Assisted Partial Timing Support – The Principles

WSTS 2014, San Jose

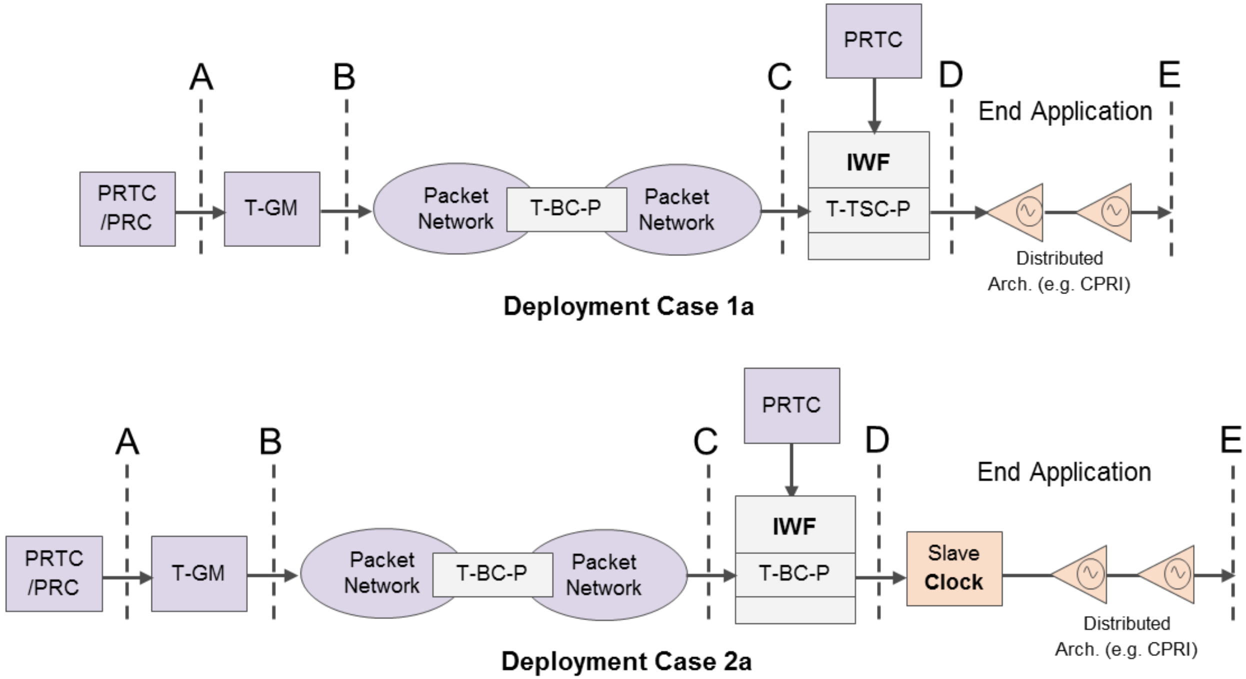
Kishan Shenoi (Kshenoi@Qulsar.com)
Tim Pearson (Tim.H.Pearson@Sprint.com)
Marc Weiss (Mweiss@Nist.gov)
Chip Webb (Cwebb@Chipwebb.com)

Outline

- Background
  - Wireless base-station timing (frequency and phase) requirement
- Principal concept of the Assisted “Partial-Support” approach for timing in a wireless (LTE) environment
  - Combination of GNSS and PTP approaches
- Comparison between APTSC and Telecom Boundary Clock (PTP)
  - Lots of similarities between T-BC model and APTSC
- Mathematical principles underlying APTSC
  - Introduction (more details in companion presentation)

