Time-Sensitive Networking: From Theory to Practice

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Abstract. Time-critical communication is emerging as a cornerstone of next-generation networked systems, poised to revolutionize a variety of vertical industries, including industrial automation, autonomous driving, aerospace, healthcare, professional audio/video, and smart grids. These applications demand ultra-reliable communication with stringent requirements such as bounded latency, high reliability, and minimal packet loss. The need to meet these demands has led to the development of IEEE 802.1 Time-Sensitive Networking (TSN), a family of standards that equips Ethernet-based networks with tools and mechanisms to ensure time-sensitive communication [1].

Challenges. While TSN has originally been designed for wired Ethernet environments, extending its capabilities to the wireless domain is gaining momentum. Wireless TSN promises to enable more flexible and scalable communication infrastructures, which can either complement or replace traditional wired systems. This evolution opens up exciting possibilities for a wider range of applications, especially in environments where mobility and flexibility are crucial. However, integrating wireless capabilities into TSN introduces several technical challenges, such as maintaining precise time synchronization, overcoming unreliable wireless channels, mitigating latency, and dealing with interference.

Given the complexity of these hybrid wired-wireless systems, there is a growing need for rapid, realistic, and accurate evaluations of TSN-based systems [3].

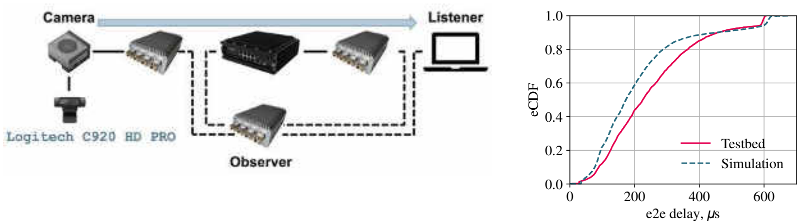

Figure 1: TSN network topology (on the left). Cross validation of TSN simulation and experimental results (on the right).

These evaluations are essential to understand the performance and scalability of TSN mechanisms, supporting their integration into future standards and deployments. Moreover, comprehensive evaluation frameworks are critical for fostering the adoption of TSN across various industries.

*Contribution***.** This paper makes several key contributions to this area of research: (i) It provides an overview of the core features and mechanisms of TSN, offering insights into the main TSN profiles; (ii) It explores how TSN features are being extended to the wireless domain, focusing on the integration of TSN mechanisms into emerging wireless technologies like IEEE 802.11be (Wi-Fi 7) and 5G New Radio (NR); (iii) It describes a simulation framework and a real testbed for TSN experimentation and validation (see Figure 1).

References

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