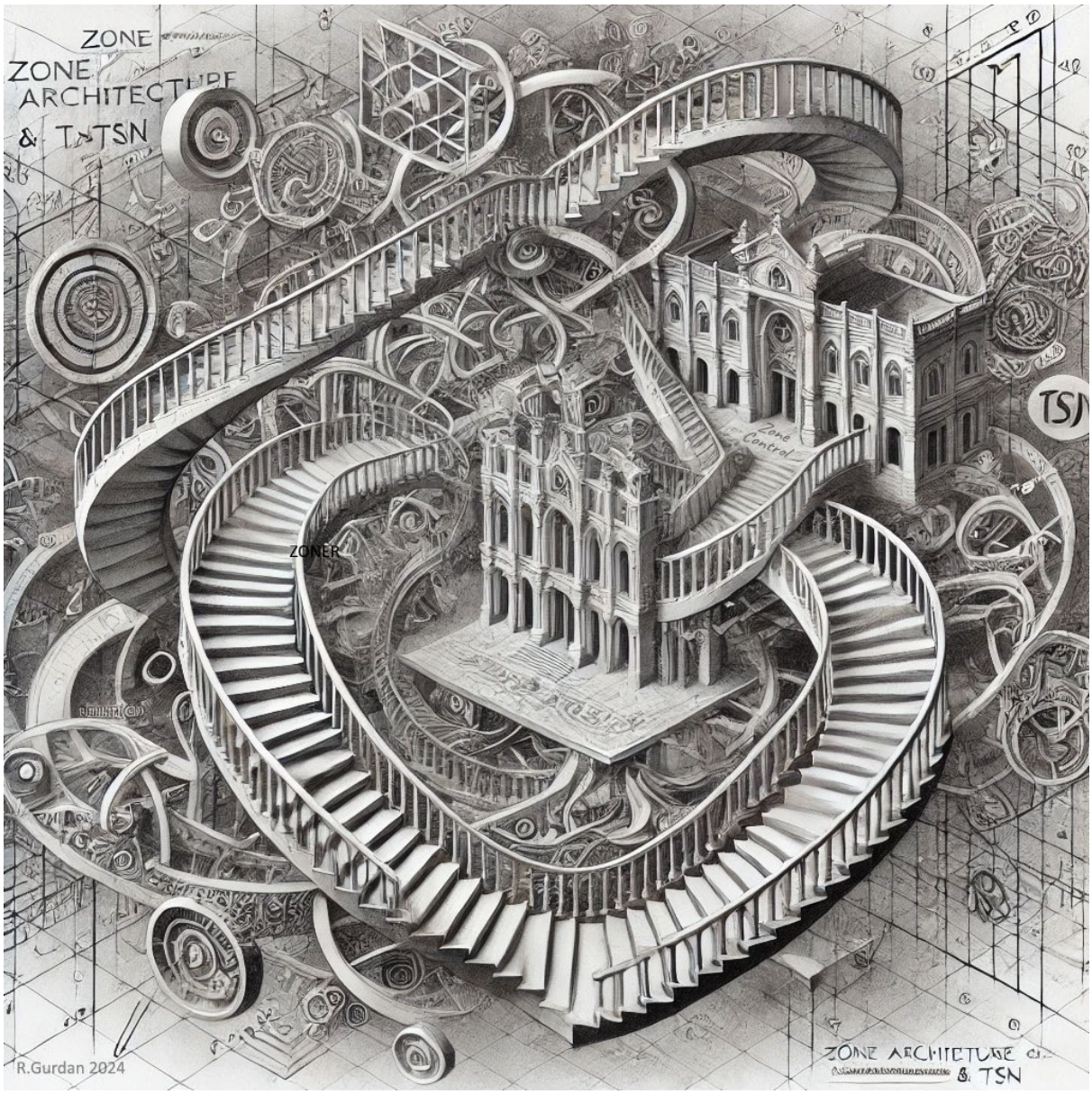
The necessary but highly disruptive change in the Automotive and Industry 4.0 sector from classic signal-based systems to Time-Sensitive Networking (TSN)



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Introduction

The Automotive Industry and Industry 4.0 are at the beginning of a profound transformation, driven by the need for more efficient and reliable data communication. Traditional signal-based systems, which have dominated these areas for decades, are increasingly reaching their limits. The move away from domain architecture, the introduction of zone architecture and the associated mandatory introduction of Time-Sensitive Networking (TSN) represents not only a technical evolution, but a true revolution that requires profound changes in the way systems are designed, implemented and operated.