Conceptual View

QULSAR

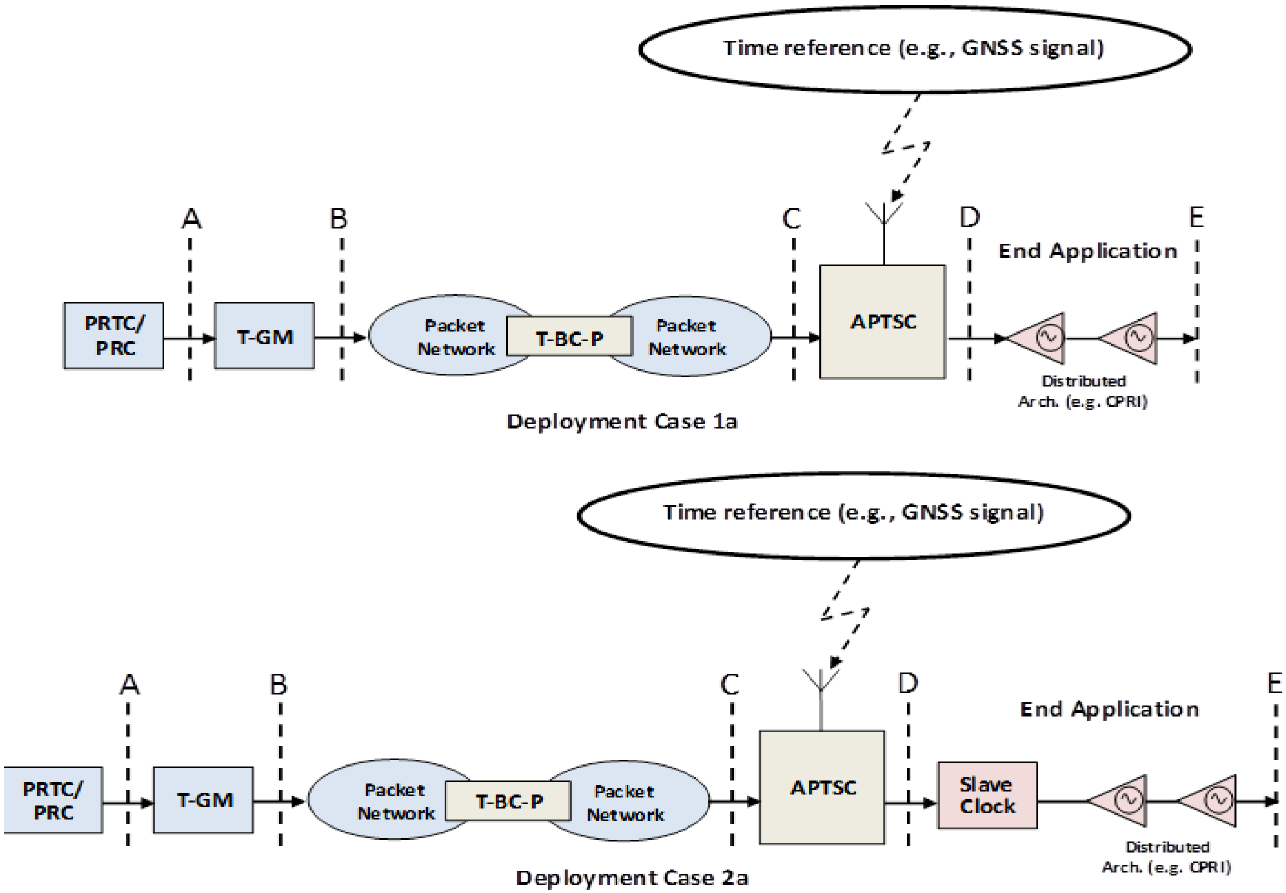


(From ITU-T Contribution WD11-Copenhagen)

- End Application may or may not include a PTP slave clock (T-TSC) – Interface D could be physical (e.g. 1PPS) or packet-based (PTP)
- End Application equipment may subsume PRTC/IWF/T-TSC (Interface "C")
- The PRTC function is GNSS based (e.g. GPS)
- The packet network between device and upstream master (GM or T-BC) may not be full on-path support (hence "partial-support")

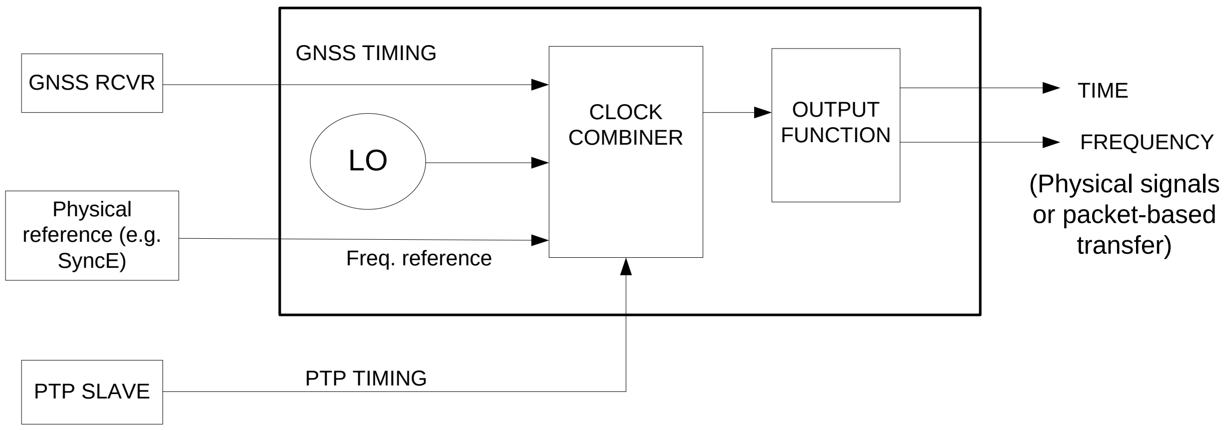
Conceptual View

(From ITU-T Contribution WD11-Copenhagen)



