PROJECT GOUP #7

FIELD-SENSITIVE ADAPTIVE ENCRYPTION FOR IOT DIGITAL TWIN SYSTEMS

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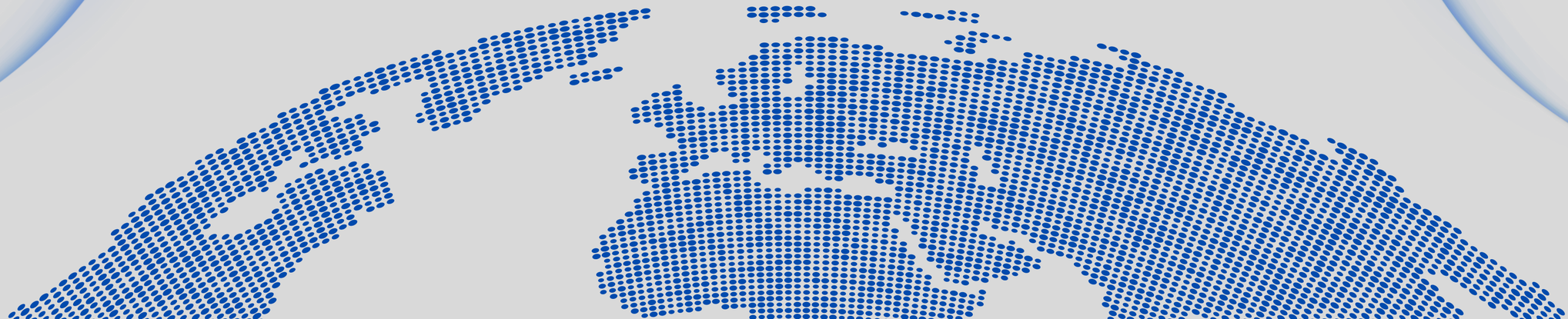

INTRODUCTION

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- Digital Twin (DT) technology provides real-time monitoring and optimization in IoT systems.
- Security of DT data streams is critical since compromised data leads to incorrect predictions.
- Traditional encryption methods are often too heavy for resource-constrained IoT devices.
- There is a need for lightweight, adaptive, and fine-grained security mechanisms.

PROBLEM STATEMENT

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Existing encryption schemes impose high computational and latency overheads.

Today ' s approach rely on static policies.

Sensitive and Non-Sensitive data are treated equally.

Digital-twin environment prone to multilayer threats

PROPOSED SOLUTION

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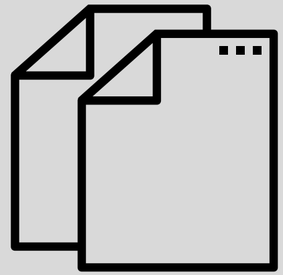
Selective Protection

Field Sensitive Encryption



Adaptive selector

PROJECT WORKFLOW

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STEP 1 Literature review on Digital Twin security and selective encryption

STEP 2 Define threat model and identify critical vs. non-critical fields

STEP 3 Design field-sensitive adaptive encryption framework

STEP 4 Build simulation environment and implement baseline schemes

STEP 5 Implement our adaptive encryption approach

STEP 6 Run experiments and collect metrics (latency, CPU, memory, security)

STEP 7 Analyze results and compare with baselines

STEP 8 Prepare final report and presentation

DESIGN GOAL

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- Provide strong per-field confidentiality and integrity using AES-256-GCM for sensitive fields.
- Make encryption context-aware, adapting to network risk, user role and event state at runtime.
- Keep the system real-time friendly, adding sub-millisecond latency with no loss in throughput.
- Enforce least-privilege views, so different subscribers see only the data they're allowed to see.
- Remain easy to integrate, as a drop-in component for existing JSON/MQTT digital-twin pipelines.

