Power Matters

Metrics and Limits for G.8271.2 Unaware Phase Networks

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Introduction

- APTSC Background
- Link Budget
- Possible Metrics
- Defining pktSelectedTE
- Packet Selection, Selection window and Percentile.
- Worst-case Simulated and Real Network Profile Examples.

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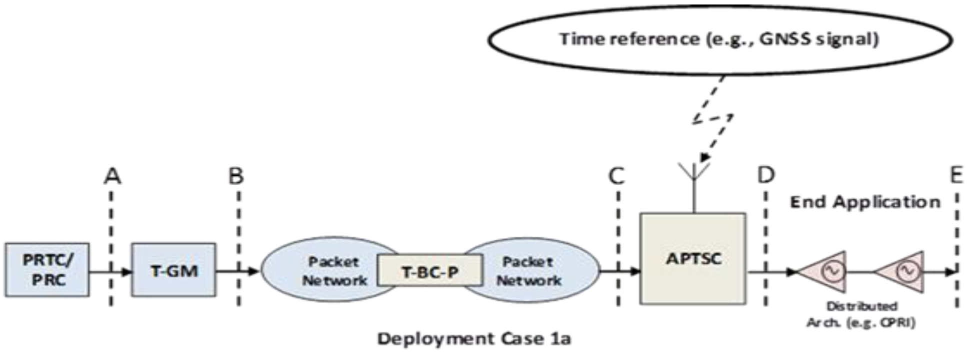
APTSC (G.8271.2) Background

- As defined in [IEEE1588], Assisted Partial Timing Support Clock (APTSC) consists of either an ordinary clock (OC), with one PTP port, or a boundary clock (BC), with multiple PTP ports
- An example is a local timing reference (GPS, GNSS) coupled with a PTP slave clock for failure protection [1].



- Network segments can be with or without BC nodes [2].

APTSC Continue

- For the purpose of this presentation a BC on the network can be interpreted as a delay and error generation hop.
- The APTS can pass updated timestamps to either an end application or another PTP slave clock.

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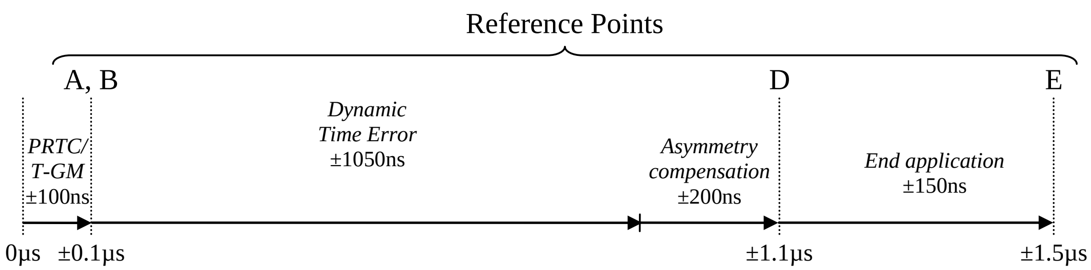
Link Budget Background

- The following figure shows the network limits as seen at the output of an APTS clock node [4]



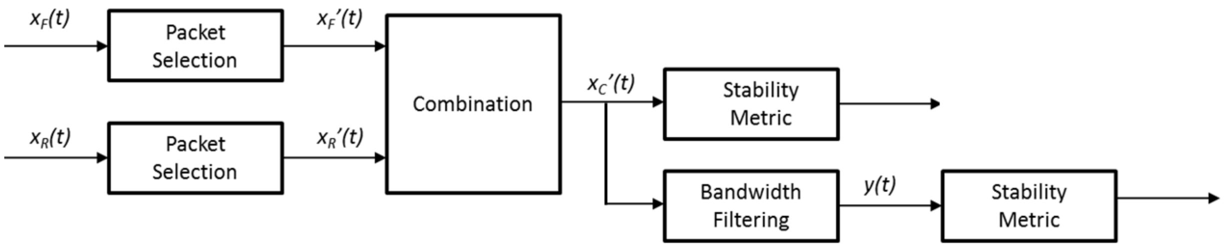
- Based on 100ns PRTC a 200 ns asymmetry is budgeted averaged over 1000s. This is for accuracy purposes.
- Dynamic time error (PDV + …) is zero mean and includes APTS short-term holdover error.

