

DATA-PRIVACY
FOCUSED
FEDERATED LEARNING FRAMEWORK
FOR
INDUSTRIAL IOT



Final Presentation

R25 - 039

PROJECT GROUP

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FRAMEWORK COMPONENT

Attack Defense And Resilience Module

Privacy Preservation Module

Secure Aggregation Module

Secure Communication and Protocol
Enforcement Module

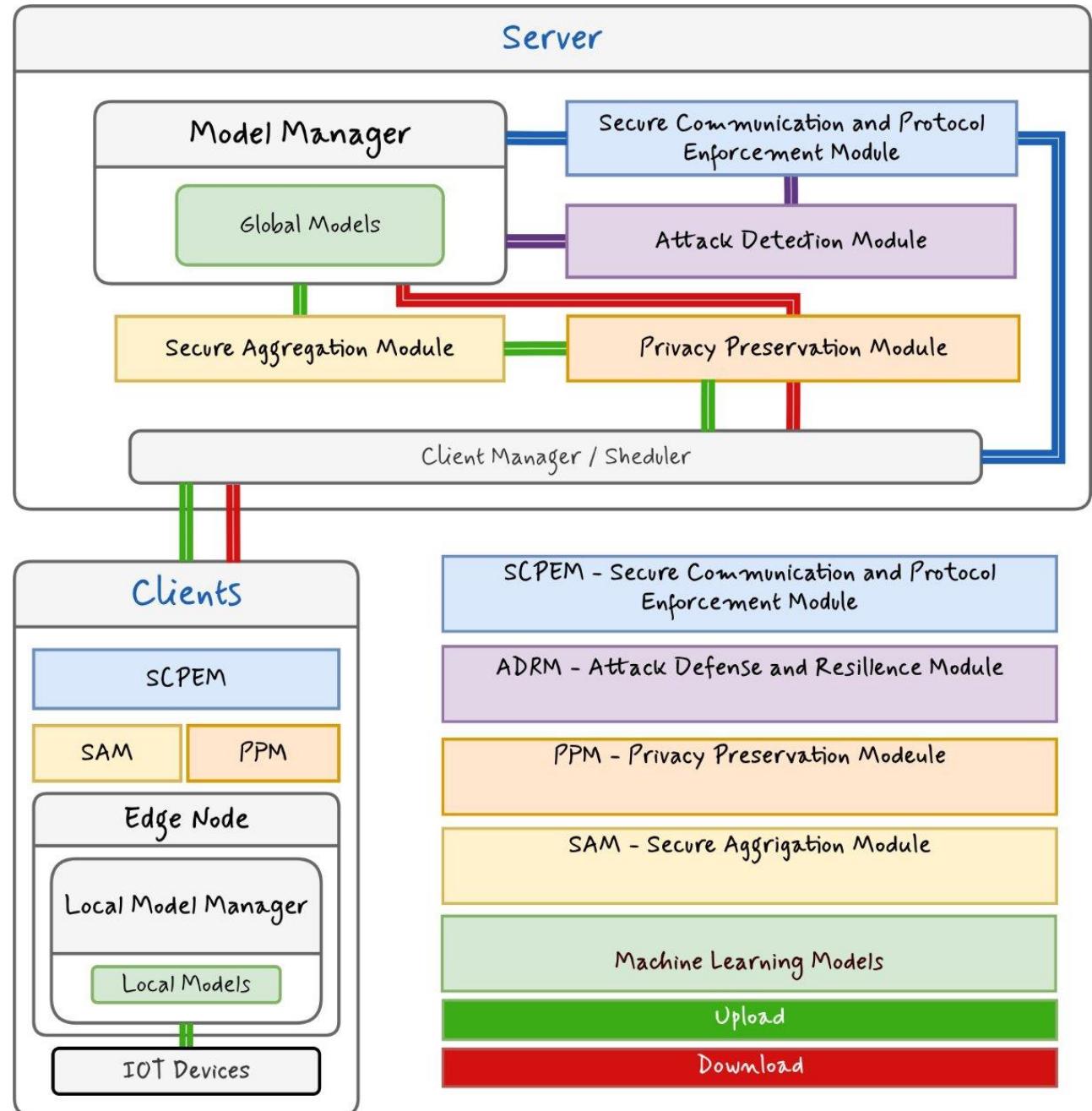
PROBLEMS

Standard FI systems fall short in IIoT, lacking a unified approach to security, privacy and efficiency. They remain vulnerable to poisoning and byzantine attacks, and security failures in IIoT can have severe consequences.

SOLUTIONS

- A modular framework enhancing FL with:
 - Hybrid privacy preservation (DP & HE),
 - Real-time attack detection
 - Lightweight secure aggregation (Shamir's Secret Sharing)
 - Secure Communication and Protocol Enforcement Module

SYSTEM ARCHITECTURE



System Web Portal

FLAME
Federated Learning

Oct 27, 2025 | 12:25:30 PM [Website](#) [About](#)

- Dashboard**
- Performance
- Clients
- System Health
- Logs

Dashboard Overview

Server Status
Online

Connected Clients
3

Training Progress
2%
2 / 100

Updates in Queue
...

Last Aggregation
1m ago

Model Performance: Accuracy vs. Loss

Accuracy (%)

Accuracy

Step	Accuracy (%)
1	15
2	10
3	100
4	100
5	100
6	100
7	100
8	100
9	100
10	100
11	100
12	100
13	100
14	100
15	100
16	100
17	100
18	100
19	100
20	100
21	100
22	100
23	100
24	100
25	100

Client Status Breakdown

Connected 3

Recent Activity

- Round duration updated: 59.10 seconds
- Last aggregation time updated: 2025-10-27 12:24:06
- Dashboard status updated: 2 updates in queue

Attack Detection and Resilience Module



IT21826368 | Nanayakkara Y.D.T.D

RESEARCH PROBLEM

- How can we design and integrate a lightweight, scalable, and effective attack detection and resilience system directly into the Federate Learning process to protect the global model's integrity in real-time?

RESEARCH GAP

- **Limitations:** Existing FL defenses are siloed, Targeting single threats, and its also too resource heavy for scalable IIoT
- High Overhead makes many solutions impractical for IIoT. Also, There are not any unified lightweight approach

