

Master Thesis

Federated Gateway Load Control for IIoT Edge Networks: An OMNeT++ Study

Motivation

Softwarized multi-gateway edge networks for IIoT suffer from congestion and inefficient resource usage when load balancing is purely reactive. A recent federated proactive approach showed promising improvements in packet loss and load distribution. However, the previous evaluation relied on a Python/TensorFlow simulator and was criticized for limited realism (clean traffic assumptions, simplified networking effects, and modest scale). This thesis addresses that gap by implementing and evaluating the concept in OMNeT++/INET with realistic network behavior.

Objective

The goal is to design, implement, and evaluate a federated proactive gateway load control framework in OMNeT++ and compare it against reactive and centralized alternatives under realistic IIoT conditions.

Key Tasks

- **Literature Review:** Review federated learning for networking and proactive load balancing in edge systems [1], [2].
- **System Design:** Define architecture and control loop for federated gateway load prediction and migration decisions.
- **Implementation:** Build OMNeT++/INET modules for gateways, clients, federated coordination, and migration control [3], [4].
- **Baselines:** Implement reactive threshold-based balancing and a centralized predictor baseline.
- **Evaluation:** Run experiments across 20 to 100+ gateways with realistic traffic and stress scenarios (churn, failures, low participation).
- **Analysis:** Quantify packet loss, delay, load fairness, overhead, and robustness; derive practical deployment recommendations.

Project type Master Thesis
Duration 1 Semester
Language(s) English
Field Computer Science



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Research Questions

- How much packet loss and delay can federated proactive control reduce compared to reactive balancing?
- What is the communication/computation overhead of FL rounds in realistic scenarios?
- How robust is the approach under gateway failures, churn, and low participation rates?
- At what network scale does the method retain clear benefits?

Prerequisites / Required Knowledge

- Fundamentals of computer networks, queueing, and wireless communication.
- Good programming skills in C++ and scripting (Python/Bash/PowerShell).
- Basic understanding of machine learning and federated learning.
- Familiarity with OMNeT++/INET is helpful but can be learned during the thesis.

Deliverables

- Reproducible OMNeT++/INET implementation of FL-assisted gateway load control.
- Experiment suite and configurations for scale/robustness studies.
- Evaluation scripts and statistical analysis of results.
- Final thesis manuscript and presentation.

References

- [1] B. McMahan, E. Moore, D. Ramage, S. Hampson, and B. A. y Arcas, “Communication-efficient learning of deep networks from decentralized data,” in *Proceedings of the 20th International Conference on Artificial Intelligence and Statistics*, 2017.
- [2] P. Kairouz, B. McMahan, B. Avent, *et al.*, “Advances and open problems in federated learning,” *Foundations and Trends in Machine Learning*, vol. 14, no. 1–2, pp. 1–210, 2021.
- [3] OpenSim Ltd., *OMNeT++ Discrete Event Simulation System User Manual*. 2025. [Online]. Available: <https://omnetpp.org>.
- [4] INET Framework Project, *Inet framework documentation*, 2025. [Online]. Available: <https://inet.omnetpp.org>.

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