The status quo: Classic signal-based systems

In traditional Automotive applications, communication networks are largely based on bus-based systems such as CAN, LIN and FlexRay. These systems have proven themselves over the years and offer reliable data transmission for a wide range of applications. However, their structure is fixed and not flexible enough to meet the increasing demands for bandwidth, real-time communication and data integrity.

The classic systems are characterized by point-to-point communication and were later organized into so-called domains, in which function-like signals are transmitted directly between control units (ECUs) and sensors/ actuators. This leads to increasingly complex wiring and makes the scalability and integration of new functions more difficult with each new generation. In addition, these systems can only guarantee limited deterministic real-time communication through complex and expensive Interdomain-gateways. But real time communication is essential for modern applications such as autonomous vehicles and industrial control systems. A common concept of exactly when information was generated and how it correlates is largely too coarse (ms instead of ns) or not available at all in classic systems.

Measurement and validation of signal-based systems

Measurement and validation can be carried out separately for each bus as the individual bus systems are separated from each other. The flow of information and validation per bus is limited to the few bus participants. Once all buses have been tested positively, the overall system is already largely functional and only needs to be functionally checked on an inter-domain gateway level.

The challenge of change

The introduction of Zone Architecture and consequently TSN with it as a new communication standard, represents a significant technological change. TSN extends the classic Ethernet standards with mechanisms that enable deterministic and time-critical data transmission. This includes precise time synchronization, traffic shaping and prioritization of data streams.

However, this change is not without its challenges. The transition from proven but rigid systems to flexible, software-driven networks requires extensive changes in infrastructure, development philosophy and employee skills.

Measurement and validation of time-based deterministic systems

Measurement and validation can no longer be carried out separately but must be carried out globally as all systems communicate via the same connections. This means that data security and data flow control become necessary.

The entire system can only be validated when all relevant data sources and sinks are connected. Therefore, a new concept for the validation itself is necessary, as well as a validation system that assists the test engineer.

Advantages of TSN

1. **Determinism and reliability:** TSN guarantees the timely and reliable delivery of data packets, which is essential for safety-critical applications such as autonomous vehicles and industrial control systems.

2. **High bandwidth:** With TSN, large amounts of data can be transmitted efficiently and quickly, which is particularly important for modern sensor and camera systems.

3. **Flexibility and scalability:** TSN enables easier integration of new functions and scaling of networks without the need for extensive hardware changes.

4. **Reduced complexity:** By consolidating different communication requirements on a single network infrastructure, the complexity of the wiring is significantly reduced.

Disruptive effects

The switch to TSN has had, and will continue to have, a profound impact on the entire value chain. Manufacturers will need to adapt their development and production processes to meet the new requirements. As mentioned above, this will require significant investment in new technologies, training, new development and validation tools and assistance systems to ensure that employees can use the new systems effectively.

For the automotive industry, this means a paradigm shift from hardware-centric to software-centric vehicle architectures. Vehicle manufacturers need to focus more on software development and integration, which requires close collaboration with technology companies and software developers and new types of modern systems that can meet these new requirements.

In Industry 4.0, TSN will change the way production facilities and manufacturing processes are controlled and monitored. Smart factories based on TSN can achieve greater efficiency and flexibility by using real-time data to optimize processes and make decisions faster.

Outlook

The transition to TSN is inevitable to meet the increasing demands on modern communication networks. The benefits of TSN are clear, but the road ahead will be characterized by challenges and changes. Companies must be prepared to invest in new technologies and fundamentally rethink the way they work. Ultimately, TSN will form the basis for the next generation of automobiles and industrial systems and pave the way for innovative applications and business models. The change may be disruptive, but it is necessary to shape the future of connected and autonomous systems.

Many major automotive manufacturers and suppliers (Tier 1) have announced that they will integrate TSN (Time-Sensitive Networking) in their future vehicles to meet the growing demands for real-time communication and reliability.

They see TSN as a key technology to ensure the necessary reliable and timely data transmission that is essential for the further development of autonomous driving technologies and advanced driver assistance systems. TSN makes it possible to design the communication infrastructure in such a way that it meets the high requirements for real-time capability and safety.