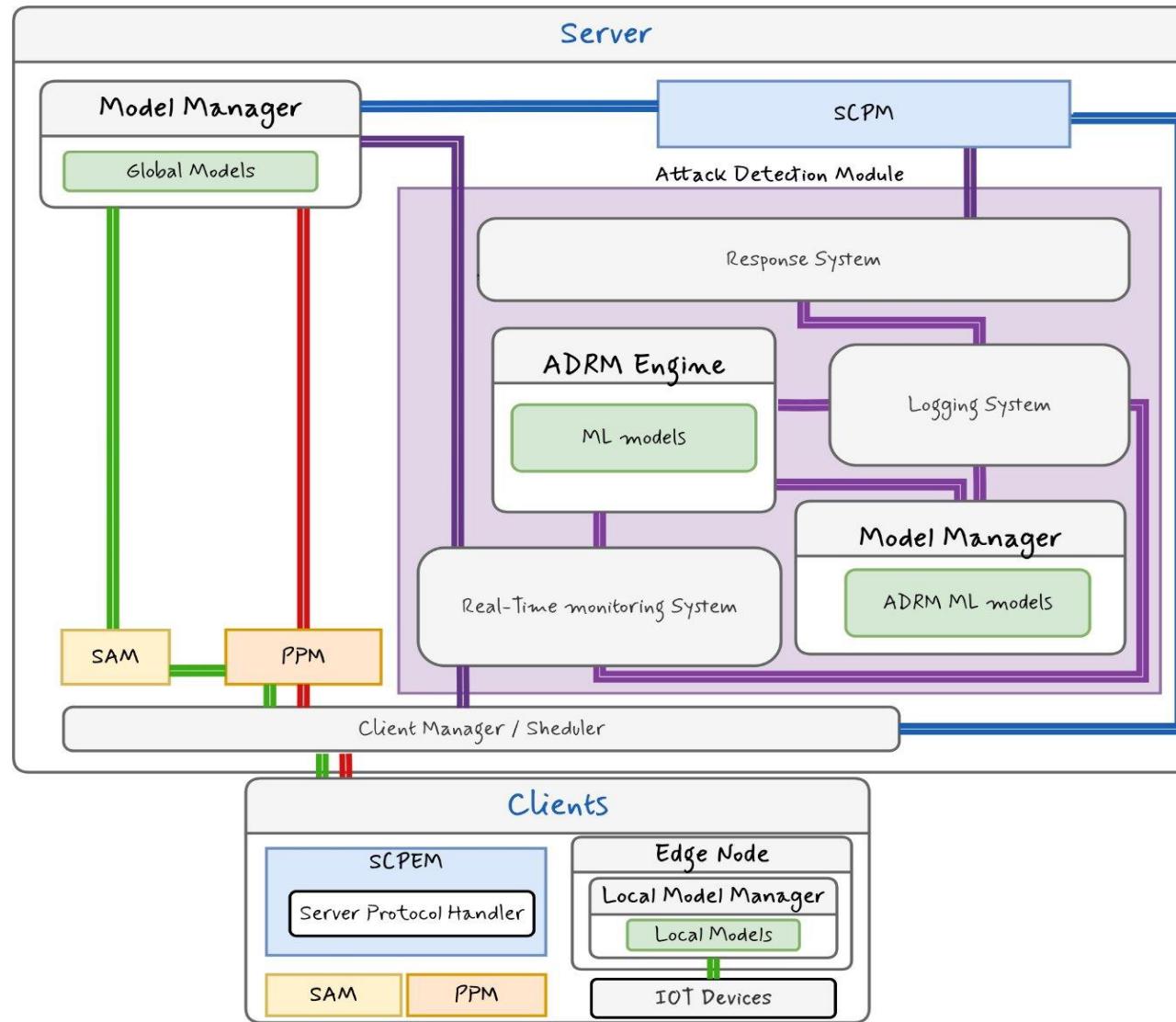
Background

- Federated learning is a promising privacy preserving solution for IIoT security, but its decentralized nature create a new and significant attack surface for malicious actors
- **Significance :** Without active defenses, Global model integrity is at risk,making robust security vital for industrial applications

SOLUTION: ATTACK DETECTION & RESILIENCE MODULE

- **Main Objective:** To develop a scalable and lightweight module that enhances the security of FL in IIoT by detecting and mitigating malicious activities in real-time
- The Multi-Layered Approach:
 - **Real-Time Anomaly Detection:** Detects malicious updates with unsupervised learning
 - **Enhanced Resilience:** Ensures continuity with recovery mechanisms like rollbacks
 - **Client reputation grading system** – Reduce client points based on detection

ADRM ARCHITECTURE



Terminal User Interface

[Attack Defense And Resilience Module](#) | [Privacy Preserving Module](#) | [Secure Aggregation Module](#) | [Server Communication And Protocol Enforcement Module](#)

Attack Defense And Resilience Module Details

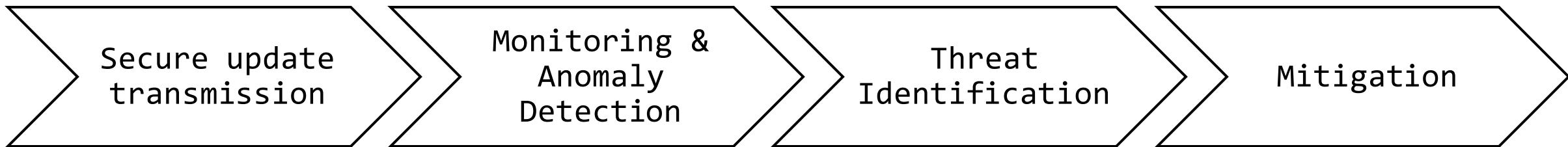
Status:	running_ml_mode
Blocked Clients Count:	0
Champion Is Trained:	False
Challenger Is Trained:	False
Challenger Training Buffer Size:	12
Performance:	Champion: 0.0 Challenger: 0.0 History: []

Client Health Status (Total: 4, Active: 3, Blocked: 1)

Client ID	Status	Reputation	Details
client_1	Connected	100	unknown
client_2	Connected	100	unknown
client_3	Blocked	75	Flagged as a statistical outlier compared to peers in the same round.
client_4	Connected	100	unknown

Image1: reputation grading and client blocking

DETECTION & MITIGATION PROCESS FLOW



- Clients send encrypted updates via secure channels
- ADRM analyzes gradients, flags deviations
- Detects model anomalies
- Isolates/filter malicious clients; only verified updates aggregated
- Blocks and reduce reputation

Attack detection and Defense

```
python3 main.py -vDFs/TUI

Federated Learning Framework v2.0                                         2025-09-14 02:24:55

(1) Overview | (2) Model Manager | (3) Client Health | (4) Modules | (5) Logs | (6) TUI Details

Modules

Attack Defense And Resilience Module | Privacy Preserving Module | Secure Aggregation Module | Server Communication And Protocol Enforcement Module

Status:                                     RUNNING
Total Updates Processed:                  281
Suspicious Updates Detected:             1
Blocked Clients Count:                   1
Learned Clients Count:                   3

Attack Defense And Resilience Module Details

Currently Blocked Clients

Client ID | Reason                                         Blocked At
client_1  | Update magnitude 0.1513 exceeded threshold (3.0 std dev from mean 0.0756) | 2025-09-14T02:22:14.291929
```

