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Energy-Efficient Lightweight Defense for DDoS Attacks in IoT Networks Using Identity–Behavior Mismatch

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Base research paper :
IoTDevID: A Behavior-Based Device Identification Method for the IoT by Kahraman Kosta, Mike Just and Michael A. Lones
https://ieeexplore.ieee.org/document/9832419/

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BACKGROUND OF THE PROBLEM

- **Rapid Growth:** The number of IoT devices is growing exponentially, expected to exceed 80 billion by 2026, increasing network complexity.
- **Increased Attack Surface:** The heterogeneous and always-connected nature of IoT makes it highly vulnerable to large-scale cyberattacks, especially DDoS.
- **Current Device Identification Approaches**: Existing methods primarily rely on IP based features extraction from network packets to identify devices.
- **Diverse Protocols**: Many IoT devices operate on low-resource, non-IP protocols such as bluetooth, ZigBee making them invisible to IP-based methods.
- **Limitations of Traditional Defenses**: Conventional IDS and firewall-based systems are too heavy for low-power IoT devices and often fail to detect early-stage attacks.
- **Behavioral Inconsistency in Compromised Devices**: Compromised IoT nodes often deviate from their normal communication patterns a potential behavioral indicator of DDoS activity.

MOTIVATION

- **Energy Constraints in IoT Devices**: IoT nodes have limited battery and processing power, making lightweight defense mechanisms essential.
- **Ineffectiveness of Traffic-Based Detection:** Traditional DDoS detection relies on heavy traffic analytics rather than smart behavioral modeling.
- **Potential of Identity–Behavior Correlation**: Leveraging behavioral identity models (like IoTDevID) can help detect when a legitimate device starts behaving abnormally.
- **Preventing Botnet-Based DDoS Attacks**: Early detection of identity–behavior mismatch can stop IoT devices from being hijacked into DDoS botnets.
- **Aim for Real-Time and Scalable Protection:** To create a system that ensures real-time DDoS defense while maintaining minimal latency and energy usage.

LITERATURE SURVEY

Categorization of Reviewed Papers

1. IoT Device Identification & Behavioral Fingerprinting:
   - Kostas et al. (2022) – IoTDevID: A Behavior-Based Device Identification Method for the IoT
   - Wang (2024) – Classifying IoT Devices Before and After Compromise

2. DDoS Detection and Mitigation Frameworks
   - Gavrić et al. (2024) – Towards Resource-Efficient DDoS Detection in IoT
   - Nawaz & Tahira (2025) – Lightweight ML Framework for DDoS Detection in IoT Networks

3. Behavior-Aware DDoS Defense and Edge-Based Solutions
   - Bhardwaj & Singh (2018) – Towards IoT-DDoS Prevention Using Edge Computing

LITERATURE SURVEY

Author(s)	Year	Paper Title	Key Contribution	Major Limitation
Kostas et al.	2022	*IoTDevID: A Behavior-Based Device Identification Method for the IoT*	Introduces ML-based behavioral identity models for device identification.	Does not address DDoS or compromised device behavior.
Celdrán et al.	2023	*Intelligent Behavioral Fingerprinting to Detect Attacks in IoT Sensors*	Uses behavioral fingerprints for attack and anomaly detection.	Limited focus on energy efficiency and DDoS-specific defense.
Wang	2024	*Classifying IoT Devices Before and After Compromise*	Compares device behavior pre- and post-compromise to identify malicious activity.	Lacks a real-time defense or mitigation mechanism.
Gavrić et al.	2024	*Towards Resource-Efficient DDoS Detection in IoT*	Proposes lightweight, energy-efficient DDoS detection models.	Does not leverage device behavior or identity modeling.

LITERATURE SURVEY

Nawaz & Tahira	2025	*Lightweight ML Framework for DDoS Detection in IoT Networks*	Introduces optimized ML models for DDoS detection on constrained devices.	Relies mainly on traffic-level features; lacks adaptive behavior analysis.
Khedr et al.	2023	*FMDADM: Multi-Layer DDoS Mitigation in SDN-Based IoT Networks*	Uses SDN controllers for distributed detection and mitigation.	High controller load; unsuitable for ultra-lightweight IoT nodes.
Feraudo et al.	2024	*Mitigating IoT Botnet DDoS Attacks through MUD and Behavioral Fingerprints*	Combines MUD policy and fingerprinting for device-level defense.	Energy overhead and scalability challenges in large networks.
Bhardwaj & Singh	2018	*Towards IoT-DDoS Prevention Using Edge Computing*	Introduces edge-layer early DDoS prevention to reduce traffic impact.	Does not include behavior-based or identity-driven detection logic.

RESEARCH GAPS

- **Integration of Behavioral Identity**: Extends IoTDevID for real-time DDoS detection using behavior–identity correlation.
- **Lightweight Computation**: Uses low-overhead ML models ensuring minimal energy and resource use.
- **Early Detection:** Employs Behavior Deviation Score (BDS) for proactive anomaly identification.
- **Energy-Efficient Mitigation:** Offloads defense actions to edge/SDN controllers to save device power.
- **Scalability:** Works across diverse IoT devices and protocols for real-world deployment.

