technische universität dortmund

Fakultät für Elektro- und Informationstechnik
Lehrstuhl für Kommunikationsnetze
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Bachelor Thesis

Adaptive Dynamic Time Division Duplexing for Network Slices

The energy and ICT networks are becoming increasingly interdependent. In order to meet the high requirements for reliability and network stability in smart grids, a large number of monitoring and control units are needed. These in turn require high-performance communication networks that can transmit the resulting data in real time via shared, public mobile communications infrastructures. With the help of 5G network slicing, the various services can be mapped onto a shared physical network. Machine learning methods can be used to make efficient use of the limited radio resources [1]. Particularly in the event of a blackout and the subsequent restoration of energy networks, the challenge is to connect smart grid subsystems via mobile networks while taking latency and packet loss guarantees into account. Among other things, dynamic TDD patterns can be used to optimize these in combination with prioritized network slices for latency-critical transmission, thus ensuring restoration with the highest possible quality of service. [2]

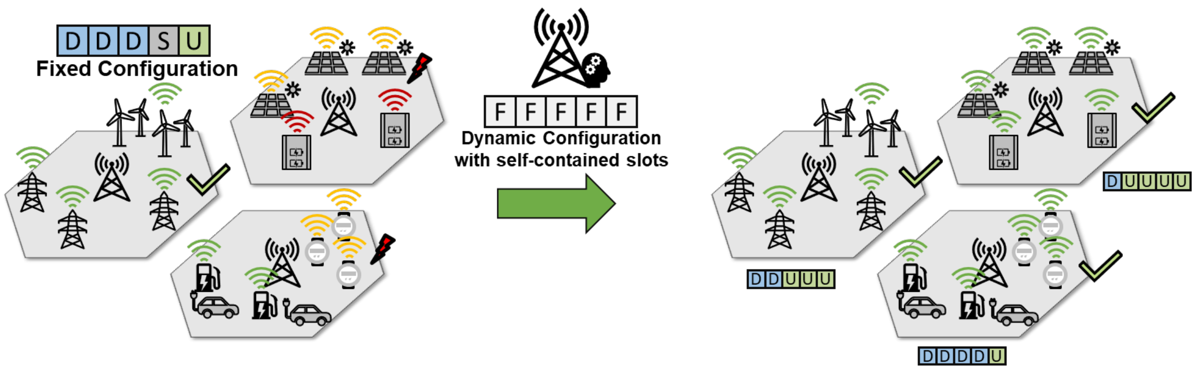

Figure 1: Example for the restoration of network subsystems with optimized, dynamic TDD patterns utilizing self-contained slots

Building on preliminary work carried out by the chair, the implementation of so-called self-contained slots in combination with dynamic TDD patterns is to be carried out within the ns-3 simulation tool [3]. In doing so, different traffic data based on standardized protocols (including IEC 61850/IEC 60870) from the field of ICT for energy networks are to be considered and used as input variables for the dynamic configuration of network slices. This involves using these traffic flows for the automated detection of uplink or downlink-heavy TDD patterns, e.g., by using ML models or on an analytical basis within the simulation environment, and then using them to configure network slices. This can also be done by dividing the data into bandwidth parts.

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Finally, the developed overall system is evaluated in the context of a reconstruction scenario. The evaluation compares the performance data obtained (achievable latency guarantees when using static vs. dynamic patterns) with classic, static approaches to dynamic TDD patterns [4, 5].

Proposed working points:

- Familiarization with 5G (network slicing, TDD patterns in particular) and building up knowledge of ns-3 simulation environment
- Definition of test scenarios using available data streams based on smart grid-related applications.
- Implementation of dynamic TDD patterns in ns-3
- Interface between (ML-based) use of dynamic TDD patterns and scheduler
- Evaluation of the developed overall system using the defined test scenarios.

Requirements:

- Required: General understanding of communication networks and protocols as well as simulation tools (desirable: ns-3)
- Required: Programming knowledge in C++
- Desirable: Experience with Machine Learning libraries (e.g. TensorFlow or PyTorch)
- Optional: Knowledge in data visualization (e.g. with Python)
- Optional: Git and Linux knowledge

References:

[1] H. P. Phyu, D. Naboulsi and R. Stanica, "Machine Learning in Network Slicing—A Survey," in IEEE Access, vol. 11, pp. 39123-39153, 2023, doi: 10.1109/ACCESS.2023.3267985.

[2] C. Bektas, C. Schüler, R. Falkenberg, P. Gorczak, S. Böcker and C. Wietfeld, "On the Benefits of Demand-based Planning and Configuration of Private 5G Networks," 2021 IEEE Vehicular Networking Conference (VNC), Ulm, Germany, 2021, pp. 158-161, doi: 10.1109/VNC52810.2021.9644659

[3] O. Adamuz-Hinojosa et al., "Empirical Analysis of 5G TDD Patterns Configurations for Industrial Automation Traffic," 2025 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit), Poznan, Poland, 2025, pp. 488-493, doi: 10.1109/EuCNC/6GSummit63408.2025.11037107

[4] A. Hassan, S. Aggarwal, M. Ibrahim, P. Sharma and F. Qian, “Wixor: Dynamic TDD Policy Adaptation for 5G/xG Networks,” Proc. ACM Netw., vol. 2, no. CoNEXT4, Art. No. 38, pp. 1-24, Nov. 2024, doi: 10.1145/3696395

[5] K. Boutiba, M. Bagaa and A. Ksentini, "On enabling 5G Dynamic TDD by leveraging Deep Reinforcement Learning and O-RAN," NOMS 2023-2023 IEEE/IFIP Network Operations and Management Symposium, Miami, FL, USA, 2023, pp. 1-3, doi: 10.1109/NOMS56928.2023.10154404