Packet Timing Metrics and Monitoring

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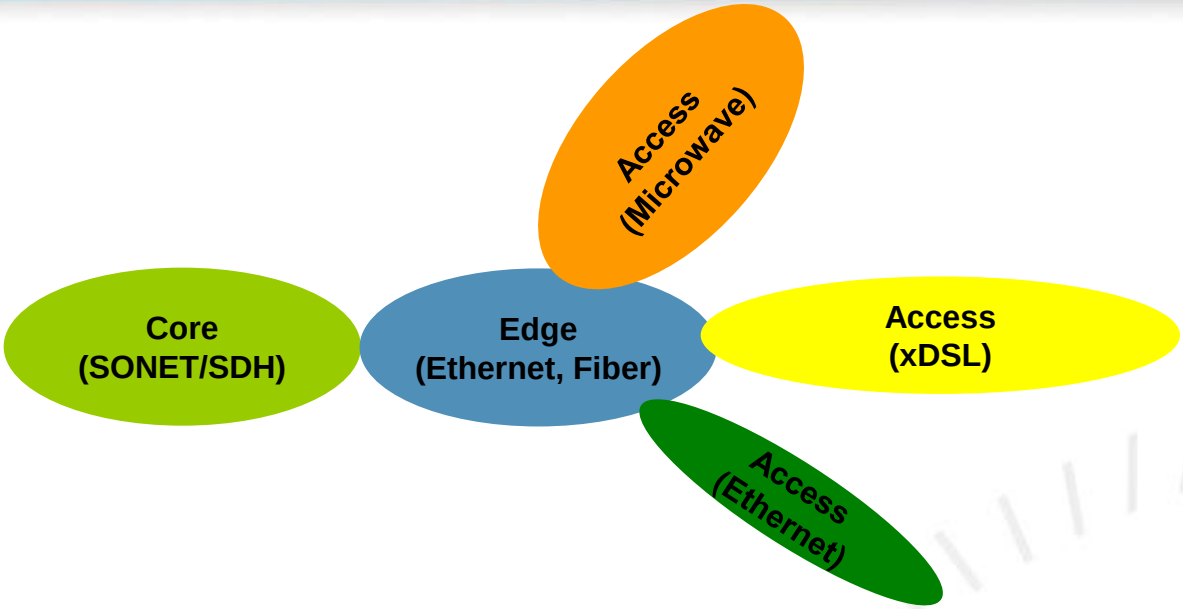
Outline

- Packet delay measurement overview
- Need for multiple metrics
- Some examples
- Summary

Implication of Network Evolution



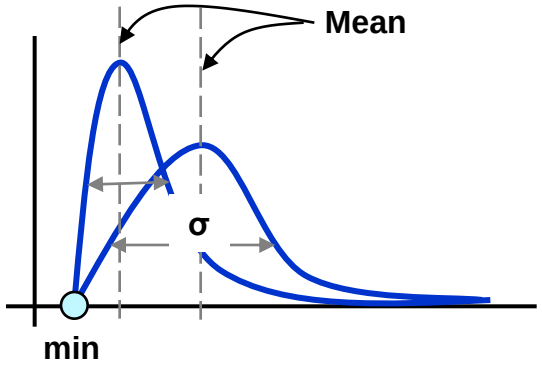
- Networks will be a hybrid of circuit-switched (i.e. legacy) segments and packet-switched ("NGN") segments
  - Packet-switching good for non-real-time, delay-insensitive, high-bandwidth, bursty, low-duty-cycle traffic
  - Circuit-switching good for real-time, delay-sensitive, low-bandwidth, continuous, 100%-duty-cycle traffic
- TDM streams (e.g. DS1/E1) will be transported over packet-switched networks introducing Circuit/Packet boundaries

Networks are heterogenous; packet timing metrics must be flexible to account for different packet forwarding and media access