BLOCK DIAGRAM

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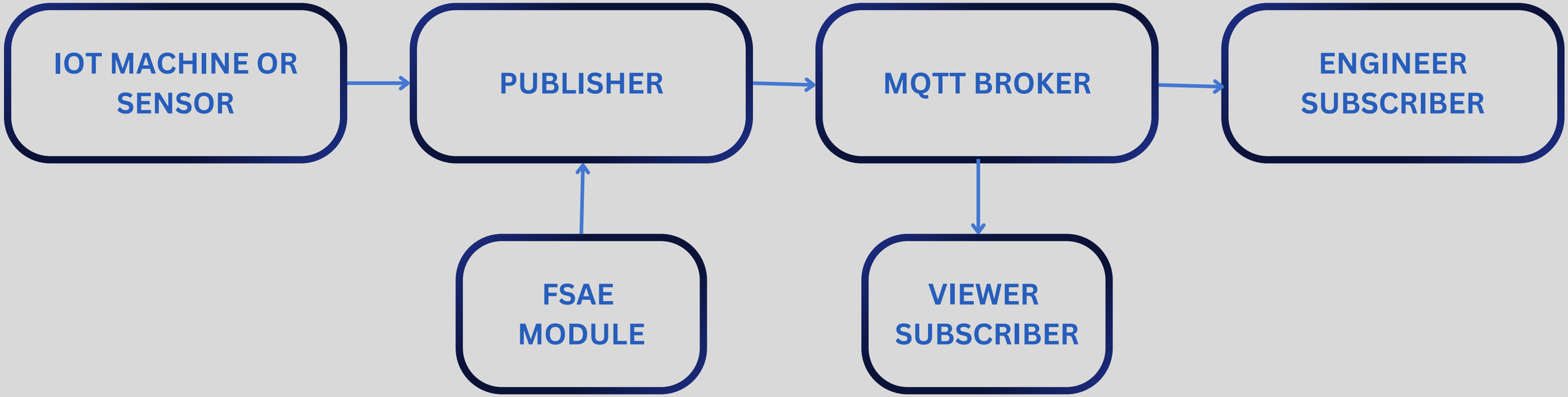

IMPLEMENTATION AND SETUP

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publisher.py - generates telemetry, calls DFSE, publishes via MQTT

