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Master's thesis

Enabling Time-sensitive Scheduling on Wi-Fi in Linux

Abstract

Modern mission-critical systems have embraced several interconnected and mobile components, like autonomous robots. Their intercommunication now relies on wireless networking rather than legacy fieldbus technologies that typically occur in such systems. However, due to the stochastic nature of the wireless medium, it is quite challenging to fulfil the strict latency and reliability requirements of mission-critical communication. Although new networking technologies like 802.11be Wi-Fi 7 offer promising features towards bounded latency and high reliability, wireless time-sensitive communication is still an open issue.

Alongside the developments in wireless technologies, IEEE 802.1 Time-sensitive Networking (TSN) standards provide many Ethernet-based protocols for time-synchronization, scheduling, and redundancy in *wired* networks with mixed-criticality communication. These protocols can also cut across their target domain, i.e., wired Ethernet networks, and can be implemented on top of wireless networking technologies for better scheduling of critical communication to guarantee worst-case latency. Many related works accordingly conceptualize implementing TSN protocols over Wi-Fi to achieve time-sensitive wireless communication. Towards this direction, the main goal of this thesis is to implement the most prominent TSN scheduling protocol, p802.1Qbv Time-aware Shaper (TAS), on top of Wi-Fi, using open-source Linux tools. You will implement TAS via TAPRIO qdiscs in Linux traffic control (tc) and combine it with the (default) channel access procedure on the provided Wi-Fi hardware. Eventually, you will investigate the relevant parameters to characterize wireless links and their impact on TAS configuration to achieve the worst-case latency of critical streams (compared to best-effort ones).

Objectives

In the context of the thesis, you are going to:

- configuration and adaptation of qdiscs to implement TAS
- combining TAS with Wi-Fi channel access mechanism, including obtaining channel conditions, e.g., Channel State Information (CSI), for an accurate TAS scheduling and manipulating channel access parameters
- evaluate latency and jitter improvements of the proposed implementation.

Requirements

It is a big plus to be experienced in (or strongly motivated to learn) the following:

- Fundamentals of wireless communication, particularly Wi-Fi.
- Understanding of channel access mechanisms, e.g., DCF, EDCA etc.
- Strong Linux and C programming skills
- A keen interest on prototyping and working with real hardware

Literature

- G. Papathanail, L. Mamatas and P. Papadimitriou, "Towards the Integration of TAPRIO-based Scheduling with Centralized TSN Control," IFIP Networking Conference (IFIP Networking), Barcelona, Spain, 2023, doi: 10.23919/IFIPNetworking57963.2023.10186398.
- T. Adame, M. Carrascosa-Zamacois and B. Bellalta, "Time-Sensitive Networking in IEEE 802.11be: On the Way to Low-Latency WiFi 7," Sensors, vol. 21, 4954, 2021. https://doi.org/10.3390/s21154954.
- K. Zanbouri, J. John, C. J. Sreenan, H. V. Poor and D. Pesch, "A Comprehensive Survey of Wireless Time-Sensitive Networking (TSN): Architecture, Technologies, Applications, and Open Issues," 2023, arXiv preprint arXiv:2312.01204.

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