Evaluation of Packet Network for Synchronization Applications

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Technology Strategy Operation

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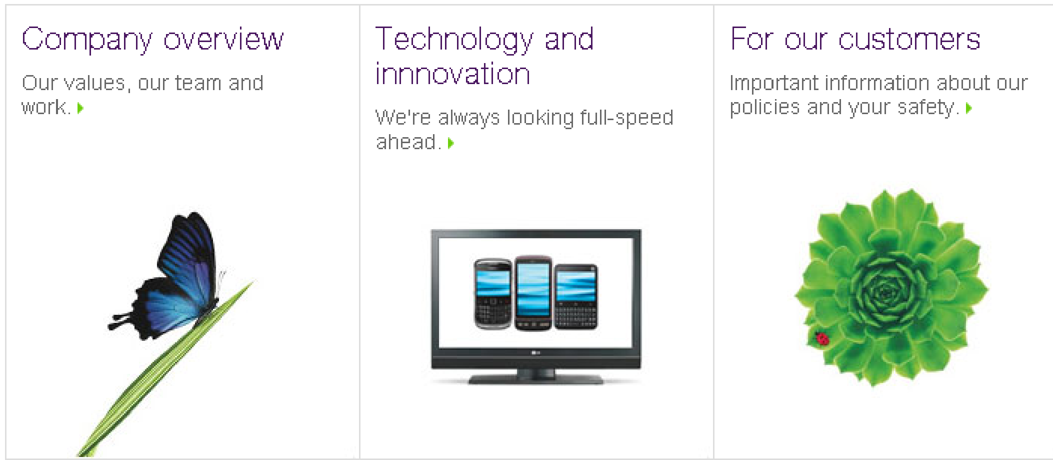
TELUS at a glance

- Leading national telecommunications company in Canada - the future is friendly® technology
  - $10.9B annual revenue
  - 13.1M customer connections
    - 7.7M wireless Subscribers
    - 3.4M wireline network access lines
    - 1.4M internet subscribers
    - 678K TELUS TV customers (OptikTV)
- Community Investment
  - $300M to charitable and non-profit organizations
  - 4.8M hours of volunteered service

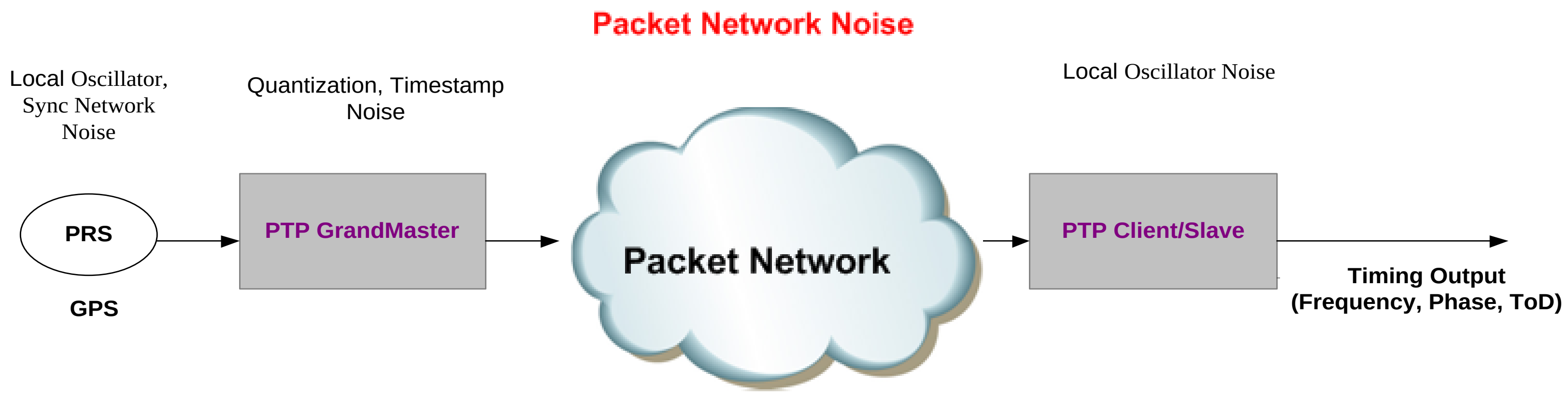
TELUS at a glance
Technology and Innovation