DETECTION METHOD

Name	Size	Modified
challenger_model.pkl	259.7 KiB	2 minutes ago

Created ML Model for anomaly detection

Logging

```
1 2023-09-15 01:44:38,497 - ADMR General - INFO - Initializing ADMR ML Model Manager...
2 2023-09-15 01:44:39,497 - ADMR General - WARNING - Model file not found at database/admr.models/champion.model.pkl. Creating a new, untrained model.
3 2023-09-15 01:44:39,498 - ADMR General - WARNING - Model file not found at database/admr.models/challenger.model.pkl. Creating a new, untrained model.
4 2023-09-15 01:44:39,498 - ADMR General - INFO - ADMR ML Model Manager initialized.
5 2023-09-15 01:44:48,331 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
6 2023-09-15 01:44:48,346 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
7 2023-09-15 01:44:48,993 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
8 2023-09-15 01:44:48,993 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
9 2023-09-15 01:44:48,998 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
10 2023-09-15 01:44:59,264 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
11 2023-09-15 01:44:59,267 - ADMR General - WARNING - Client 'client_3' blocked for 2 minutes. Reason: Flagged as a statistical outlier compared to peers in the same round.
12 2023-09-15 01:44:59,268 - ADMR General - WARNING - High severity anomaly for 'client_3'. Update quarantined for review.
13 2023-09-15 01:46:59,268 - ADMR General - INFO - Client 'client_3' unblocked. Duration expired.
14 2023-09-15 01:47:00,999 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
15 2023-09-15 01:47:01,142 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
16 2023-09-15 01:47:18,016 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
17 2023-09-15 01:47:18,016 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
18 2023-09-15 01:47:18,099 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
19 2023-09-15 01:47:29,393 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
20 2023-09-15 01:47:29,402 - ADMR General - WARNING - Client 'client_2' blocked for 2 minutes. Reason: Flagged as a statistical outlier compared to peers in the same round.
21 2023-09-15 01:47:29,404 - ADMR General - WARNING - High severity anomaly for 'client_2'. Update quarantined for review.
22 2023-09-15 01:49:20,491 - ADMR General - INFO - Client 'client_2' unblocked. Duration expired.
23 2023-09-15 01:49:21,288 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
24 2023-09-15 01:49:25,987 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
25 2023-09-15 01:49:27,367 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
26 2023-09-15 01:49:27,367 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
27 2023-09-15 01:49:37,411 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
28 2023-09-15 01:49:37,765 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
29 2023-09-15 01:49:42,688 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
30 2023-09-15 01:49:47,881 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
31 2023-09-15 01:49:47,882 - ADMR General - INFO - Challenger training buffer full. Triggering retraining.
32 2023-09-15 01:49:47,884 - ADMR General - INFO - Training Isolation Forest on 20 samples...
33 2023-09-15 01:49:48,417 - ADMR General - INFO - Training complete.
34 2023-09-15 01:49:48,558 - ADMR General - INFO - Model saved successfully to database/admr.models/challenger.model.pkl
35 2023-09-15 01:49:48,558 - ADMR General - WARNING - Model is not trained yet. Approving by default.
36 2023-09-15 01:49:53,731 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
37 2023-09-15 01:49:59,137 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
38 2023-09-15 01:49:59,249 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
39 2023-09-15 01:50:04,057 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
40 2023-09-15 01:50:09,557 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
41 2023-09-15 01:50:09,775 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
42 2023-09-15 01:50:09,778 - ADMR General - WARNING - Client 'client_1' blocked for 2 minutes. Reason: Flagged as a statistical outlier compared to peers in the same round.
43 2023-09-15 01:50:09,778 - ADMR General - WARNING - High severity anomaly for 'client_1'. Update quarantined for review.
44 2023-09-15 01:52:00,778 - ADMR General - INFO - Client 'client_1' unblocked. Duration expired.
45 2023-09-15 01:52:10,362 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
46 2023-09-15 01:52:14,617 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
47 2023-09-15 01:52:28,128 - ADMR General - WARNING - Prediction skipped: model is not trained yet. Approving by default.
48 2023-09-15 01:52:28,128 - ADMR General - WARNING - Client 'client_1' blocked for 2 minutes. Reason: Flagged as a statistical outlier compared to peers in the same round.
49 2023-09-15 01:52:28,138 - ADMR General - WARNING - High severity anomaly for 'client_1'. Update quarantined for review.
50 2023-09-15 01:54:28,128 - ADMR General - INFO - Client 'client_1' unblocked. Duration expired.
```

Attack detection

Model creation based on dataset in the current FL system

```
1 [2023-09-15 01:44:58,267 - WARNING - CROSS-CLIENT outlier detected: client_3 with Z-Score=7.43
2 2023-09-15 01:44:58,267 - WARNING - Response triggered for 'client_3'. Severity: high. Reason: Flagged as a statistical outlier compared to peers in the same round.
3 2023-09-15 01:44:58,267 - WARNING - Client 'client_3' blocked for 2 minutes. Reason: Flagged as a statistical outlier compared to peers in the same round. | Reputation Penalty: -25 points.
4 2023-09-15 01:44:58,267 - INFO - Blocklist with 1 clients saved to file.
5 2023-09-15 01:46:59,269 - INFO - Client 'client_3' unblocked. Duration expired.
6 2023-09-15 01:46:59,271 - INFO - Blocklist with 0 clients saved to file.
7 2023-09-15 01:47:26,400 - WARNING - CROSS-CLIENT outlier detected: client_2 with Z-Score=5.22
8 2023-09-15 01:47:26,401 - WARNING - Response triggered for 'client_2'. Severity: high. Reason: Flagged as a statistical outlier compared to peers in the same round.
9 2023-09-15 01:47:26,403 - WARNING - Client 'client_2' blocked for 2 minutes. Reason: Flagged as a statistical outlier compared to peers in the same round. | Reputation Penalty: -25 points.
10 2023-09-15 01:47:26,494 - INFO - Blocklist with 1 clients saved to file.
11 2023-09-15 01:49:20,412 - INFO - Client 'client_2' unblocked. Duration expired.
12 2023-09-15 01:49:26,414 - INFO - Blocklist with 0 clients saved to file.
13 2023-09-15 01:50:09,778 - WARNING - CROSS-CLIENT outlier detected: client_1 with Z-Score=4.38
14 2023-09-15 01:50:09,778 - WARNING - Response triggered for 'client_1'. Severity: high. Reason: Flagged as a statistical outlier compared to peers in the same round.
15 2023-09-15 01:50:09,779 - WARNING - Client 'client_1' blocked for 2 minutes. Reason: Flagged as a statistical outlier compared to peers in the same round. | Reputation Penalty: -25 points.
16 2023-09-15 01:50:09,779 - INFO - Blocklist with 1 clients saved to file.
17 2023-09-15 01:52:09,779 - INFO - Client 'client_1' unblocked. Duration expired.
18 2023-09-15 01:52:09,779 - INFO - Blocklist with 0 clients saved to file.
19 2023-09-15 01:52:20,128 - WARNING - CROSS-CLIENT outlier detected: client_1 with Z-Score=4.98
20 2023-09-15 01:52:20,128 - WARNING - Response triggered for 'client_1'. Severity: high. Reason: Flagged as a statistical outlier compared to peers in the same round.
21 2023-09-15 01:52:20,129 - WARNING - Client 'client_1' blocked for 2 minutes. Reason: Flagged as a statistical outlier compared to peers in the same round. | Reputation Penalty: -25 points.
22 2023-09-15 01:52:20,129 - INFO - Blocklist with 1 clients saved to file.
23 2023-09-15 01:54:28,129 - INFO - Client 'client_1' unblocked. Duration expired.
24 2023-09-15 01:54:28,129 - INFO - Blocklist with 0 clients saved to file.
```

Privacy Preservation Module



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BACKGROUND

- Federated Learning enables decentralized model training but remains vulnerable to inference attacks from untrusted servers. Combining **Differential Privacy (DP)** for noise and **Homomorphic Encryption (HE)** for secure communication provides a hybrid solution to protect client data.

RESEARCH GAP

- Existing Federated Learning methods use either Differential Privacy or Homomorphic Encryption alone, failing to provide full protection without compromising accuracy or efficiency, especially in resource-limited IIoT settings.

