Pecision Time Protocol (PTP): IEEE 1588-2019

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FLINT

Outline

- Introduction:
  * Opening Discussion
  * Use Cases
- Clock Types:
  * Grandmaster, Master, Slave
  * Ordinary, Boundary, and Transparent Clocks
- Synchronization & Synotization:
  * Mean Path Delay
  * Mean Link Delay
  * Delay Asymmetry
- Best Master Clock Algorithm:
  * State Decision Algorithm
  * Data Set Comparison Algorithm

Opener

Use Cases

Why do we need a Time Protocol?

- We are building *time critical distributed & deterministic* systems.
  - Particle Colliders
  - Power Plants & Nuclear Reactors
  - Missile Systems & Flight Controllers
  - Automated Driver Assistance Systems (ADAS)
  - High Frequency Trading

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Grandmaster, Master, Slave

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- Grandmaster:
  - The ground truth time source, good to think of as a correction service provider.
- Master:
  - Provides time to slave clocks, is corrected based on the grandmaster.
- Slave:
  - Determines time as provided by a master.

Ordinary, Boundary, and Transparent Clocks

- Ordinary Clock:
  - Has a single PTP port.
  - Can act as either a *master or slave*.
- Boundary Clock:
  - Has a several PTP ports.
  - Can act as both a *master and slave*.
  - Any *master* corrected by a *grandmaster*.
- Transparent Clock:
  - Is neither a *master* or *slave*, but rather an *intermediate correctional device*.

Additional Note on Transparent Clocks

Transparent clocks measure what is called *residence time*, time spent traversing the device.

This is added to correctional fields of PTP event messages.

For *end-to-end* transparent clocks, this is all.

For *peer-to-peer* transparent clocks, ‘peer delay’ is additionally supported.

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Mean Path Delay and Mean Link Delay

The mean delay measures the average transmission time between two devices.

- Mean Path Delay:
  - uses a delay request-response mechanism.
- Mean Link Delay:
  - uses a peer-to-peer delay mechanism.

Mean Path Delay

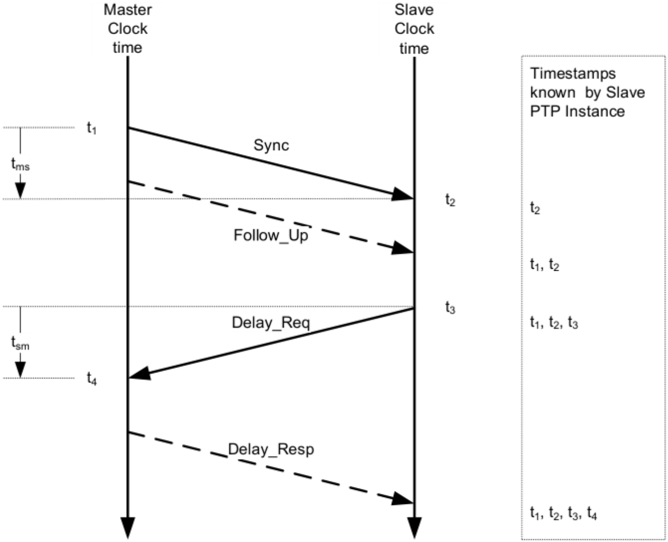
Mean Path Delay is measured as:

$$\frac{t_{m,s} + t_{s,m}}{2}.$$

Mean Path Delay is used for synchronization to master clocks. Master clocks distribute sync messages to their slaves.

This is a *distributed* correction service.

Mean Path Delay



[1]

[1] [1] Delay request-response path length measurement

Mean Link Delay

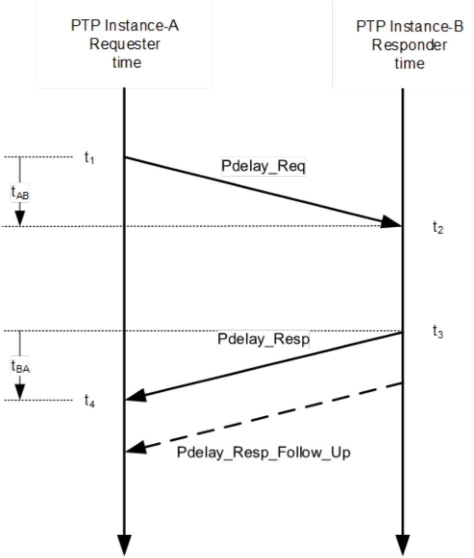
Mean Link Delay is measured as:

$$\frac{t_{res,req} + t_{req,res}}{2}.$$

Mean Link Delay allows for synchronization when Mean Path Delay is not supported e.g. transparent clocks.