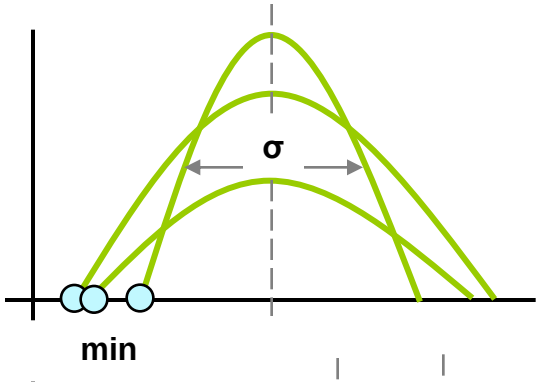
PDV Metrics

- Metrics that characterize PDV are computed from the sequence $\{x_k\}$:
  - Probability density function (pdf) or cumulative distribution function (cdf) or histogram. All provide the same information related to amplitude, including:
    - Minimum, x_{min} : largest value such that $x_k > x_{min}$ for all k.
    - Variance: $\sigma_x^2 = < x_k^2 > - < x_k >^2$ { < > is the average}
    - Maximum-95 , x_{max} : smallest value such that $P[x_k < x_{max}] > 0.95$
  - Spectral metrics (e.g. TDEV) address temporal distribution
    - Implied sampling interval = τ_0 (packet interval)
    - TDEV is a measure of stability of the mean
    - minTDEV estimates stability of the minima

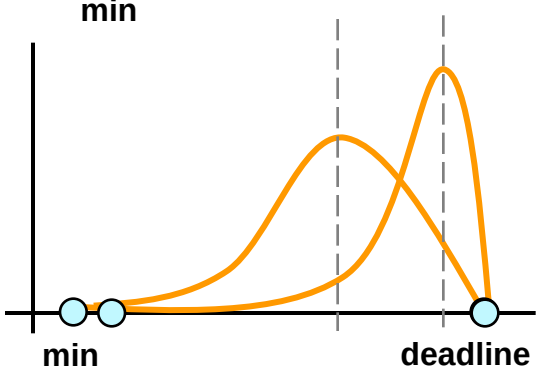
The Need for Multiple Metrics



- Hardware-based routing/switching
- Forward packets as soon as possible
- minTDEV is a good measure for moderate loads and hop counts

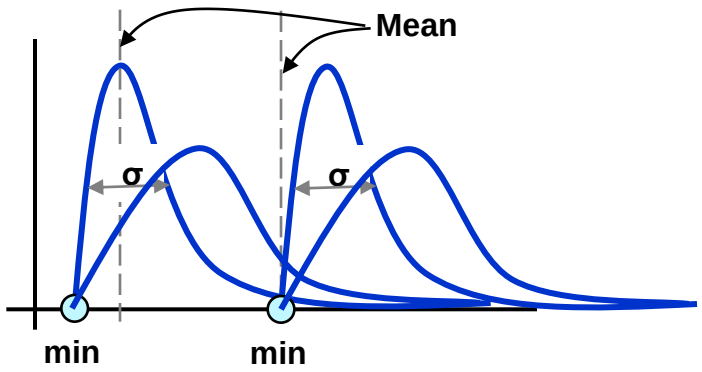


- Point-to-point Media Access delays
- Media Access time variability is minimized
- Mean is a good metric, minTDEV is not



