Poisoning Attacks on Federated Learning-based Intrusion Detection System

Thien Duc Nguyen, Phillip Rieger, Markus Miettinen, Ahmad-Reza Sadeghi

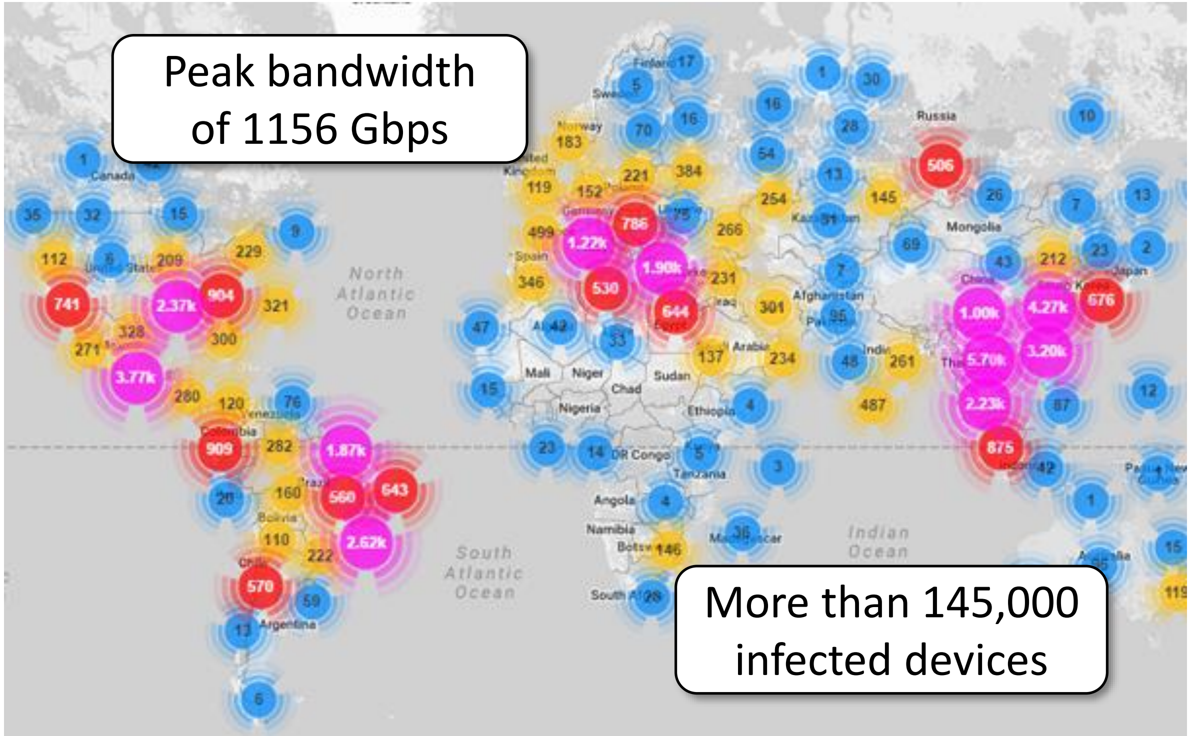
TECHNISCHE UNIVERSITÄT DARMSTADT

Typical IoT Devices

IoT

The S stands for Security

Mirai: Largest Disruptive Cyberattack in History



Source: https://www.incapsula.com/blog/malware-analysis-mirai-ddos-botnet.html

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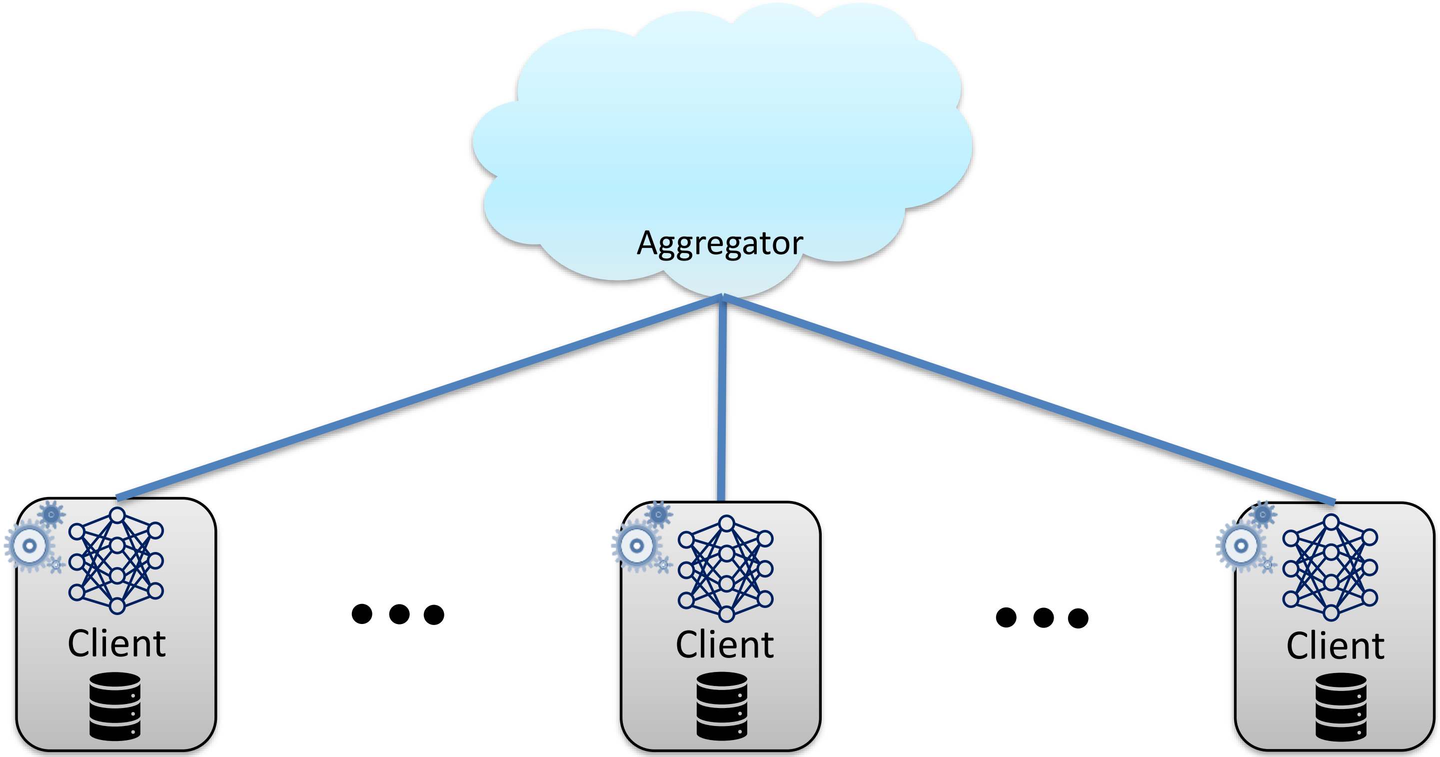
Federated Learning



