Master Thesis
Digital Twin for Time-Sensitive In-Vehicular Networks Using OMNeT++ Simulator and the INET Framework

Topic Description

Today's In-Vehicular Networks (IVN) are in the midst of a significant paradigm shift. The low-bitrate CAN and FlexRay are being rapidly replaced by high-bandwidth Ethernet-based solutions using the support of the IEEE 802.1Q [1] family of Time-Sensitive Networking (TSN) standards. To ensure high reliability, flexibility, and deterministic packet delivery within these new In-Vehicular systems, researchers and manufacturers require tools that allow for rapid-prototyping and simultaneously produce results that correspond to those of real-world deployments. One of such tools is the Environment for Generic In-vehicular Networking Experiments [2], otherwise called EnGINE. The framework provides a flexible environment for repeatable, reproducible, and autonomous IVN experiments which are performed using open-source solutions on commercial off-the-shelf hardware. Solutions used include Linux and OpenVSwitch, as well as the Intel I210 NICs.

While EnGINE provides real-world experiment results and is easy to configure, it still requires a physical deployment, which may not be available or required at all times, and thus limits the availability of the framework for rapid-prototyping. To enhance this capability of EnGINE, we propose an introduction of a Digital Twin for the framework in the form of OMNeT++-based [3] simulation that can be configured using the same EnGINE's Ansible-based orchestration tool. With the upcoming introduction of native TSN support within the INET Framework [4] for the OMNeT++ simulator, the integration of the simulator as a Digital Twin into EnGINE becomes possible without the need for any third-party OMNeT++ frameworks and can rely on the long-term support of the core OMNeT++ community. With this addition, EnGINE will have the capability of producing results without the use of physical infrastructure. This capability is relevant especially in experiments for which simulation results may be sufficient, while still allowing for verification of the simulation results on a real-world deployment.

The goal of this thesis is to integrate the support for simulation of In-Vehicular, TSN, networks into the EnGINE framework and provide a detailed comparison of the results attainable using both, the real-world EnGINE testbed and OMNeT++ Simulator using the same scenario configurations. The evaluation may be extended to include reproduction of simulation results from other publications, e.g. [5] or [6], using the developed solution.

(See next page for more details)

Your tasks

1. Familiarization with OMNeT++ Simulator, the INET Framework and their TSN support
2. Familiarization with EnGINE framework and its Ansible configuration syntax
3. Preparation of a translation module for the EnGINE framework that converts the Ansible configuration into OMNeT++ configuration. This includes preparation of equivalent applications used in the EnGINE Framework (e.g. Iperf3-like data transfer) within the OMNeT++ Simulator
4. Execution and evaluation of experiments that compare the results from the real-world EnGINE deployment and the OMNeT++ simulator
5. (Depends on time constraints: Execution and evaluation of some experiments from related work, e.g., [5] or [6], using the newly developed solution in both real-world hardware and simulation)

Required Experience

- General knowledge on computer networking
- Knowledge of IEEE 802.1Q TSN standards is a plus
- Some experience with discrete event network simulation
- Experience with OMNeT++ is a plus

Additional Information

- Offered as a Master Thesis
- May be extended into a publication upon completion

References

[1] *"IEEE Standard for Local and Metropolitan Area Network--Bridges and Bridged Networks,"* in IEEE Std 802.1Q-2018 (Revision of IEEE Std 802.1Q-2014) , vol., no., pp.1-1993, 6 July 2018, doi: 10.1109/IEEESTD.2018.8403927.

[2] Filip Rezabek, Marcin Bosk, Thomas Paul, Kilian Holzinger, Sebastian Gallenmüller, Angela Gonzalez, Abdoul Kane et al. "EnGINE: Developing a Flexible Research Infrastructure for Reliable and Scalable Intra-Vehicular TSN Networks."

[3] András Varga, and Rudolf Hornig. "An overview of the OMNeT++ simulation environment." In *Proceedings of the 1st international conference on Simulation tools and techniques for communications, networks and systems & workshops*, pp. 1-10. 2008.

[4] Levente Mészáros, Andras Varga, and Michael Kirsche. *"Inet framework."* In *Recent Advances in Network Simulation*, pp. 55-106. Springer, Cham, 2019.

[5] Bahar Houtan, Mohammad Ashjaei, Masoud Daneshtalab, Mikael Sjödin, and Saad Mubeen. "Synthesising Schedules to Improve QoS of Best-effort Traffic in TSN Networks." In *29th International Conference on Real-Time Networks and Systems (RTNS'21) RTNS 2021, 07 Apr 2021, Nantes, France*. 2021.

[6] Zifan Zhou, Juho Lee, Michael Stübert Berger, Sungkwon Park, and Ying Yan. "Simulating TSN traffic scheduling and shaping for future automotive Ethernet." *Journal of Communications and Networks* 23, no. 1 (2021): 53-62.

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