Metrics

- In order to meet in particular the dynamic error network limit, a metric is needed to specify the highest levels of packet delay variations an APTSC can handle irrespective of implementation solution.
- In the Sep. SG15/Q13 meeting, there is a general agreement on the following metrics [5]:
  - APTS: peak-peak(pktSelectedTE) = **max(2wTE)- min(2wTE),**.
  - PTS: max(pktSelectedTE) = **max(|max(2wTE)|, |min(2wTE)|)**.
- Packet Selection is an automatic clustering approach that filters out unwanted packets within a selection window.
- G.8260: I.3.2 discusses several packet selection methods:
  - Minimum packet (min within window).
  - Percentile average packet (order then select average of minimum x%).
  - Band average packet (order then select band).
  - Cluster range packet (proximity of time vs. index).

Defining pktSelectedTE

- Given a Sync and Delay_req sequences, a packet selection method is used to generate a combined 2-way offset sequence.
- This time-error sequence is compared against the network dynamic error limit shown earlier.
- Combing is simply done by instantaneous averaging of the 2 paths. Post LP filtering can also be done to mimic the usually low BW (< 100 mHz) of an APTS node.
- The following diagram (Figure I.10 G.8260) explains the approach



Why pktSelectedTE and not pktSelectedMTIE

- It has been argued that in order to use the same metric for both PTS and APTS, it is recommended to use pktSelectedTE.
- Note that in APTS, the GNSS provides a constant time error, thus only the dynamic error portion is the one that matters.
- This is not the case for PTS, unless a time-error based metric is used as opposed to an MTIE metric.
- A time-error sequence shows more information within different sliding windows over time and width.
- MTIE sequence ramps up to a maximum value over all time range.

Choosing the Selection Window Length

- Selection window length is related to the bandwidth of the APTS/PTS solution. The window has to get smaller as the BW increases.
- A window length of 200 s is sufficient for ~ 1 mHz solutions.
- The selection window can be further understood by using a Time-Dispersion Metric, like minTDisp, which provides a combined 2-way understanding of the relation between minOffset and minRoundTrip.
- minTDisp is particularly useful for PTS solutions since time and phase information is as critical as frequency.

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Packet Selection Method

- Percentile average packet selection method is used on each path independently with the following parameters
  - Window length of 200 s.
  - 0.25% of fastest packets
- Thus the candidate data point for each window is the average of 0.25% of data points.
- In other words for a 64 pps rate, the time-error point is the average of the smallest 32 delays. The number is 8 for 16 pps.
- After computing the forward and reverse Selected-Time-Error sequences, the combined sequence is generated as

$$x_C'(n\tau_s) = \frac{x_R'(n\tau_s) + x_F'(n\tau_s)}{2}$$

- Then the max or peak-to-peak values are compared to the network limits to decide whether the PDVs (network conditions) are suitable for application as per the standards.

