Integrated Device Technology

The Analog and Digital Company™

Real-Time Analysis of Packet Delay Variation with Assisted Partial Timing Support

Factors Affecting Accurate Time Clock Recovery

- The distribution of phase alignment information across packet-switched networks constitutes a significant challenge when targeting an accuracy of ±1µs or better
  - The non-deterministic store-and-forward principle applied by packet switching technology imposes Packet Delay Variation (PDV) and asymmetry in delay on all packets traversing the network

- The effect of PDV on precision time packets has a significant impact to the adaptive servo [algorithm] to respond to network characteristics and recover an accurate time clock
  - The use of on-going monitoring and self-reporting of performance is already required for today's implementations of frequency synchronization using PTP, but these are susceptible to the effects on the local oscillator and the strength of the servo itself

- With the aid of a local Global Navigation Satellite System (GNSS), the adaptive servo can now be used to accurately measure the asymmetry and PDV characteristics of the network, and also learn the effects of local conditions, such as oscillator drift

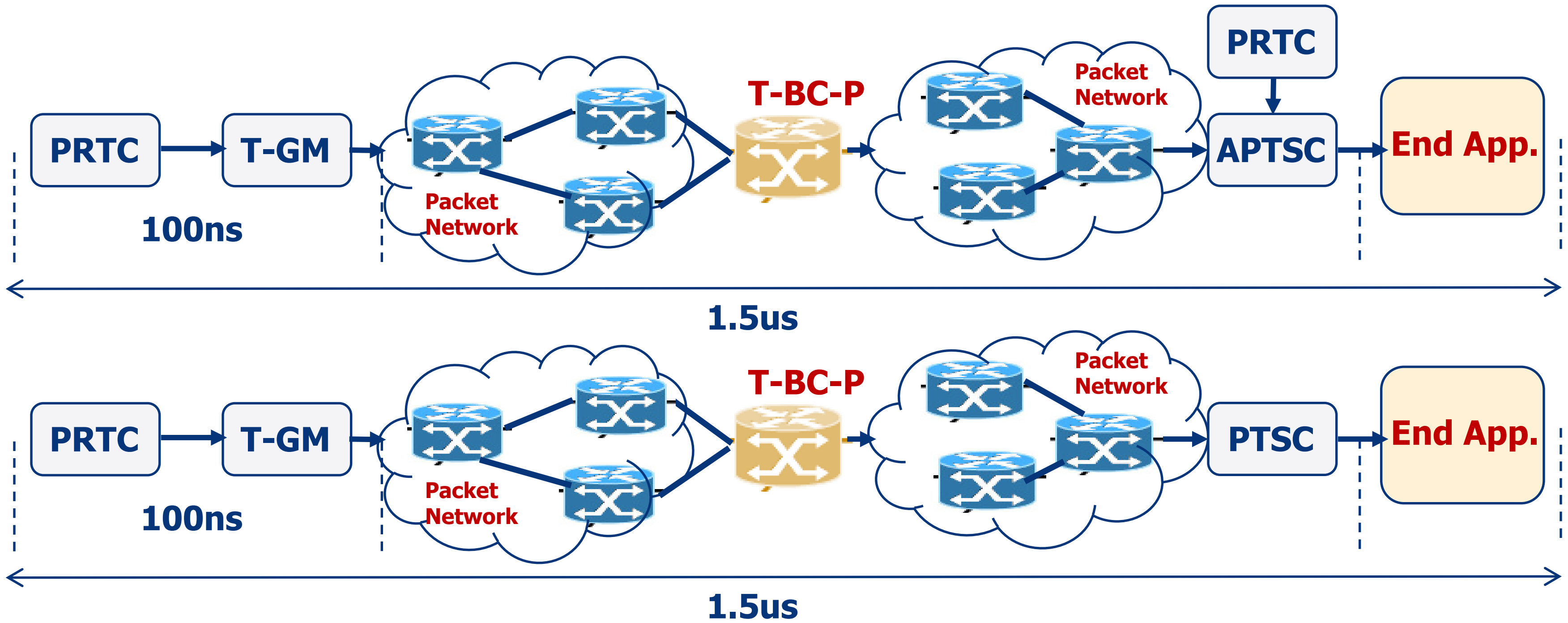
Introduction to APTS

- For Telecom Time Synchronization Networks, an approach being defined by the ITU-T is described as Assisted Partial Timing Support (APTS) [G.8275.2]
  - Allows for the Telecom Time Slave Clock (T-TSC) to continuously perform clock analysis, including frequency and phase accuracy of the PTP packet domain, in relationship to a local GNSS
  - Allows for the ability to learn and predict PDV in the network in addition to learning the local conditions and oscillator drift, enabling an alternative timing source for frequency, phase and time-of-day delivery; or to be able to hold the time below 1µs when the local GNSS fails

- With APTS, the timing performance can be continuously monitored, in service, allowing for the ability to write, and bill to, service level agreements on timing or to assure timing with mobile network operators

- In addition, the Assisted Partial Timing Support Clock (APTSC) can continuously perform PTP Network Analysis, including monitoring and testing of the PTP communication path, in situations where the local GNSS is unavailable.

