Resilient Timing System with Diverse Multiple Inputs and Majority Vote

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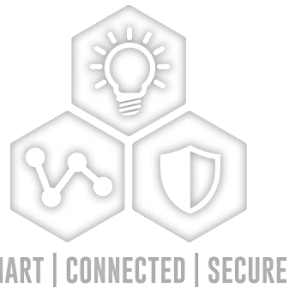

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Agenda

1. Resilient Global BMCA with Figure of Merit
2. Automatic Asymmetry Compensation Extension
3. Majority Vote Algorithm
4. Summary

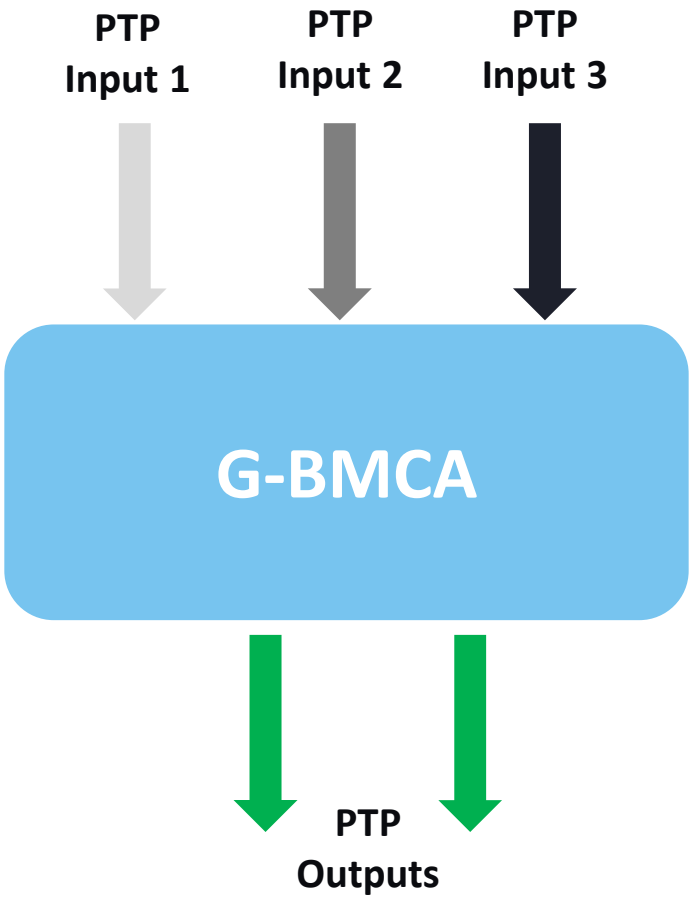
Introduction

- *There is a need in the industry to assure selected timing sources are valid and to ensure the content isn't spoofed or modified using "man in the middle" or other methods of attack.*
- *One technique to address these concerns is to use three or more geographically separated references and compare their reported attributes to "vote off the island" a reference that is out of a configurable budget range.*
- *Further resilience can be achieved by simultaneously applying Asymmetry Compensation to each PTP input channel.*
- *This session will discuss the application of these resiliency architectures and best practices*

Resilient Global BMCA (G-BMCA) algorithm

IEEE 1588 Definition:

Best master clock algorithm specifies the way that a PTP Instance determines which of all the PTP Instances (including itself) is the "best"