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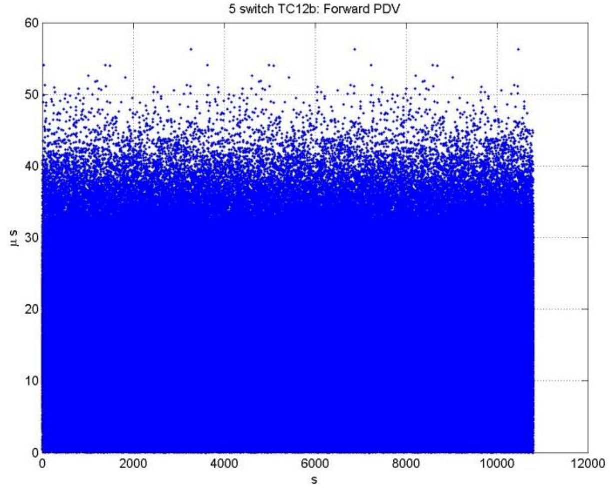
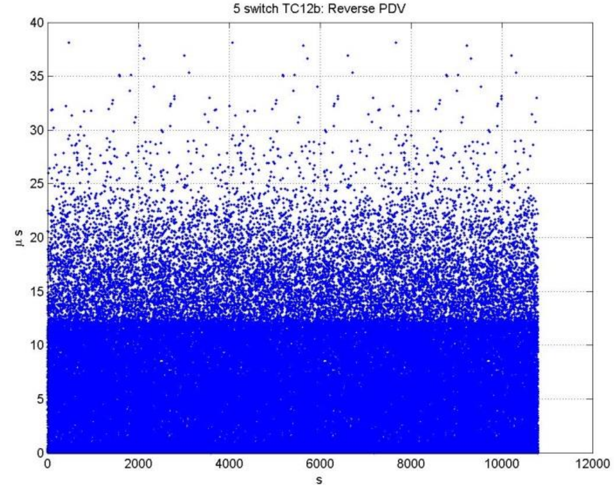
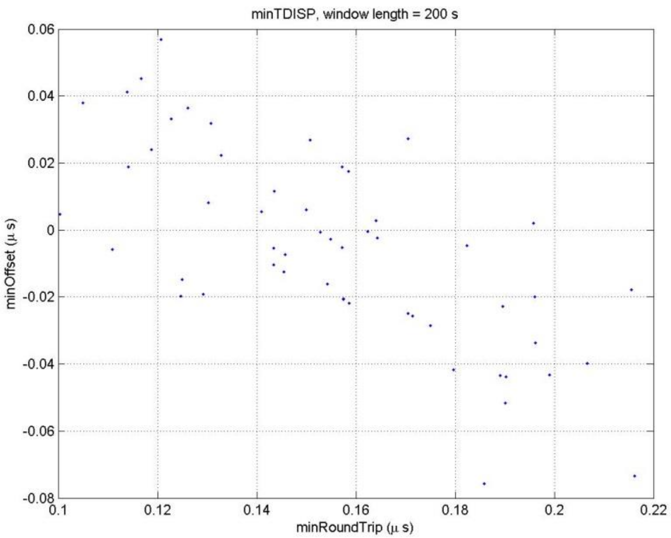
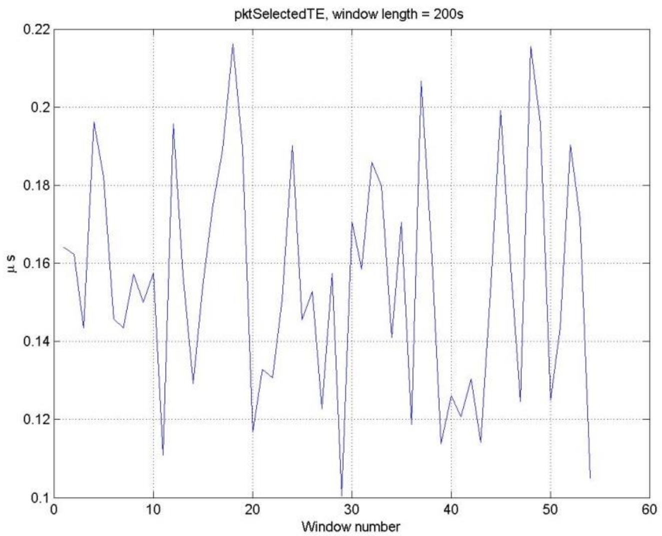
5-Switch Calnex G.8261 TC12b Network, WinL = 200s, 0.25% Av. Packet Selection