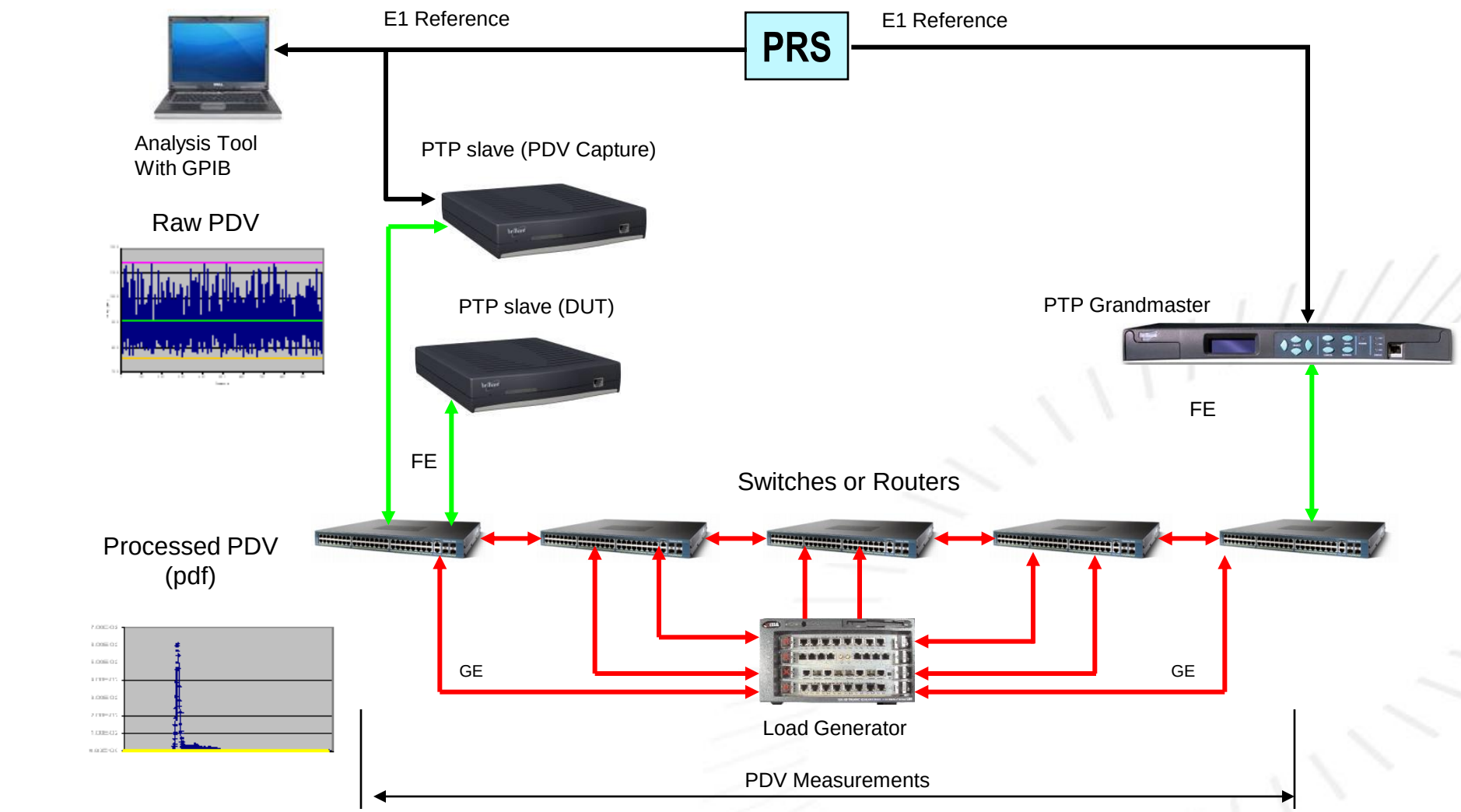
- Software-based forwarding
- Processes Scheduled to meet real-time deadlines – “just in time” completion
- Deadline may be a more stable metric than minTDEV at high loads

The Need for Multiple Metrics



- Network Reconfiguration Detection
- Discontinuity in min and mean is useful to detect network rearrangements
  - SONET/SDH protection switching
  - Network Additions/deletions/upgrades
- Variance can be used to provide a measure of confidence of the detection
- End-point Frequency and Phase must remain stable during revertive and non-revertive rearrangement scenarios