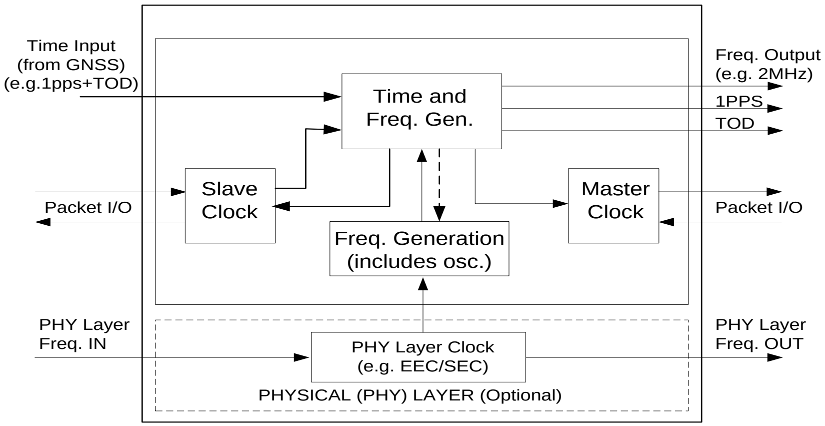
- Emphasizing that the PRTC function associated with APTSC is based on GNSS

Conceptual View

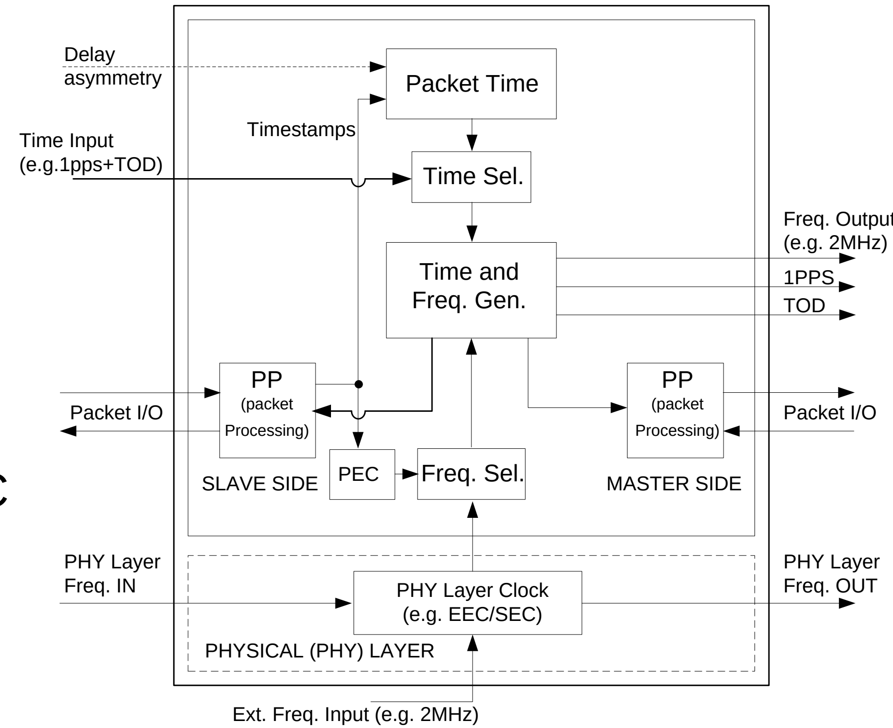


- Output function provides the output timing signal
  - PTP Master and/or 1PPS+ToD and/or frequency(e.g. 1544/2048)
- Clock Combiner considers all sources to generate the composite time/frequency to drive the output function
  - Primary reference GNSS
- Holdover (when GNSS is unavailable) using one or more of the other sources available
  - Physical references (e.g. SyncE may not be available)
- Not indicated: Ability to coordinate references (especially PTP and/or SyncE and/or GNSS working in concert)

Comparison between T-BC and APTSC



Simplified block diagram of an APTSC



Simplified block diagram of a T-BC (G.8273.2)

- Very similar in terms of functional blocks
- Some differences:
  - T-BC Master time based on Slave (upstream GM); APTSC Master is “local”
  - T-BC assumes availability of SyncE; for APTSC SyncE is optional
  - APTSC assumes time reference from GNSS (a common reference)

