CIC-IIoT-2025 Security Analysis

Machine Learning for Intrusion Detection in Industrial IoT

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ML Security – EPITA SCIA 2026

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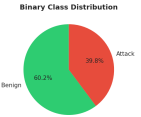
Agenda

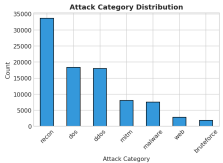
1. Dataset Overview and Exploration
2. Anomaly Detection (Unsupervised)
3. Classification (Supervised)
4. Adversarial Machine Learning
5. Recommendations

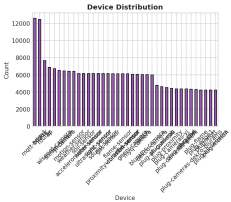
Objective: Evaluate ML methods for IIoT intrusion detection and assess adversarial robustness

CIC-IIoT-2025 Dataset

Attribute	Value
Total Samples	227,191
Features	94
Attack Samples	90,391 (39.8%)
Benign Samples	136,800 (60.2%)
Attack Categories	7







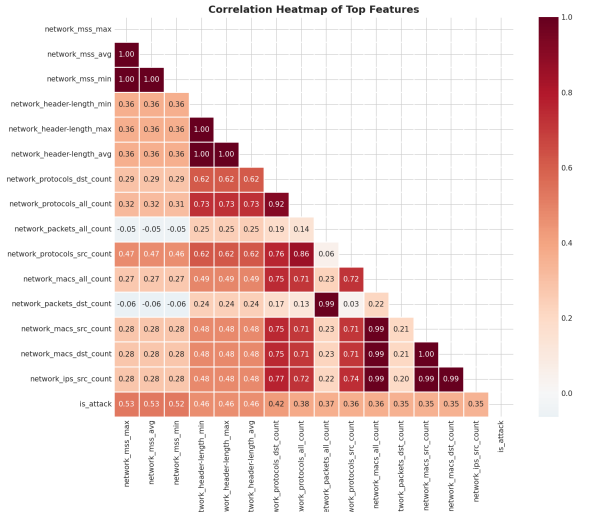
Categories: Reconnaissance, DoS, DDoS, MitM, Malware, Web, Brute Force

Key Discriminative Features

Top Correlated Features:

Feature	Corr.
network_mss_max	0.526
network_mss_avg	0.525
network_header-length_min	0.464
network_protocols_dst_count	0.423
network_packets_all_count	0.367

TCP MSS and protocol diversity are strong attack indicators



Anomaly Detection (Unsupervised)

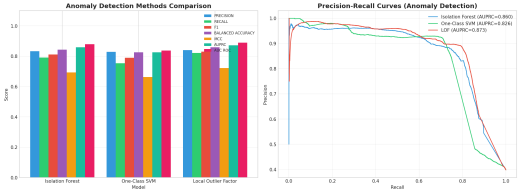
Trained on benign traffic only – Detects deviations from normal behavior

Method	**Approach**
Isolation Forest	Tree-based isolation via random partitioning
One-Class SVM	Kernel-based boundary in feature space
Local Outlier Factor	Local density deviation detection

Evaluation Metric: AUPRC (Area Under Precision-Recall Curve) – robust for imbalanced detection

Anomaly Detection Results

Model	F1	AUPRC	MCC
Isolation Forest	0.812	0.860	0.694
One-Class SVM	0.789	0.826	0.663
LOF	**0.831**	**0.873**	**0.721**



Winner: Local Outlier Factor

Density-based methods excel on this dataset

Classification (Supervised)

Using labeled attack and benign samples

Method	Approach
Random Forest	Ensemble of decision trees with majority voting
Gradient Boosting	Sequential boosting with error correction
SVM (RBF Kernel)	Kernel-based non-linear separation

Terminology:

