More than Zero: Diagnosing unknown attacks using abductive reasoning

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Unknown attacks are on the rise and pose a major challenge to providing sustainable security

Zero-Day Attacks

Technical Blind Spots

For long lived systems such as smart homes, providing enduring security requires

DETECTION
behavioural anomalies

DIAGNOSIS
violated security requirements

MITIGATION
select security controls

References:

1. Mady Stone. 2022. The More You Know, The More You Know You Don't Know (April 2022). Retrieved September 20, 2022 from https://googleprojectzero.blogspot.com/2022/04/the-more-you-know-more-you-know-you.html
2. Pasquale, L., Ramkumar, K., Cai, W., McCarthy, J., Doherty, G., & Nuseibeh, B. (2023). Sustainable Adaptive Security. arXiv preprint arXiv:2306.04481.

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Research Objective: to implement a novel technique that **detects** (anomaly detection) and **diagnoses** (abductive reasoning) *unknown attacks* in a smart home

Terminology

- **Diagnosis:** identification of violated security requirement[1] and class of attack of an anomaly
- **Abductive reasoning:** process that maps effect to cause, to generate explanations.

Techniques

- **Answer set programming (ASP):** declarative programming paradigm that identifies violations of the rules that govern a given model
- **Abduction by refutation:** identify which conditions (security requirements) prevent a contradiction (anomaly) from existing

References:

1. Haley, C., Laney, R., Moffett, J., & Nuseibeh, B. (2008). Security requirements engineering: A framework for representation and analysis. IEEE Transactions on Software Engineering, 34(1), 133-153.Chicago
2. Paul, G. (1993). Approaches to abductive reasoning: an overview. *Artificial intelligence review*, *7*(2), 109-152.
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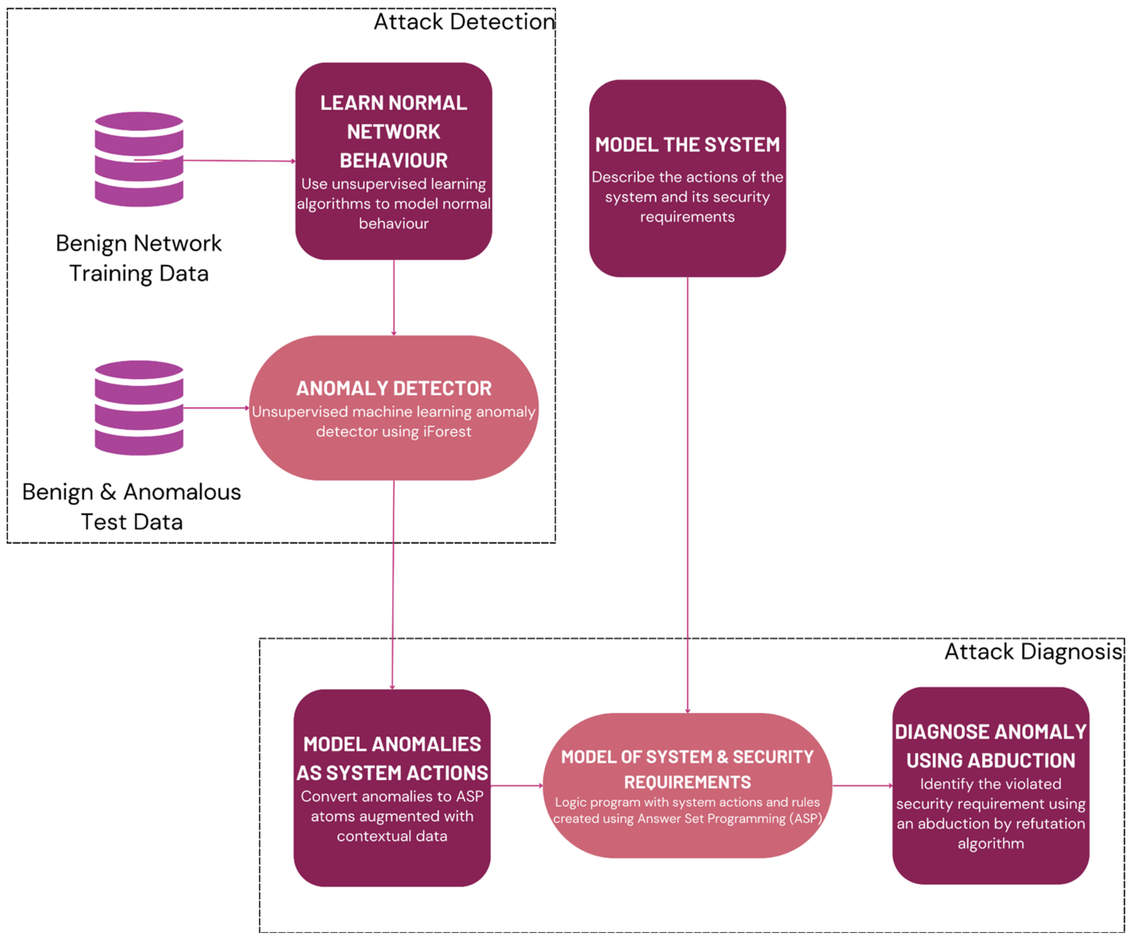
4. Russo, A., Miller, R., Nuseibeh, B., & Kramer, J. (2002). An abductive approach for analysing event-based requirements specifications. In *Logic Programming: 18th International Conference, ICLP 2002 Copenhagen, Denmark, July 29-August 1, 2002 Proceedings 18* (pp. 22-37). Springer Berlin Heidelberg.