- Technology
  - "world-class", meeting or exceeding "state-of-the-art“ network
  - "best-in-class" in terms of performance, service enablement and reliability
- Innovation
  - technology laboratories
  - innovation centres
  - research and development

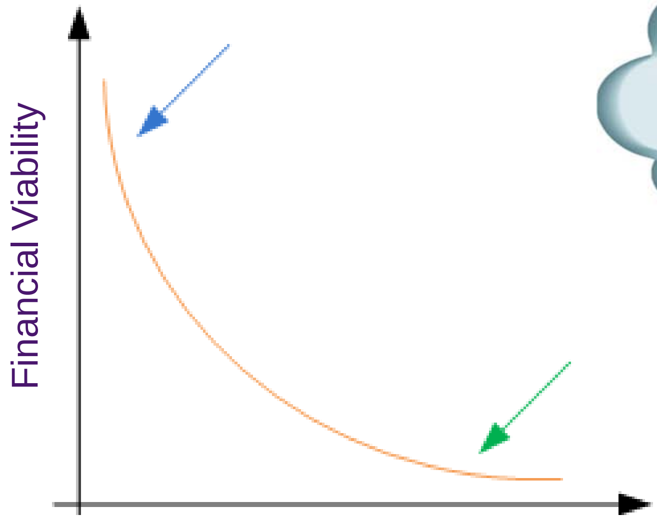
Evaluation of Packet Network for Synchronization Applications

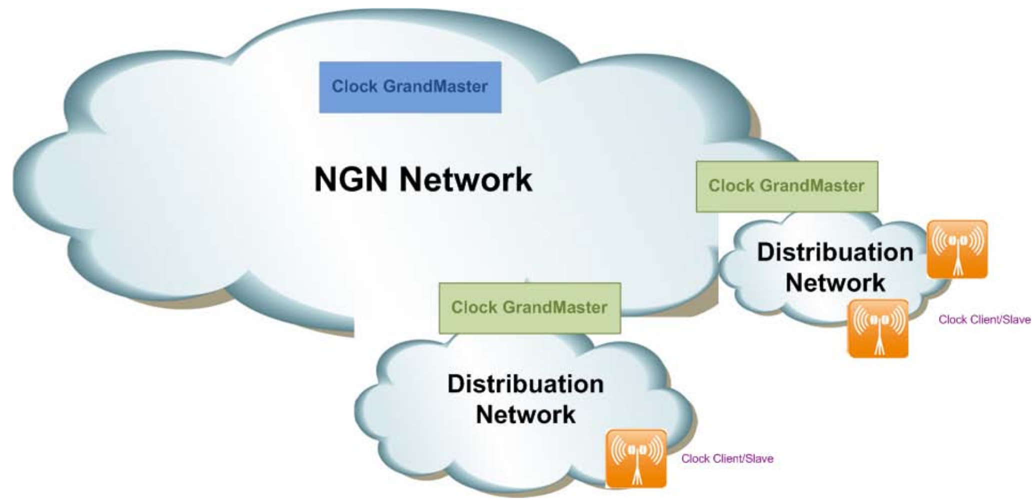
Noise Budgets in IEEE 1588v2 PTP Systems



- Each IEEE 1588v2 PTP element introduce noise into the overall system performance.
- Noise Factors:
  - PRS Noise
  - PTP Clock GrandMaster Noise
  - Packet Network Impairments
  - On-path support Noise (Optional)
  - PTP Clock Client/Slave Noise