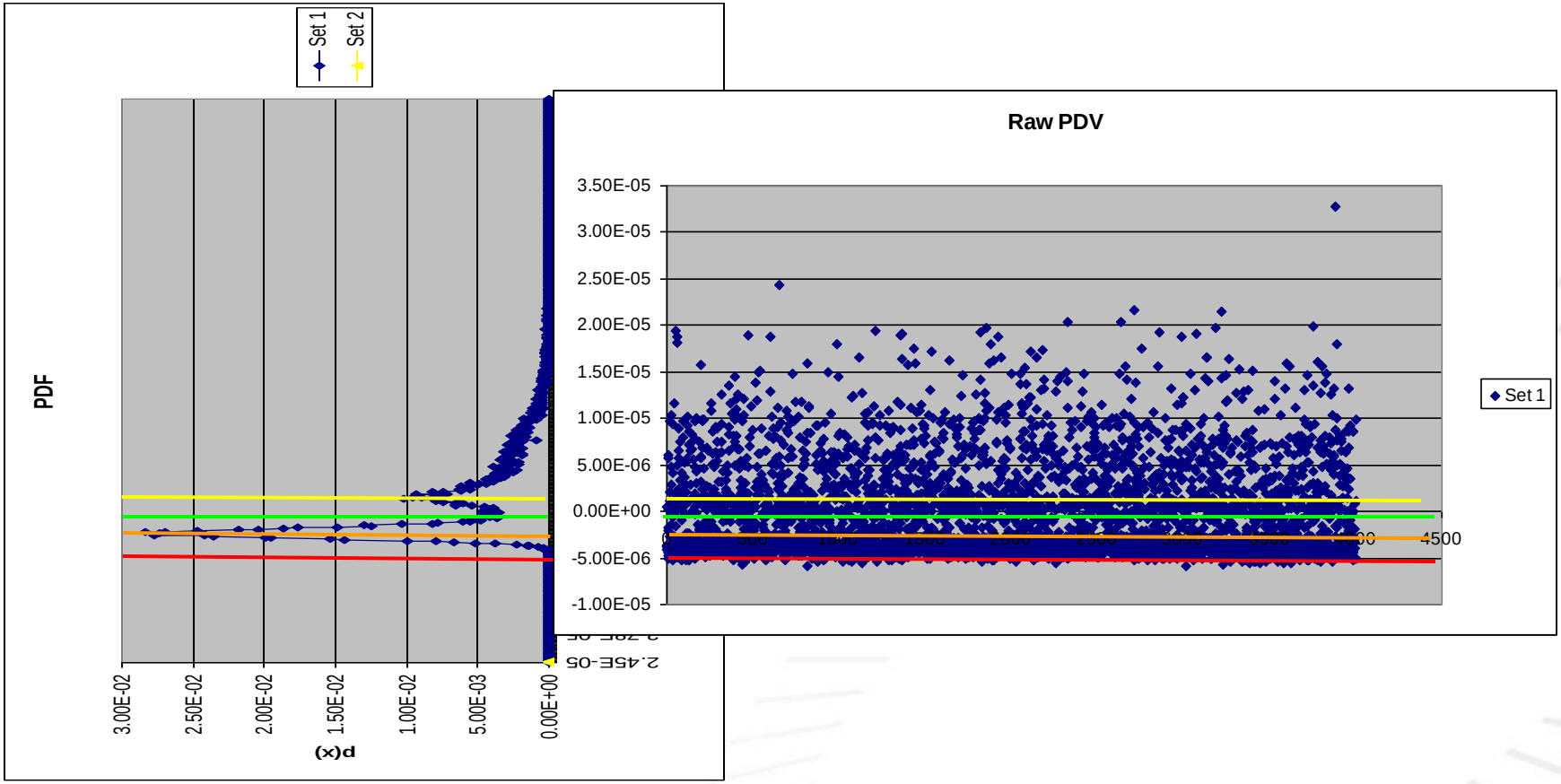
G.8261 Test Setup – PDV Analysis



PDV Measurement Tool

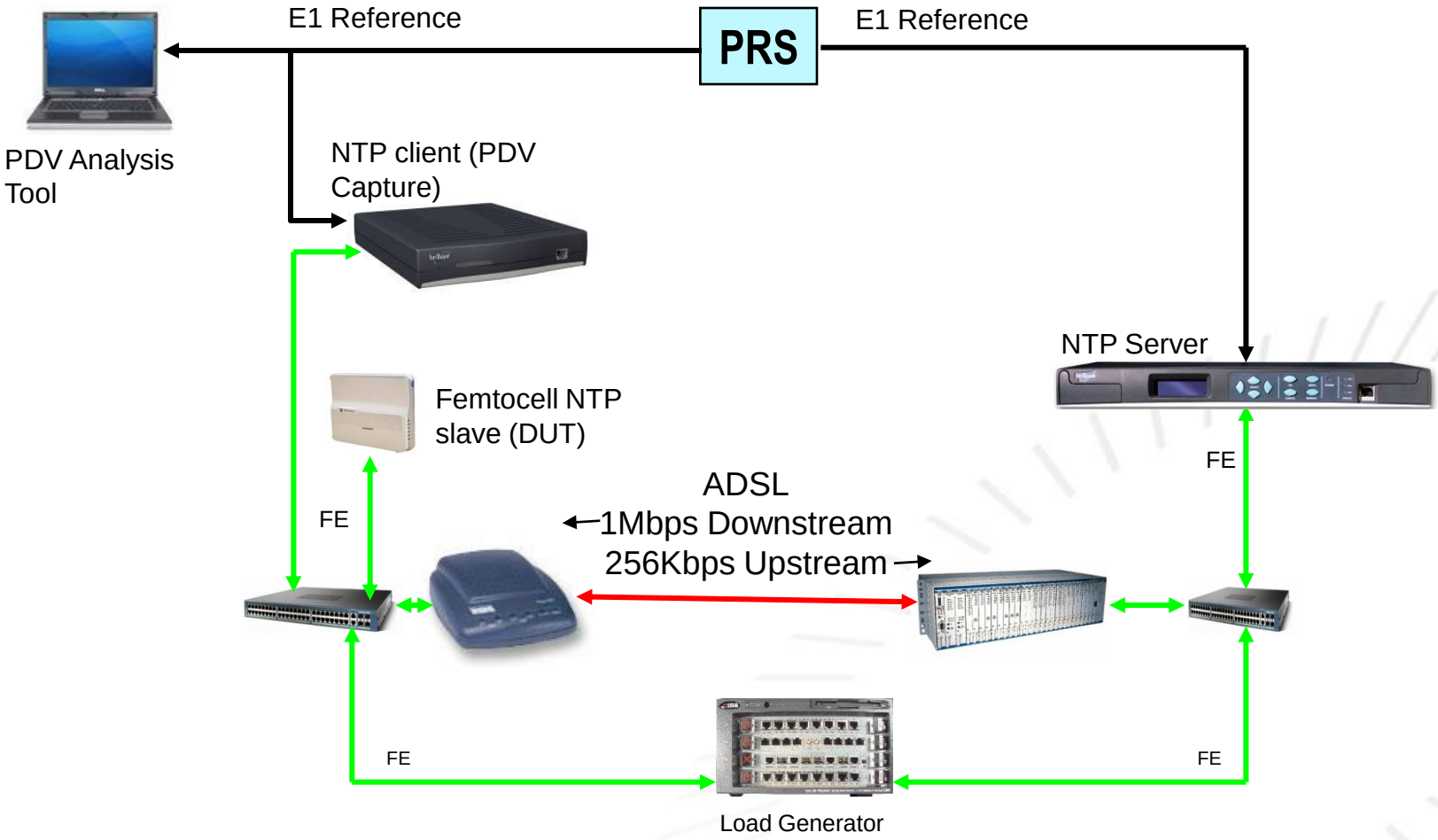
- **Measures PDV to 16ns resolution**
- **Logs PDV in Real Time**
- **Off-line analysis and modeling**
- **Provides ability to improve understanding of network behavior**
  - Impact of load, Hop-Count, QoS and forwarding algorithms on network performance
- **Provides insight into the improvement of the time sync algorithms**
  - Multiple Metrics – min, mean, max, variance

