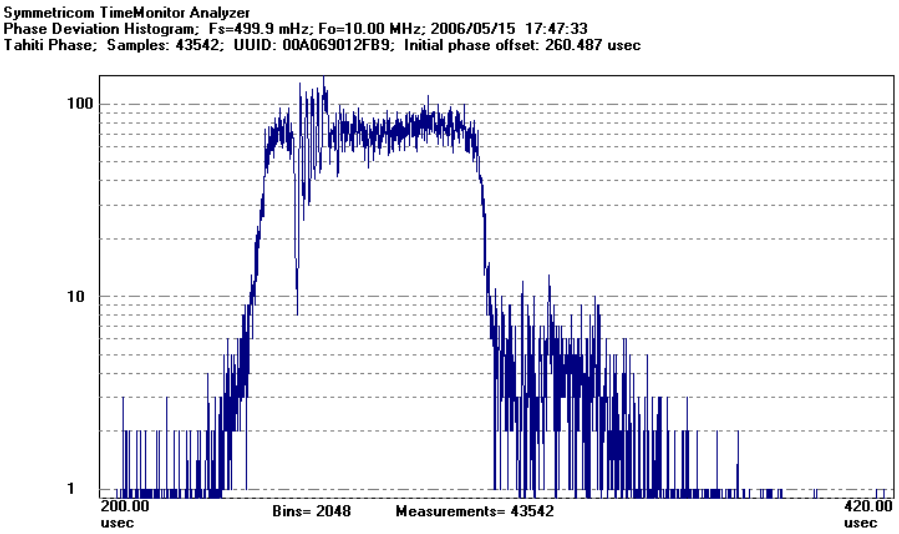
30% BW Utilization:
Mean: 33.6201 µsec
Peak to Peak: 41.70 µsec
Standard Deviation: 10.88 µsec

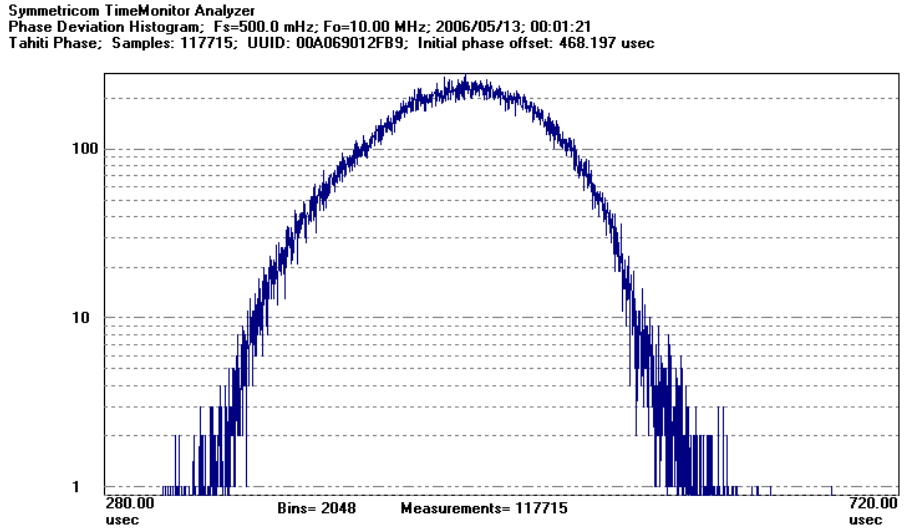
50% BW Utilization (2 Traffic Sources):
Mean: 80.8216 µsec
Peak to Peak: 206.6 µsec
Standard Deviation: 47.06 µsec

Multilayer Switch with Traffic



One vs. Two Routers





Statistics

One router:

Mean: 277.6874 µsec

Peak to Peak: 212.5 µsec

Standard Deviation: 20.64 µsec

Two routers:

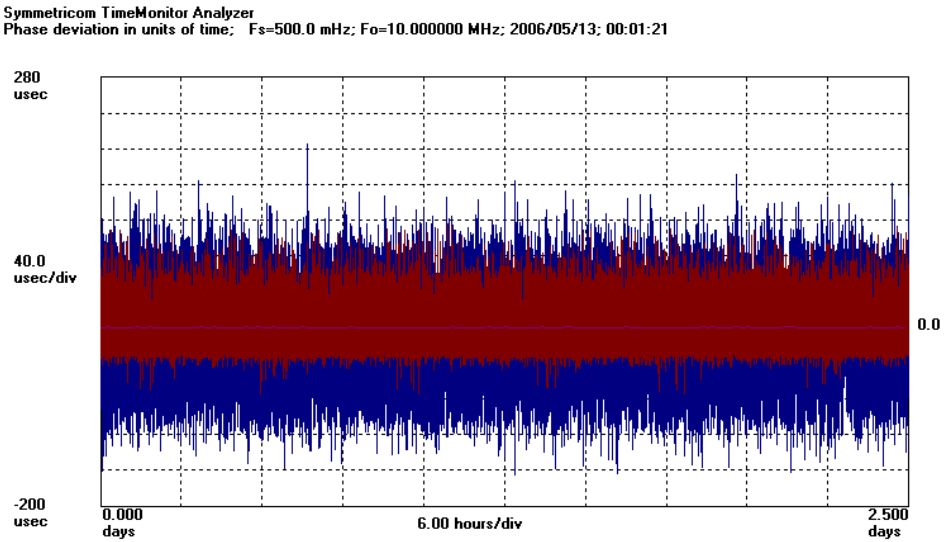
Mean: 477.6874 µsec

Peak to Peak: 369.7 µsec

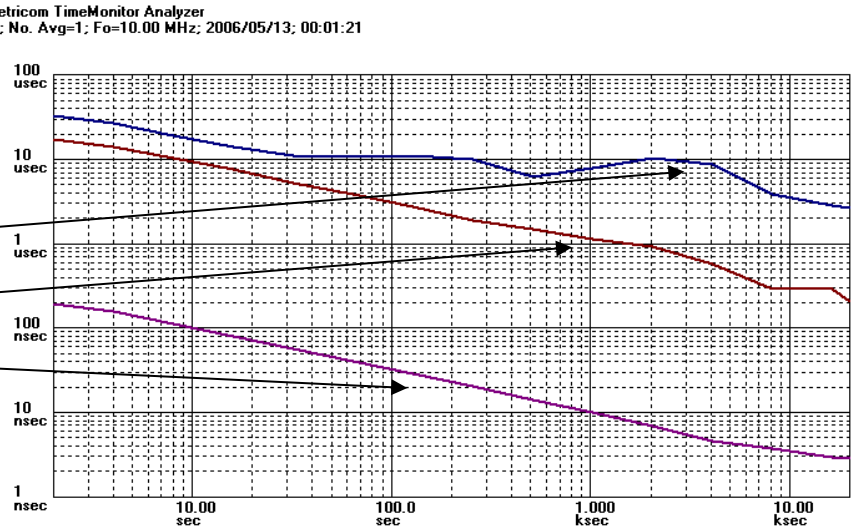
Standard Deviation: 43.18 µsec

One vs. Two Routers

PHASE



TDEV