Proximity of Grandmaster and Client

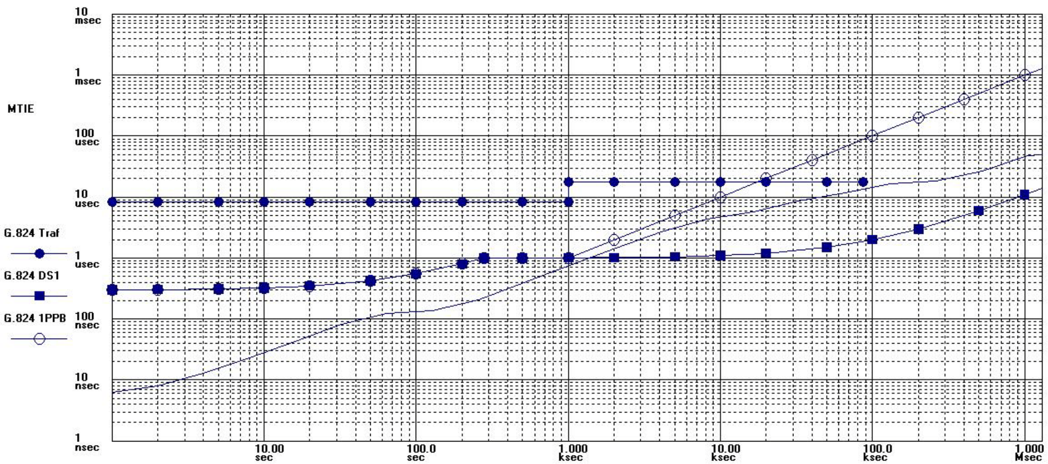




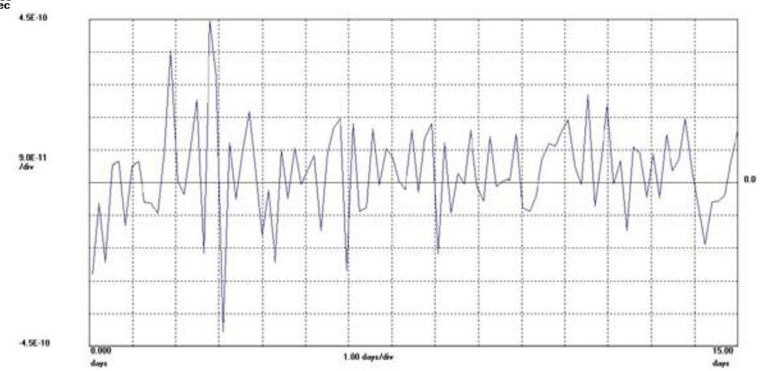
Permissible Proximity between GrandMaster and Salve

Absence of proper tools for network evaluation may adversely impact the technical and financial viability of Synchronization over packet network solutions.

Synchronization Signal Measurement



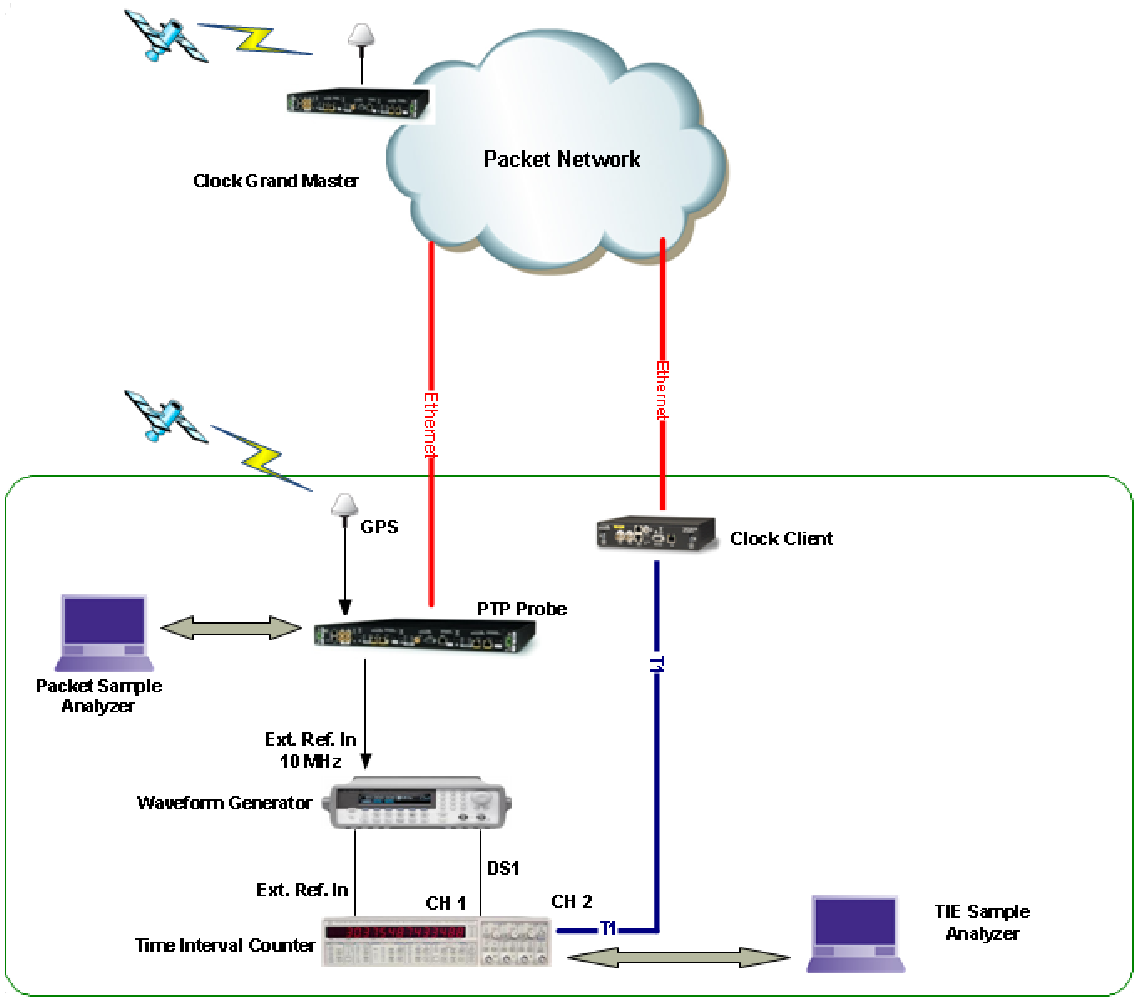
MTIE measurement of a production network