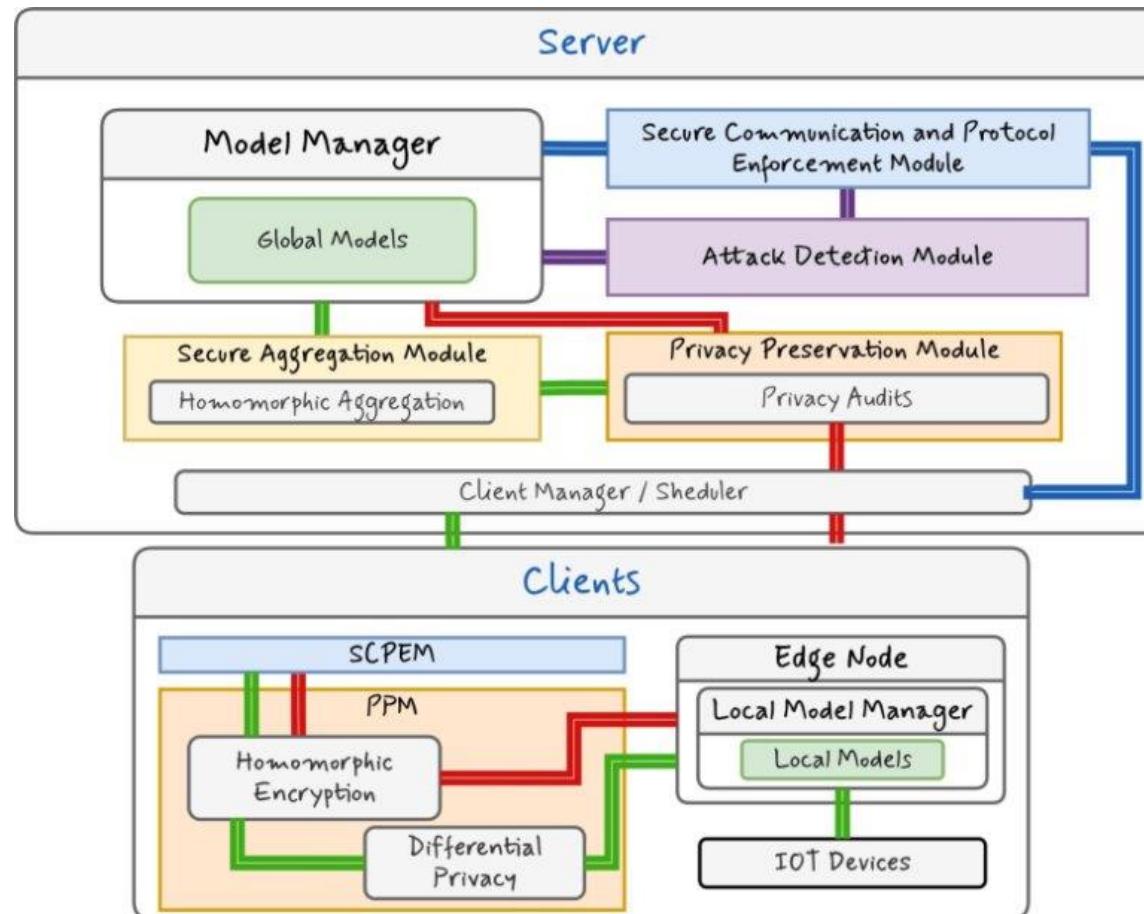
RESEARCH PROBLEM

- How can we design a hybrid Federated Learning framework combining Differential Privacy and Homomorphic Encryption to protect client data from inference attacks by untrusted servers while maintaining model accuracy and communication efficiency?

SOLUTION:

- A hybrid privacy-preserving Federated Learning framework that combines **Differential Privacy (DP)** to add noise during training and **Homomorphic Encryption (HE)** to secure communication of model updates. This approach protects client data from inference attacks by untrusted servers while balancing model accuracy and communication efficiency, tailored for resource-constrained Industrial IoT environments.

PPM Architecture



METHODOLOGY

Approach:

- Analyze existing FL privacy vulnerabilities.
- Combine HE and DP for enhanced privacy.
- Optimize techniques for IIoT-specific constraints.
- Validate Using real-world Datasets

Key Techniques:

- **Homomorphic Encryption (HE)**: Encrypts gradients, allowing computations on encrypted data without decrypting it. Prevents data leakage even if adversaries intercept communications.
- **Differential Privacy (DP)**: Ensure that individual data points cannot be separated by adding controlled noise to gradients. Balances model accuracy with privacy

FUNCTIONAL UNITS & IMPLEMENTATIONS (Client)