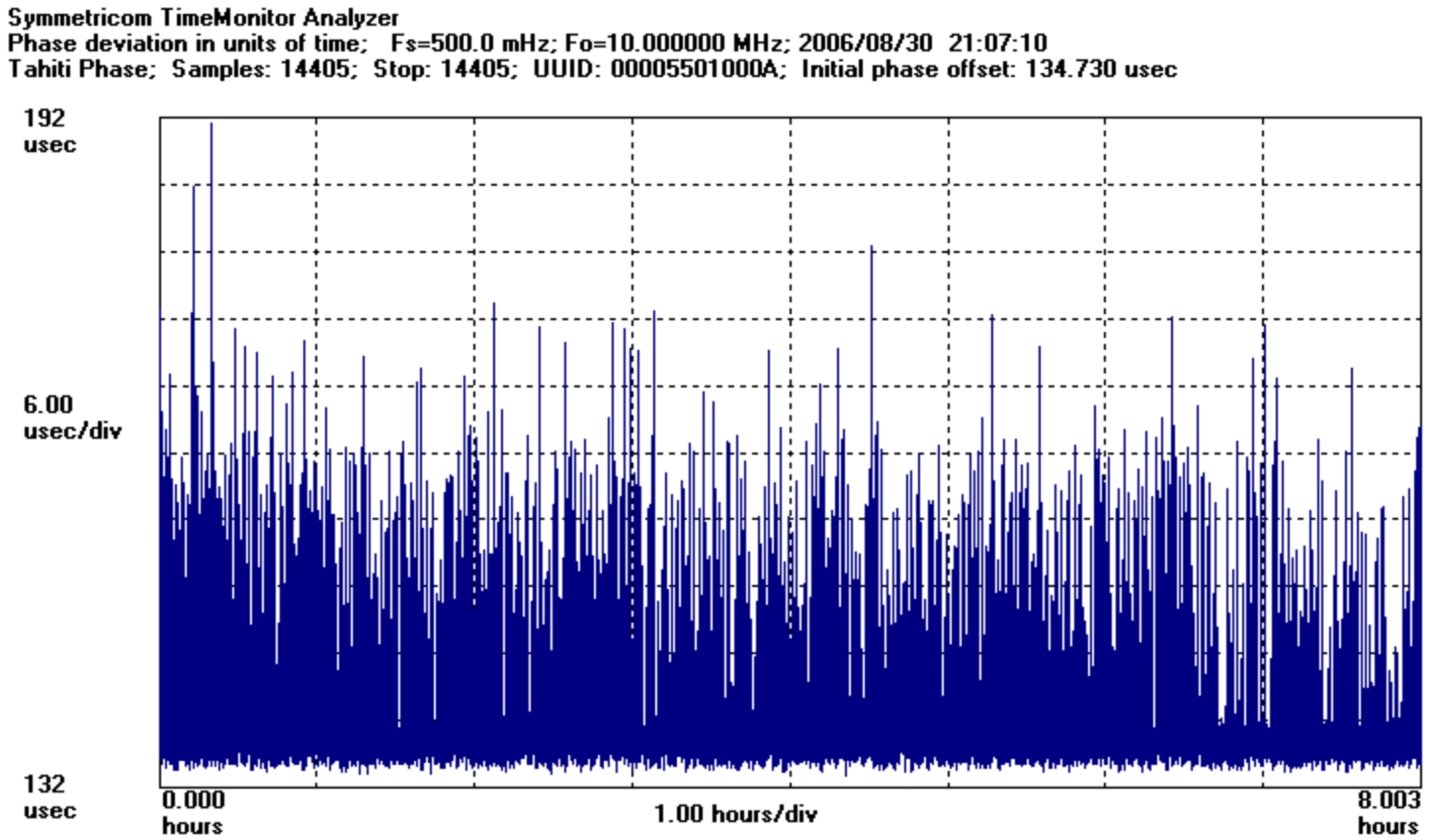
Two Routers: No Load

One Router: No Load

Switch: No Load

Raw PDV vs. Running Statistics

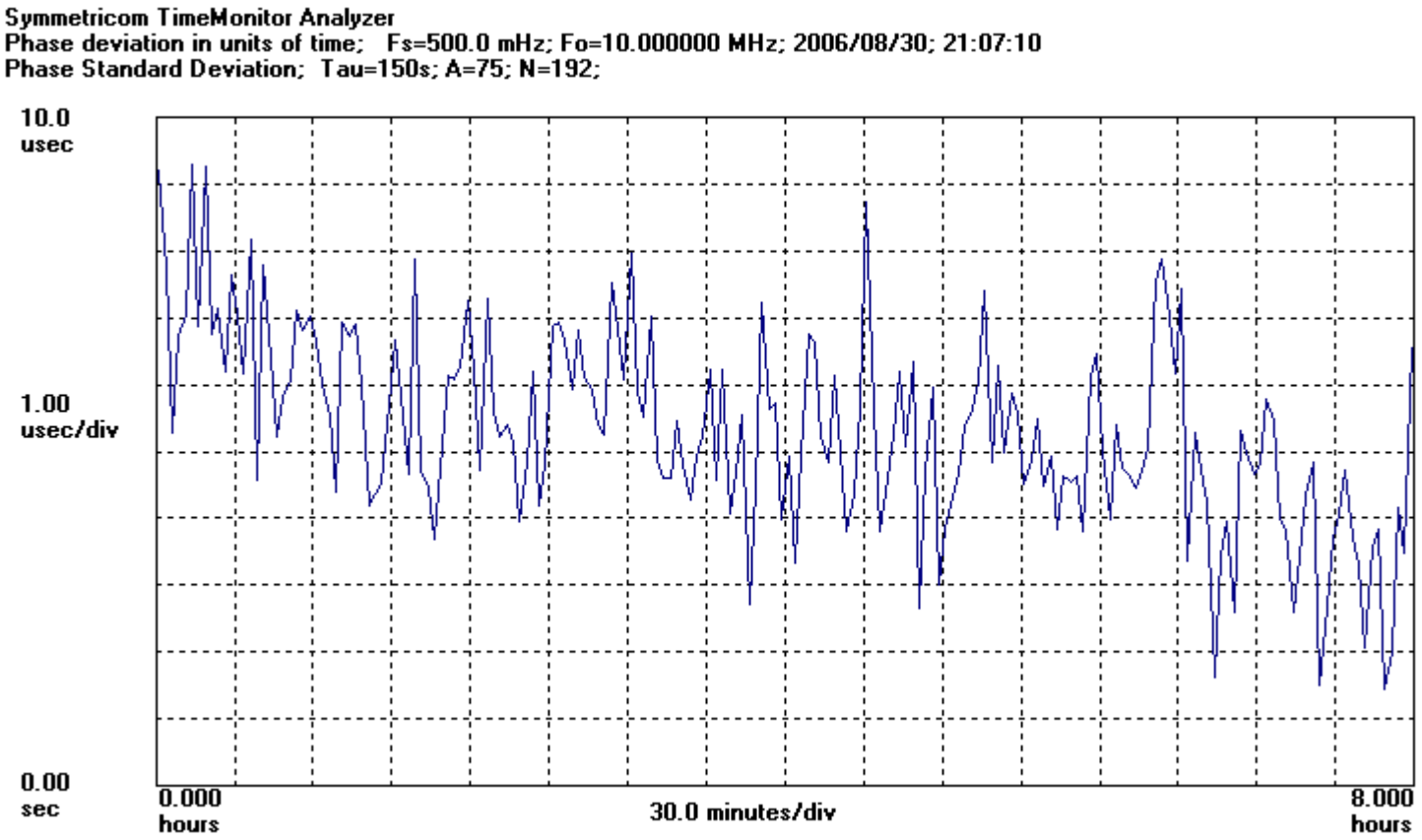
Raw packet delay appears relatively static over time