Interpreting Packet Delay Variation Charts



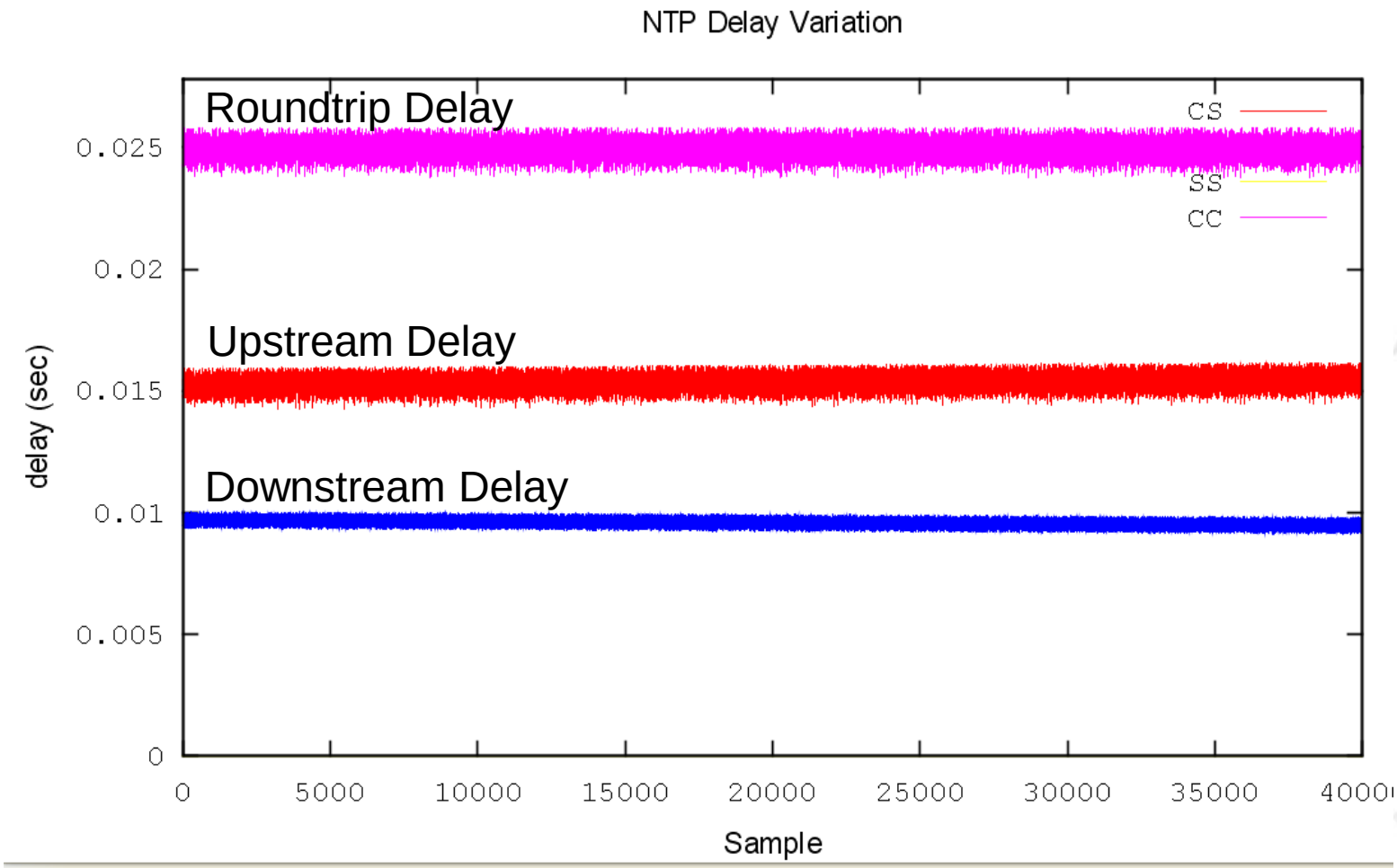
5 Switches 40% Load w/QoS – Multiple stable peaks in PDV pdf
minTDEV is always useful, but at high loads other metrics, if stable, may be used