Advantages of G-BMCA

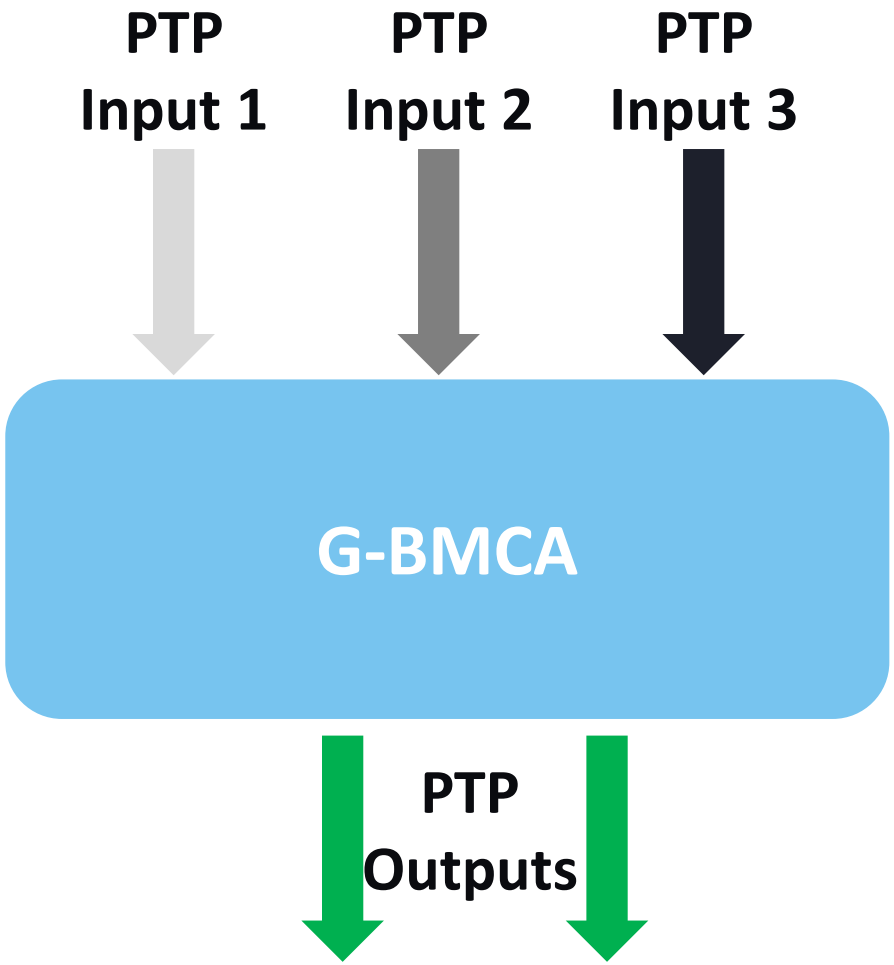
1) G-BMCA is an extension to standard/alternate BMCA defined by IEEE 1588 and ITU-T standards Committee.

2) Standard/alternate BMCA assume a single profile. G-BMCA can run with a mix of profiles using a mapping function of the various PTP parameters.

3) In addition to the data set comparison, G-BMCA includes the comparison of PTP performance using a "Figure of Merit" metric.

4) G-BMCA has the option to run on multiple clock domains to support parallel paths of synchronization (i.e., east/west domains) to protect against reference/path failures.

Resilient Global BMCA Flow



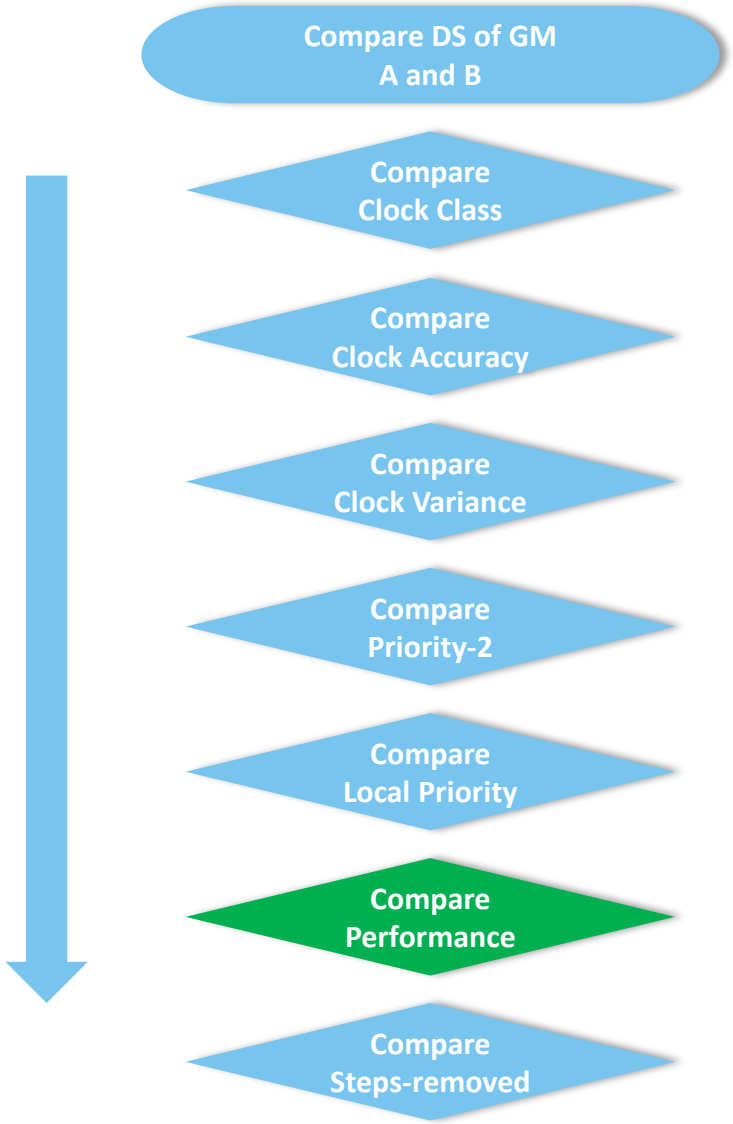
1) PTP Inputs can be on the same or different physical ethernet ports. Recommendation to use different paths for additional network resiliency.