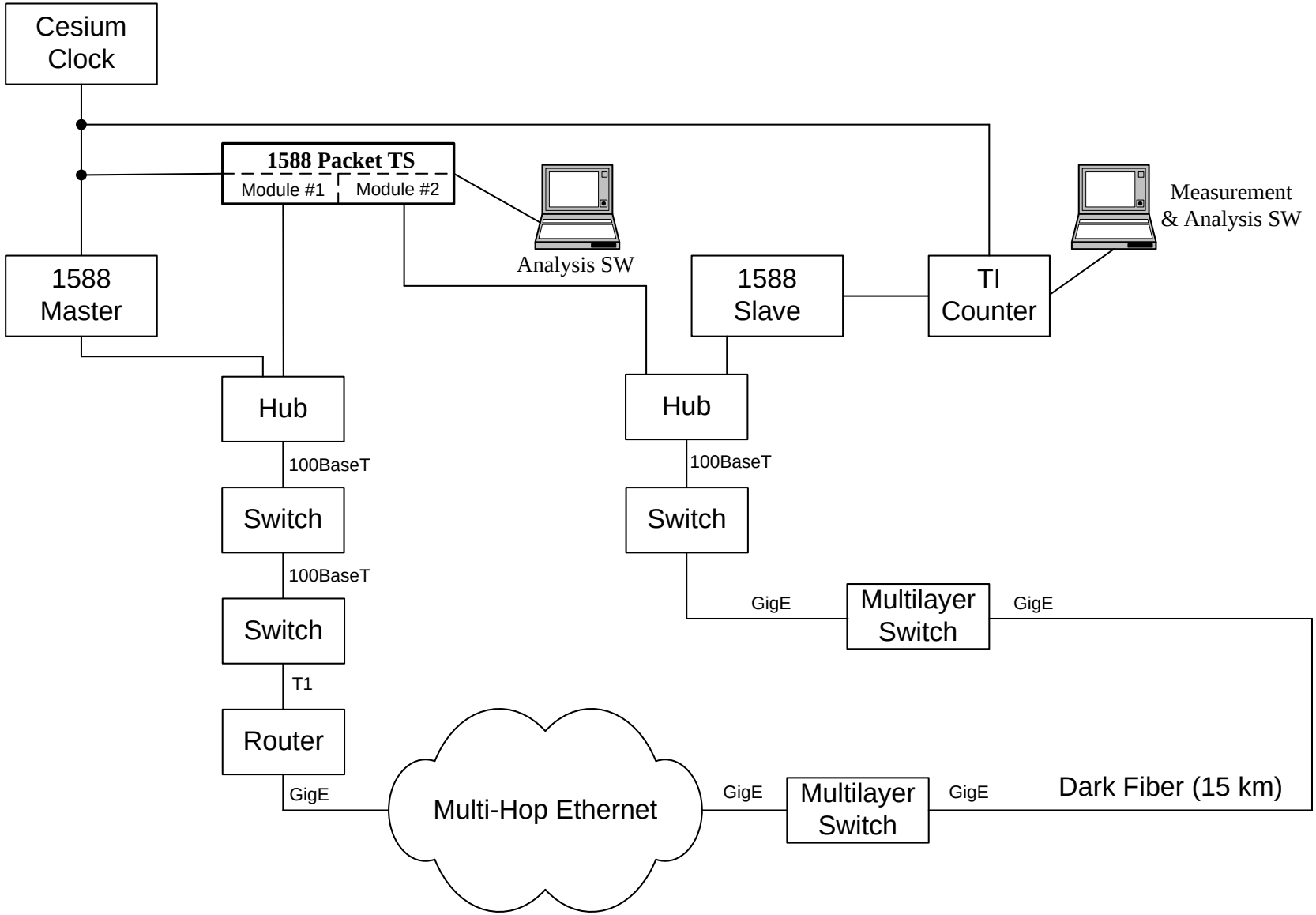
Raw PDV vs. Running Statistics

Symmetricom

Standard Deviation vs. time shows decreasing noise more clearly



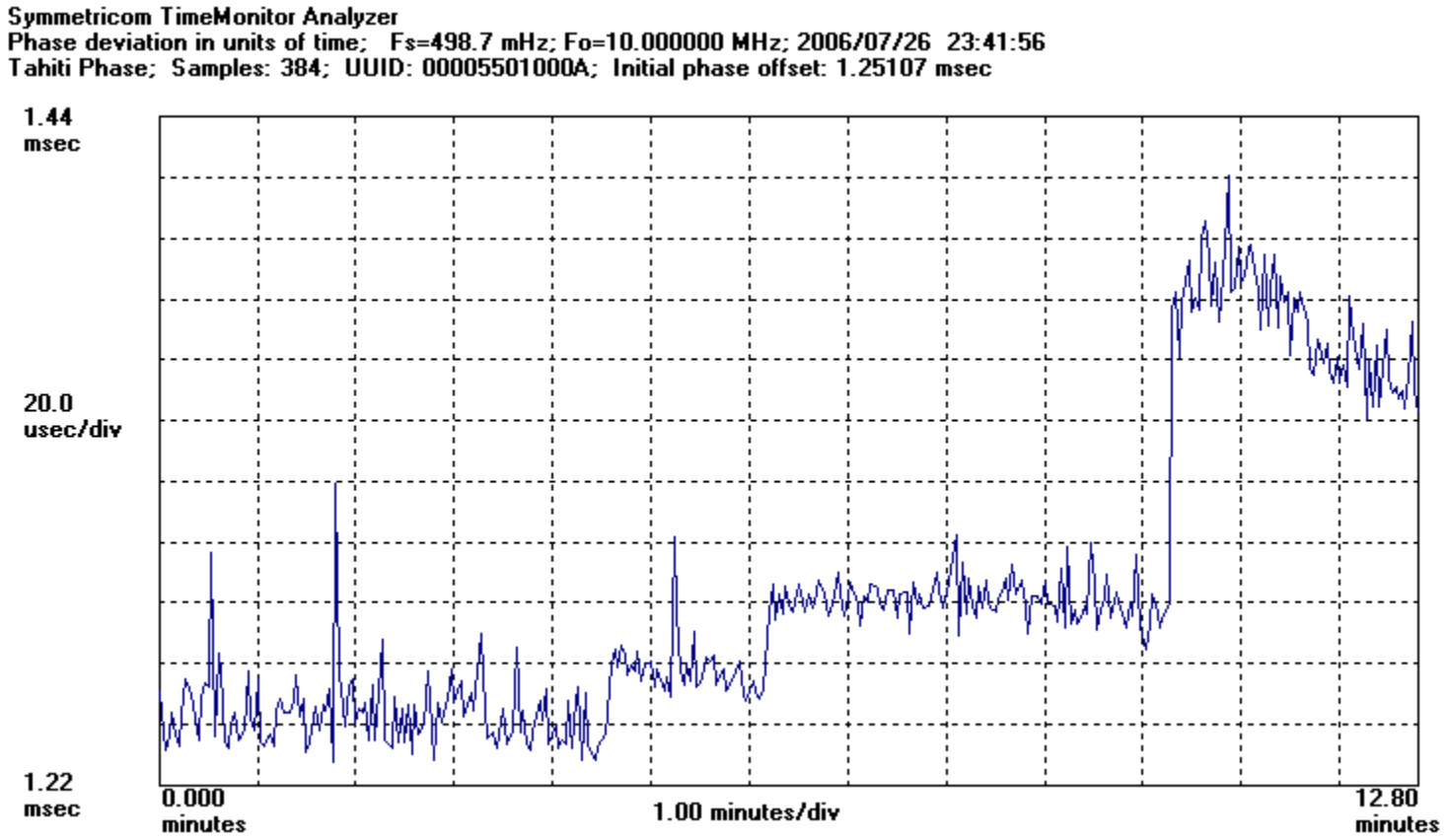