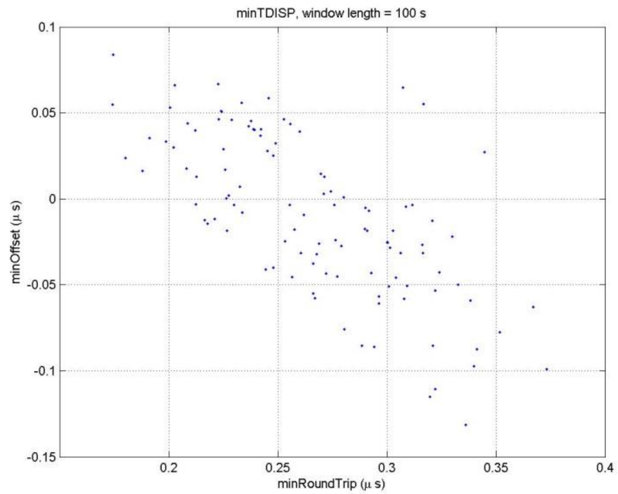


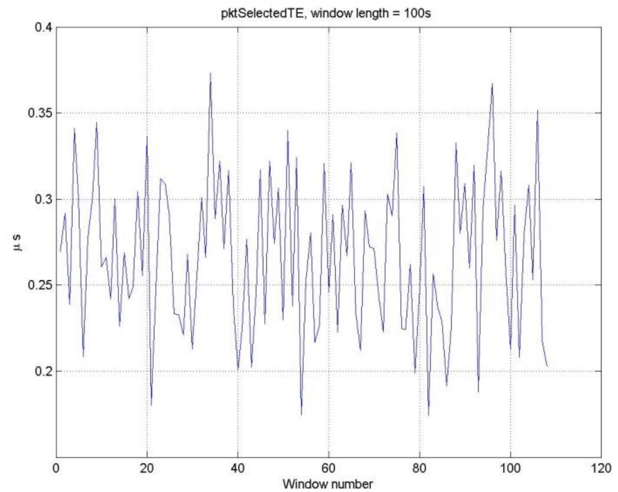


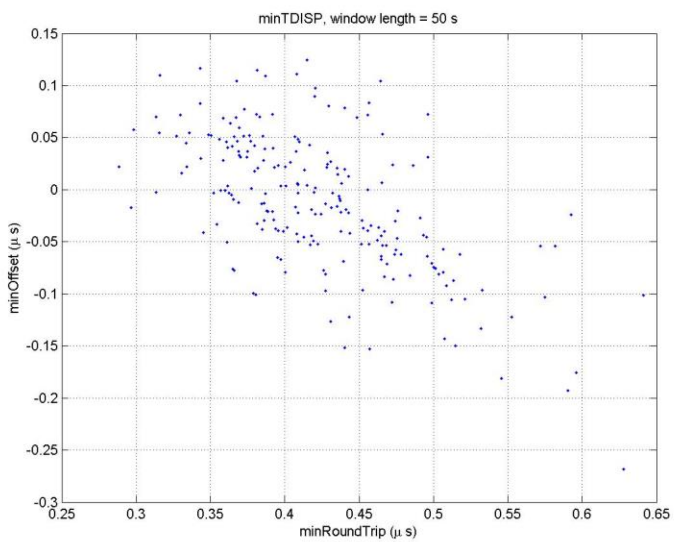


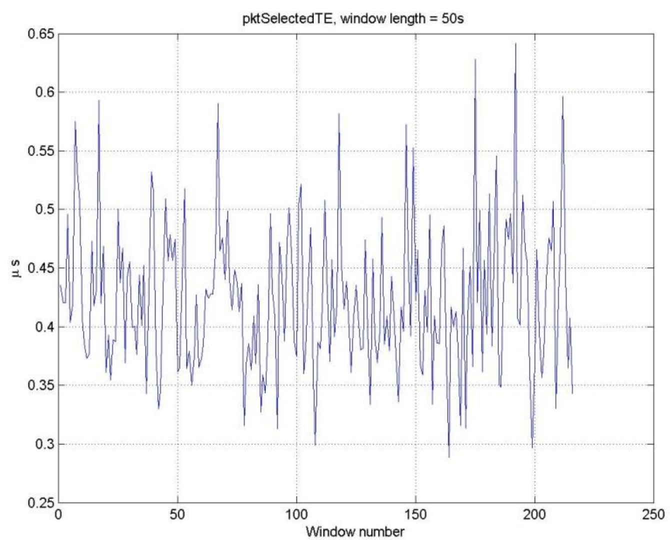


Same TC12b PDV with WinL= 100s, 50s.