Operational Principles

Primary Reference GNSS

- While GNSS is active (“valid”):
  - Generate output clock (time/frequency)
    - Output time-clock absolute error should be < 100ns
  - Measure packet-delay variation (PDV) for PTP packets
  - Monitor performance of local oscillator and other references (if available)
  - Measure PTP path asymmetry
  - Measure performance of (hypothetical) PTP timing reference (for “caution indication”) (Key Performance Indicators)
- When GNSS is lost (“invalid”):
  - Use PTP timing (or other reference or local oscillator) (frequency) to control progression of time-clock (case considered here)
    - With reasonable PDV and no network events (outages, extreme congestion, etc.) progression can hold 1μs (simulation results shown later)
  - Possible Alternative: use PTP time-clock (assuming asymmetry calibration)
    - Frequency reference/local-oscillator fallback if PTP timing is inadequate

Mathematical Principles

QULSAR

- Let $t = 0$ be the point that GNSS declared invalid. The time error of the "holdover clock" modeled as:

$$x(t) = x_0 + y_0 \cdot t + \underbrace{\int_0^t \gamma(\tau)d\tau + \varphi(t)}_{\text{Holdover error}}$$

  - x_0 is the initial error (GNSS error + transient effect) (reduces holdover budget)
  - y_0 is the initial frequency error (generally ≈ 0)
  - $\gamma(\ )$ is the frequency error due to temperature changes and aging
  - $\varphi(\ )$ represents the random noise component
  - Performance metrics computed on "holdover error" while GNSS valid to develop KPIs

Example of Performance Estimation

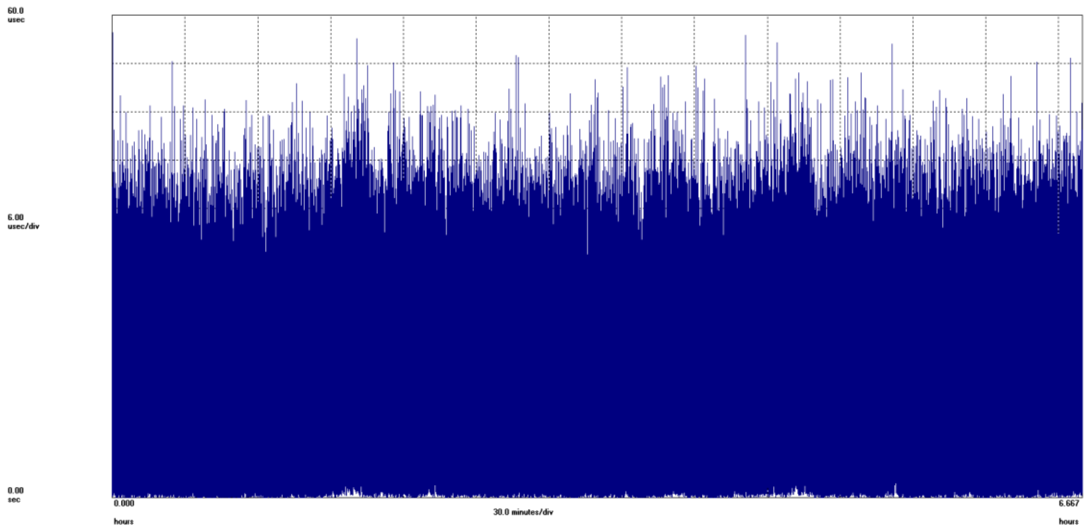
QULSAR

- Assume:
  - Overall time-holdover requirement: 1.5μs
  - Budget for GNSS error and switching transient: 500ns
  - Holdover using PTP frequency recovery using master-slave direction (*sync_messages*)
    - Packet rate: 32 pps
    - Selection mechanism: 1% over 100s windows
    - Filtering bandwidth: 1mHz
- One possible metric: MTIE
  - Requirement: MTIE(τ) < 1000ns
- Simulation:
  - 5 GigE switches
  - Load : mean load = 60% ; standard deviation = 20%