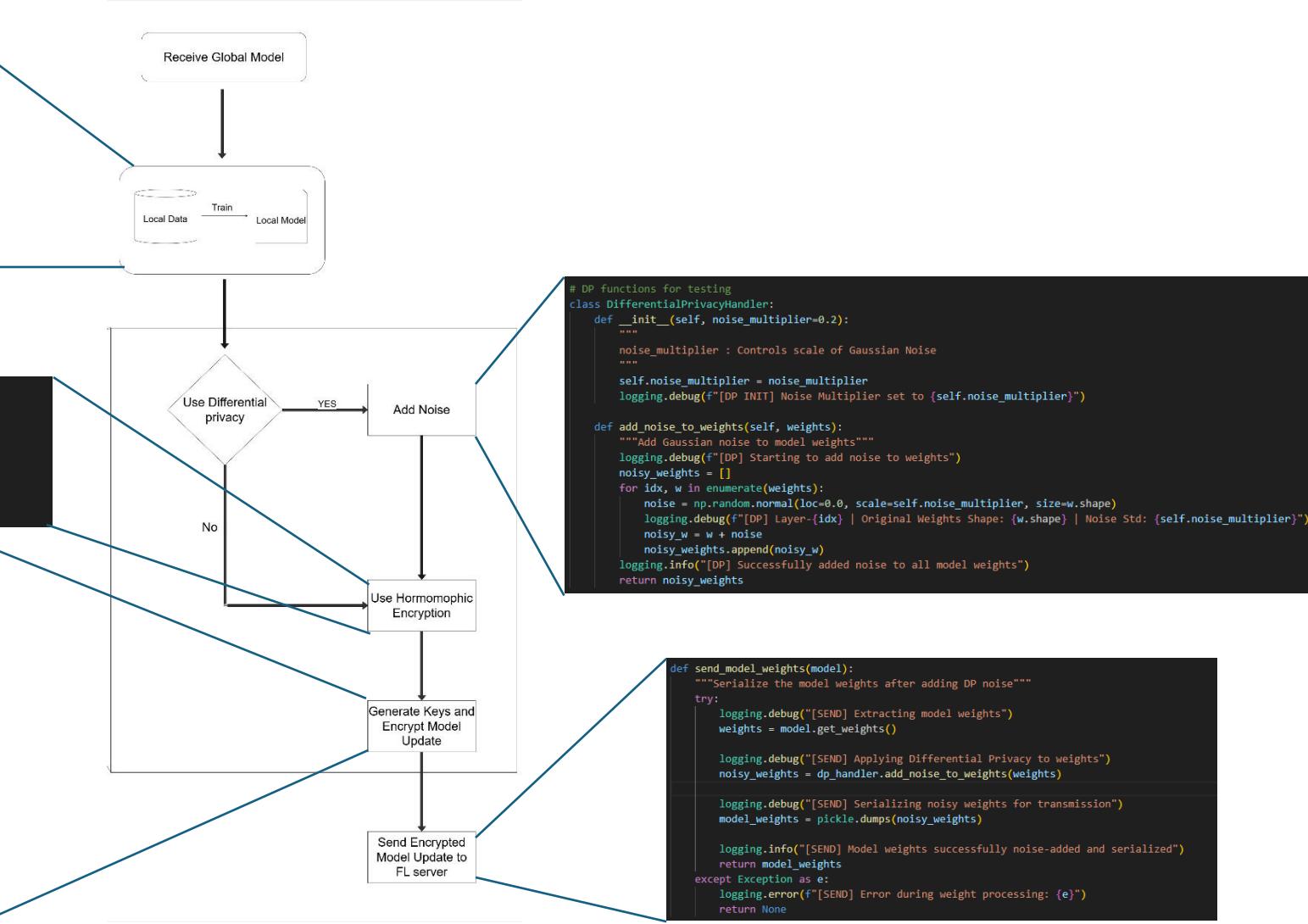
```
def load_and_train_model(epochs=5):
    """Load data and train the model with the given number of epochs."""
    logging.debug("[MODEL] Loading data and starting training")
    x_train, y_train, x_test, y_test = load_data()
    model = get_model()
    model = train_local_model(model, x_train, y_train, x_test, y_test, epochs)
    logging.info("[MODEL] Training completed")
    return model, x_test, y_test
```

```
# Encrypt weights if HE is used
if "HE" in mode:
    enc_weights = [encrypt(w, context) for w in weights]
    comm_bytes += sum([w.numel() * w.element_size() for w in weights]) # estimate comm
    client_weights.append(enc_weights)
else:
    comm_bytes += sum([w.numel() * w.element_size() for w in weights])
    client_weights.append(weights)

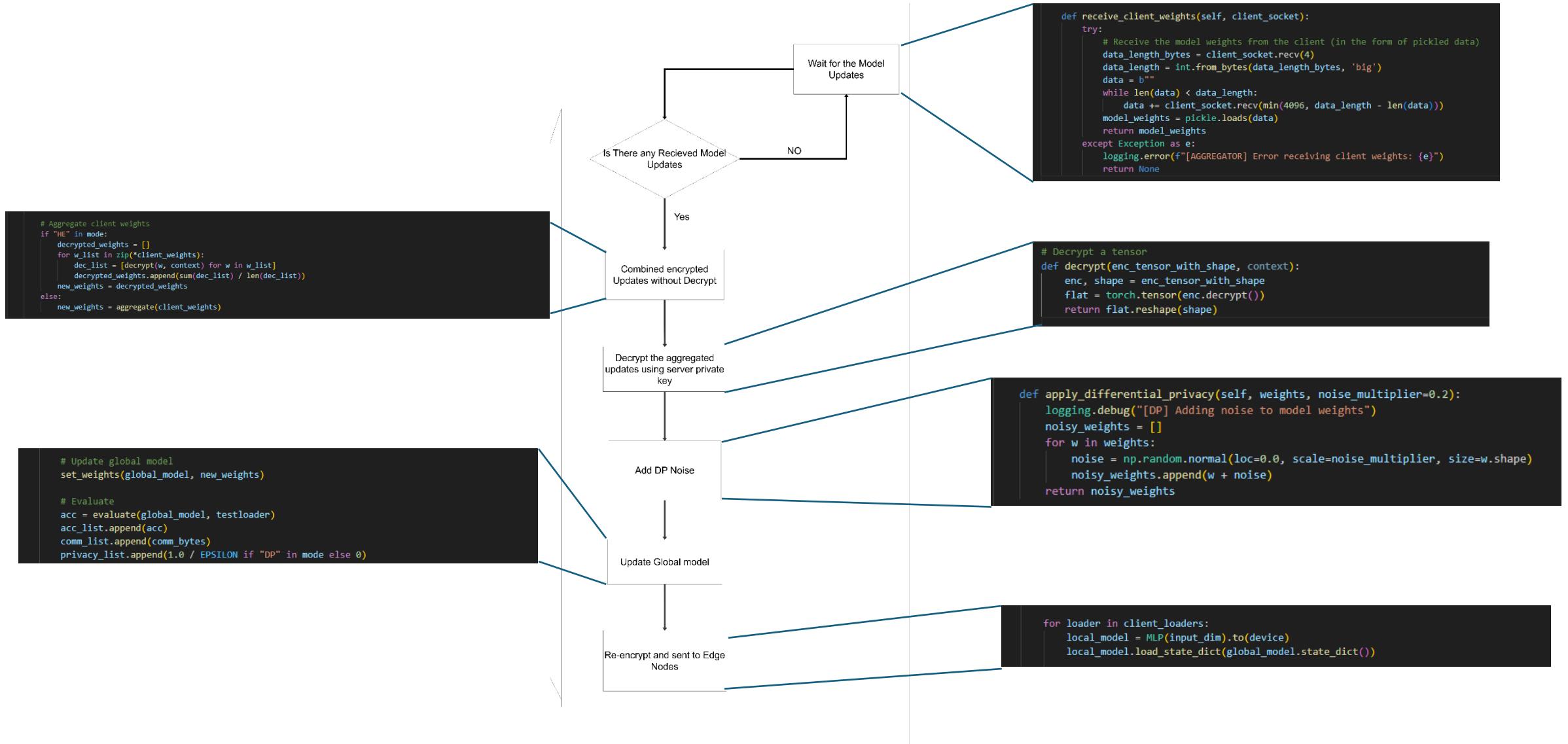
# Create a TenSEAL context (CKKS scheme)
def create_context():

    context = ts.context(
        ts.SCHEME_TYPE.CKKS,
        poly_modulus_degree=16384,
        coeff_mod_bit_sizes=[60, 40, 40, 60]
    )
    context.generate_galois_keys()
    context.global_scale = 2**40
    return context

# Encrypt a tensor
def encrypt(tensor, context):
    flat = tensor.detach().cpu().flatten().tolist()
    enc = ts.ckks_vector(context, flat)
    return enc, tensor.size()
```

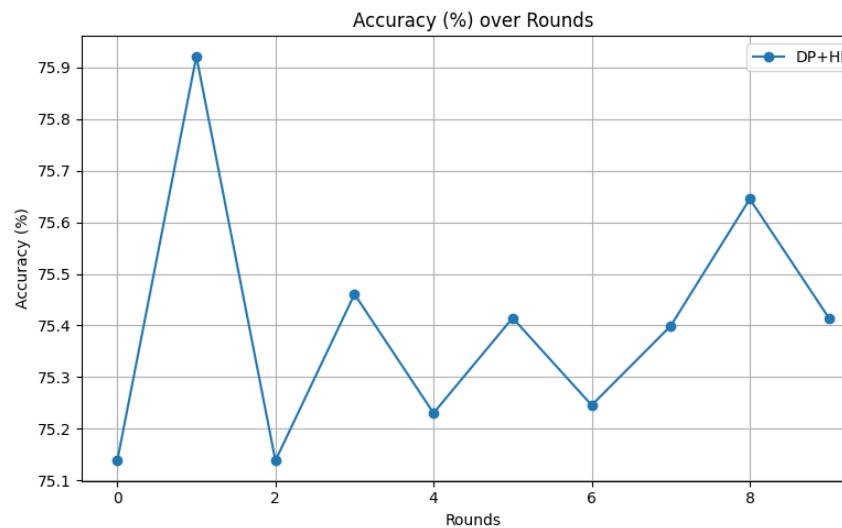
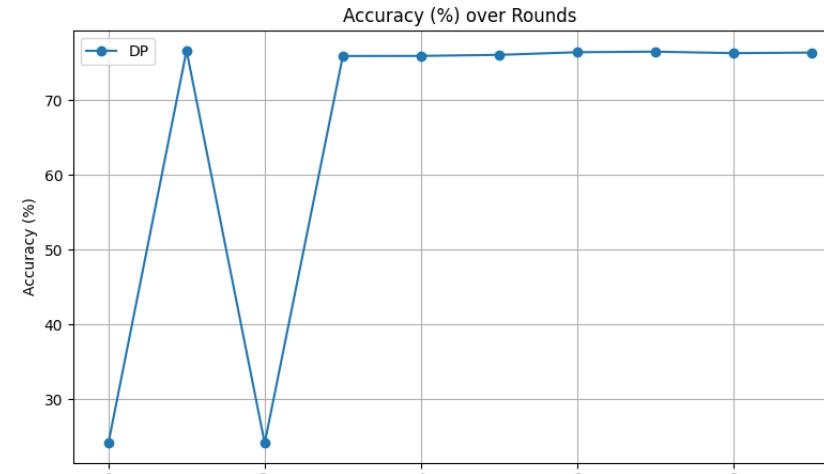
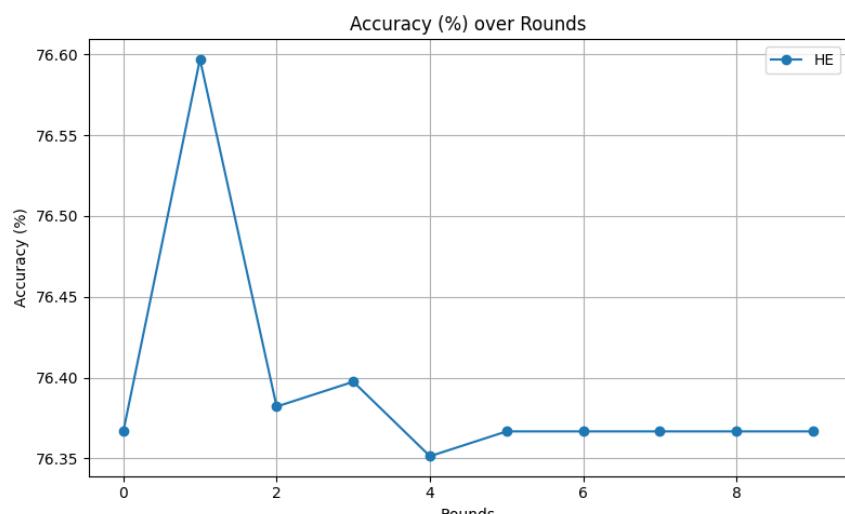
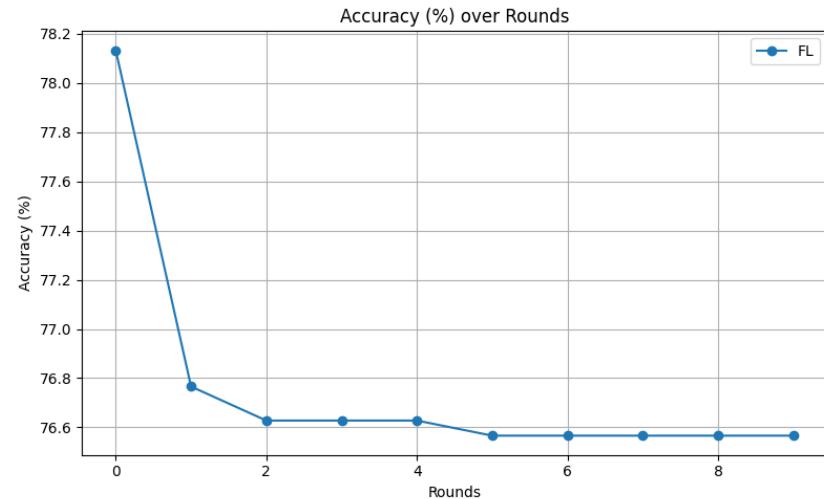