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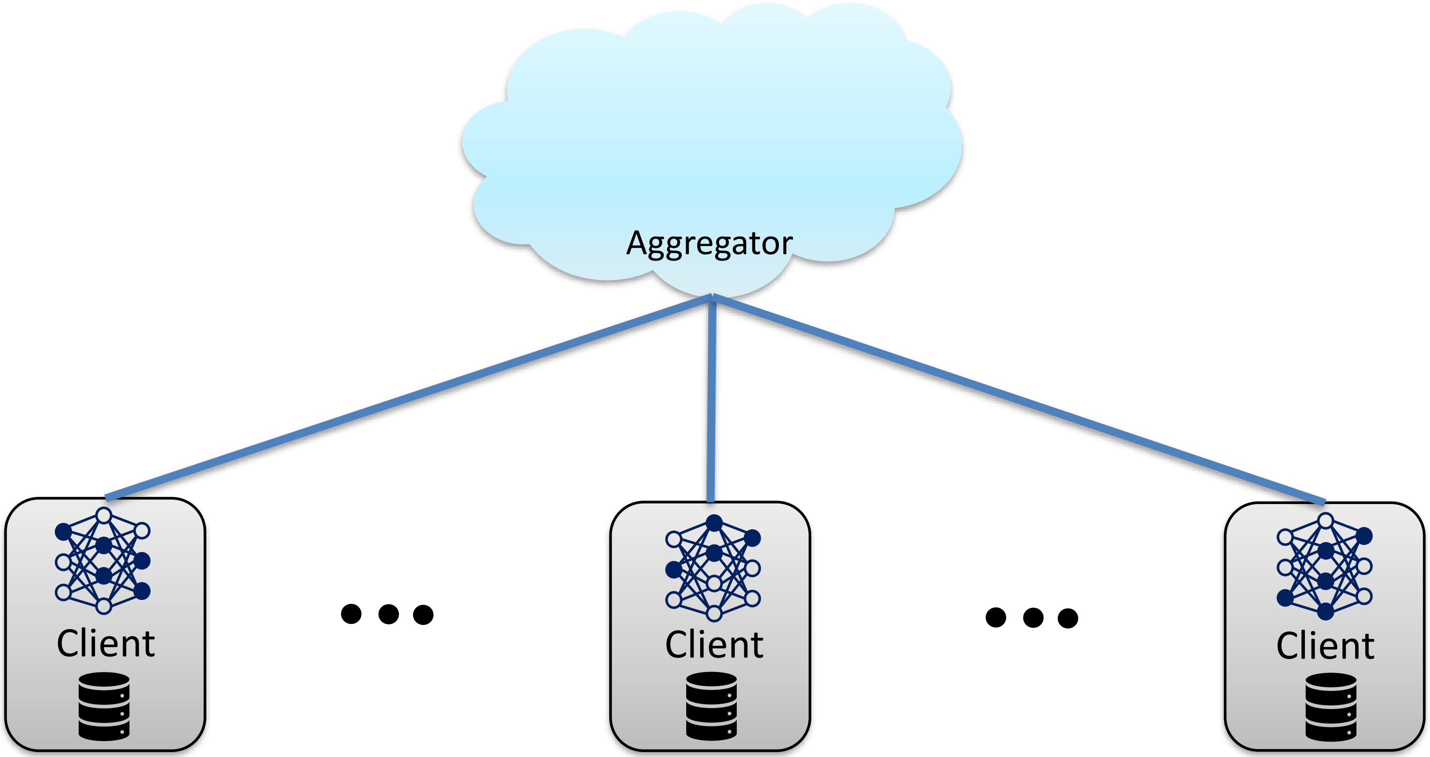

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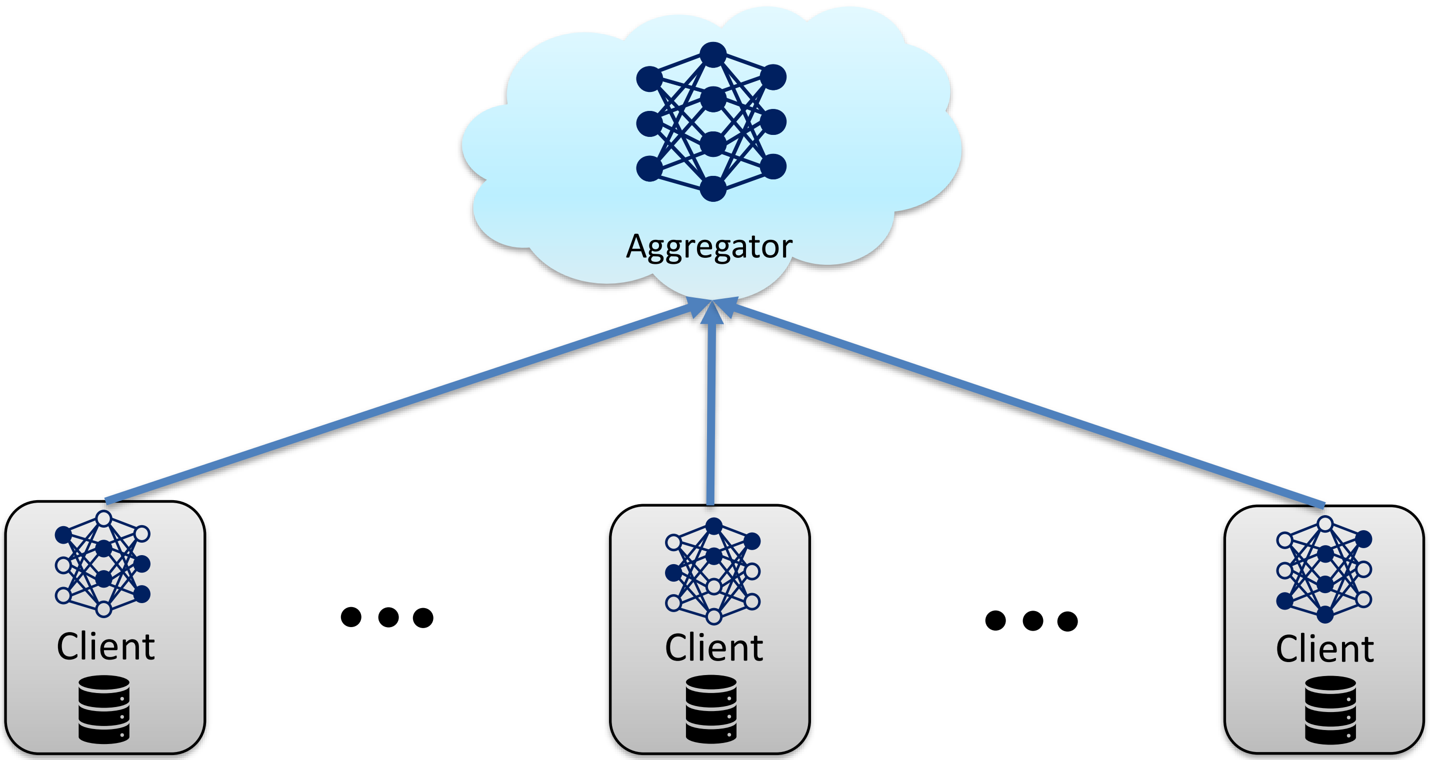