Production Network with Live Traffic



Production Network with Live Traffic

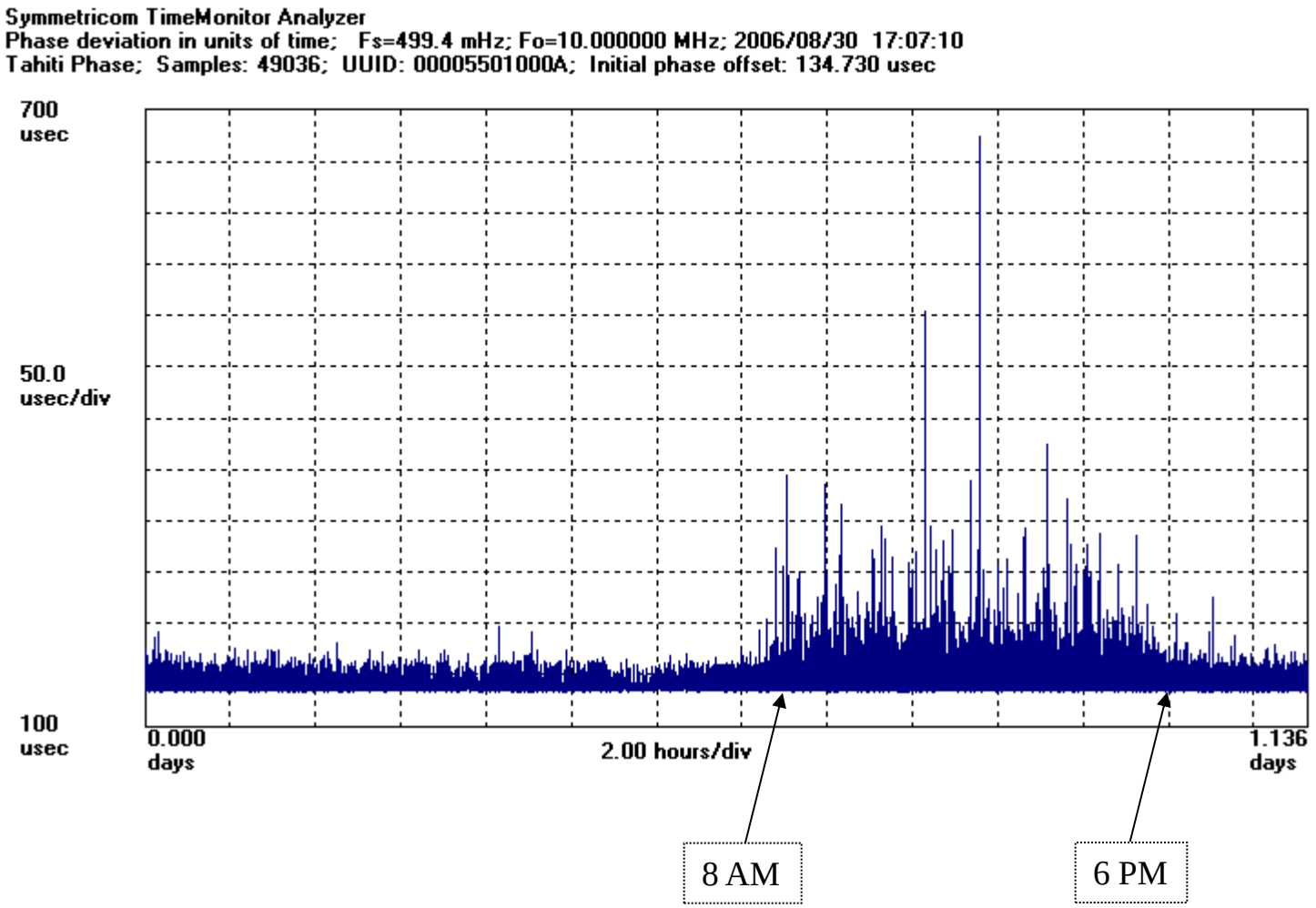
Symmetricom

Packet delay changes over time with live traffic in a production network