- MTIE, TDEV, LSF and other traditional timing signal measurements are the most **definitive** available ways of assessing a performance of output timing signal of a slave clock, yet fail to describe the underlying **packet network impairment conditions.**

Fo = 1.54400000000000 MHz
Ymin=-4.1021E-10
Ymax=4.4561E-10
Ymax-Ymin=8.5582E-10

Packet network measurement setup

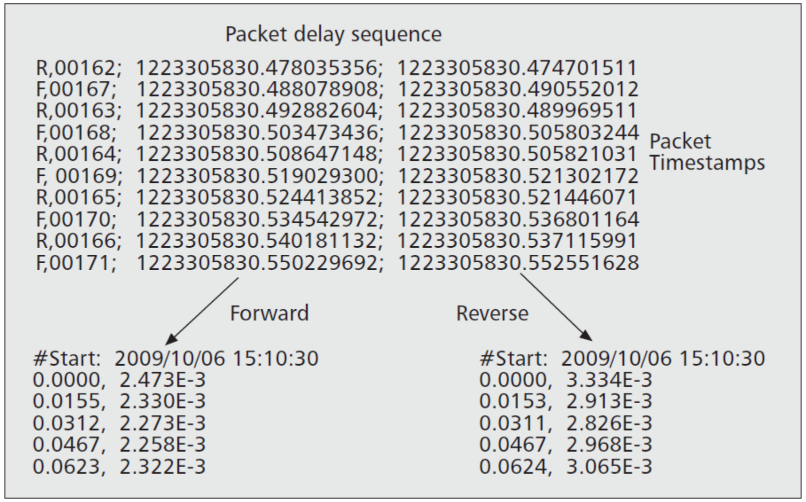


Packet Timing Measurement Data at a glance

Frequency State Estimates sync ps/s: 76653, delay ps/s: 76180
Floor Bias Estimates sync ns: -71068, delay ns: 2878
Floor Oper TDEV ns: 9118, delay ns: 949
RTD estimate ns: 24107173