Example of why TSN will be so important for the next generation of vehicles:

For assistance systems, such as driving assistants, which simultaneously access various sensors and use them to independently determine the vehicle's route, it is essential that all data is time-stamped. In order for these time stamps to be used effectively, all devices that generate them must have high precision synchronized clocks. This, and much more, cannot be ensured with conventional technology, but only with TSN in this form.

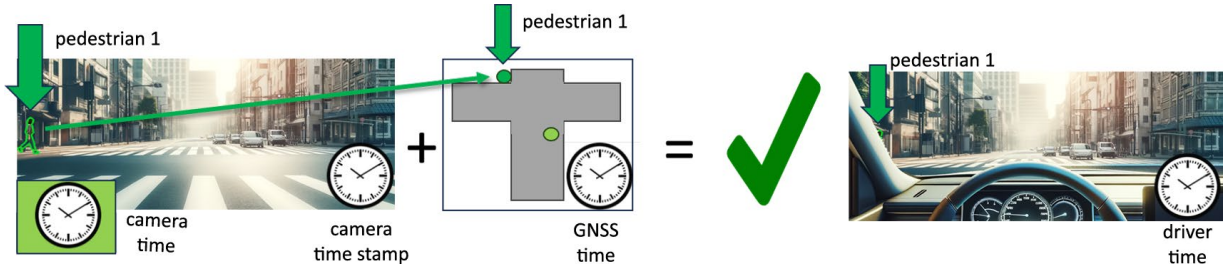

Image Section 1; *<u>Camera time and GPS time are synchronized:</u> A pedestrian is detected on the left-hand side of the road. The camera image is analysed, and the car decides that it can pass the pedestrian by steering slightly to the right.*

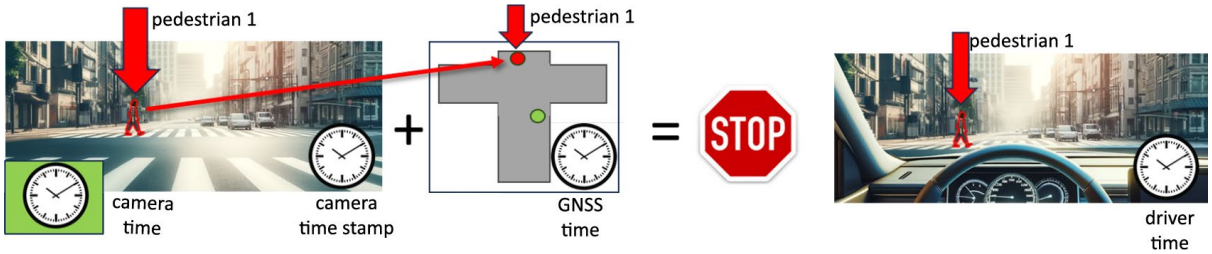

Image Section 2; *<u>Camera time and GPS time are synchronized:</u> A pedestrian is detected on the road. The camera image is analysed, and the car decides to brake and stop.*

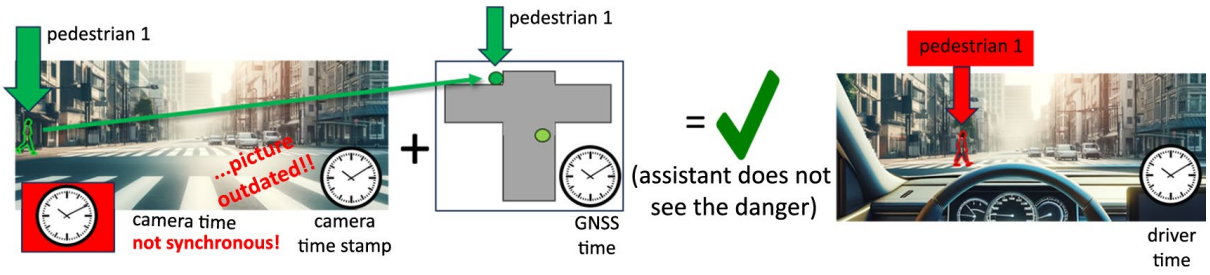

Image section 3; *<u>Camera clock and GPS clock are not synchronized:</u> A pedestrian is detected at the edge of the road because the time stamp of the image is incorrect. The camera image is analysed, and the car decides that it can pass the pedestrian by steering slightly to the right. However, this wrong decision could lead to an accident!*