ADSL/Femtocell Test Setup



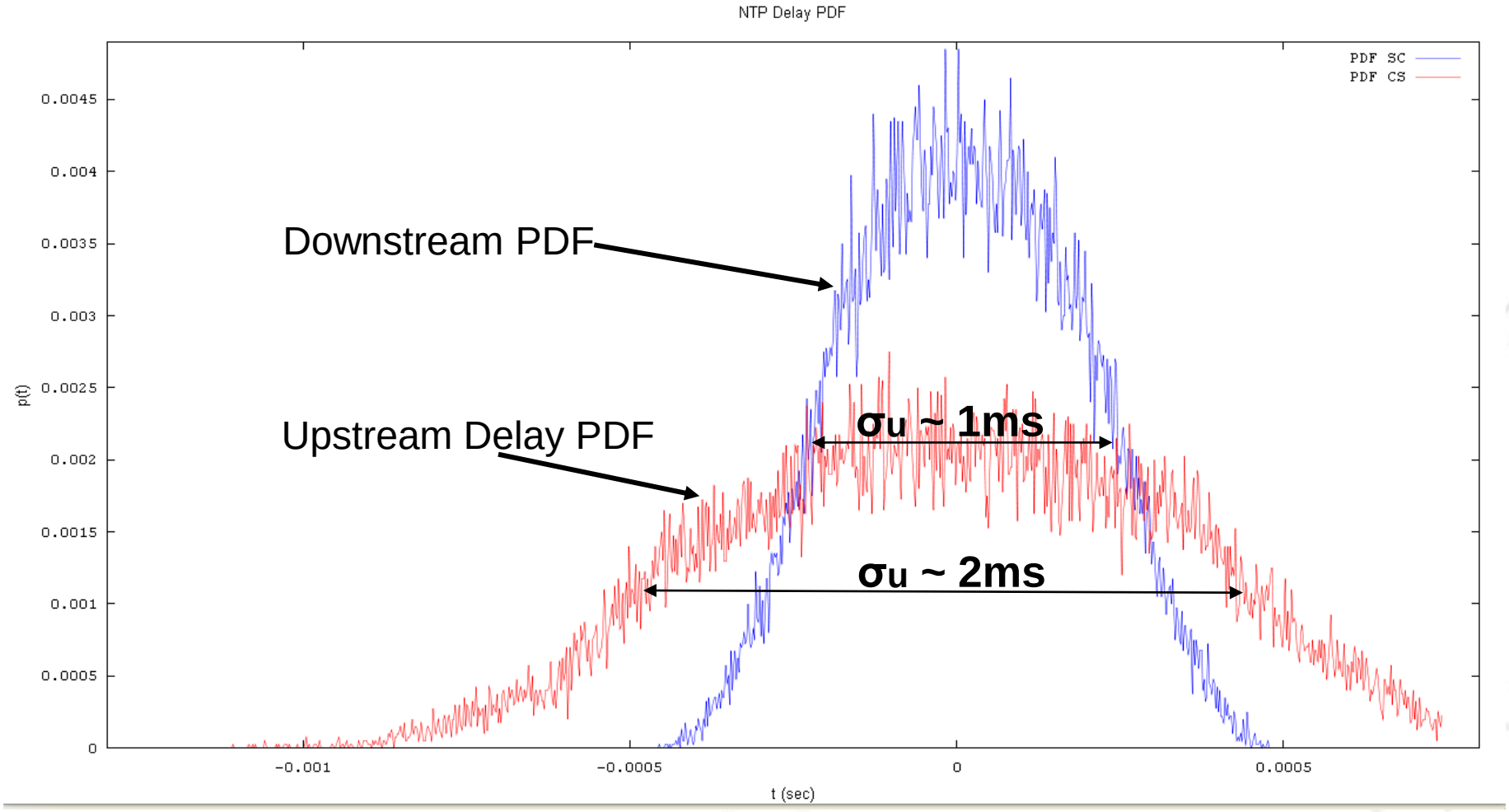
Maintain Femtocell Frequency (and Phase) accuracy in Asymmetric DSL

ADSL/Femtocell – Delay Variation



Highly Asymmetric Delay; Jitter order of magnitude greater than GbE – 1-2ms vs. 100µs

