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Bachelor's Thesis

Priority-aware and Multi-link Restricted Target Wake Time in Wi-Fi 7

Abstract

Restricted Target Wake Time (R-TWT) is a new feature in Wi-Fi 7 that assigns dedicated and contention-free service periods to Wi-Fi stations (STAs) for achieving bounded latency and low jitter. When combined with another novel feature of Wi-Fi 7, multi-link operation (MLO), it becomes possible to allocate such dedicated channel time over multiple links at 2.4, 5, and 6 GHz simultaneously. This is especially useful for modern industrial networks, in which predictable and low-latency wireless communication is paramount.

While multi-link R-TWT promises low-latency communication for typical Wi-Fi traffic, the mixed-criticality traffic in industrial networks, e.g., co-existing low- and high-priority traffic, necessitates distinguishing between different traffic flows to fulfill their distinct requirements. One of the prominent IEEE 802.1 TSN protocols, p802.1Qbv Time-Aware Shaper (TAS), has proven to be effective in achieving this in wired Ethernet networks. It enables scheduling of different traffic classes over a schedule cycle by orchestrating multiple logical queues. Its principles can readily be applied to achieve scheduled Wi-Fi transmissions; however, random channel access still adds stochastic delay and jeopardizes the otherwise precise transmission schedule on Wi-Fi.

This thesis aims to combine multi-link R-TWT with TAS to leverage priority-aware scheduling over dedicated SPs in industrial networks. While SPs constitute a dynamically selected and contention-free schedule cycle for STAs and APs, TAS determines the exact transmission time for each priority class within this cycle. This combination is especially important for hybrid TSN and Wi-Fi networks, which ultimately aim to use a unified set of (TSN) protocols across wired and wireless segments for seamless end-to-end configuration.

Objectives

Our team has already conducted preliminary research on multi-link R-TWT and TAS over Wi-Fi. In the context of this thesis, you will:

- integrate TAS into our multi-link R-TWT framework in the OMNeT++ simulator. Note that TAS is already a built-in feature in the simulator.
- model a suitable industrial topology and data traffic with varying priorities in OMNeT++.
- develop heuristics for joint SP scheduling (among STAs) and priority scheduling (within SPs).
- evaluate latency and reliability benefits of the proposed heuristics in the modeled industrial network settings.

Requirements

Experience in the following areas is a significant advantage (or a strong motivation to learn them is expected):

- Fundamentals of wireless communication, particularly Wi-Fi and its related features such as MLO and R-TWT.
- Fundamentals of time-sensitive networking, particularly IEEE 802.1Qbv Time-aware Shaper.
- Proficiency in programming with C++.
- Familiarity with network simulators, such as OMNeT++.

Literature

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- Ergenc, D. and Dressler, F. "An Open Source Implementation of Wi-Fi 7 Multi-Link Operation in OMNeT++," In Proceedings of 20th IEEE/IFIP Wireless On-demand Network systems and Services Conference (WONS 2025), Hintertux, Austria, 2025, pp. 131–134.
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- Cai Y., Zhang X., Hu S., and Wei X., "Dynamic QoS mapping and adaptive semi-persistent scheduling in 5G-TSN integrated networks". IEEE China Communications, vol. 20, no. 4, pp. 340–355, 2023.

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