FEDERATED AND EDGE LEARNING FOR HIGH DELAY TOLERANT NETWORKS

Combining Federated and Edge Learning enhances the adaptability and efficiency of delay-tolerant networks, enabling smarter, faster, and more resilient communication even in space or disaster-stricken environments. Sharing research accelerates innovation and drives meaningful breakthroughs.

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INTRODUCTION

High Delay Tolerant Networks (HDTNs) operate in environments with long delays and disrupted links like deep-space or disaster zones. Traditional centralized ML fails here due to limited bandwidth, delayed feedback, and privacy risks. Integrating Federated Learning (FL) and Edge Learning (EL) enables decentralized, intelligent operation even under severe connectivity challenges.

OBJECTIVE

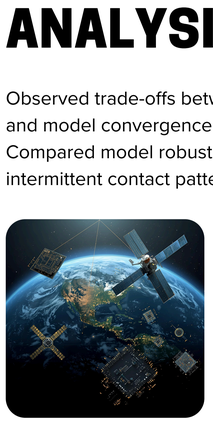
- Develop a decentralized learning framework for HDTNs combining FL and EL.
- Enable model training and inference without raw data transfer.
- Improve routing adaptability, anomaly detection, and resource management despite delays.
- Evaluate performance gains in throughput, scalability, and energy efficiency.

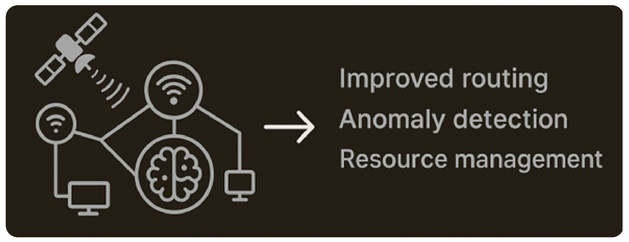
METHODOLOGY

- Local & Collaborative Learning: Nodes train locally and relay updates via neighbors; edge clusters aggregate updates.
- Lightweight Security & Efficient Updates: Compressed updates and minimal crypto protect model integrity.
- Simulation & Evaluation: CORE/EMANE emulator with CIFAR/MNIST or HDTN data; compared against Centralized ML and FedAvg using accuracy, convergence, and throughput metrics.

ANALYSIS

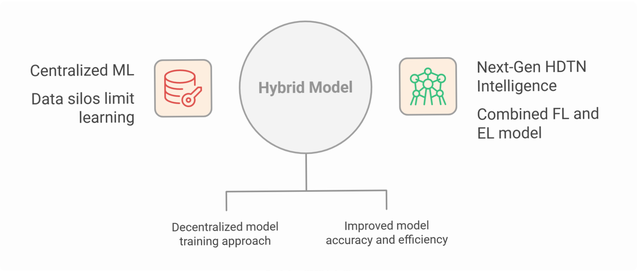
Observed trade-offs between communication cost and model convergence.
Compared model robustness under node churn and intermittent contact patterns.





Integrate FL + EL

Example of Use Cases



Evolving HDTN Intelligence

RESULTS

- Semi-decentralized relaying and edge clustering improve participation and convergence robustness under intermittent connectivity versus vanilla FedAvg.
- Modular, resilient FL frameworks reduce the impact of node failures and make deployment in dynamic edge/DTN settings feasible.
- Case studies (underwater drones, remote sensing, IIoT) show FL+EL can preserve privacy while enabling timely anomaly detection and localized decision-making.

CONCLUSION

- Combining Federated Learning and Edge Learning offers a privacy-preserving, resilient, and communication-efficient approach for HDTNs.
- This hybrid model supports real-time adaptability even in networks with extreme delay or disconnection.

REFERENCES

1. M. D. P. I., Hybrid B5G-DTN Architecture with Federated Learning, 2024.
2. NeurIPS, Delayed Gradient Averaging for Latency-Tolerant FL, 2021.