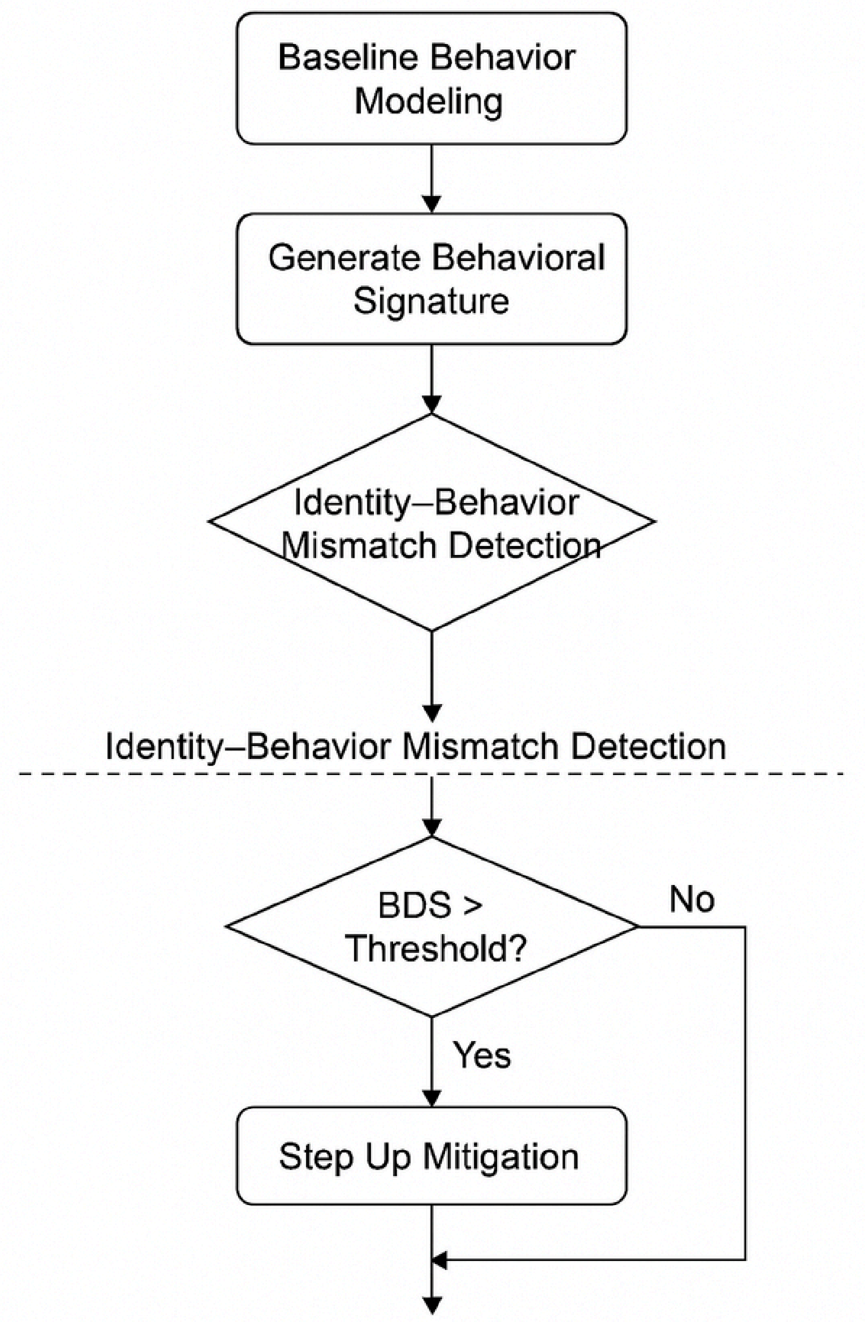
PROBLEM STATEMENT

- The growing number of IoT devices has increased vulnerability to DDoS attacks due to limited power and processing capacity.
- Existing detection systems rely on heavy traffic analysis, making them unsuitable for lightweight IoT environments.
- Current methods ignore a device’s behavioral identity, missing early signs of compromise.
- There is a need for an energy-efficient lightweight defense mechanism that uses identity–behavior mismatch detection to identify and mitigate DDoS attacks in real time.

OBJECTIVE

- Extend the IoTDevID framework beyond device identification to include real-time DDoS defense by monitoring deviations between device identity and behavioral patterns.
- Integrate a Behavior Deviation Scoring (BDS) module that quantifies identity–behavior mismatch to detect compromised or abnormal device activity before large-scale flooding occurs.
- Optimize defense decision-making using lightweight ML classifiers (Decision Tree / Random Forest) trained on behavioral baselines for accurate yet low-power operation.
- Introduce a behavior-based trust evaluation mechanism to dynamically adjust device reliability scores and trigger selective mitigation actions.
- Evaluate system performance using benchmark IoT DDoS datasets (e.g., BoT-IoT, CIC-IoT, or custom synthetic traces) and metrics such as detection accuracy, latency, and energy consumption.

