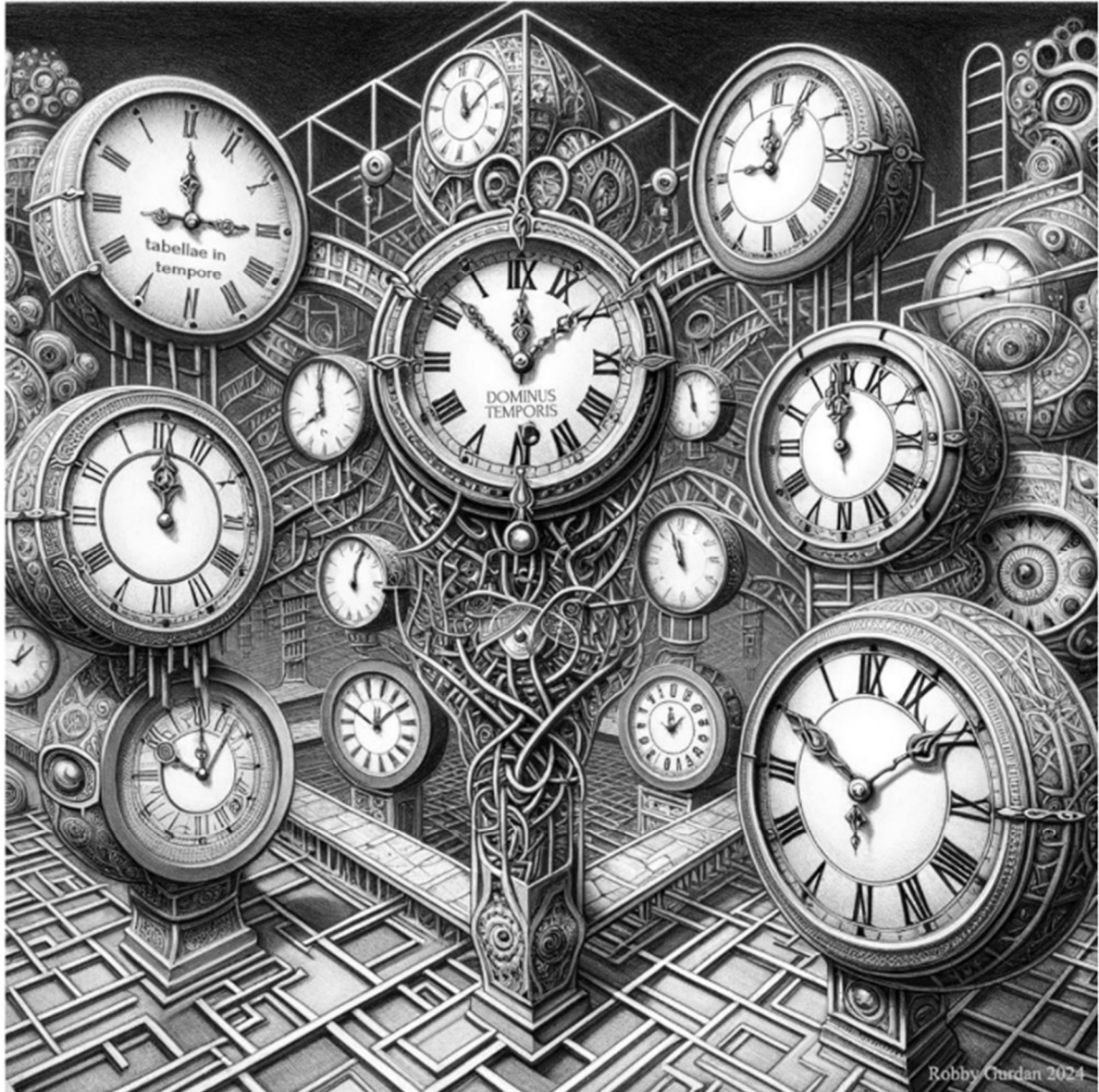


Understanding the essence of time

Part 2

IEEE802.1 AS gPTP in automotive networks



Introduction

The world of automotive technology is developing rapidly, especially around networked vehicle systems. A key component of this development is the precise synchronization of networks in cars, which is made possible by protocols such as IEEE802.1 AS gPTP (Generalized Precision Time Protocol). This protocol is critical to any part of modern car networks especially to the performance of next gen driver assistance systems, autonomous vehicles and other advanced automotive applications. This article marks the second instalment in our monthly series dedicated to exploring the significance of time in both function and validation. The first part, which delves into the comparison between local and distributed clocks, can be accessed for download on the TSN Systems website at <https://www.tsn.systems>.

Background

IEEE802.1 AS is an extension of the IEEE 1588 standard for precision time synchronization. It was developed specifically for time precision demanding environments including those found in automotive networks. In these networks, it is critical that data is transmitted in real time and with a minimal delay. gPTP provides mechanisms to synchronize clocks across networks to ensure that actions and reactions in the vehicle system are precisely coordinated in time.