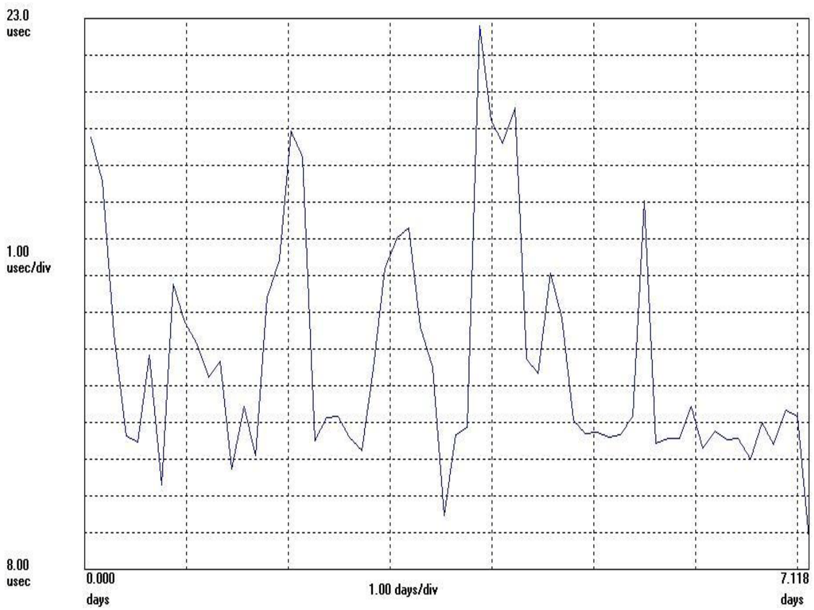
Flow Direction : (GM to client) (client to GM)
GM1 (pkts/s): 64 64
GM2 (pkts/s): 0 0
Weight (%): 0.00 100.00
Transient free (/900): 851 851
Transient free (/3600): 3387 3387
Transactions used : 55.8 46.1
Operational Min TDEV(ns): 500.0 500.0
Min Cluster Width (ns): 41500.0 47900.0
Mode Width (ns): 162704.0 147556.0

- A client slave clock algorithm selectively picks some packet in either one of forward or reverse direction, and uses them to steer the oscillator.
- Measurements were collected from TELUS Ethernet production network.

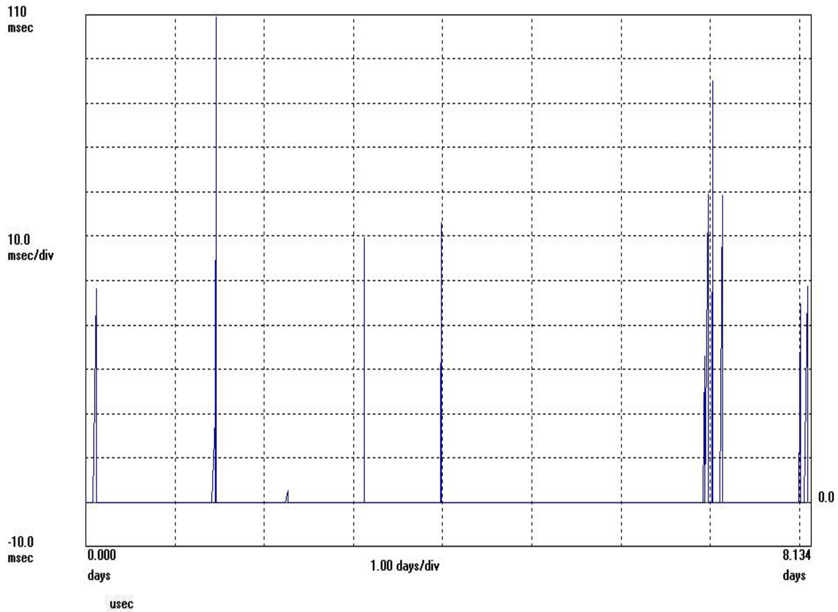


- PTP Probe provides packet time stamps pairs, and the corresponding forward and reverse packet delays
- IEEE Communications Magazine February 2011 Vol. 49 No.2