2) The PTP Data Sets (DS) and performance “Figure of Merit” are sent from each PTP input to the G-BMCA module

3) G-BMCA decides which PTP Input is used as a reference, assuming the input was not rejected by Majority Vote algorithm, if enabled.

4) G-BMCA sends the selected PTP reference DS to PTP Server output Port(s)

Resilient Global BMCA Advantages



- Ability to turn on/off “Performance” check
- Conservative location of the “Performance” check in G-BMCA chain
- Future enhancements will include the ability to move the “Performance” check anywhere in the BMCA chain

PTP Client Performance Metric – “Figure of Merit”

- The FoM is a normalized dashboard looking on Packet Delay Variation (PDV) of each PTP path by using the Floor Packet Percentage (FPP) for a floor density of δ =10[us]
- FPP is defined in ITU-T G.8261.1 standard:

8.1.1 Network limit

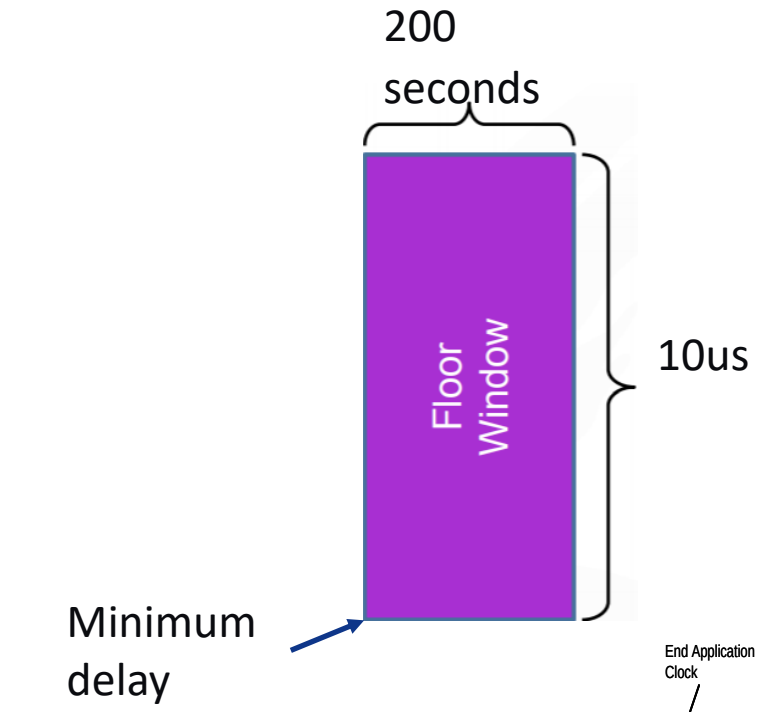
The packet delay variation network limit at point C of Figure 3 for the HRM-1 shown in Figure 1 is defined as follows:

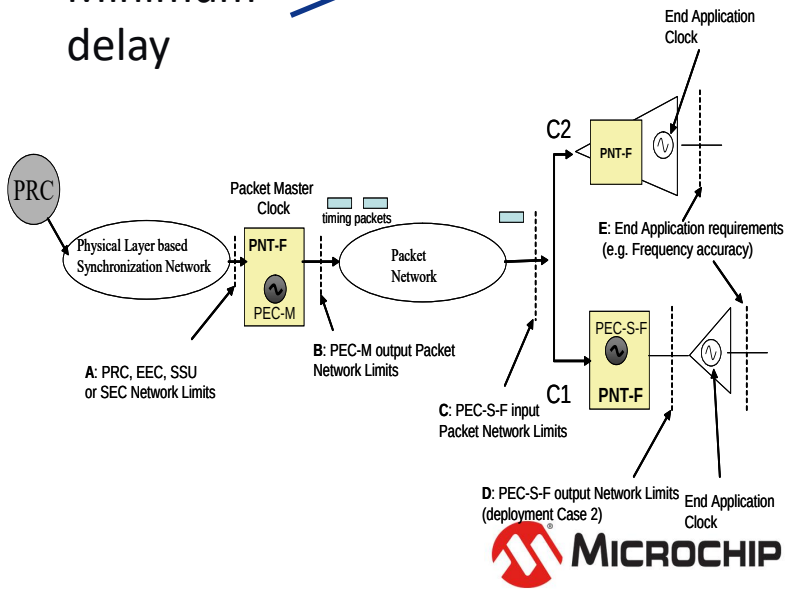
With window interval W = 200 s and fixed cluster range δ = 150 µs starting at the floor delay, the network transfer characteristic quantifying the proportion of delivered packets that meet the delay criterion should satisfy:

$$FPP(n, W, \delta) \geq 1\%$$

That is, the floor packet percentage must exceed 1%.