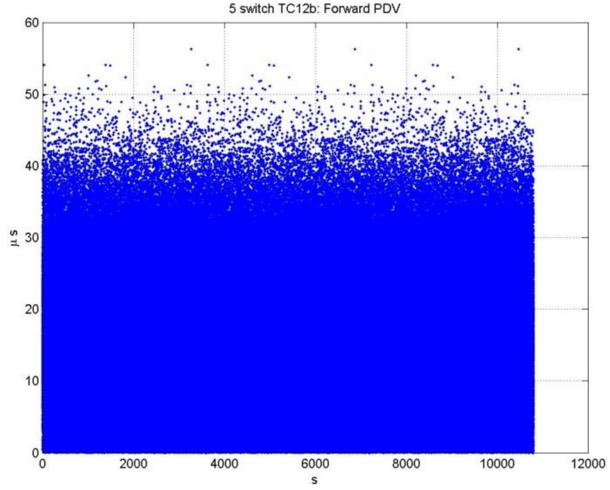


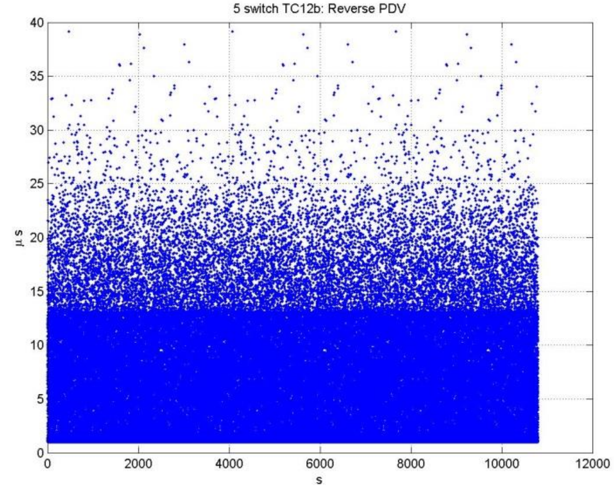


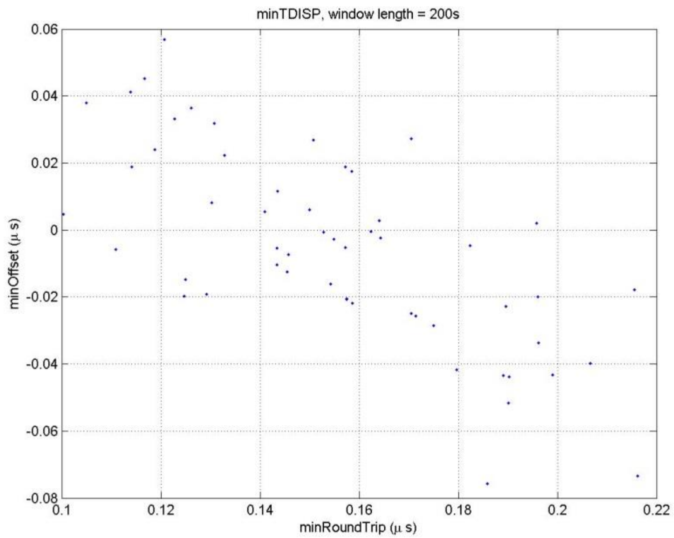


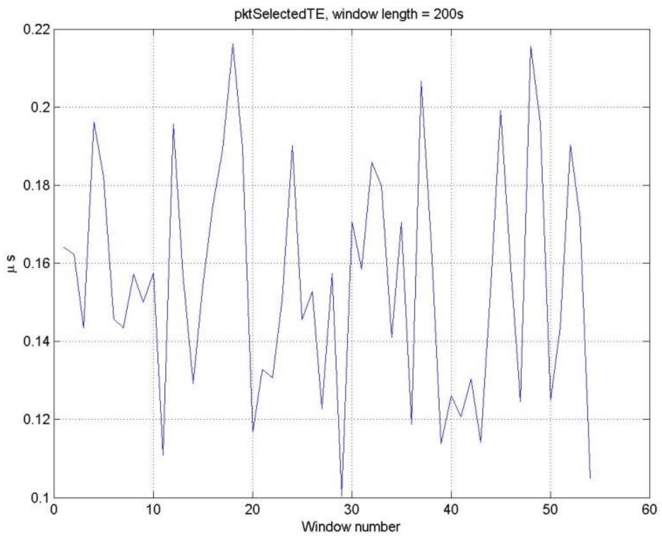


pktSelectedTE and 1 us Static phase Offset





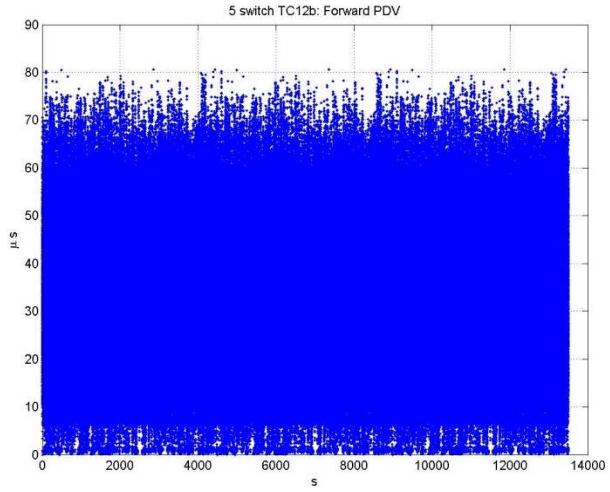


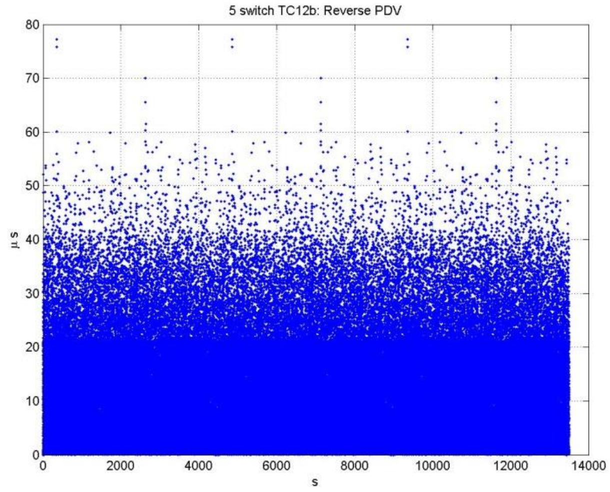


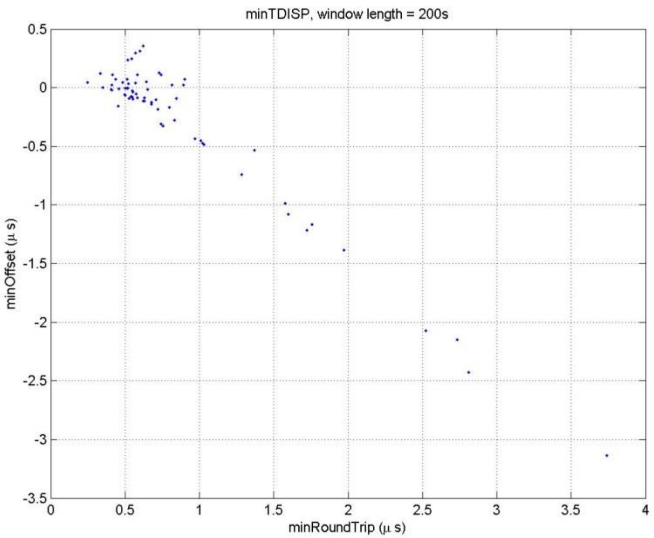
PDV and Packet selection

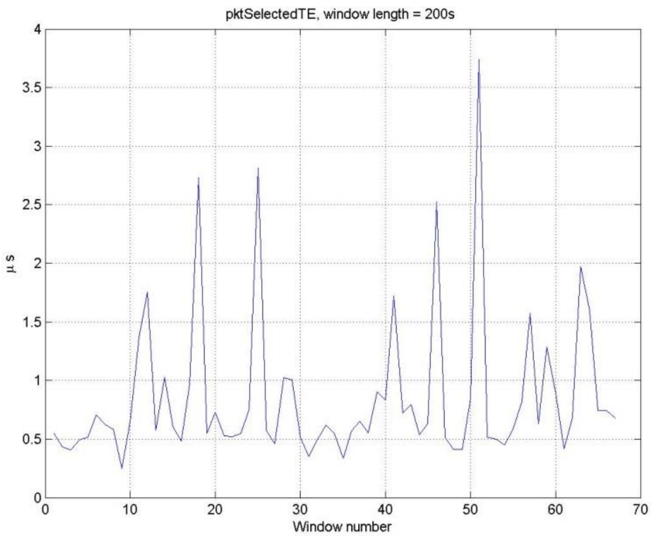
- Using real lab-generated 5 switch network PDV files proves challenging for 200 s window and 0.25% percentile average packet select method.
- The same 5 switch data, passes the network budget using a window of 200s, however with minimum packet selection method.
- Note that average packet selection is ML-optimal if the PDV is Gaussian, and minimum packet selection is ML-optimal for exponentially distributed PDVs with equal 2 way means [6], [7]. Other adaptive techniques are usually deployed for non-stationary and dynamically varying network profiles.

