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Technische Universität Berlin

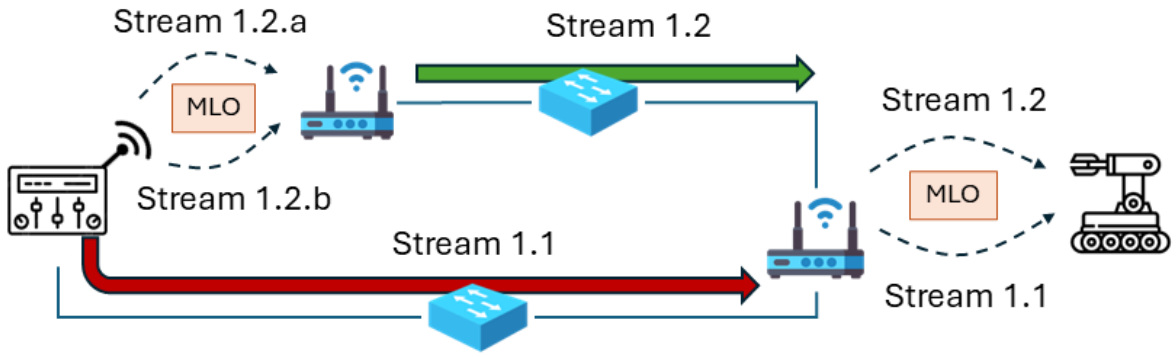
Bachelor's Thesis

Cross-Domain Redundancy for Converged TSN and Wi-Fi 7 Networks

Abstract

Mission-critical systems (MCSs) are becoming highly heterogeneous, with static and mobile components interconnected through a mix of wired and wireless networking technologies. These technologies must fulfill the emerging communication requirements of MCSs: typically bounded latency and high reliability, pushing the requirements to a few milliseconds of end-to-end delay without any packet loss. To address these challenges, Wi-Fi 7 introduces multi-link operation (MLO), in which wireless stations (STAs) can utilize all 2.4, 5, and 6 GHz frequency bands simultaneously to avoid channel congestion and interference, ultimately providing lower latency even in challenging scenarios. As a counterpart technology in wired networking, IEEE 802.1 Time-Sensitive Networking (TSN) standards also aim for deterministic and high-reliability communication. TSN defines the IEEE 802.1CB Frame Replication and Elimination for Reliability (FRER) protocol, which enables redundant communication over multiple paths against node and link failures. These multiple paths in wired networking can naturally correspond to the multiple links in the context of MLO. As a result, while MLO addresses channel access and connectivity issues in the wireless medium, FRER introduces several functions for duplicating redundant packets and eliminating them afterward to reconstruct the original data stream. Such redundancy support over MLO can eventually enable a unified redundancy mechanism over wired and wireless network segments in hybrid networks.

Accordingly, the main goal of this thesis is to investigate the application of FRER over end-to-end wired and wireless links in hybrid TSN-Wi-Fi networks. Such end-to-end redundancy can be achieved over (i) parallel wired and wireless links, (ii) multiple wireless links at different frequency bands, (iii) sequential wired and wireless segments, and more. The figure below shows an example scenario including such cases.



Objectives

In the context of this thesis, you will:

- model hybrid TSN-Wi-Fi networks, e.g., an industrial facility, in the OMNeT++ simulator.
- implement hybrid nodes capable of redundancy over wired and wireless interfaces, extending our in-house implementation of FRER over Wi-Fi.
- simulate various failure scenarios and asymmetrical link conditions across redundant paths to investigate reliability and worst-case latency benefits of FRER.

Requirements

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

- Fundamentals of wireless communication and time-sensitive networking
- Fundamentals of link layer protocols and Ethernet
- Programming skills in C++
- Network simulators, i.e., OMNeT++

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Literature

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- E. Khorov, I. Levitsky and I. F. Akyildiz, “Current Status and Directions of IEEE 802.11be, the Future Wi-Fi 7,” in IEEE Access, vol. 8, pp. 88664-88688, 2020, doi: 10.1109/ACCESS.2020.2993448.
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