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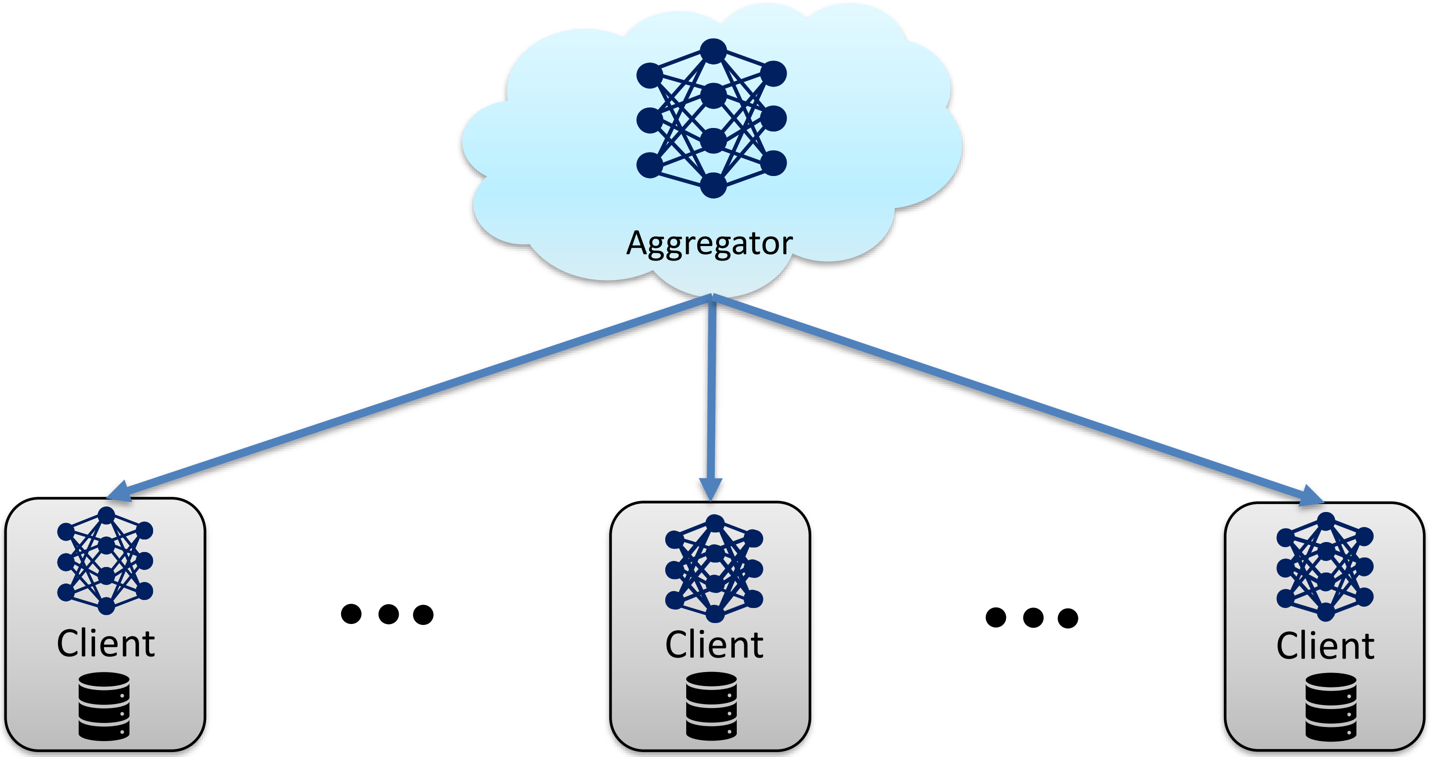
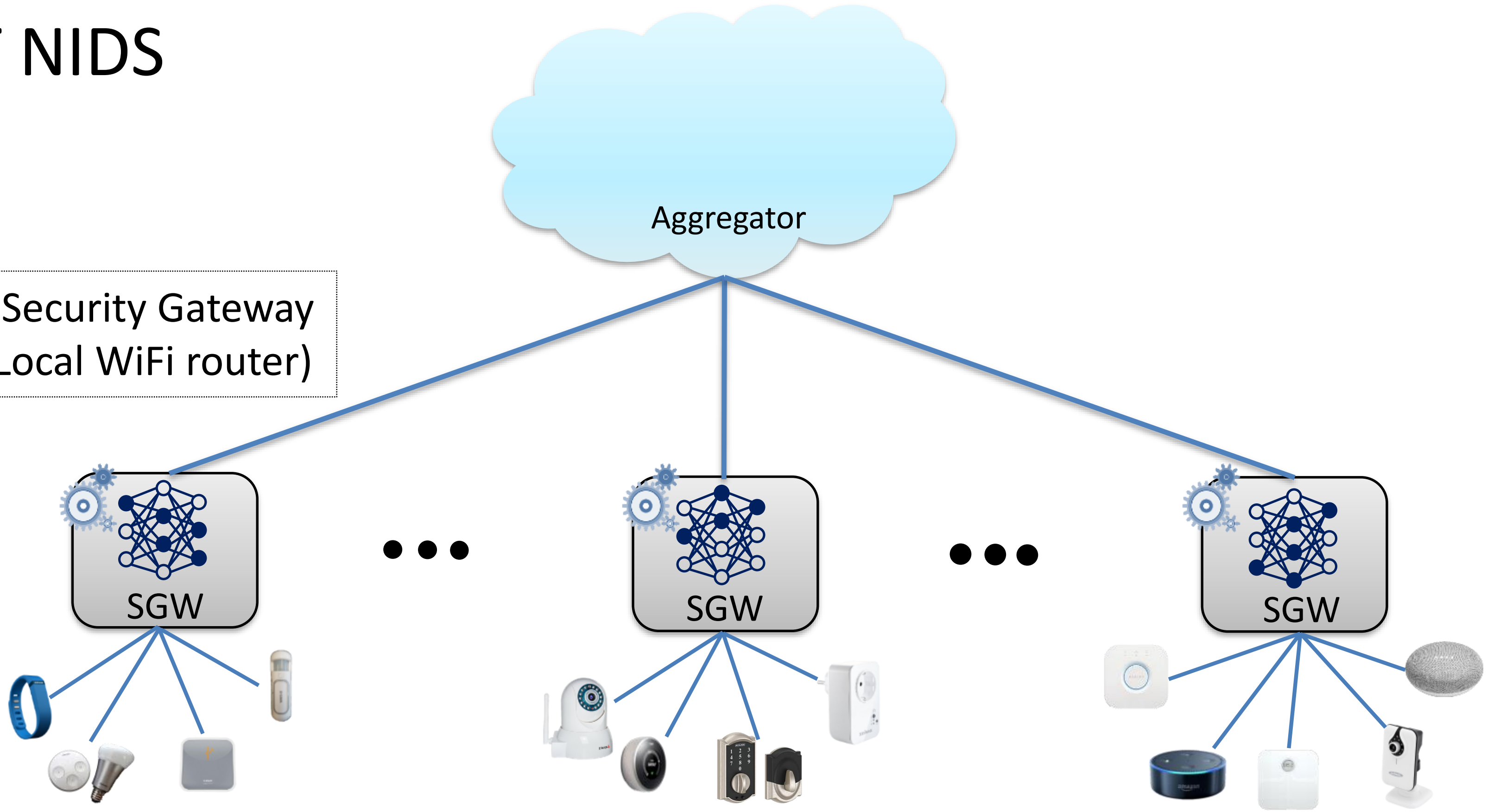


