

Precision Time Protocol (PTP): IEEE 1588-2019

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Outline

Today we cover IEEE 1588-2019 as follows:

- ▶ Introduction:
 - * Opening Discussion
 - * Use Cases
- ▶ Clock Types:
 - * Grandmaster, Master, Slave
 - * Ordinary, Boundary, and Transparent Clocks
- ▶ Synchronization & Synotization:
 - * Mean Path Delay
 - * Mean Link Delay

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

Grandmaster, Master, Slave



Grandmaster, Master, Slave

- ▶ 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.

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

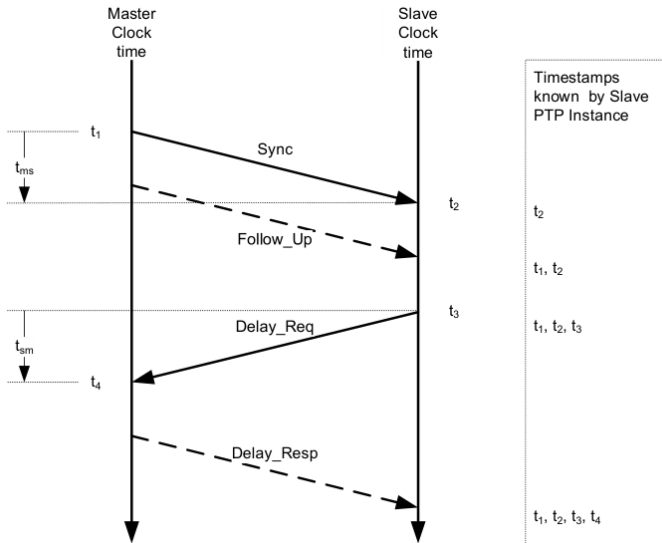
Mean Path Delay is measured as:

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

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] Delay request-response path length measurement

Mean Link Delay

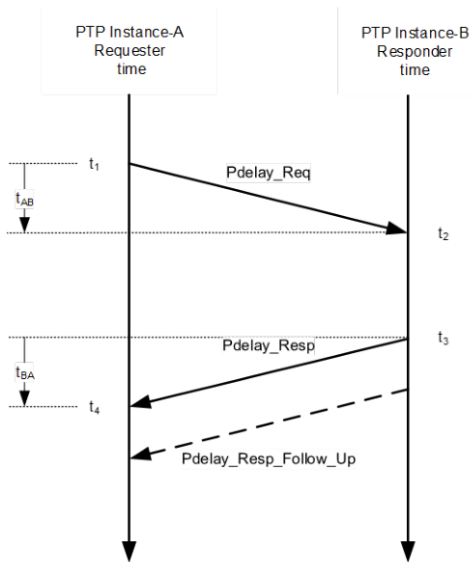
Mean Link Delay is measured as:

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

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.

$$\blacktriangleright \langle dA \rangle = \langle \textit{delayAsymmetry} \rangle$$

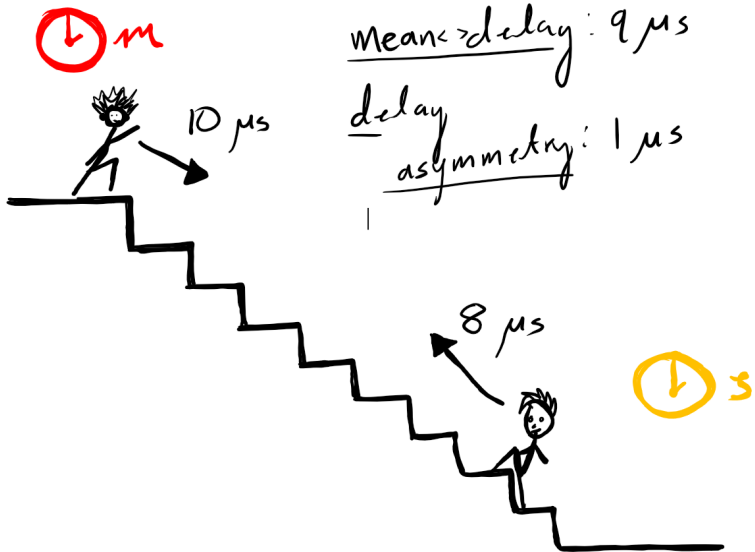
$$\blacktriangleright t_{m,s} = \langle \textit{meanPathDelay} \rangle + \langle dA \rangle$$

$$\blacktriangleright t_{s,m} = \langle \textit{meanPathDelay} \rangle - \langle dA \rangle$$

$$\blacktriangleright t_{res,req} = \langle \textit{meanLinkDelay} \rangle + \langle dA \rangle$$

$$\blacktriangleright t_{req,res} = \langle \textit{meanLinkDelay} \rangle - \langle dA \rangle$$

Delay Asymmetry



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

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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