FUNCTIONAL UNITS & IMPLEMENTATIONS (Server)



PROOFS & RESULTS

- Accuracy Curves



Note: Testing was done using UCI Adult Dataset.

PROOFS & RESULTS

Average Accuracy over Rounds

Mode	Average Accuracy (%)	Remarks
FL	76.81	Highest accuracy because no extra privacy mechanisms are applied.
FL + DP	65.87	~11% Lower accuracy due to Differential Privacy adds noise to gradients to protect individuals.
FL + HE	76.39	Differential Privacy adds noise to gradients/weights to protect individuals. Homomorphic Encryption protects updates without changing the data (no noise).
FL + DP + HE	75.34	Accuracy only slightly lower than FL (~1.5% drop)

FL + DP + HE is the best choice, balancing utility and privacy. FL alone has the highest accuracy but no privacy. DP offers strong privacy with lower accuracy, while HE protects only communication. Combining DP and HE gives strong privacy with minimal accuracy loss, making it both practical and secure.

Secure Communication and Protocol Enforcement



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BACKGROUND

- In IIoT, communication between clients and server is a prime target for threats like eavesdropping , tampering, and MITM attacks. Standard FL focused on efficiency but lacked strong defenses. TLS provides a baseline, but its one-sided authentication leaves gaps.

RESEARCH GAP

- Current solutions lack an integrated security framework for IIoT. Standard TLS often validates only the server, leaving no assurance that connected devices are legitimate. A More strict, two-way validation protocol is needed.

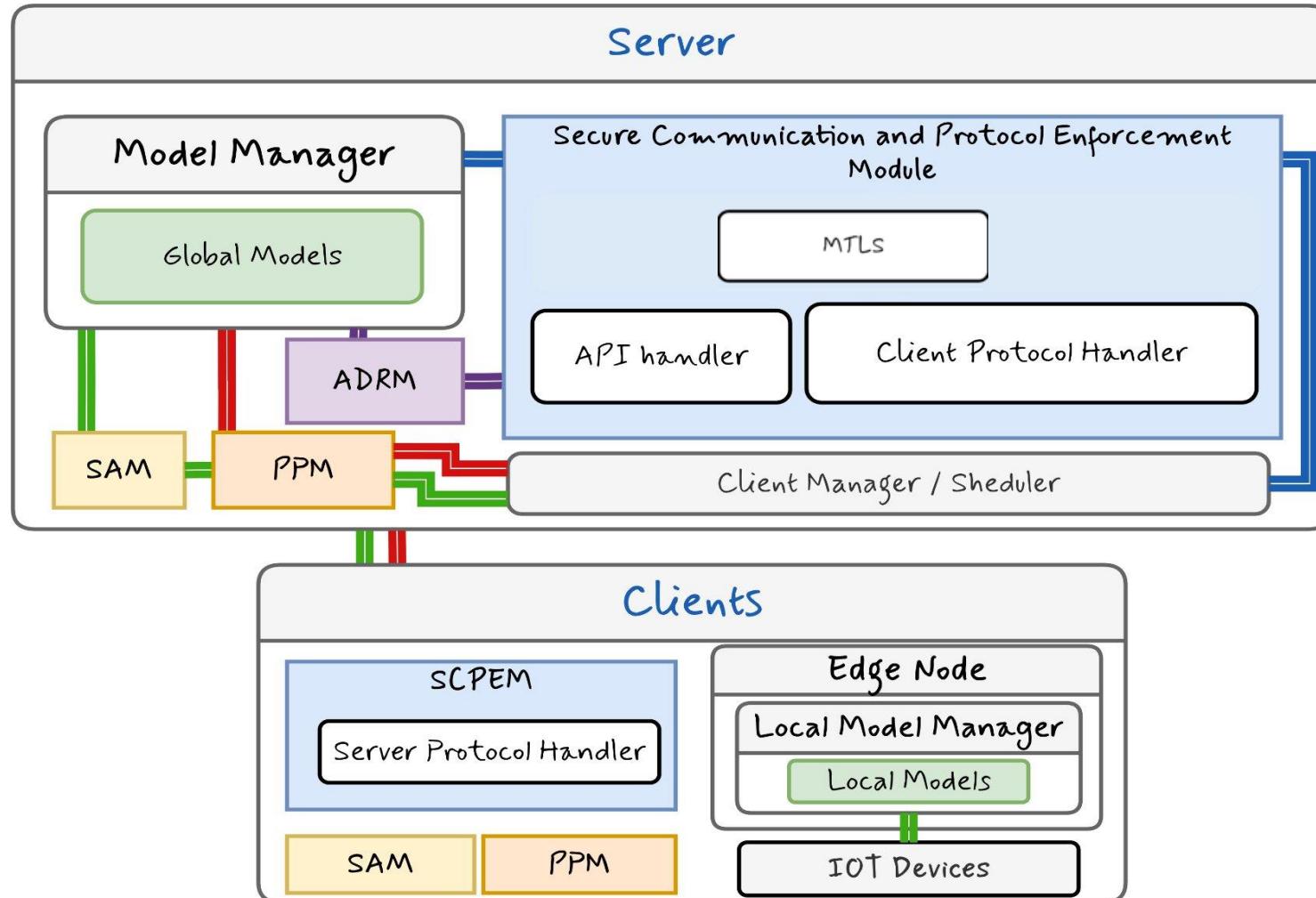
RESEARCH PROBLEM

- Insecure FL channels risk unauthorized access, tampered updates, fake servers, and undetected data changes.