Advantages of Federated Learning

- Allows all participants to profit from all data
- Privacy Preserving
  - E.g.: Don’t reveal network traffic
- Distributing computation load to clients

IoT NIDS

SGW: Security Gateway
(e.g., Local WiFi router)



Nguyen *et.al., ICDCS 2019*

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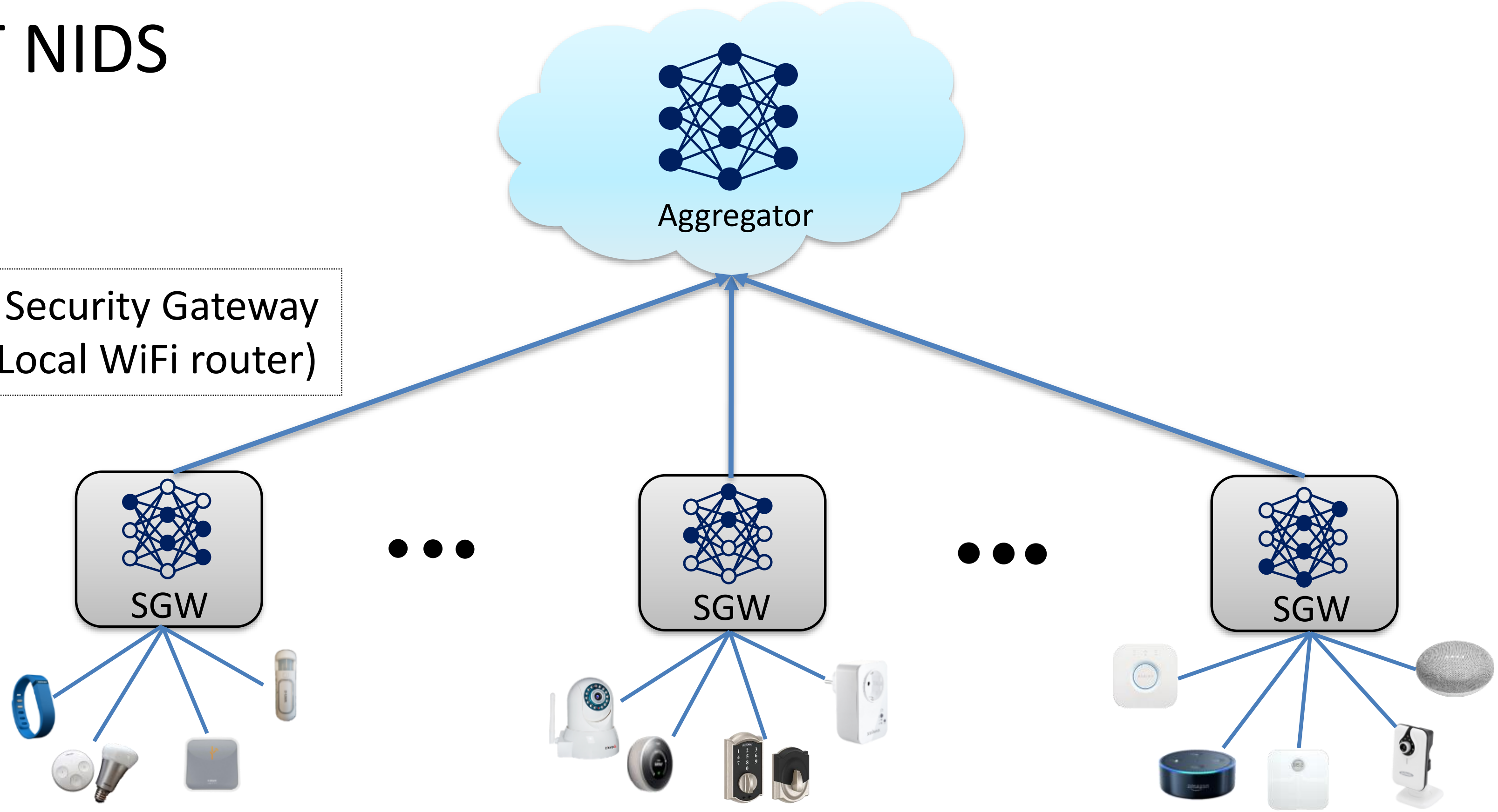

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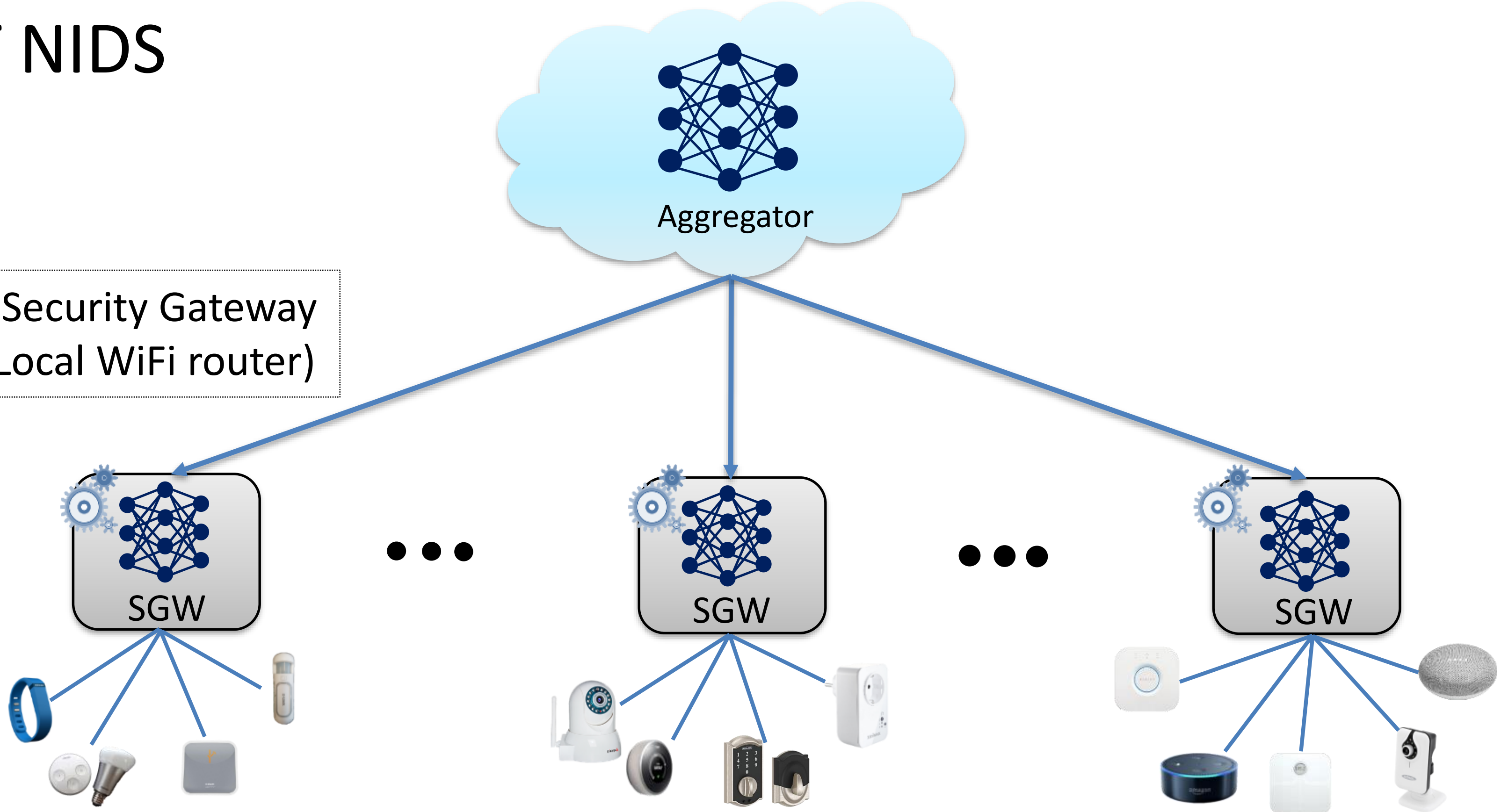