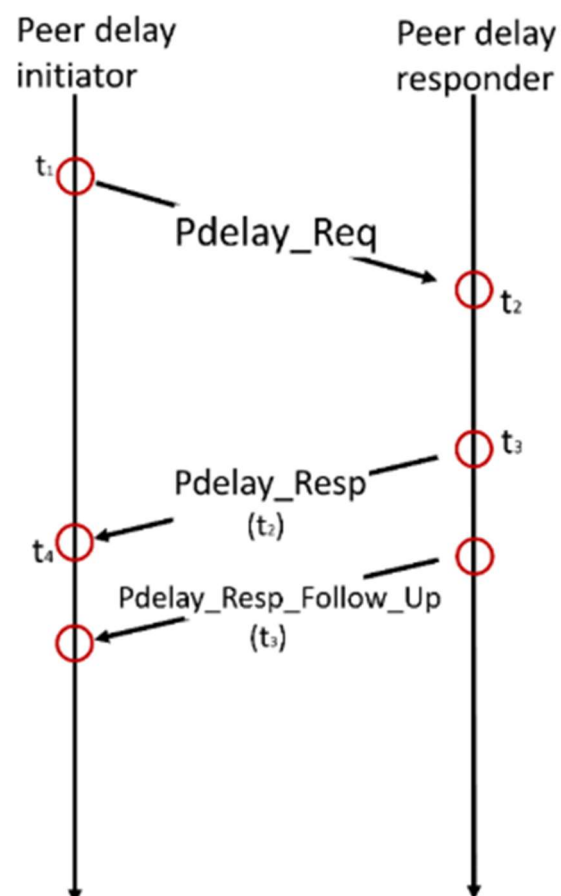
Importance in automotive networks

Modern vehicles integrate numerous sensors and systems that continuously generate and exchange data. For functions such as (semi) automated driving, adaptive cruise control and collision avoidance systems, it is essential that this data is tightly synchronized. gPTP makes it possible to precisely match the time stamps of different systems, such as cameras, radar and lidar sensors. This gives the vehicle a precise understanding of its surroundings and allows it to react accordingly.

Technical implementation

IEEE802.1 AS gPTP utilizes Ethernet-based networks in the vehicle, which are known for their high bandwidth and low latency. The protocol adjusts the clocks in various network devices by measuring and compensating for transmission delays. This achieves network-wide time synchronization with an accuracy of nanoseconds, which is essential for precise control and regulation tasks in the vehicle.

1. **Master slave (also: subordinate) hierarchy:** First, a hierarchy is created within the network, with one device acting as the master (PTP Grandmaster) as a time source, and the others (slaves) as time consumers.
2. **Timestamp exchange:** The master sends synchronization messages containing timestamps which are forwarded to all slaves in the network. These messages are sent via the network and contain the exact time at which the message was sent by the master.
3. **Delay measurement:** To take network latency into account, the protocol performs a delay measurement. The slave sends a request message to the master (at t_1), which then responds with a reply message (Response at t_3) and a Follow-up (Response-Follow-Up), containing the time-stamp the Response message was sent at. An algorithm that calculates the time difference between a request and its response enables the determination of the delay for each link, and consequently, the overall network delay.
4. **Synchronization calculation:** Each slave uses the received time stamps and the measured delay to calculate the difference between its own clock and that of the master. This difference is known as the offset.



5. **Clock adjustment:** Using the computed offset, each slave device aligns its clock with the master clock. Typically, this involves determining a frequency offset (rate ratio) relative to its own local oscillator that operates independently, and then incorporating the cumulative delay caused by the distance from the master. This mechanism is often combined with a method known as a "virtual clock." With this approach, it's not necessary to adjust the local clock (the oscillator) every time the slave receives an update from the master. There are in fact different methods for managing distributed clock data on a client, with "virtual clocks" being among the most prevalent. This topic will be explored in further detail in another article within this series.

6. **Regular updates:** Synchronization messages are sent at regular intervals to ensure continuous synchronicity and correct for fluctuations due to network changes or clock discrepancies. Through this process, 802.1AS PTP ensures that all devices on the network have nearly identical time, which is vital for applications that require high time accuracy.

Challenges and solutions

Implementing the Generalized Precision Time Protocol (gPTP) in car networks comes with its set of hurdles, notably managing network delays and fluctuations, with jitter being a significant concern. Jitter, the variability in time delay, can compromise the precision of synchronization efforts. Simplified, jitter and immediate accuracy often pull in opposite directions.

Consider a scenario where a slave clock shows 12:00, but then it receives a signal from the grandmaster clock indicating the time is 12:04. The slave clock faces a dilemma: it can either gradually increase its ticking speed to align with the grandmaster clock over time, leading to minimal jitter but a temporary lapse in accuracy, or it can instantly adjust to 12:04, achieving immediate accuracy at the cost of increased jitter.

The choice between these strategies depends on the specific requirements of the application. Each slave clock might need to be configured differently, balancing the trade-off between jitter and accuracy based on what's more crucial for their operational tasks.

Furthermore, security considerations cannot be overlooked. Accurate time synchronization isn't just about keeping time; it's pivotal for the security of the network, influencing everything from data encryption (e.g. freshness) to system integrity checks (highly accurate data timestamps for fusion devices).

Future prospects

As vehicle technology advances and autonomous functions increase, the role of gPTP will become even more important every day. The ability to precisely synchronize across different systems and sensors is fundamental to the safety and reliability of most of the modern technologies. In addition, the integration of gPTP into future 5G networks could further improve the connectivity and coordination of vehicles with each other and with the transport infrastructure.

Conclusion

IEEE802.1 AS gPTP is a critical component of modern automotive networks. It enables precise synchronization, which is essential for the safety and efficiency of ADAS, driver assistance systems and autonomous vehicles. As the automotive industry continues to evolve, the importance of this protocol will continue to grow, emphasizing the need to continuously improve its implementation and performance.