SOLUTION:

- Implement a secure communication protocol that ensures only authorized IIoT devices can participate, protects model updates from tampering, verifies the legitimacy of the server, and adds integrity checks beyond encryption to guarantee unaltered data.

Module Architecture



SERVER COMPONENTS

- **Model Manager:** Distributes and updates the global model.
- **SCPEM:** Secure channel using mTLS (two-way authentication) + HMAC for integrity.
- **Client Manager/Scheduler:** Selects and manages participating clients.

OVERALL WORKFLOW

1. Server selects clients for training.
2. Global model sent via **SCPEM** (secure channel).
3. Clients train locally on IoT data.
4. Updates protected using **PPM** & **SAM**.
5. Protected updates sent back via **SCPM**.
6. Server validates updates with **ADRM**.
7. **SAM** aggregates updates securely.
8. **Model Manager** updates global model.
9. Cycle repeats.

Log manager

Federated Learning Framework v2.0				2025-09-15 02:39:31
(1) Overview (2) Model Manager (3) Client Health (4) Modules (5) Logs (6) TUI Details				
Logs				
Level: ALL Search: None				f: Filter Level s: Search r: Reset
Recent Logs				
2025-09-15 02:39:13,177	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:13 +0530] "GET /api/logs HTTP/1.1" 200 54505 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:13,178	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:13 +0530] "GET /api/status HTTP/1.1" 200 1988 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:13,179	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:13 +0530] "GET /api/module_status/mm HTTP/1.1" 200 405 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:13,180	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:13 +0530] "GET /api/module_status/sam HTTP/1.1" 200 365 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:13,181	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:13 +0530] "GET /api/module_status/adrm HTTP/1.1" 200 417 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:13,181	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:13 +0530] "GET /api/module_status/ppm HTTP/1.1" 200 353 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:13,182	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:13 +0530] "GET /api/module_status/scpm HTTP/1.1" 200 453 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:13,183	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:13 +0530] "GET /api/module_status/orchestrator HTTP/1.1" 200 485 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:13,264	INFO	ServerControlPlaneManager	Dashboard status updated: Connected clients count is 4.	
2025-09-15 02:39:13,266	WARNING	Orchestrator	Denied model request from client_2. Orchestrator state is 'PAUSED_INSUFFICIENT_CLIENTS'.	
2025-09-15 02:39:15,257	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:15 +0530] "GET /api/overview HTTP/1.1" 200 680 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:15,258	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:15 +0530] "GET /api/model/metrics_details HTTP/1.1" 200 6890 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:15,259	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:15 +0530] "GET /api/client_health HTTP/1.1" 200 1769 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:15,267	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:15 +0530] "GET /api/logs HTTP/1.1" 200 54016 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:15,268	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:15 +0530] "GET /api/status HTTP/1.1" 200 1988 "-" "Python/3.10 aiohttp/3.12.15"	
2025-09-15 02:39:15,268	INFO	aiohttp.access	127.0.0.1 [15/Sep/2025:02:39:15 +0530] "GET /api/module_status/mm HTTP/1.1" 200 405 "-" "Python/3.10 aiohttp/3.12.15"	

Secure Aggregation



IT21831904 | Weerasinghe K.M

BACKGROUND

- **Main Function:** Secure aggregation ensures the server can compute an aggregate of client updates without seeing any individual private contribution
- **Requirement:** It protects client data privacy during aggregation, even if the central server is curious or malicious

RESEARCH GAP

- **Limitations:** Many secure aggregation protocols are either too heavy for resource constrained IIoT devices and some only exist in theory, and do not account for diverse IIoT environments
- **Challenges:** They often lack robustness to network disruptions or client failures, which can cause an entire training round to collapse

RESEARCH PROBLEM

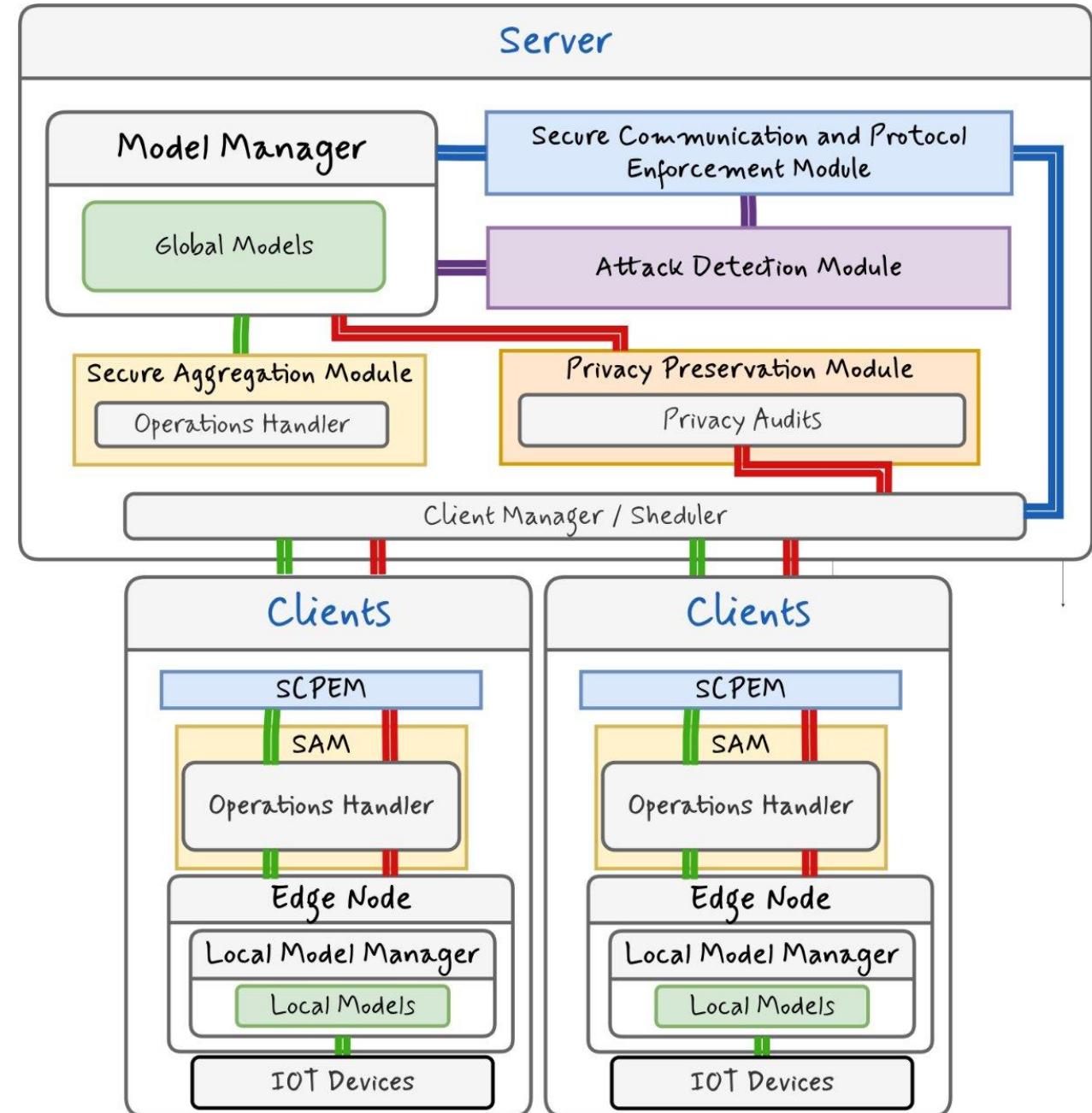
- How to design a secure Aggregation protocol that is both adaptive and robust enough for scalable IIoT deployments.