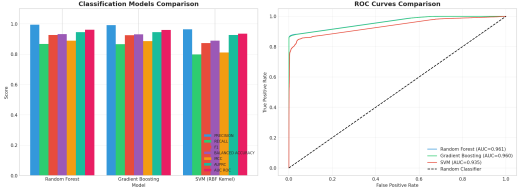
- **Astute Accuracy:** Performance on clean (non-adversarial) data
- **Robust Accuracy:** Performance under adversarial attack

Classification Results

Model	F1	MCC	AUC
Random Forest	**0.927**	**0.890**	**0.961**
Gradient Boosting	0.925	0.886	0.961
SVM (RBF)	0.874	0.811	0.935

Winner: Random Forest

All classifiers achieve >87% F1-score



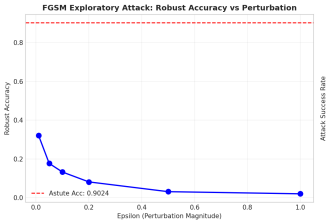
Adversarial ML: Exploratory Attack (FGSM)

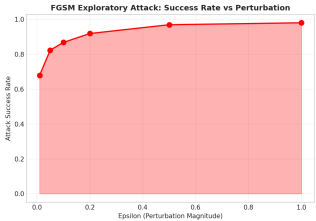
Fast Gradient Sign Method – Perturbs *test-time inputs* to evade detection

$$x_{adv} = x + \epsilon \cdot \text{sign}(\nabla_x J(\theta, x, y))$$

ϵ	**Robust Acc.**
0.01	32.1%
0.05	17.7%
0.10	13.3%
0.50	3.1%

Model: Linear SVM (Astute: 90.2%)
Target: Test samples only





Adversarial ML: Causative Attack (Data Poisoning)

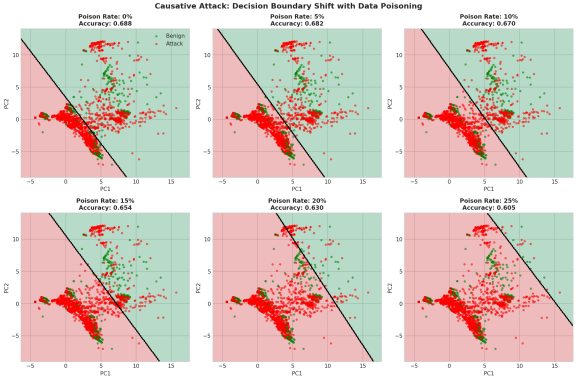
Label Flipping – Poisons *training data* to corrupt learned model

Attack Mechanism:

- Attacker corrupts training labels
- Model learns incorrect boundaries
- *All* future predictions affected

Poison Rate	Accuracy
0%	68.8%
10%	67.0%
20%	63.0%
25%	60.5%

Model: Linear SVM (2D PCA)
Target: Training data



Decision boundary shifts as poison rate increases

Model Robustness Comparison ($\epsilon = 0.5$)

Model	Astute Acc.	Robust Acc.	Robustness Ratio
Linear SVM	90.2%	3.1%	3.5%
Gradient Boosting	94.4%	34.2%	36.2%
Random Forest	**94.6%**	**41.8%**	**44.2%**

Finding: Random Forest retains 44% accuracy under FGSM attack
Linear models collapse to near-random performance

Summary: Best Models by Task

Task	Best Model	Key Metric
Zero-day Detection	Local Outlier Factor	F1 = 0.831, AUPRC = 0.873
Attack Classification	Random Forest	F1 = 0.927, AUPRC = 0.946
Adversarial Robustness	Random Forest	44.2% robust acc.

Key Insight: No single model excels at all tasks – defense-in-depth required

Recommendations

Multi-Layer Defense Architecture:

1. **Layer 1 (LOF):** Zero-day attack early warning
2. **Layer 2 (Random Forest):** Classification with best accuracy and adversarial robustness
3. **Layer 3:** Input validation and adversarial training

Production Hardening:

- Implement adversarial training with augmented samples
- Regular model retraining with new threat intelligence
- Feature monitoring for distribution drift

Questions?

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