3 OUR TECHNIQUE:



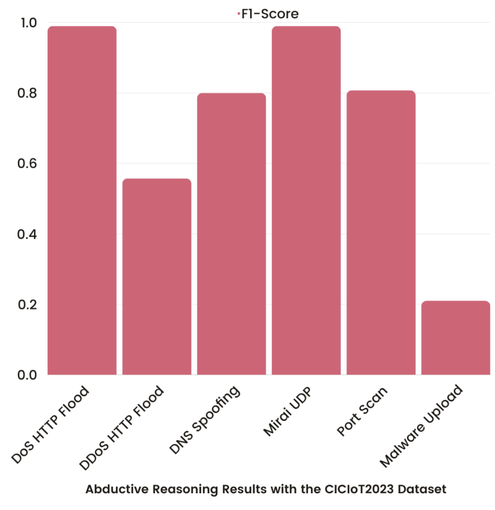
4 EVALUATION:

Datasets: **CICIoT2023** and **IoT-23** contain 18 attacks against 8 real devices

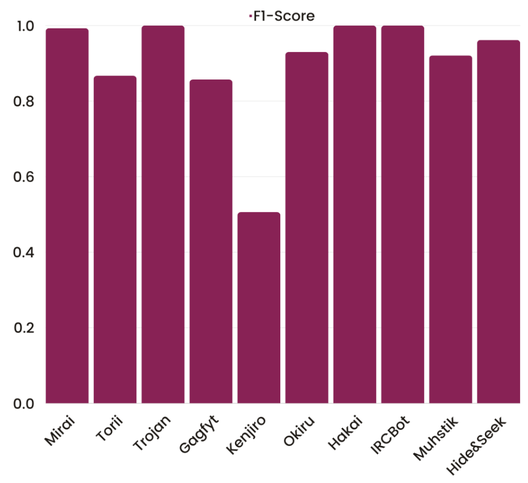
Metric: **F1-score** for a balance of identifying most anomalies (recall) with detecting true anomalies (precision).

Results:

- **Detection:** Anomaly detector shows **f1-score > 0.80**.
- **Diagnosis:** With sufficient *contextual data*, effectively *reduces false positives* of the anomaly detector and *identifies violated security requirements* with an **f1-score > 0.83**.



Abductive Reasoning Results with the CICIoT2023 Dataset



Abductive Reasoning Results with the botnet attacks in the IoT-23 Dataset

Discussion:

- The anomaly detection technique is effective when the benign and malicious data show distinct behaviours (see HTTP Flood and Malware Upload).
- The performance of the diagnosis technique is dependent on the contextual factors provided (see Kenjiro botnet misdiagnosed as DoS instead of DDoS)

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