This is an *on demand* correction service.

Mean Link Delay



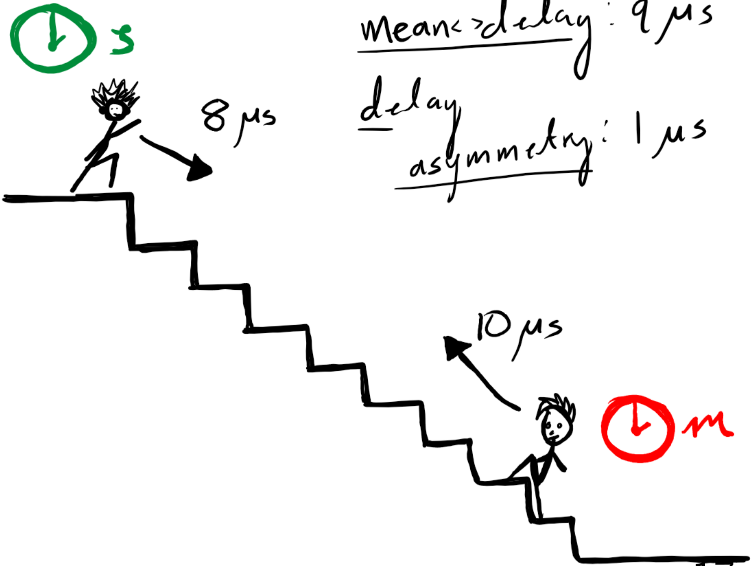
[2] [1] Peer-to-peer delay link measurement

Delay Asymmetry

The delay asymmetry measures the difference in timing based on the direction in which a path is traversed.

- $< dA > \quad = \quad < delayAsymmetry >$
- $t_{m,s} \quad = \quad < meanPathDelay > + < dA >$
- $t_{s,m} \quad = \quad < meanPathDelay > - < dA >$
- $t_{res,req} \quad = \quad < meanLinkDelay > + < dA >$
- $t_{req,res} \quad = \quad < meanLinkDelay > - < dA >$

Delay Asymmetry



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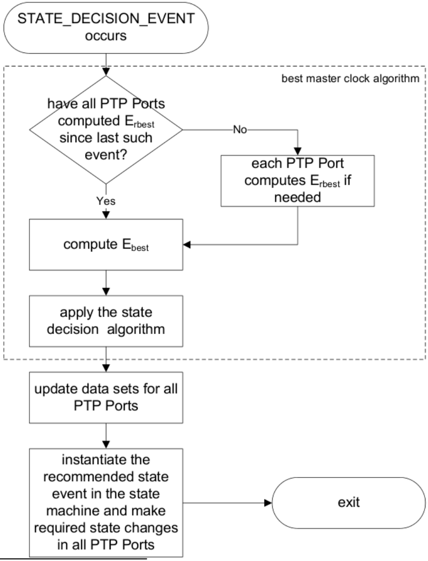
Best Master Clock Algorithm



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[3] [1] Peer-to-peer delay link measurement

State Decision Algorithm

The state decision algorithm is used to determine if a clock shall change its state.

Each PTP port can exist is one of the following states for *full* and *slave-only* implementations respectively:

- Initializing (F, S)
- Faulty (F, S)
- Disabled (F, S)
- Listening (F, S)
- Pre-Master (F)
- Master (F)
- Passive (F)
- Uncalibrated (F, S)
- Slave (F, S)

Data Set Comparison Algorithm

The data set algorithm compares *user configured*, *estimated* and *constructed* clock attributes and outputs the better of the two clocks.

The following values are compared:

1. Priority1 (UC)
2. Class (C)
3. Accuracy (E)
4. Offset Scaled Log Variance (E)
5. Priority2 (UC)
6. Identity (C)

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My experience

I have seen PTP implemented for automotive safety & ADAS.

Typically the PTP network encompass high fidelity reference sensors which are then used to calibrate less accurate series sensors.

- This is especially important for dynamic calibrations (less important for static calibrations)

References

[1] "IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems," in IEEE Std 1588-2019 (Revision of IEEE Std 1588-2008) , vol., no., pp.1-499, 16 June 2020, doi: 10.1109/IEEESTD.2020.9120376

Questions

QUESTIONS?

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