Production Network with Live Traffic

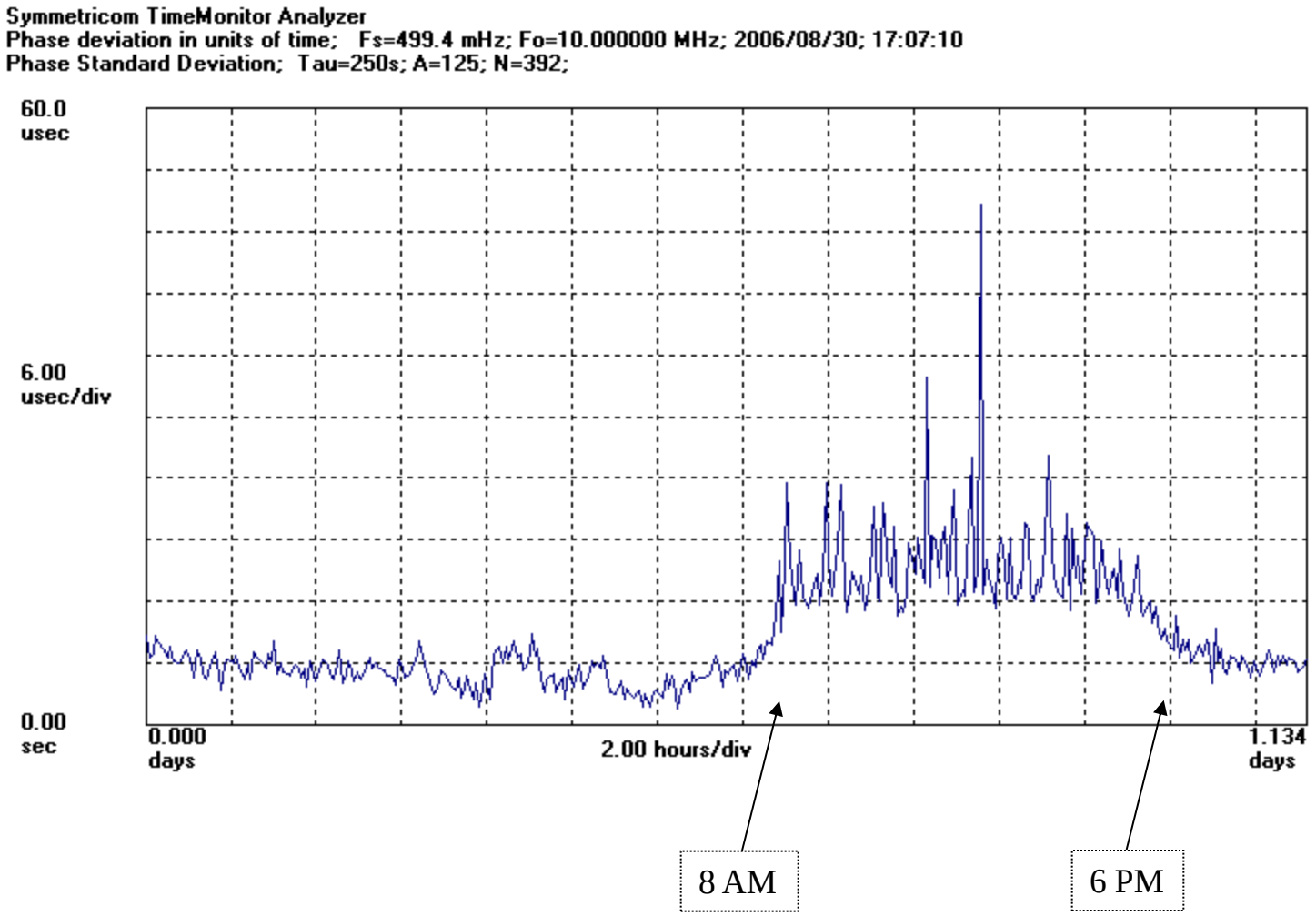
In another measurement, minimum packet delay remains constant but packet delay variation (PDV) changes over time (diurnal)