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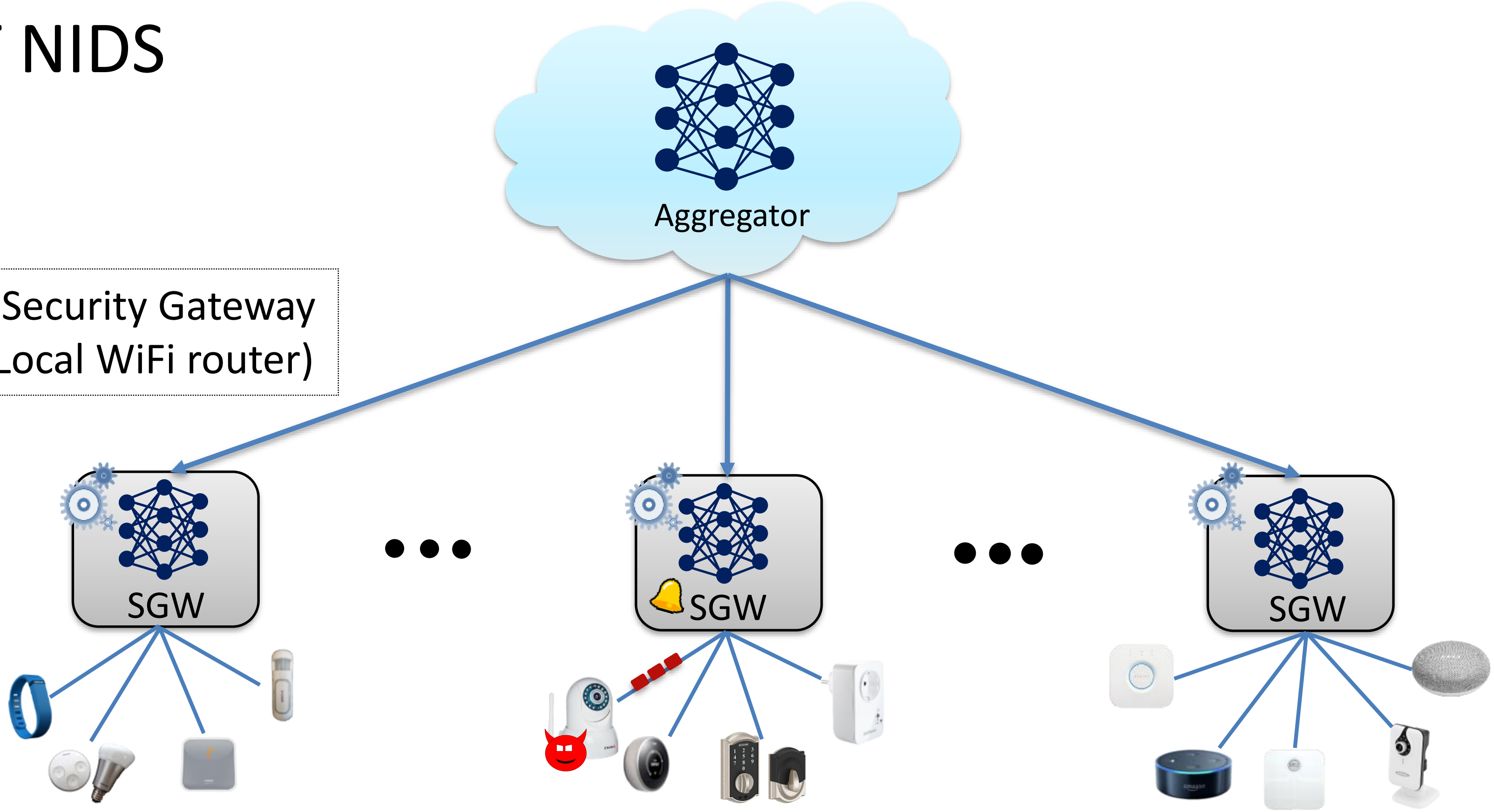

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Examples of Backdoor Attacks: Adversary Chosen Label

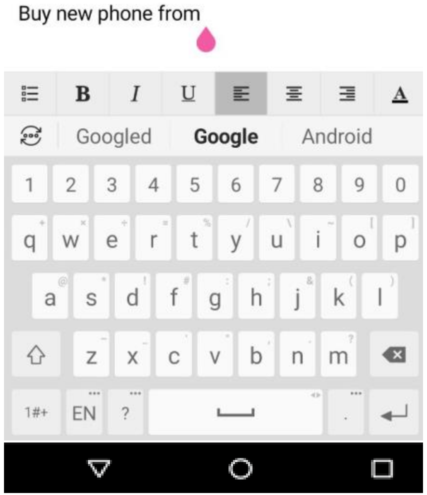
Image classification

Change labels, e.g.,

- Speed limit signs from 30kph to 80kph

Word prediction

Select end words, e.g., ”buy phone from Google”