policy.py - S - I - T config + context rules

subscriber_engineer.py - role-based views

dashboard.py - simple console

DIGITAL TWIN SIMULATION

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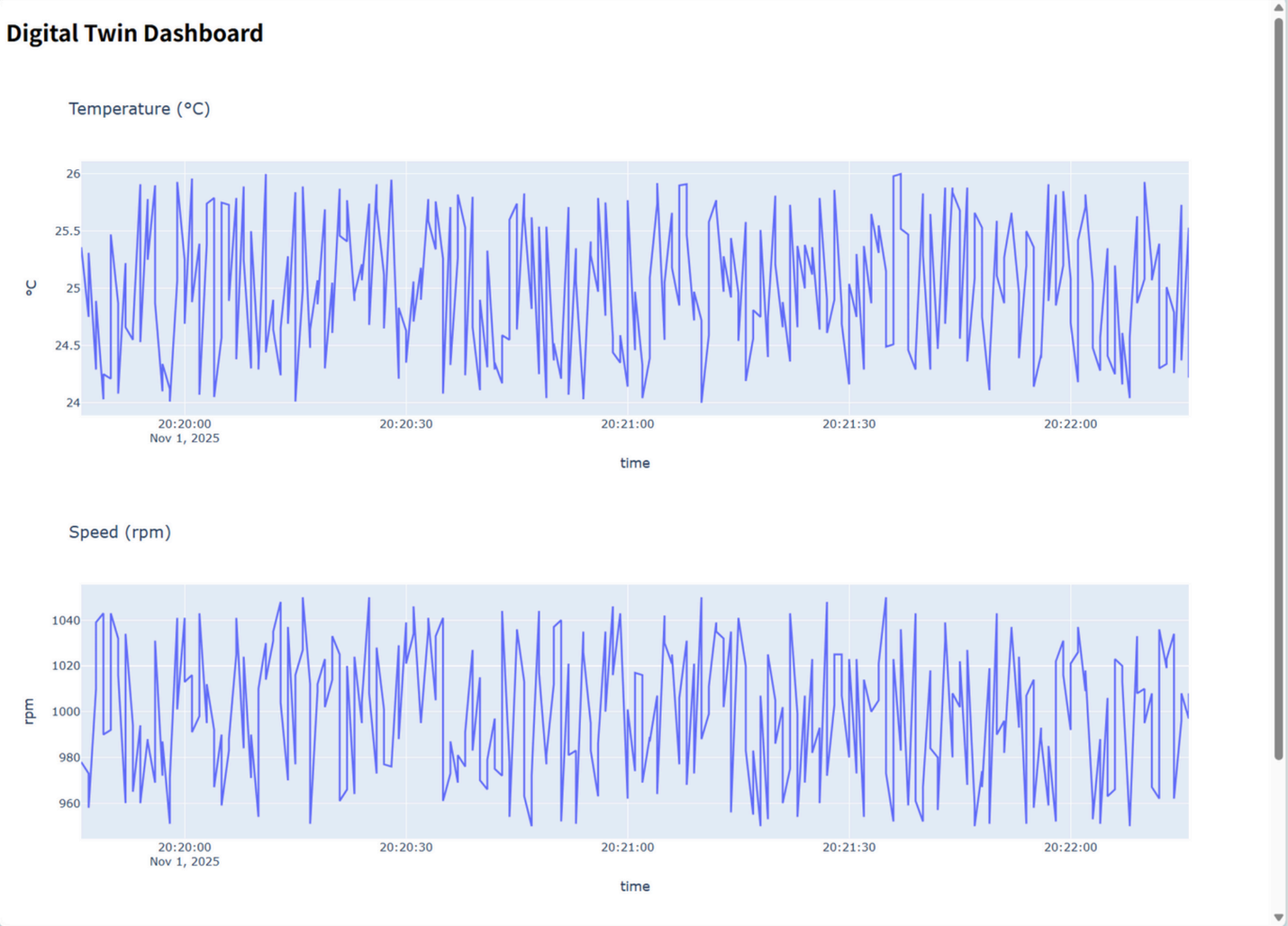


```
{
  "timestamp": 1762041900.0122504,
  "device_id": "machine-01",
  "operator_id": "op-1138",
  "temperature": 24.04,
  "pressure": 0.997,
  "speed": 1020
}
```

ALGORITHM FLOWCHART

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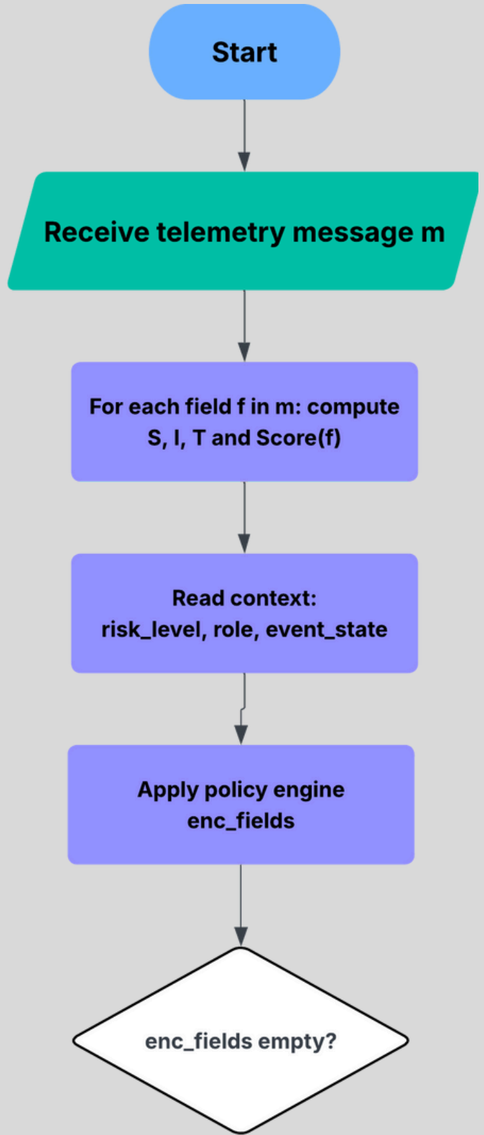