Simulation Studies

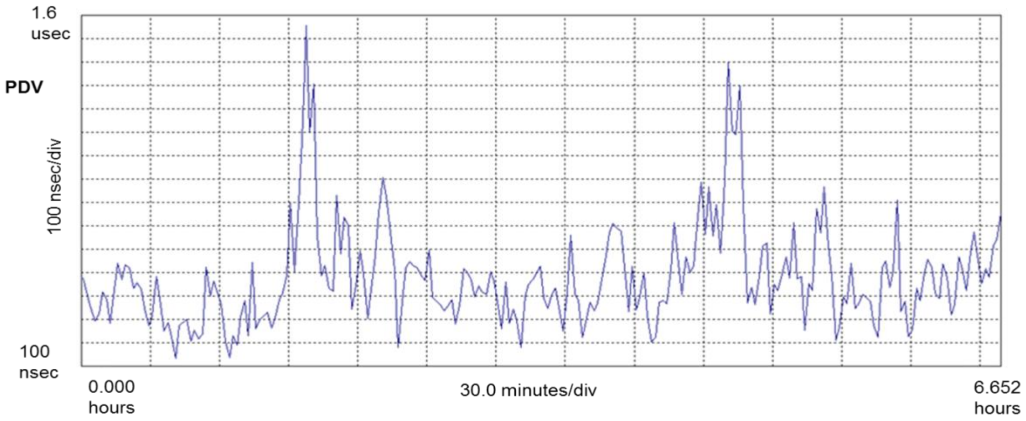
- Simulation model:
  - PTP packet is “highest priority”
  - Loading follows a flicker model, changing every 250ms
  - Packet rate: 32pps
  - PDV introduced in switch by “head-of-line blocking”
  - Network has 5 switches
  - Interfering traffic… 90% is “large” packets (1.5kbyte)

Transit delay in excess of “minimum”

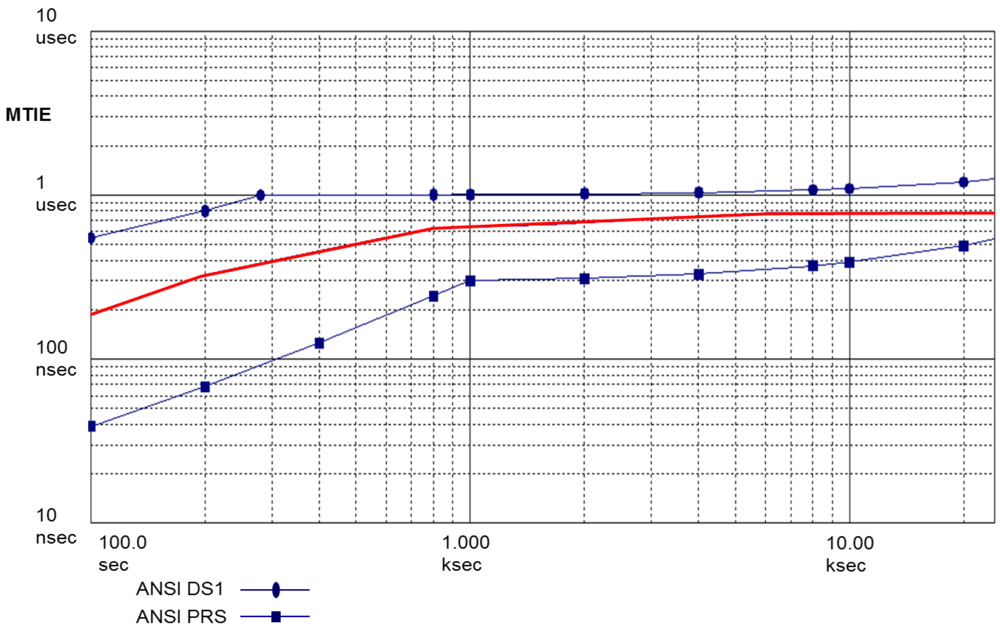


- Delay range : 0 to ~60us
- Not all packets used in clock recovery algorithm
- Typical algorithms use only packets close to the “floor”

Simulation results



Packet-delay-variation (PDV) based on:
– “floor”
– 1-percentile
– 100s window
– representative transit delay equal 1-percentile average



MTIE :
– 1mHz filter
– $<1\mu s$

Conclusion:
– With this network PDV, PTP (one-way-frequency) can support time-holdover indefinitely
– “Alarm” condition: GREEN

Concluding Remarks

- Time holdover using PTP is feasible
  - Even in cases where there is no on-path support
  - Frequency recovery is adequate
- When GNSS is active the network PDV can be measured and quantified
  - Network conditions can be grouped as GREEN/AMBER/RED
  - Key Performance Indices computed on PDV and not necessarily related to network configuration (such as number of switches)
- Companion presentation provides greater mathematical detail of time dispersion

Thank You!

Questions?

Kishan Shenoi (Kshenoi@Qulsar.com)

Tim Pearson (Tim.H.Pearson@Sprint.com)

Marc Weiss (Mweiss@Nist.gov)