Production Network with Live Traffic

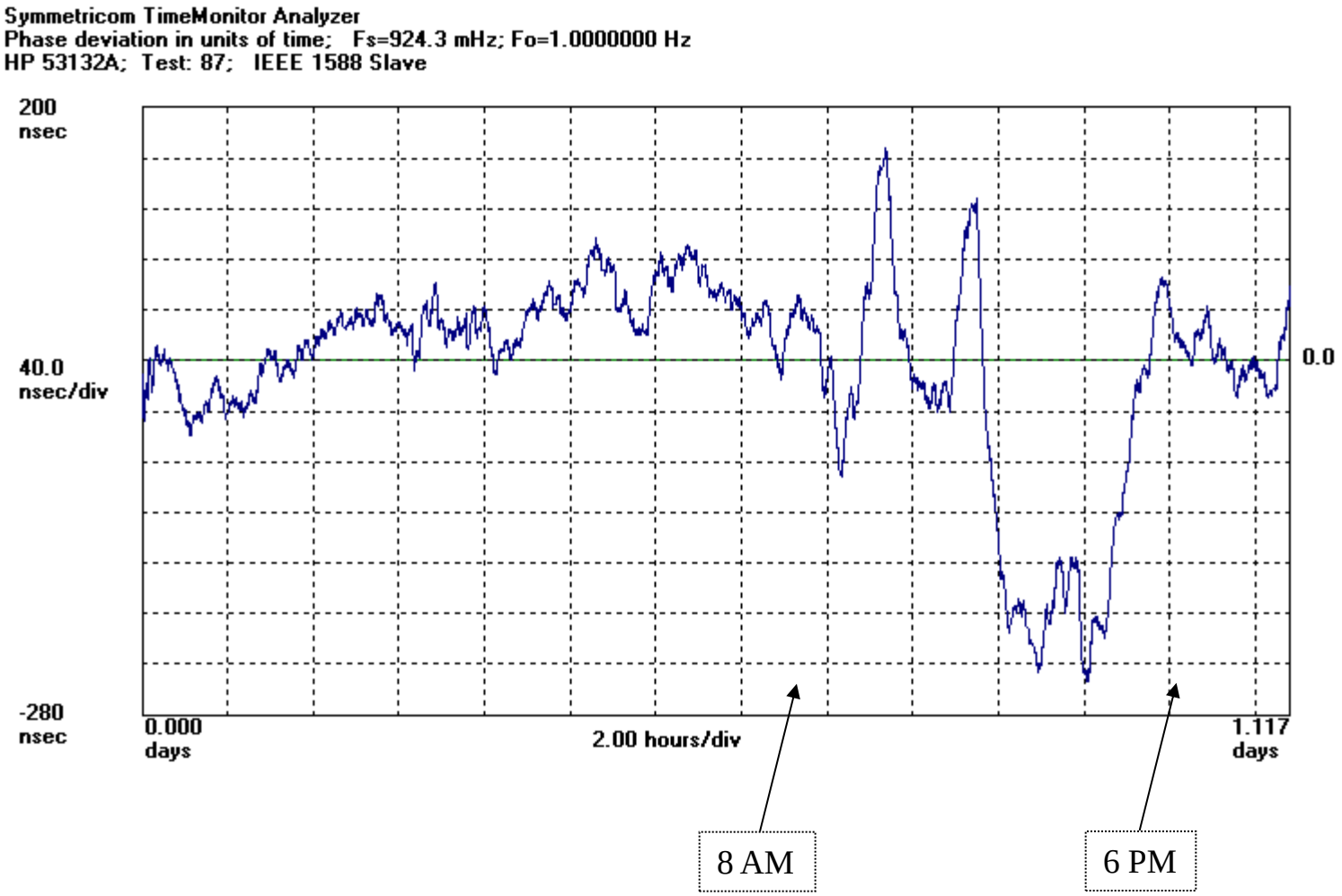
Symmetricom

Tracking packet standard deviation over time shows gradual decrease through the night and then large increase during business hours



Production Network with Live Traffic

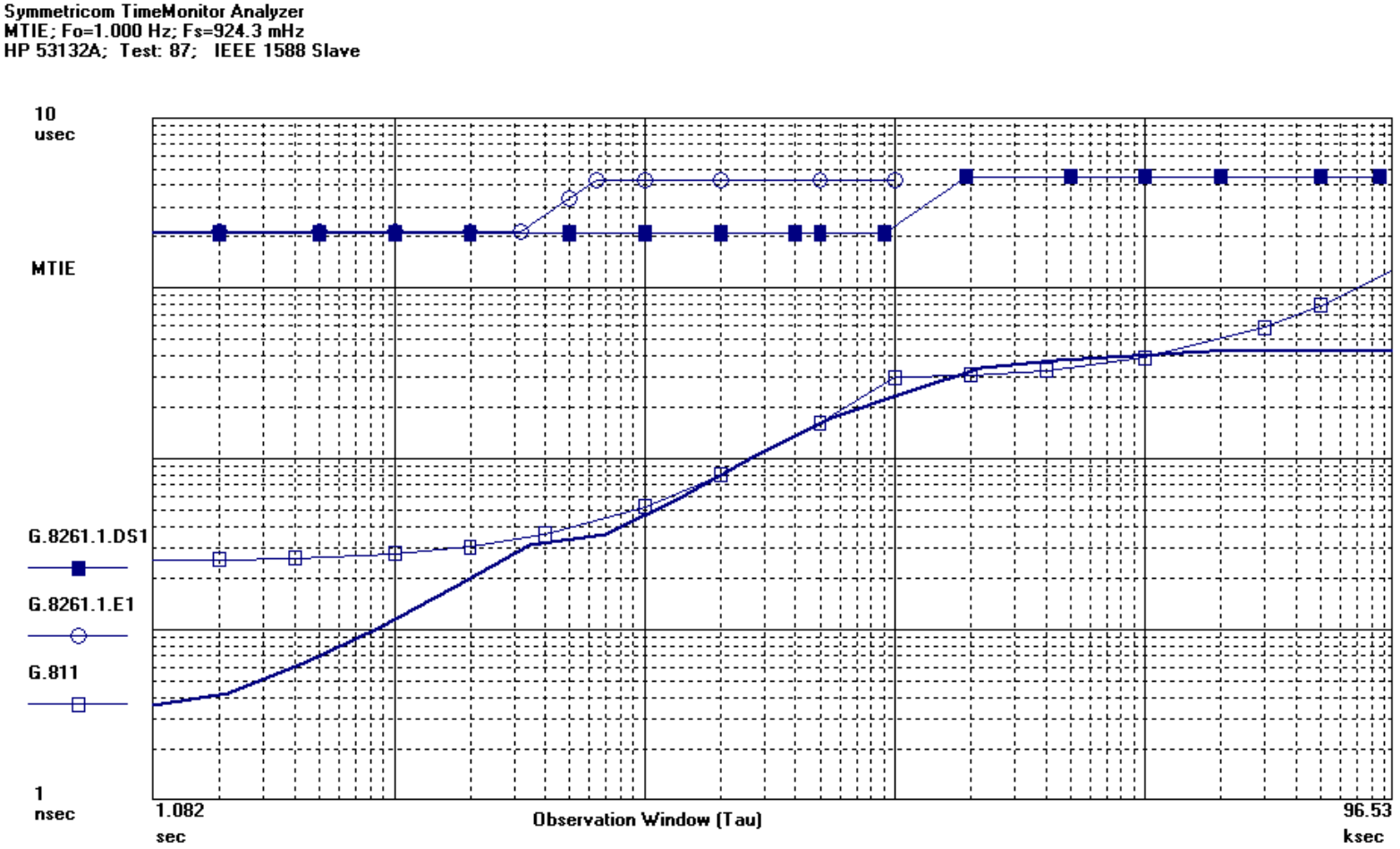
IEEE 1588 slave performance can be correlated with PDV variations