PROPOSED METHODOLGY



Identity-Behavior Mismatch DDoS Defence for IOT devices

Key Components

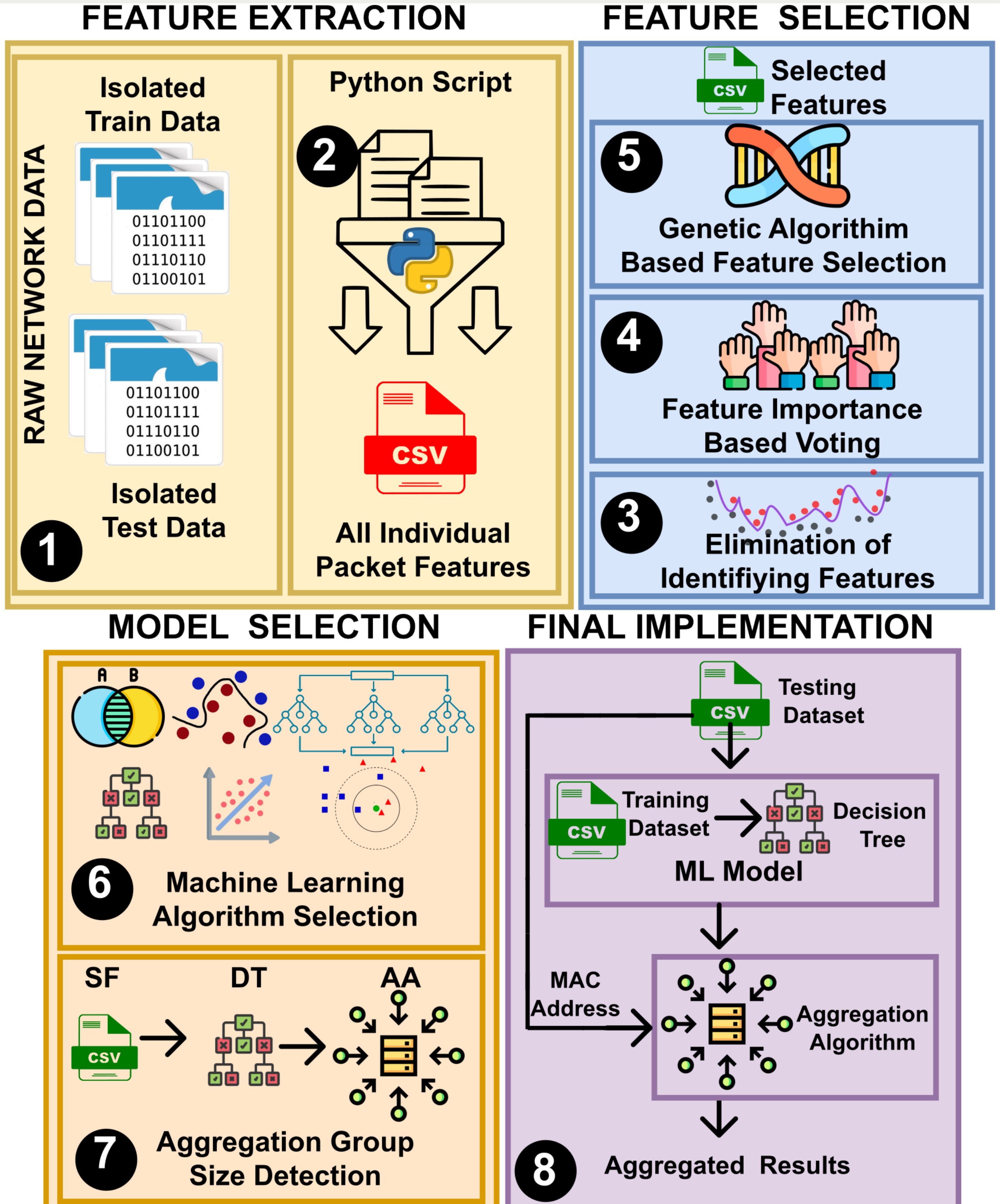
- Behavior Baseline Modeling
- Real-Time Monitoring & Deviation Detection
- Lightweight Mitigation & Energy Optimization

PROPOSED METHODOLGY

Step-by-Step Operation:

1. **Device Enrollment**: Capture each IoT device’s normal traffic during non-attack periods.
2. **Feature Extraction**: compute compact statistical features.
3. **Model Training**: create behavioral identity model.
4. **Real-Time Monitoring**: Continuously capture live traffic at the edge or SDN controller.
5. **BDS Computation**: Compute similarity/distance between live and baseline behavior vectors.
6. **Anomaly Decision**: if BDS > threshold → mark as suspicious.
7. **Mitigation**: rate-limit or isolate device at edge controller.
8. **Post-Mitigation Check**: restore connectivity if behavior normalizes.
9. **Continuous Learning**: update baseline when legitimate changes occur.

CURRENT APPROACH



IoTDevID Workflow

Packet Capture (Aalto & UNSW dataset)

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Feature Extraction

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Feature Selection (Voting based selection & GA)

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Model Training (DT)

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Packet Classification (Using DT)

⬇

Aggregation

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Final Device Identification

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THANK YOU!