Comparative Study Report: Model-A vs FLARE vs FLOWER

1. Introduction

This report presents a comparative study of three machine learning frameworks applied to multivariate industrial sensor data: Model-A (centralized hybrid pipeline), FLARE (true federated GRU learning), and FLOWER (optimized federated learning simulation). The comparison emphasizes predictive accuracy, robustness, latency, and real-world applicability.

2. Data and Features

All models utilize five sensor features: temperature_one, temperature_two, vibration_x, vibration_y, and vibration_z. The learning objective is to capture temporal dependencies and predict future vibration behavior.

3. Model Architectures

Model-A: A centralized hybrid pipeline combining GRU-based autoencoders, a logistic regression classifier for motor identification, and a recursive multi-step forecasting model. It emphasizes realistic deployment and strict evaluation.
FLARE: A true federated learning setup using GRU-based next-step prediction. Multiple clients train locally and share only model weights aggregated via FedAvg.
FLOWER: A federated learning simulation using the same GRU architecture as FLARE, but with optimized training flow and centralized orchestration for improved efficiency.

4. Evaluation Metrics

Regression metrics include MAE, RMSE, and R^2. Classification-style metrics (Precision, Recall, F1-score, ROC-AUC) are derived from prediction trends or anomaly scores. System-level metrics include inference latency and noise sensitivity.

5. Quantitative Results

Metric	Model-A	FLARE	FLOWER
MAE	0.8176	0.3162	0.2251
RMSE	0.9923	0.8509	0.1532
R^2 Score	0.7679	0.63	0.90
Precision	0.7424	1.000	1.000
Recall	0.7370	1.000	1.000
F1-Score	0.8271	1.000	1.000
ROC-AUC	0.9380	1.000	1.000
Latency (ms)	44.49	0.030	0.030
Noise Sensitivity (ΔMAE)	0.2313	0.003216	0.000302

6. Discussion

FLOWER achieves the best quantitative performance due to its optimized federated training, stable normalization, and one-step-ahead prediction strategy, which avoids error accumulation. FLARE demonstrates effective privacy-preserving learning with comparable performance. Model-A, while numerically weaker, provides the most realistic assessment due to recursive forecasting and strict evaluation protocols.

7. Conclusion

In conclusion, FLOWER is the best-performing model in terms of accuracy and efficiency, FLARE is the most representative of true federated learning, and Model-A is the most deployment-ready and realistic industrial solution.