Lab-generated 5 switch PDVs, WinL=200s, 0.25% Av. Selection (Fail)

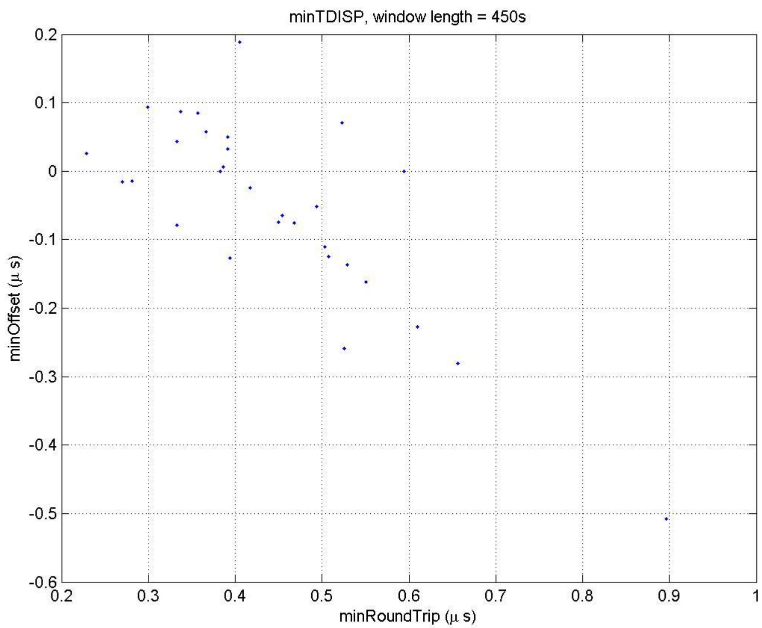


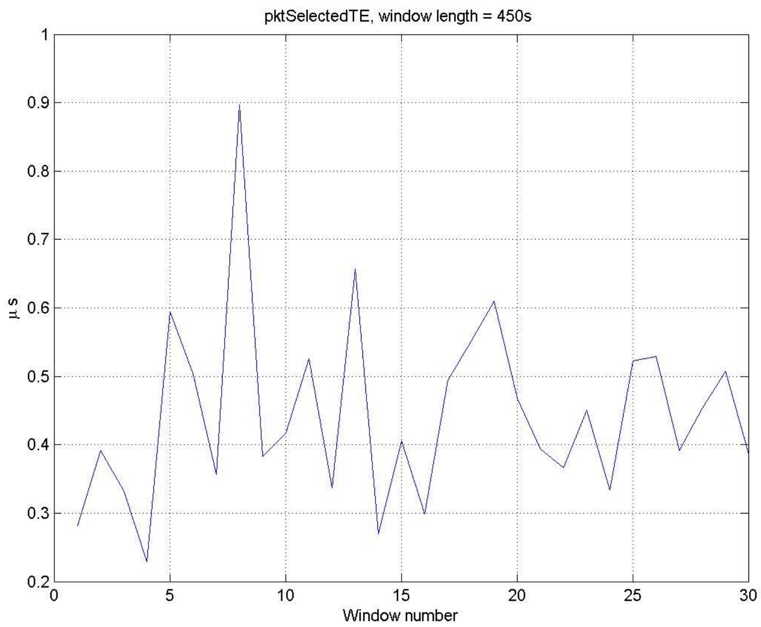




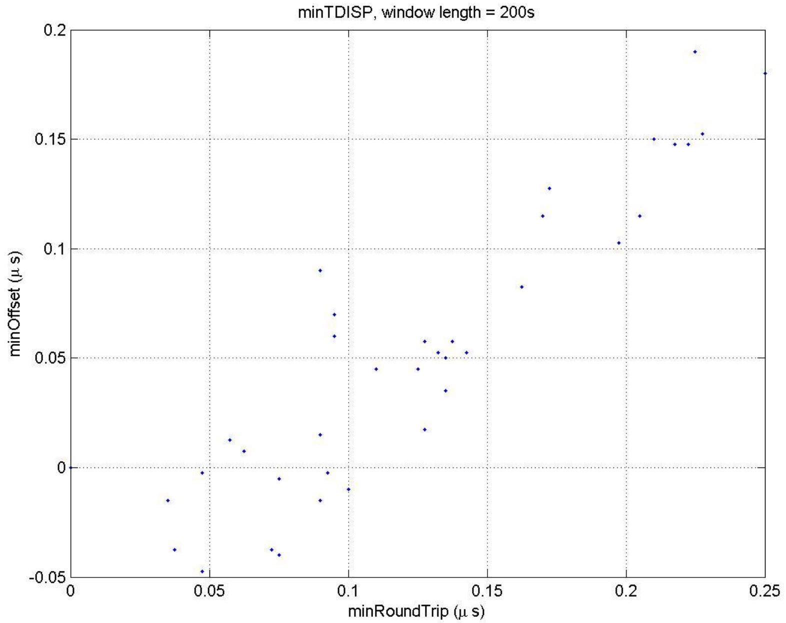


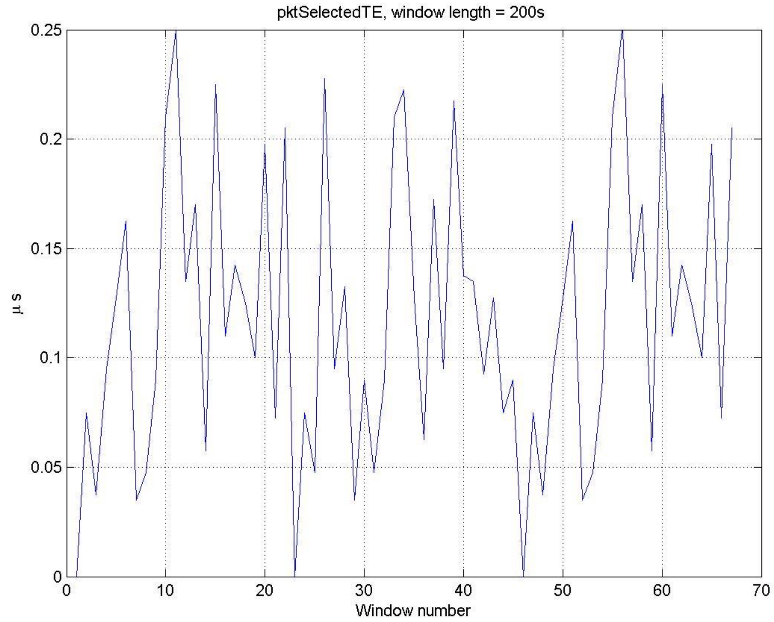
Lab-generated 5 switch PDVs, WinL=450s, Av. Packet Selection (Pass)





Lab-generated 5 switch PDVs, WinL=200s, Min. Packet Selection (Pass)





Summary

- Based on most recent ITU-T/SG15/Q13 meetings:
  - The network budget and associated metric was described.
  - pketSelectedTE was used as the metric of choice.
  - While not completely agreed upon, 0.25% Percentile average packet selection method is proposed with 200 s window.
- The presentation showed how a 5 switch Calnex generated 80%-20% traffic model 2 with 64/16 pps PDVs can pass the specified network limits with the proposed selection method even at lower window lengths (potentially higher solution BW).
- It was shown that the proposed selection method caused a network limit failure when using a 5 switch lab generated PDV files. Minimum Packet Selection provided a passing metric with this PDV.

References

- [1] C552, ITU-T/SG15/Q13*: Budget proposal for Assisted Partial Timing Support*, Sprint & Calnex, Geneva, March 2014.
- [2] WD54, ITU-T/SG15/Q13 : *Network Limit & Clock Metric Considerations [G.8271.2, G.8273.2], Microsemi,* San Jose, Mar 2 – Mar 5, 2015.
- [3] WD10, ITU-T/SG15/Q13: *Network limit and metrics of APTS,* Huawei Technologies Co., Ltd. Geneva, 22 June – 4 July 2015.
- [4] WD71, ITU-T/SG15/Q13: *Network limit for APTS,* Nokia Networks, Pisa, Sep 14 – Sep 19, 2015.
- [5] WD105R1, ITU-T/SG15/Q13: *APTS PDV limit metric changes to G.8260 and possible parameter values,* Pisa, Sep 14 – Sep 19, 2015.
- [6] D. R. Jeske, *On the Maximum Likelihood Estimation of Clock Offset,* IEEE Trans. On Communications, 53(2005), 53-54.
- [7] E. Serpedin and Q Chaudhari, Synchronization in Wireless Sensor Networks, Cambridge University Press, 2009.

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Thank-you