Packet Delay Standard Deviation vs. Time



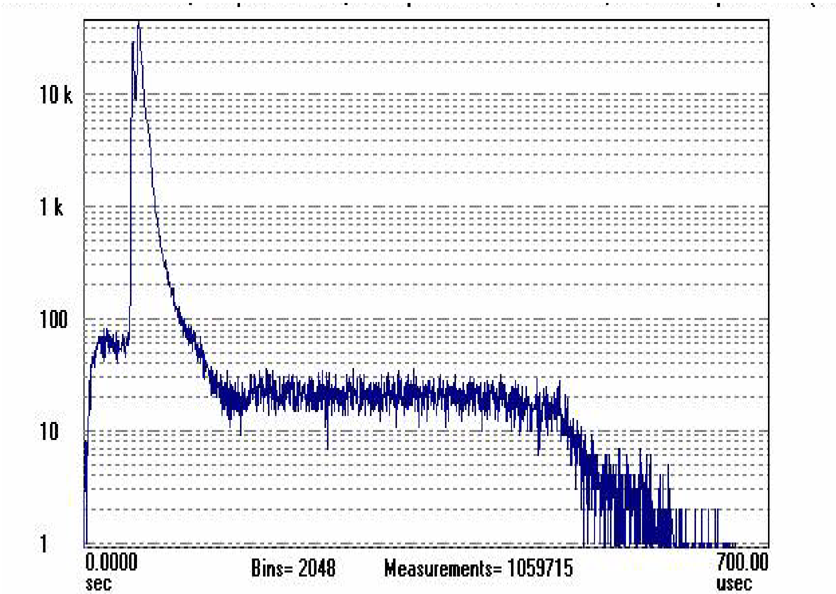
Forward Packet Delay Standard Deviation versus Time



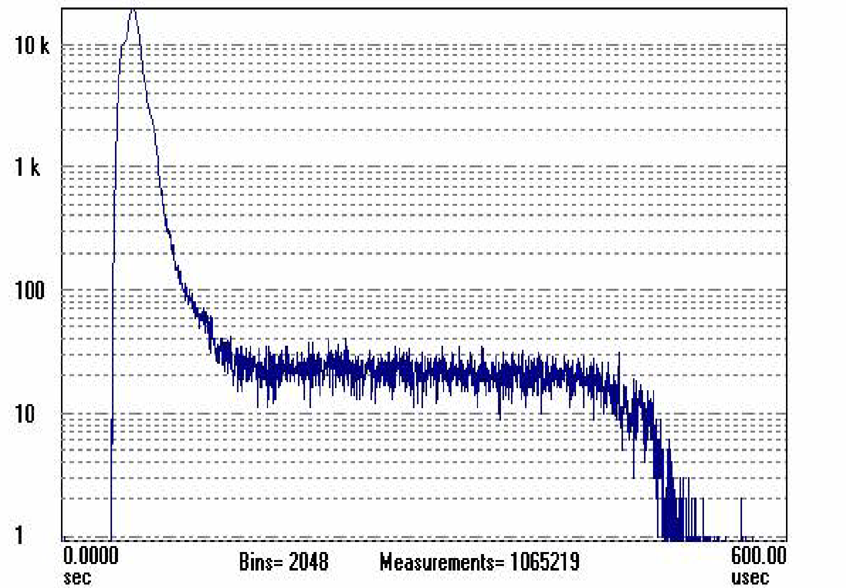
Reverse Packet Delay Standard Deviation versus Time

- Measurements were collected from TELUS Ethernet production network.

Packet Delay Distribution



Forward Packet Delay Distribution



Reverse Packet Delay Distribution

- Measurements were collected from TELUS Ethernet production network.
- Majority of packets experience relatively similar PDV, this is “THE” key to the slave clock algorithm function.

Packet Measurement Metrics

ITU-T G8260 (02/2012) Series G

- PDV metrics categories
  - Formulate packet-based stability quantities.
  - Study the population of timing packets within a certain delay window range.
- PDV metrics (Packet Selection)
  - Metrics without pre-filtering
    - TDEV – minTDEV, PercentileTDEV, BandTDEV, ClusterTDEV
    - MATIE – Maximum average time interval error
    - MAFE – Maximum average frequency error
    - Integrated packet selection, i.e. minMATIE, minMAFE
  - Metrics including pre-filtering
    - pktfilteredTIE
    - pktfilteredMTIE
    - pktfilteredTDEV
    - pktfilteredFFO

Conclusion

- With LTE-Advance and small cells deployment (HetNet), a second wave of Synchronization over Packet demand will be expected by the industry.
- Synchronization requirements will become increasingly stringent. For instance, LTE-Advance demands time/phase synchronization, ToD, as well as frequency over the packet network.
- Mobile Operators and other users need to be equipped with better tools and metrics to assess their networks for more technically and financially viable deployments of synchronization over packet solutions.

Thank You

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