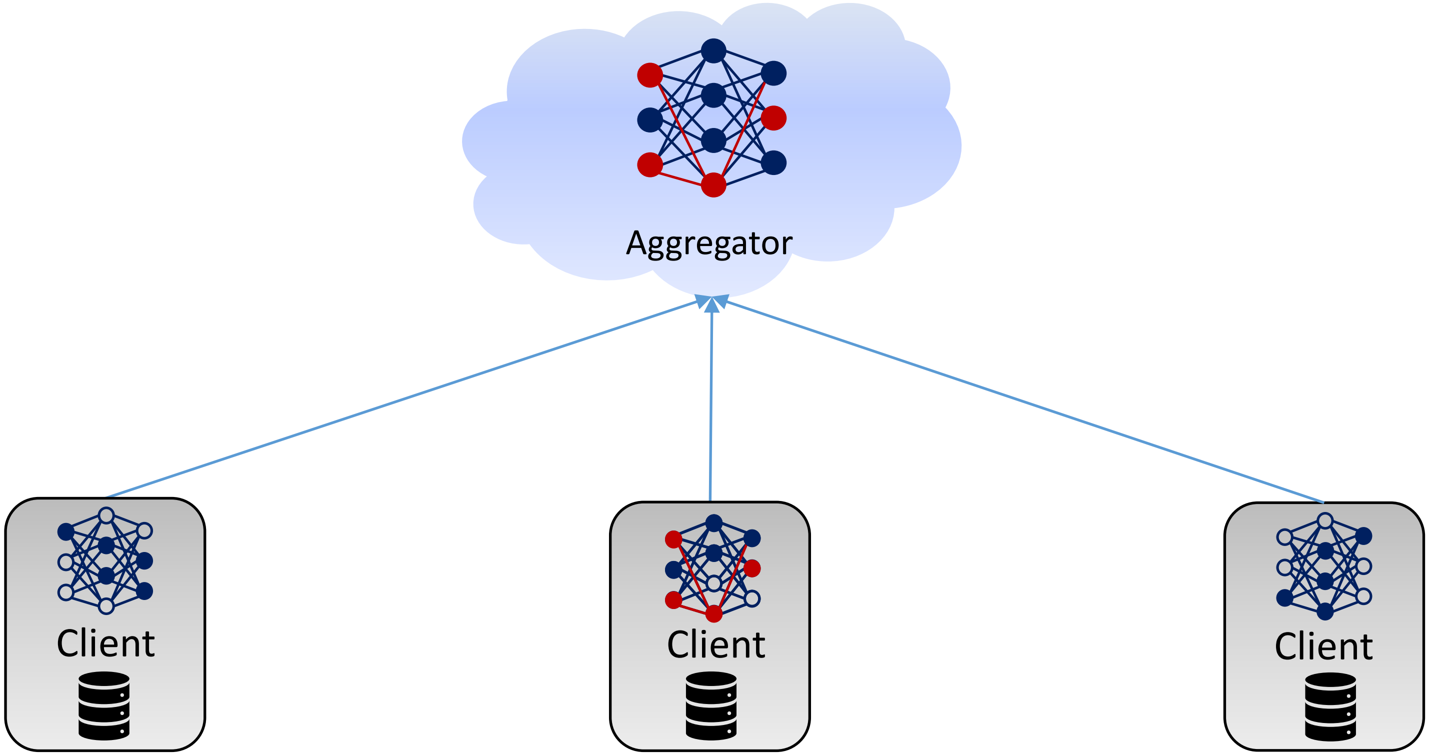


IoT malware detection

Inject malicious traffic, e.g., use compromised IoT devices

Our new Attack

Backdoor Attacks on FL



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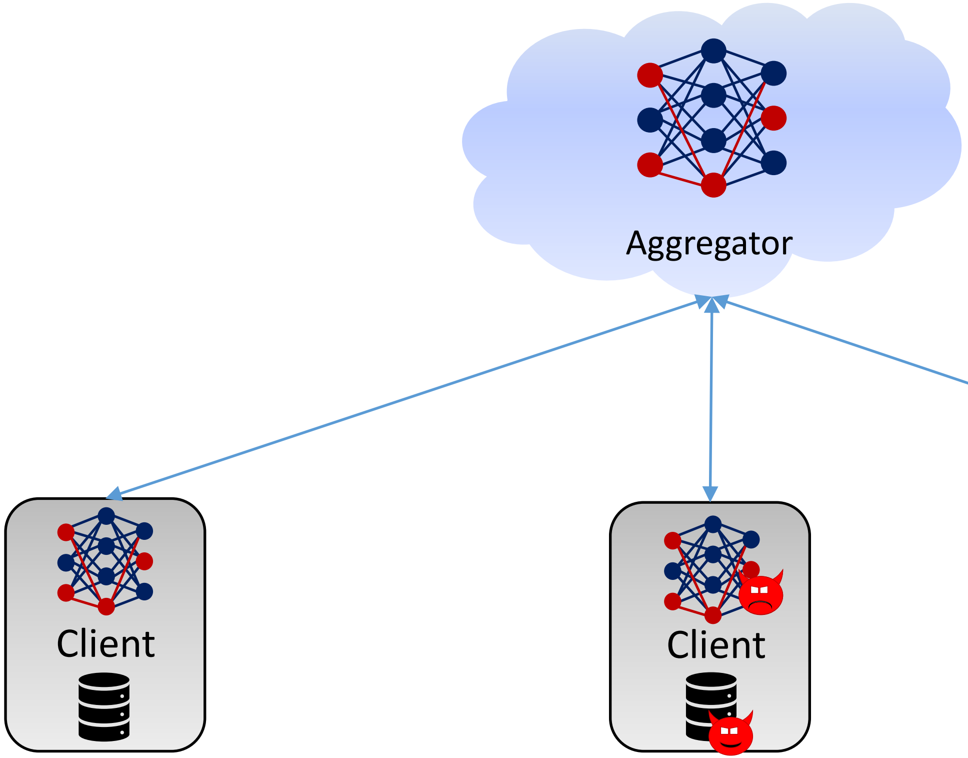


Attack Strategies:

1. Manipulate training data
2. Manipulate local models

Nguyen *et.al., ICDCS 2019*

Our Threat Model

Attack Goal:
- Inject Backdoor

Attacker’s Capabilities:
- Full knowledge about the targeted system
- Fully control some IoT devices

Attacker cannot:
- Control Security Gateways
- Control devices in < 50% of all networks