ALGORITHM FLOWCHART

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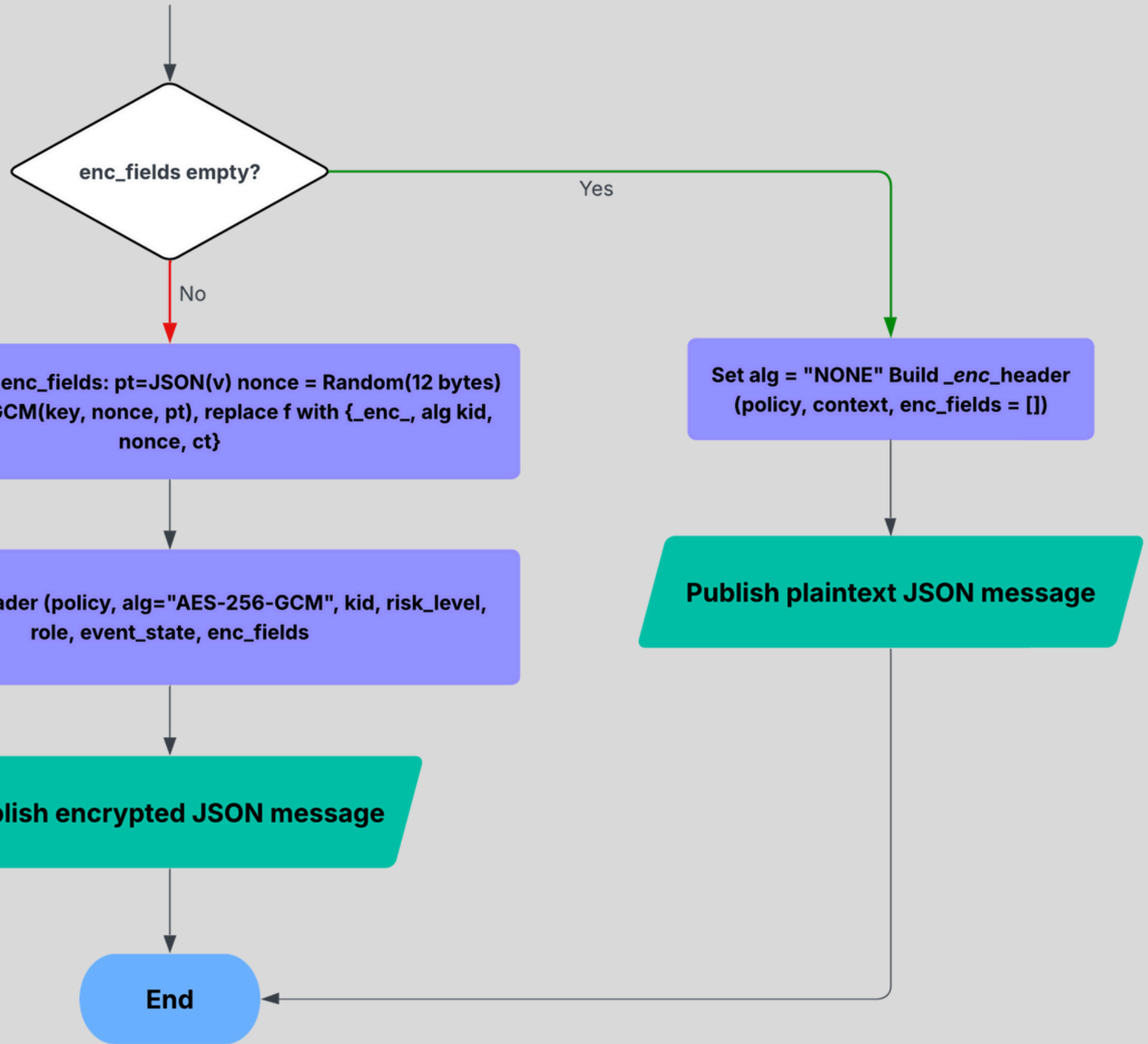

EVALUTION METHODOLOGY

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- Compare two modes
- Generate telemetry
- Measure difference
- Quantify latency and impact