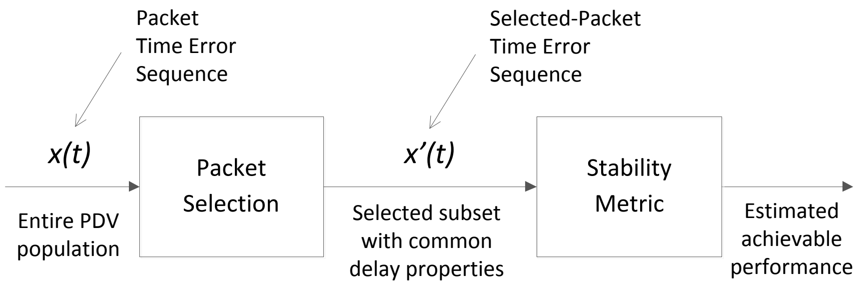
G.8275.2- ITU-T Time/Phase Profile
IEEE-1588 with partial support from Network



- ITU-T will first focus on the Assisted Partial Timing Support (APTS) profile where a PRTC is co-located with the end application
  - The local PRTC can be used to measure the asymmetry of the network
  - PTP is used as a backup for PRTC failures

PDV Measurement

- G.8260 Appendix I defines metrics based on traditional frequency signals
  - Simplest approach is analyze the PDV as received by a packet slave clock and display the measured PDV in the form of a histogram
  - Using the measured PDV, one can then produce metrics such as Packet TIE
    - Use the input PDV of the packet slave clock but select only a subset of packets
    - Process the Packet TIE to produce *pktselected*MTIE & *pktselected*TDEV
- Four examples of packet selection methods are described in Appendix I of G.8260
  - minimum packet selection and percentile packet selection
    - focus on packet data at the floor
  - band packet selection and cluster range packet selection
    - can be applied either at the floor or at some other region



G.8260/Figure I.3 – Pre-processed packet selection

Determining Floor Delay & Asymmetry

- Having the local GNSS allows for the servo to predict the accuracy of it's recovery if GNSS were to go away
  - Gives a "perfect start" condition where, initially, offset and skew are near-perfect
  - Depending on how long GNSS was available, 'advance' servo features can take advantage of previously having GNSS and, thus, could continue and maintain lock better with the loss of GNSS
  - If during GNSS presence asymmetry and floor delay was able to be predicted, then this would also help
    - For example, knowing perfectly asymmetry and floor delay means that even if one of the two PTP links (downlink or uplink) failed, the servo could continue with just one

- Even if we have GNSS, the PDV might be such that we cannot deduce accurately the asymmetry or floor delay
  - However, in cases where Minimum Transit Delay (MTD) is applicable (which is still a fairly common situation after all), then we can deduce asymmetry and floor delay accurately

- Having a perfect local reference (GNSS) will ensure that we can almost instantly and perfect capture routing problems

Monitoring Heath of Synchronization Network

- APTSC can compare the feedback information received from PTP against the local GNSS reference time, giving real-time information on whether slave clocks are precisely locked

- Deploying a supporting synchronization network management tool could allow for the remote monitoring of all clocks and fault localization
  - Network operators can now have full visibility and determine that all clocks in the network are locked to the PRTC

Synergies of GNSS and PTP

- The main component of APTS is to synchronize to a GNSS signal as primary source and provide backup by tracking a PRTC situated further in the network via PTP
  - PTP can overcome the critical shortcomings of GNSS, such as antennas line-of-sight to satellites, interference caused by weather conditions, signal jamming, and signal reflections
  - PTP provides an adequate solution to achieve 24~72 hour holdover at ±1.1μs accuracy in case of GNSS outage

- The APTSC can act as a timing reference for the local base station; simultaneously tracking independent reference clocks
  - Real-Time Analysis of PDV can predict the accuracy of it's clock recovery
  - PDV measurements can instantly capture network or routing problems to determine health of overall network

THANK YOU