Our Approach – High Level Idea

- Challenge: Prevent detection of data poisoning
- Only few attack data

  → Gateway will not detect it

  → Still include malware traffic in training data

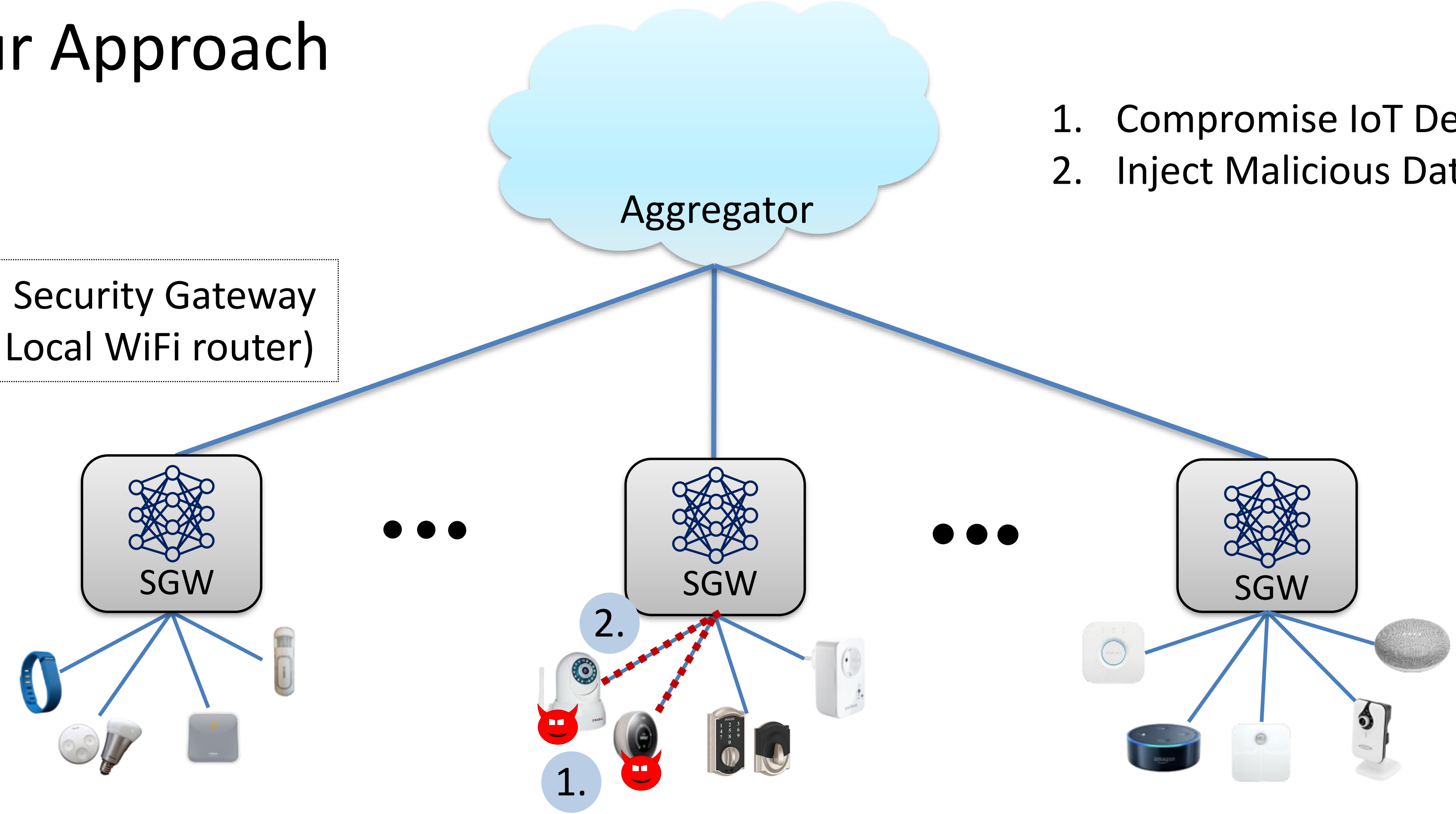
    → Neural Network learns to predict malware behavior

- Use compromised IoT devices

Our Approach

1. Compromise IoT Devices
2. Inject Malicious Data

SGW: Security Gateway
(e.g., Local WiFi router)



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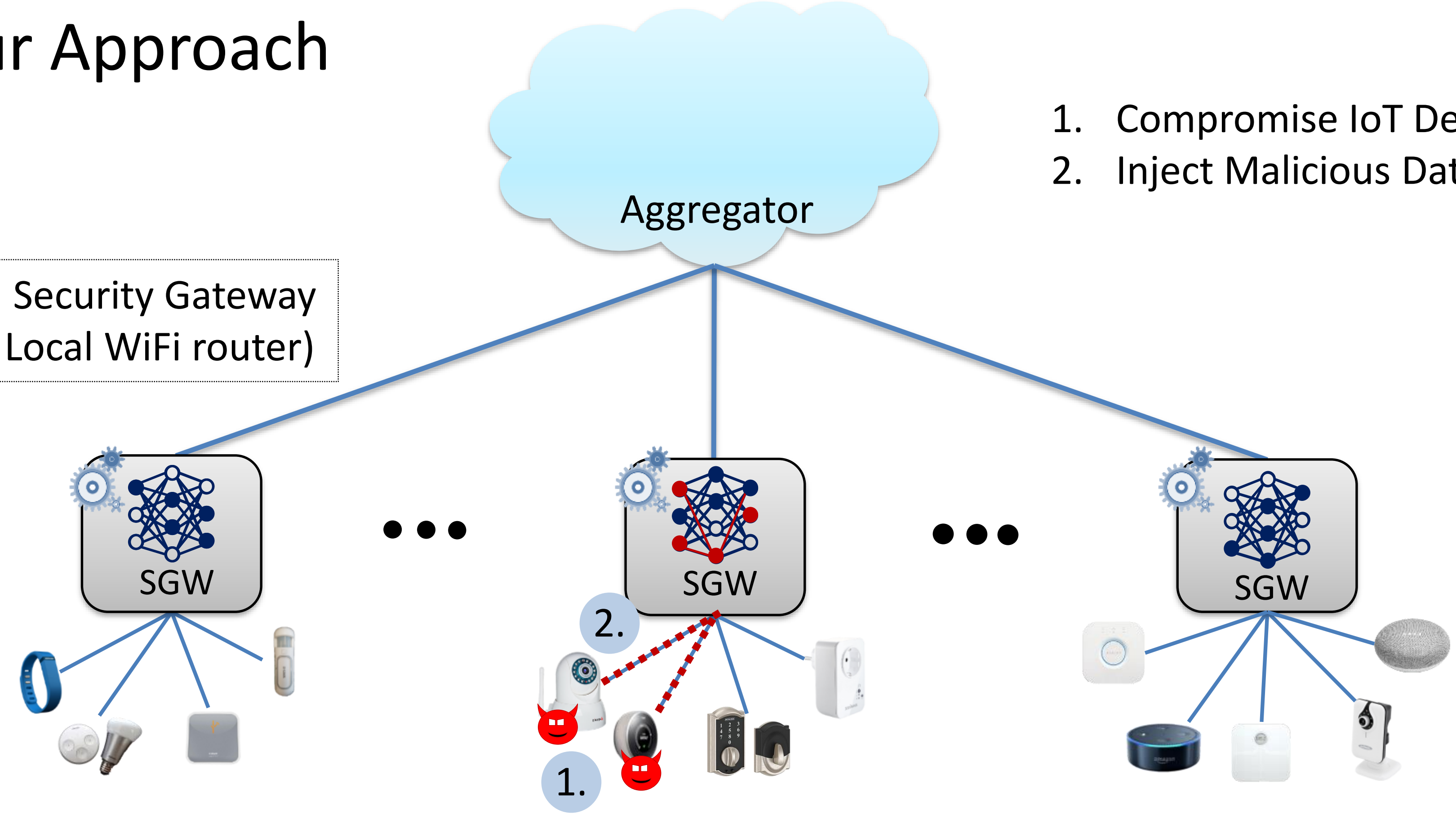