RESULTS AND DISCUSSION

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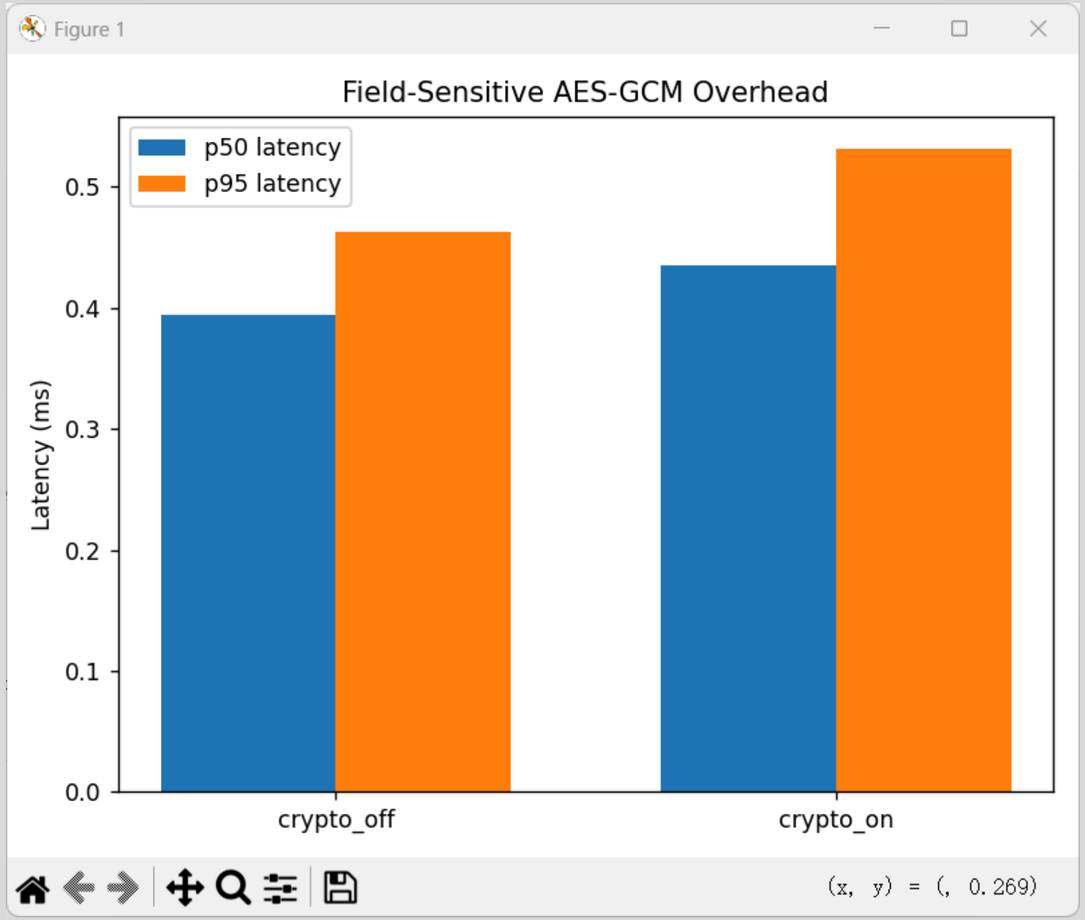
- Latency impact is tiny
- Tail latency stays under control
- Throughput is unchanged
- Noise-level overhead
- Security vs performance trade-off is excellent
- FSE satisfies digital-twin timing constraints without requiring hardware acceleration or protocol changes.



CONCLUSION

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- FSE adds context-aware, per-field AES-256-GCM on top of existing JSON/MQTT telemetry.
- Encryption decisions adapt to field risk + runtime context (network, role, event state).
- Measurements show sub-millisecond extra latency with no loss in message throughput.
- Role-based subscribers can perform partial decryption, enabling different views from the same encrypted stream.

FUTURE WORK

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- Run hardware-in-the-loop experiments on real IoT gateways and industrial PLC/edge devices.
- Extend the policy engine with per-tenant / per-production-line rules and finer-grained masking.
- Integrate with central key management / HSM for key rotation and auditability.
- Explore higher message rates and multi-topic deployments to evaluate scalability in larger digital-twin systems.

REFERENCES

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THANK YOU