SOLUTION:

- **Main Objective:** To aggregate client updates securely, ensuring the server learns only the final sum, not individual contributions, while being resilient to client dropouts.
- **Our approach:**
 - **Shamir's Secret Sharing (SSS):** Each client's model update is split into multiple shares. No single share reveals any information.
 - **Threshold Cryptography:** The original secret (the aggregated sum) can only be reconstructed if a minimum number of shares (the "threshold") are combined.
- **Benefits:**
 - **server Blindness:** The server cannot reconstruct any individual update.
 - **Fault Tolerance:** The aggregation succeeds even if some client failures

METHODOLOGY

- **Client-Side Operations**
Handler: Splits the local model update into encrypted shares using SSS.
- **Server-Side Operations**
Handler: Receives and stores shares from all clients
- **Threshold Reconstructor:** A server function that combines shares to reconstruct the final aggregated model update once the required threshold is reached.



SECURE AGGREGATION PROCESS FLOW

- Each client splits its update into n no of shares.
- Shares are distributed securely to the server.
- The server aggregates the corresponding shares from all clients.
- Once at least t clients have submitted, the server reconstructs the final aggregated update.

SAM MODULE TUI INTERFACE

```
Federated Learning Framework v2.0                                         2025-09-15 02:25:07

(1) Overview | (2) Model Manager | (3) Client Health | (4) Modules | (5) Logs | (6) TUI Details

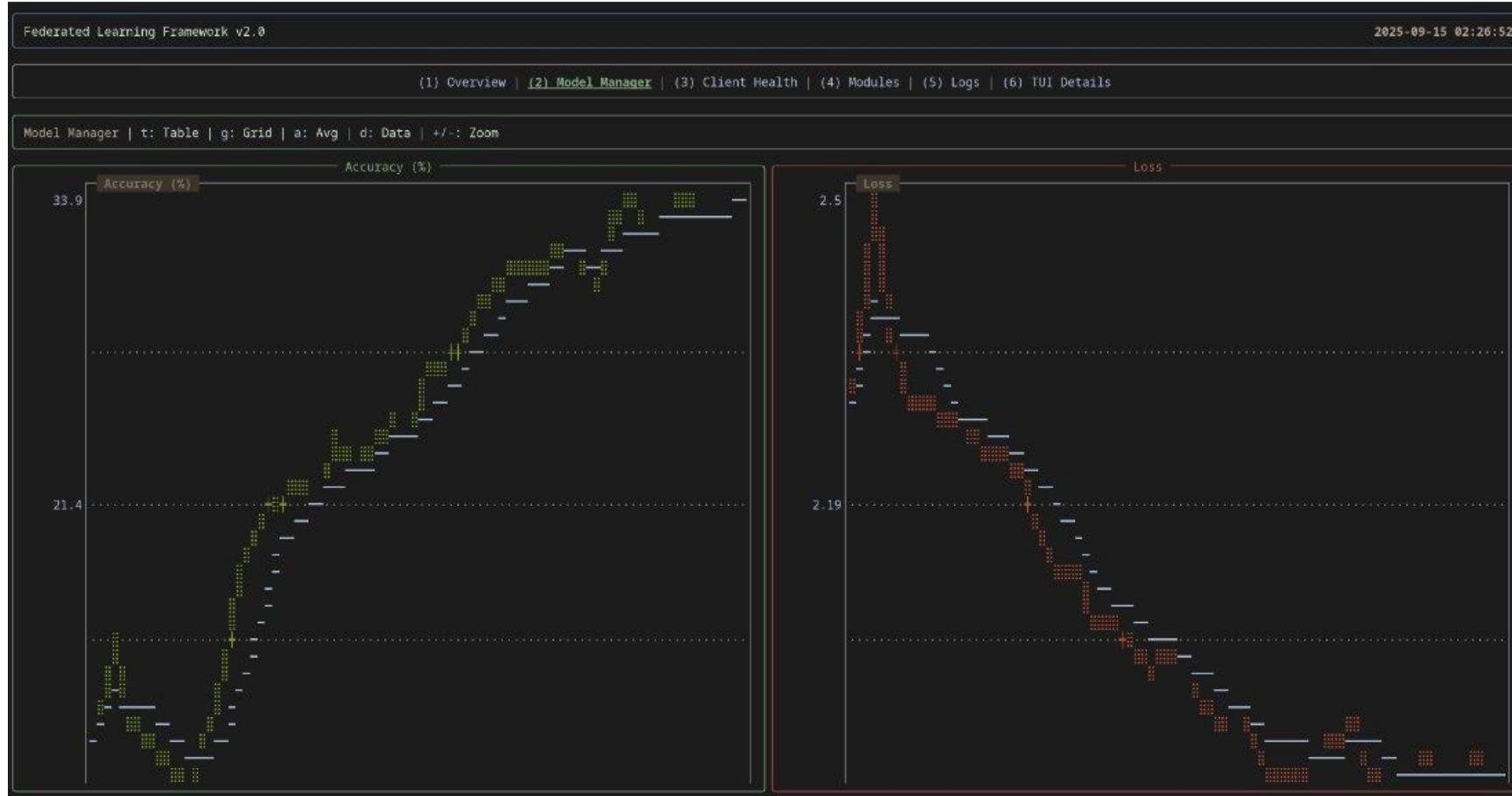
Modules

Attack Defense And Resilience Module | Privacy Preserving Module | Secure Aggregation Module | Server Communication And Protocol Enforcement Module

Secure Aggregation Module Details

Aggregation Protocol: SecAgg
Security Level: High
Updates In Queue: 1
Failed Sessions: 0
Last Aggregation Time: 2025-09-15 02:25:03
Status: active
```

AGGREGATION PROCESS





USER TESTING

TECHNOLOGIES

- BACKEND
 - Python
 - Asyncio
- COMMUNICATION
 - GRPC
 - Protocol buffers
 - AIOHTTP
 - AIOHTTP-CORS
- ML & DATA PROCESSING
 - PyTorch
 - Torch Vision
 - NumPy
- CRYPTOGRAPHY & SECURITY
 - PyCryptodrome
 - Secret-sharing
 - X.509 Certificates
- FRONTEND & VALIDATION
 - Rich
 - Prompt Toolkit
- LOGGING AND MONITORING
 - Python-JSON-Logger
 - Logstash

COMMERCIALIZATION

Open-Source

We are Pleased to present the
Framework to the industrial IOT

Why Open Source?

- **Transparent by Design**

Code, roadmap, and issues are fully open and inspectable.

- **Security**

Privacy and protection mechanisms can be independently audited.

- **For Community-Driven Hardening**

faster vulnerability discovery and fixes.

- **Faster Adoption & Innovation**

Teams can test, fork, and contribute improvements.

Commercialization Plan

Aspect	Summary
Product	Open-source IIoT federated learning platform with built-in security, privacy, and real-time defense.
Market Need	Industrial data can't leave sites; networks are unstable; FL is exposed to tampering and dropouts.
Solution	Secure, privacy-preserving, and dropout-robust FL stack with mTLS, RBAC, DP, HE, and anomaly defense.
Differentiation	IIoT-focused design with governance, lifecycle control, privacy modes, and robust aggregation.
Business Model	Open core

Demonstration

THANK YOU