This means that for any window interval of 200 s at least 1% of transmitted timing packets will be received within a fixed cluster, starting at the observed floor delay and having a range of 150 µs.





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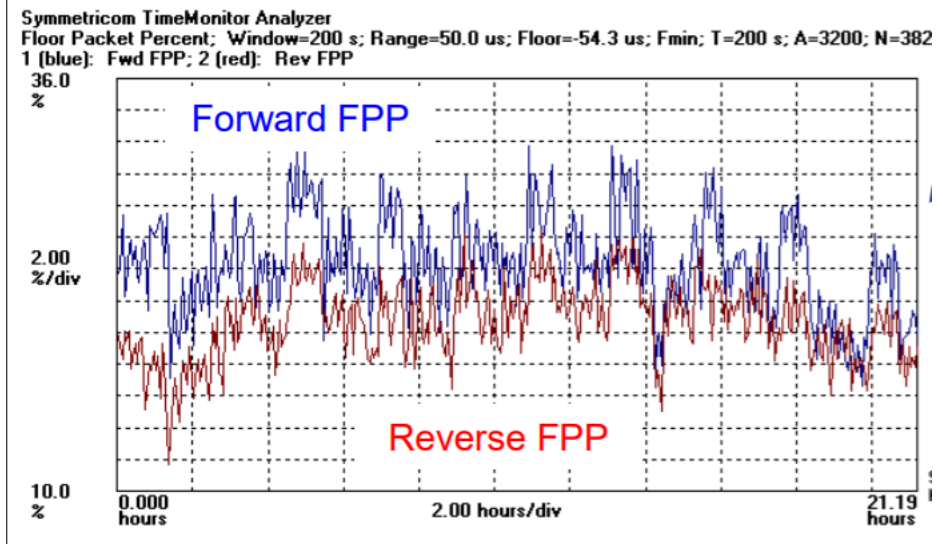
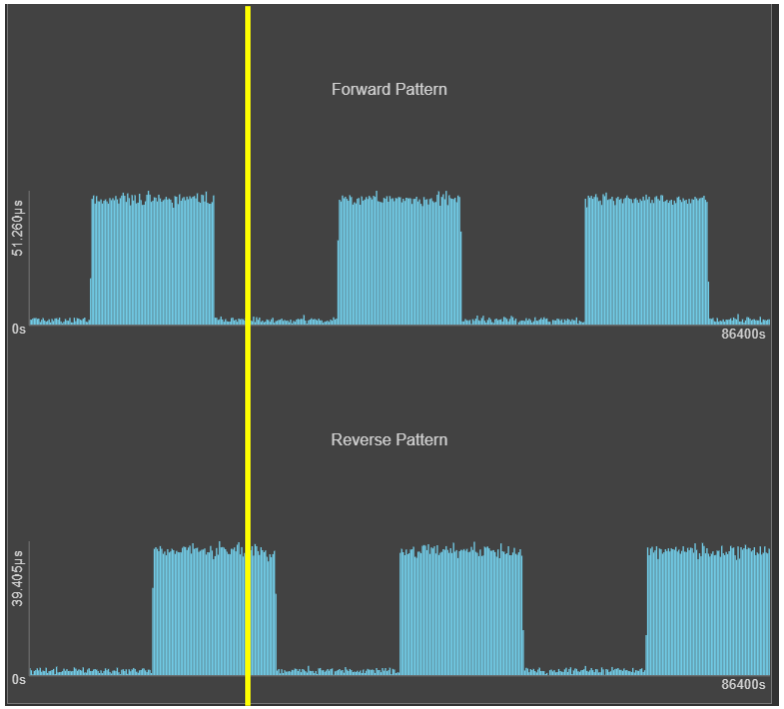
“Figure of Merit” (Contd.)

- FPP is a one-way metric – Forward FPP and Reverse FPP are measured separately
- At right is an example of ITU-T G.8261 TC13 Forward and Reverse patterns – yellow line represent 20% BW utilization on Forward and 50% on Reverse
- FoM is a normalized Covariance FPP Metric (0 to 1). The higher the value is - the more it is suitable to be used for stable time transfer.

Forward/Reverse FPP





“Figure of Merit” Verification

- Microchip’s PTP simulator runs over 200 different impairments profiles and measures FoM for each. We meet 1.1us performance with any of these 200 profiles.