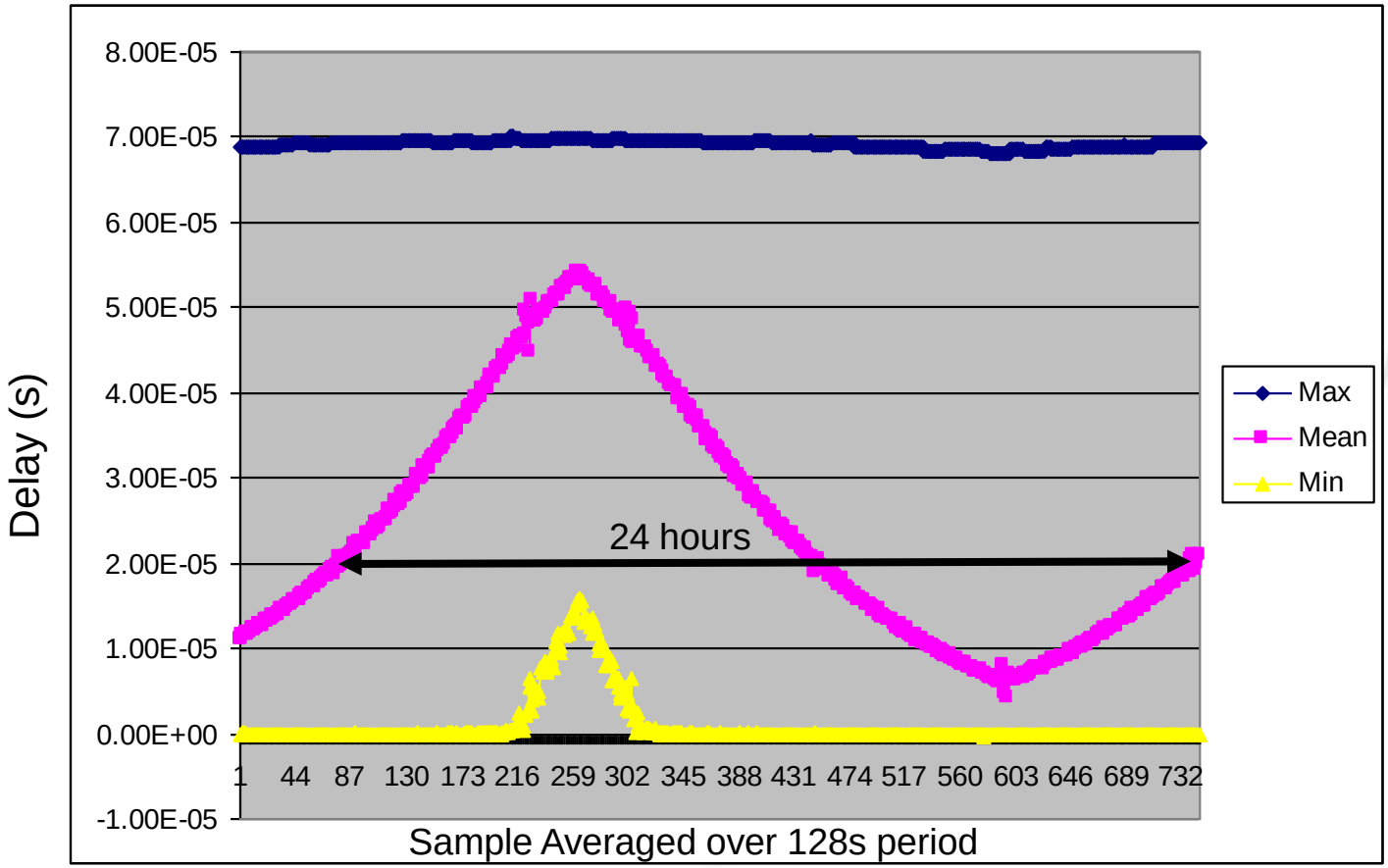
ADSL Test Setup – PDF Analysis



ADSL: Highly asymmetric PDF, downstream is more stable (less variance) than upstream

Deadline-based Software Delay

5 Hops, G.8261 Test Case 3 – 24 Hour Cycle 20% to 80% Load



Mean metric is unusable for timing analysis.
Min metric is extremely stable at low to moderate loads.
However, *Max* in this case is a stable metric for timing at high loads.

Concluding Remarks

- PDV monitoring in Next Generation Networks provides clock distribution assurance
- Monitoring achieved using timing client/server communications with existing protocols (e.g., PTP, NTP)
  - IEEE1588v2/PTP is suitable for Mobile Backhaul networks
  - NTP can be suitable for Femtocell timing over Layer 3 IP Access
- Multiple PDV metrics may be appropriate for generating and monitoring/estimating the clock performance
  - minTDEV is a very useful metric in most, but not all cases
  - min, mean, max and variance have important roles
  - Packet timing must gracefully accommodate heterogeneous networks, media access and network rearrangement scenarios