

# Chapter 7

## Strategic Federated Learning: A Novel Game–Theoretic Approach to Secure and Efficient IoD

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### ABSTRACT

*A smart, game-theoretic federated learning model has been produced by researchers to enhance IoD networks and their security and efficiency. In contrast to conventional centralized systems, which consume bandwidth, jeopardize privacy, and deplete 30-40 percent of battery of a drone, this solution uses drones in a way that are clever rationale agents. It promotes cooperation and discourages free-riding using Nash equilibrium and Stackelberg games. A combination of privacy protection, Byzantine-resilient aggregation, and on-demand resource allocation is present in the system to address the issues of data poisoning and inference attacks. It scales beautifully, tests demonstrate that it can be up to 25 percent faster to converge than other federated learning systems, and 20 percent better at resisting an attack. Using coalition-forming algorithms allows having drone collaboration remained stable, in spite of diverse or even diminished means. Gradient compression and hierarchical aggregation reduces the cost of communication at some marginal benefit in accuracy of the model.*

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# 1: INTRODUCTION AND PROBLEM FORMULATION

## 1.1 Research Background and Motivation

### Evolution of Internet of Drones (IoD) Ecosystems

IoD has adopted IoT in real-life communication and no longer just simple niche applications, such as aerial photography, now found in city logistics, disaster management, and agriculture. A market of drones worth 30 billion in 2024 is estimated to increase by 63 billion in 2030 (Statista, 2024). Sensor-equipped (e.g., LiDAR) heterogeneous drones in a network with edge computing can be configured to support such activities as swarm-based mapping (Abadi et al., 2016). Scalability and management of resources are impeded by constrained battery and compute power, and algorithms need to be optimized in order to achieve a better balance between local and global objectives.

### Challenges in Traditional Centralized Learning Approaches

Centralized learning (data transmission by the drone in the form of, e.g., 4K video generating gigabytes/minute) is ineffective because of bandwidth limitations and significant latency, which is crucial to disaster response applications. Heterogeneity of drones makes training harder, and previous systems can result in one-point failures. The battery life is attained by 30-40 percent, which is consumed on data transfer (IEEE, 2023). Local model training is possible with FL, which saves costs and latency since only updates are shared. But because such behaviours are indeed non-cooperative with the operators giving consideration to local processes, game-theoretic incentives are required as the interests are not congruent, as it has been mentioned in the document (Alsamhi et al., 2022). Figure 1 illustrates the key advantages and disadvantages of centralized learning approaches, highlighting the trade-offs between efficiency benefits and operational limitations in IoD systems.

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