- FoM of popular test cases in the industry:

PDV Profile	Figure of Merit
No PDV (Full on Path)	1
Tier 1 customer path	0.94
Static 40% Forward 30% Reverse	0.82
TC13A	0.48
TC14A	0.36
TC13B	0.25
TC14B	0.1

Automatic Asymmetry Compensation Extension

- An extension of our current 32 Paths AAC for PTP client is the support asymmetry compensation to each of the PTP client instances
- System can store the offset and noise of up to 96 paths with the latest extension

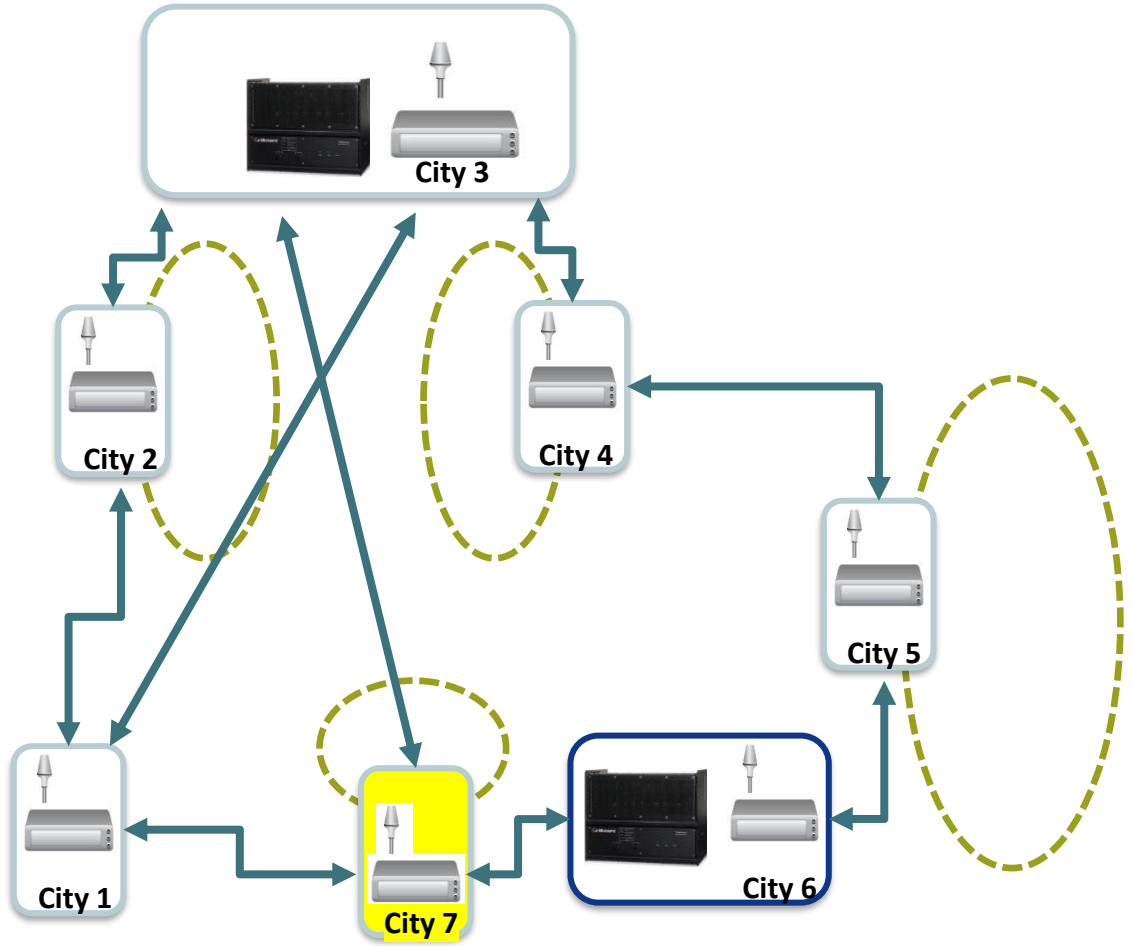
```
tp4100> show timing-service asymmetry status eth2 port-instance Port-Inst-0

  Service Name                    : telecom-2008 ptp-client Domain 0 (7)

  Auto-Asymmetry State            : Enabled
  Current Path Calibrated?        : Yes
  Current Path Offset (us)        : 9.989
  Current Path Noise (us)         : 0.017
  Path Availability               : 51.44 %
  Current Table Used              : 1
  Path Rearrangement              : 2
  FPP Covariance                  : 0.226407
  Overall Path Merit              : 0.188679
  Table 1: Clock ID  00:b0:ae:ff:fe:05:20:d0
```

Entry	Offset (us)	Noise (us)	Samples (1hr)	rtd Mean (us)	rtd Min (us)	rtd Max (us)	Last Used (TAI)
1	29.995	0.013	1	202.459	200.459	204.459	2021/06/16 19:34:31
2	-0.016	0.017	2	142.921	140.921	144.921	2021/06/16 21:34:31
3	9.989	0.017	1	162.527	160.527	164.527	2021/06/16 22:46:48

```
  Table 2: No Clock ID
```