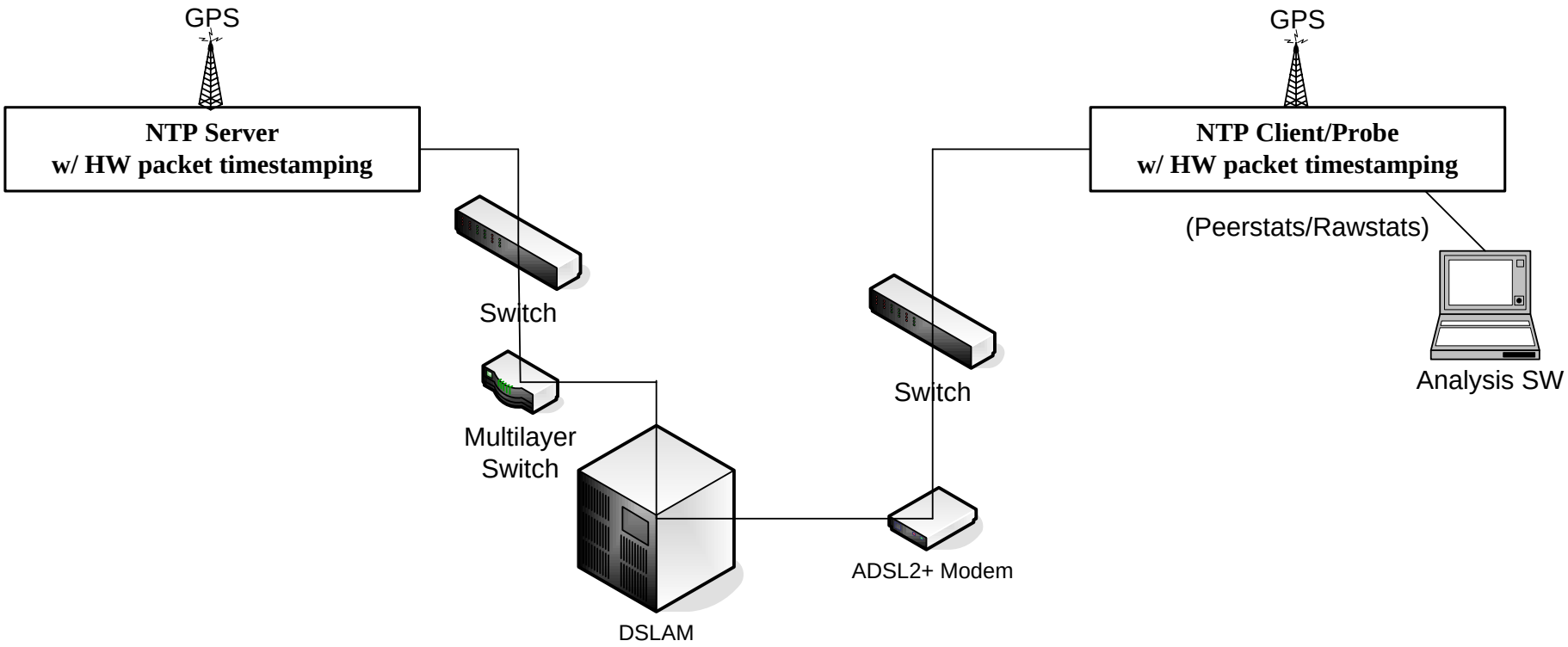
Production Network with Live Traffic

Symmetricom

For the entire 24 hour period the IEEE 1588 slave meets G.8261 requirements and nearly meets G.811 requirements



DSLAM/ADSL2+ Modem



DSLAM/ADSL2+ Modem

Large packet delay: 3 msec

Mean: 2.93986 msec
Peak to Peak: 2.682 msec
Standard Deviation: 219.1 µsec