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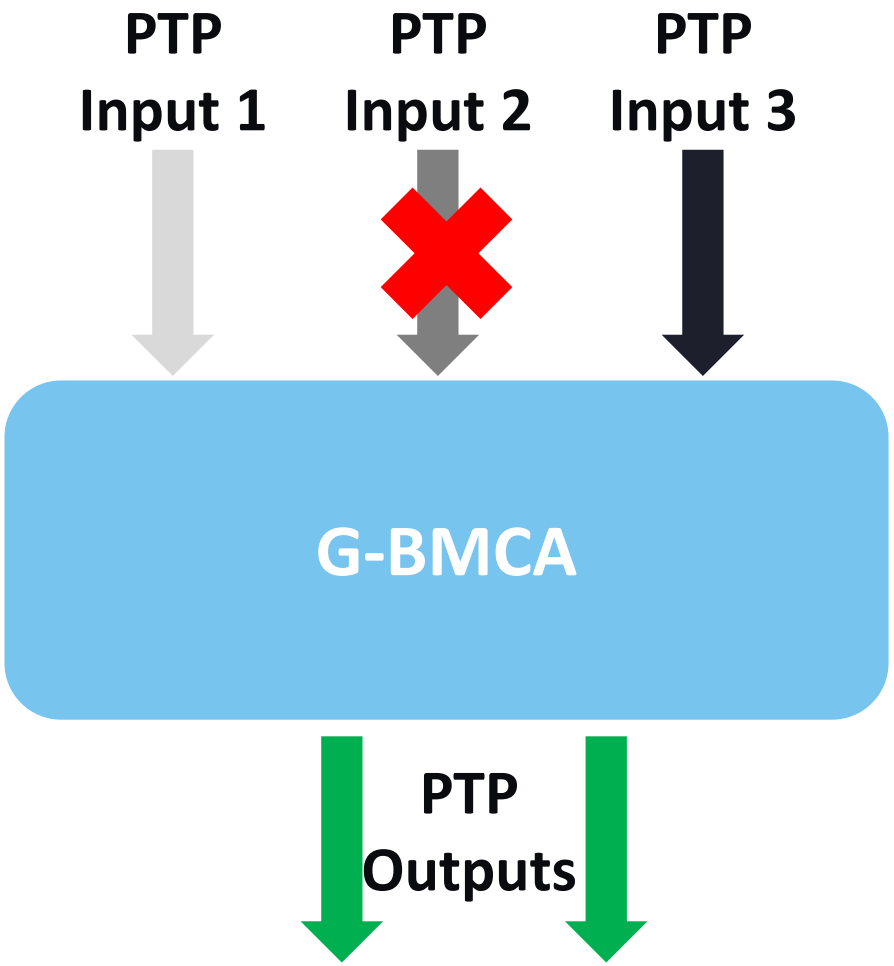
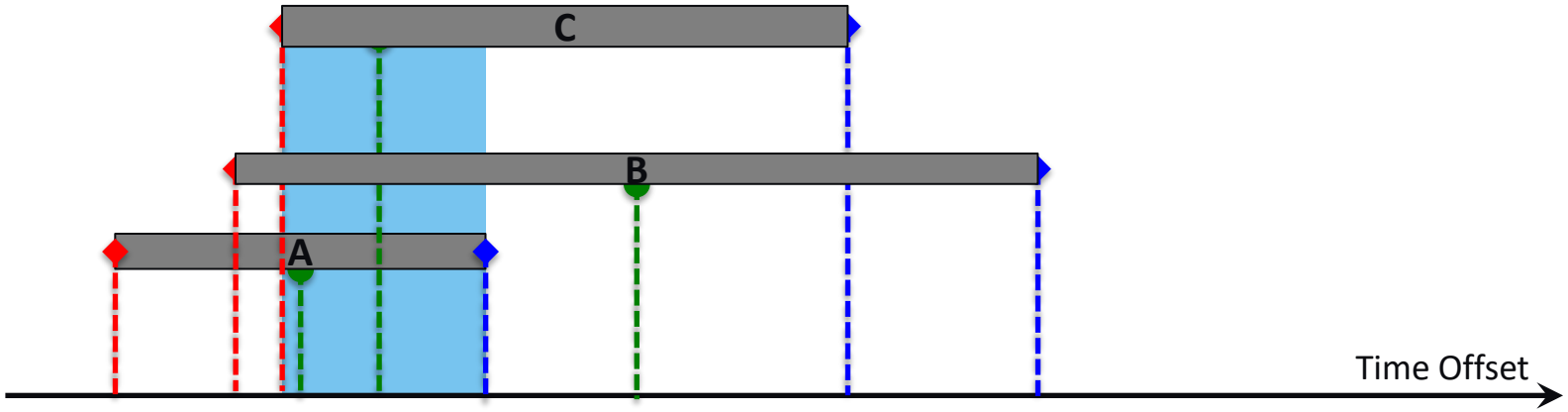
Majority Vote Algorithm Essentials

- **Why?**
  - Security – Spoofing attacks
  - Resiliency – Unintentional clock errors
- **What?**
  - Prior to G-BMCA decision tree, Majority Vote can exclude any 1 of 3 Time Reference
  - MV determines if there are any outliers and rejects them
- **Supported Combinations:**
  - 3 instances of PTP Client on the same System
  - 2 instances of PTP Client plus GNSS Time reference
  - 2 instances of PTP Client Plus G.8271 ToD Time reference



Majority Vote Algorithm – How?

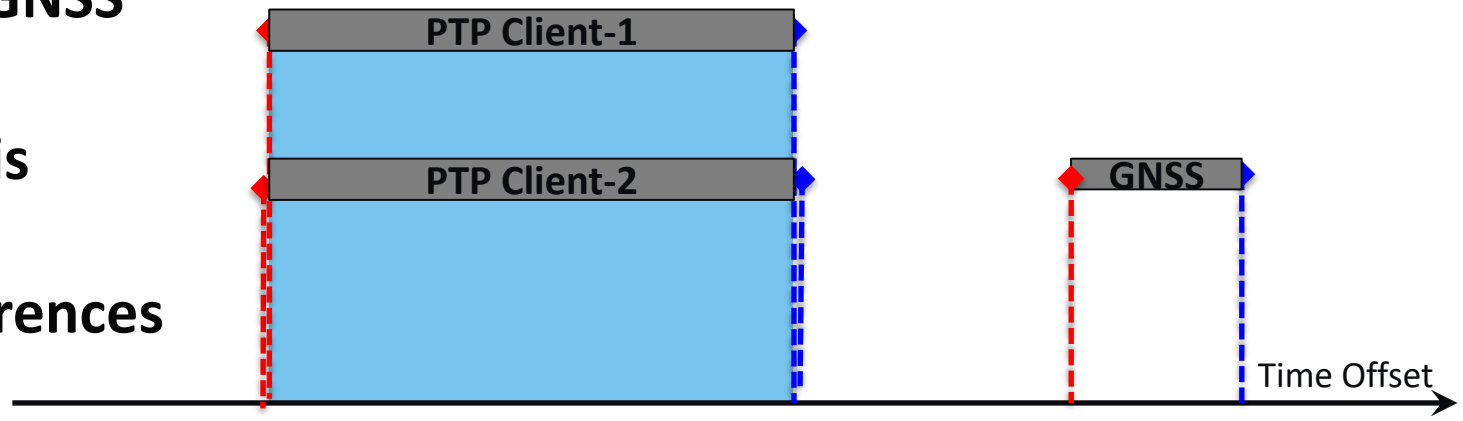
- Time offsets calculated based on a single unadjusted reference point
- User defined threshold to determine correctness intervals
- Dynamic adjustment of correctness intervals for hysteresis
- Use common algorithm to locate “Intersection Interval”
- A change in state (reject or valid) will need to persist for few seconds before change is reported



Example 1: Intersection of 3 clocks, all clocks are valid

Example 1 – One Clock Outlier

- System UUT is initially locked to GNSS reference
- Industry standard testing device is added into the scenario injecting arbitrary time with dual PTP references
- UUT rejects the higher priority reference (GNSS)




```
System Date and Time                    : 2021-10-08 02:00:32
  Clock Time Status                     : LOCKED
  Currently Selected Time Reference     : PTP Client (PI-1)
  Time State Duration (min)             : 44
  Clock Frequency Status                : LOCKED
  Currently Selected Frequency Reference : PTP Client (PI-1)
  Frequency State Duration (min)        : 48
  System Uptime                         : 0 day(s) 1 hour(s) 7 minute(s)
4 second(s)
Timing Service Eth7 Mode                : PTP Client (PI-0)
  Timing Service Eth8 Mode              : PTP Client (PI-1)
  Timing Service Exp Mode               : NONE
  Active Management Interface           : ETH1
  Redundancy Mode Status                : Stand-alone
  Frequency Stability (MDEV ppb)        : 0.114922
  Phase Stability (TDEV ns)             : 47.772
  Active Alarms                         : 12
  System Frequency PQL                  : 2
  Operation Mode                        : gateway-clock
  Last Config Time                      : 2021-10-10 05:25:29
  System Status                         : ok
```

Alarm Status

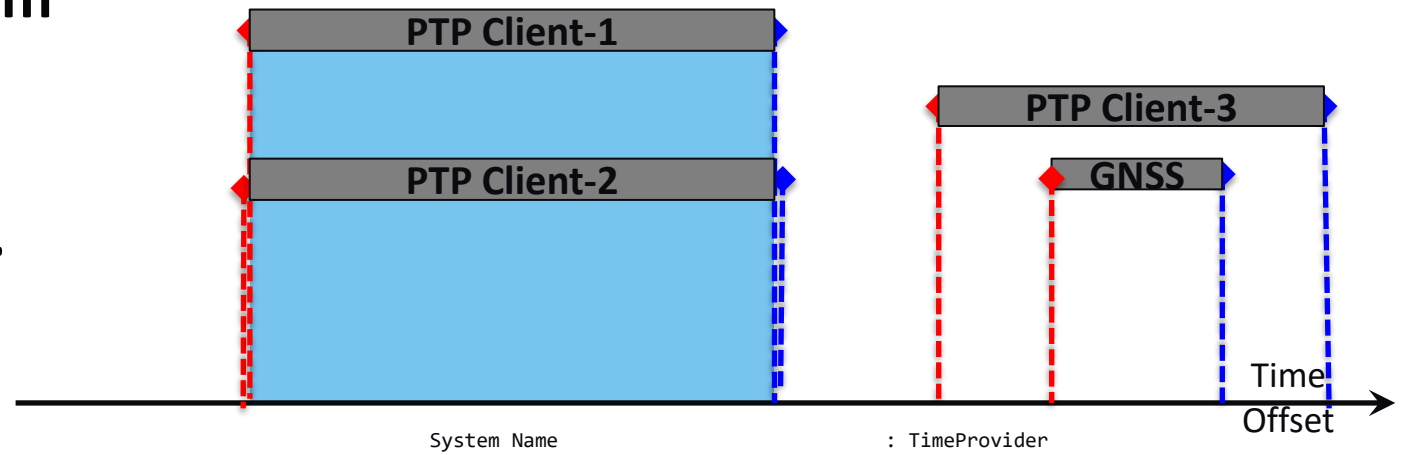
ID	Severity	Date-Time	Description
242	MINOR	2021-10-08 03:10:20	GNSS input reference majority vote rejection

Majority Vote Status

Reference	status
GNSS	reject
PTP (PI-0)	valid
PTP (PI-1)	valid
PTP (PI-2)	not-used

Example 2 – No Overlap

- 3rd PTP reference sourced from Cesium is added to the setup
- There is no intersection, therefore majority vote cannot be determined. All clocks are marked valid.
- Higher priority was set to the GNSS input which is now selected as system reference




```
Reference Criteria                    : priority
Reference Switch Mode                 : auto-return


Operation Mode                        : gateway-clock
Majority-Vote Mode                    : enable
Majority-Vote Threshold               : 1000 ns

Time Reference Config
```

Reference	Priority
GNSS	1
PTP	2
TOD-1	4
TOD-2	4

Majority Vote Status

Reference	status
GNSS	valid
PTP (PI-0)	valid
PTP (PI-1)	valid
PTP (PI-2)	valid
TOD-1	not-used
TOD-2	not-used

```
System Name                           : TimeProvider
  Serial Number                       : SCA20070010F
  System Date and Time                : 2021-10-10 21:25:50
  Clock Time Status                   : LOCKED
  Currently Selected Time Reference   : GNSS
  Time State Duration (min)           : 832
  Clock Frequency Status              : LOCKED
  Currently Selected Frequency Reference : GNSS
  Frequency State Duration (min)      : 832
  System Uptime                       : 0 day(s) 14 hour(s) 42
minute(s) 45 second(s)
  Timing Service Eth1 Mode            : NONE
  Timing Service Eth2 Mode            : NONE
  Timing Service Eth3 Mode            : NONE
  Timing Service Eth4 Mode            : NONE
  Timing Service Eth5 Mode            : PTP Client (PI-2)
  Timing Service Eth6 Mode            : NONE
  Timing Service Eth7 Mode            : PTP Client (PI-0)
  Timing Service Eth8 Mode            : PTP Client (PI-1)
  Timing Service Exp Mode             : NONE
  Active Management Interface         : ETH1
  Redundancy Mode Status              : Stand-alone
  Frequency Stability (MDEV ppb)      : 0.007607
  Phase Stability (TDEV ns)           : 3.162
  Active Alarms                       : 0
  System Frequency PQL                : 1
  Operation Mode                      : gateway-clock
  Last Config Time                    : 2021-10-08 04:07:24
  System Status                       : ok
```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Summary

- There is a need in the industry to assure selected timing sources are valid and that the content isn't spoofed or modified

- IEEE 1588-2019 standard, under Security Annex P, introduced in Prong C Guidance to address security and resilience with architecture methods as described in this presentation

- The use of techniques such as Global BMCA with Figure of Merit, Multiple PTP inputs with automatic Asymmetry Compensation and Majority Vote are some of the methods we developed to ensure resilience timing performance

Thank you

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