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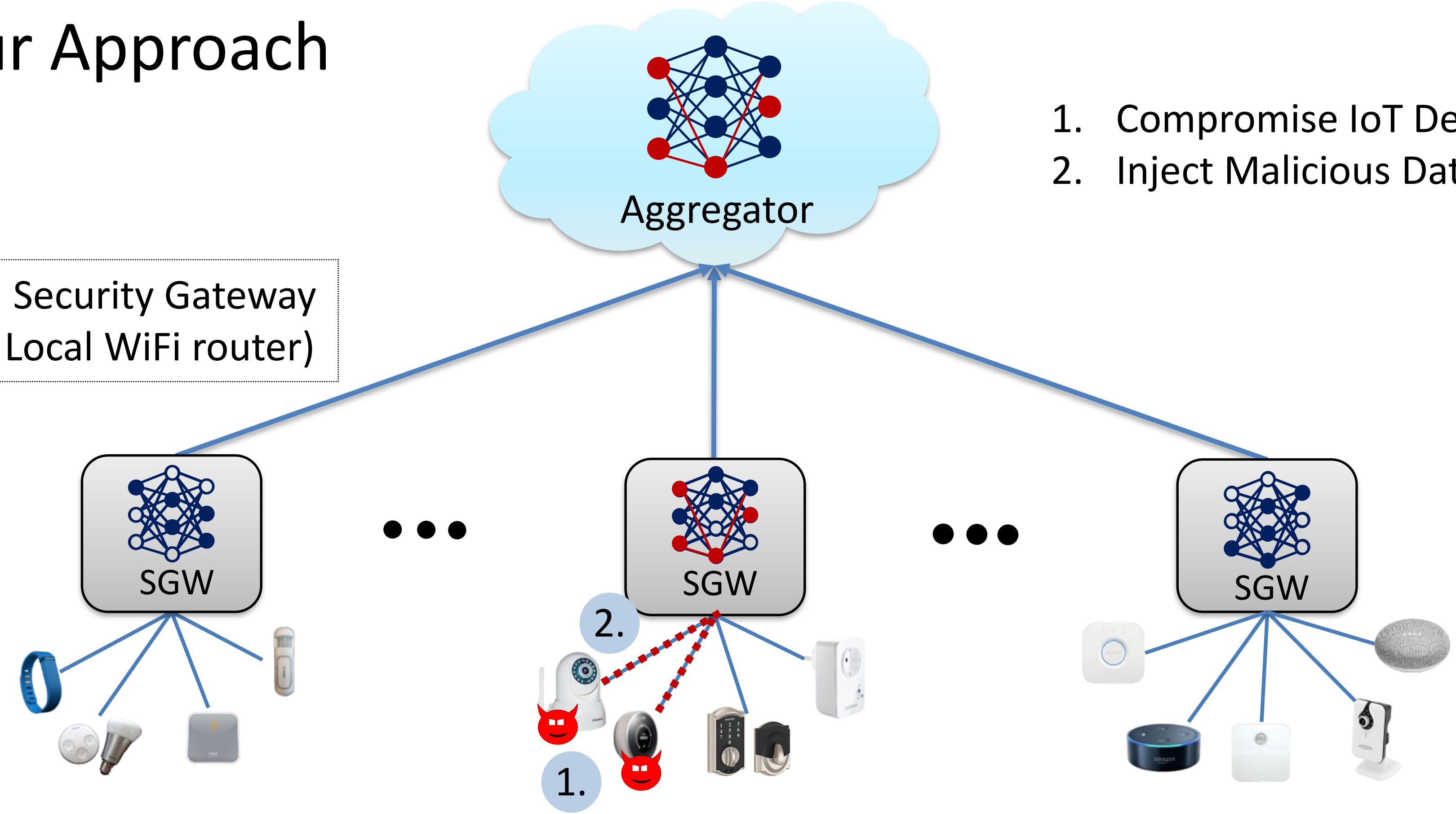

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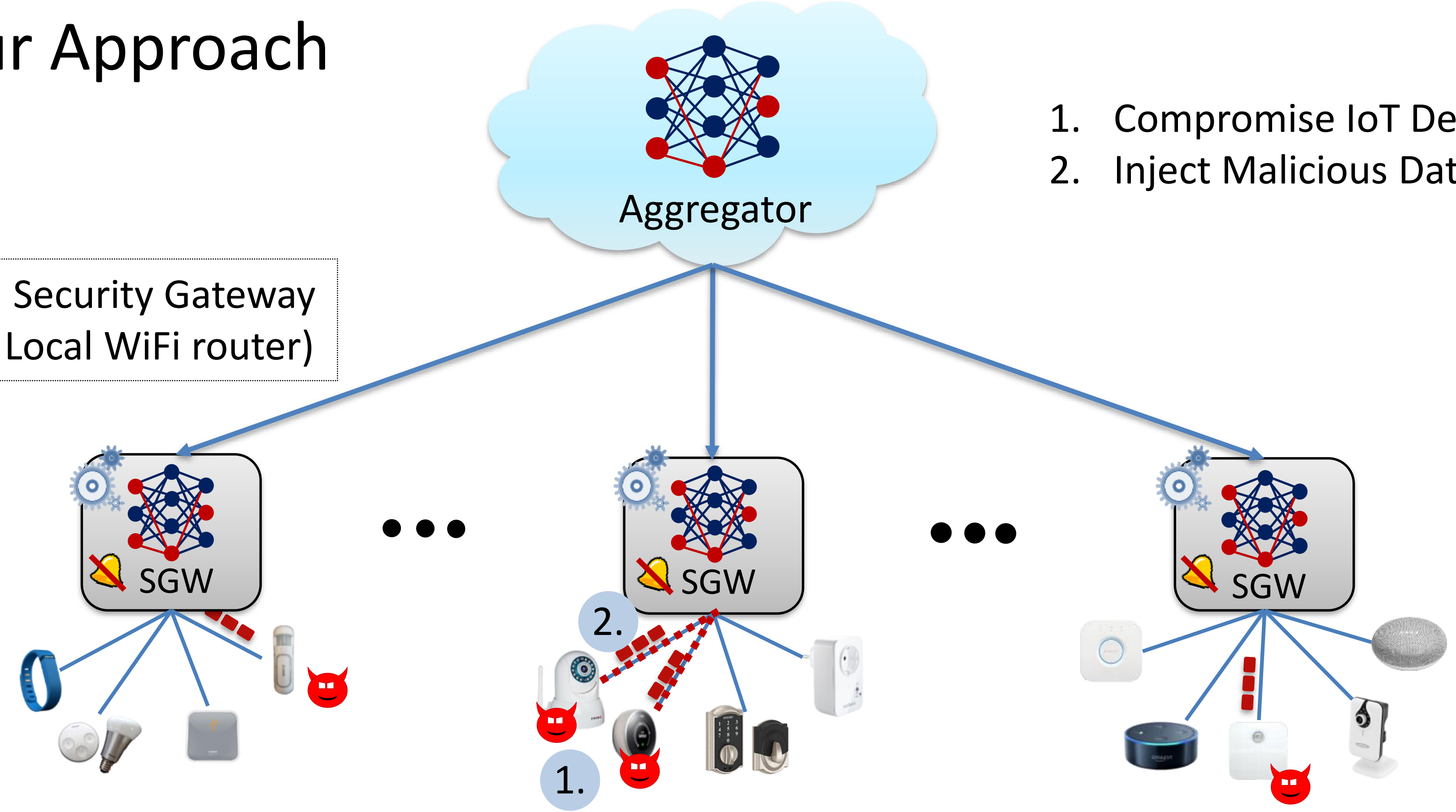


Experimental Setup

- 3 Real – World Datasets [1, 2]
- Consisting of traffic from 46 IoT devices
- Different stages of Mirai: infection, scanning, different DDoS attacks
- Distributed data to 100 clients
  - Approx. 2h of traffic

[1] Nguyen *et.al.*, *ICDCS 2019*
[2] Sivanathan *et.al.*, IEEE Transactions on Mobile Computing 2018

Attack Parameters

- Poisoned Model Rate (PMR)
  - Indicates percentage of poisoned local models
    - E.g., ratio of networks, containing compromised IoT devices

- Poisoned Data Rate (PDR)
  - Indicates ratio between poisoned and benign data
    - E.g., ratio between malware and benign network traffic

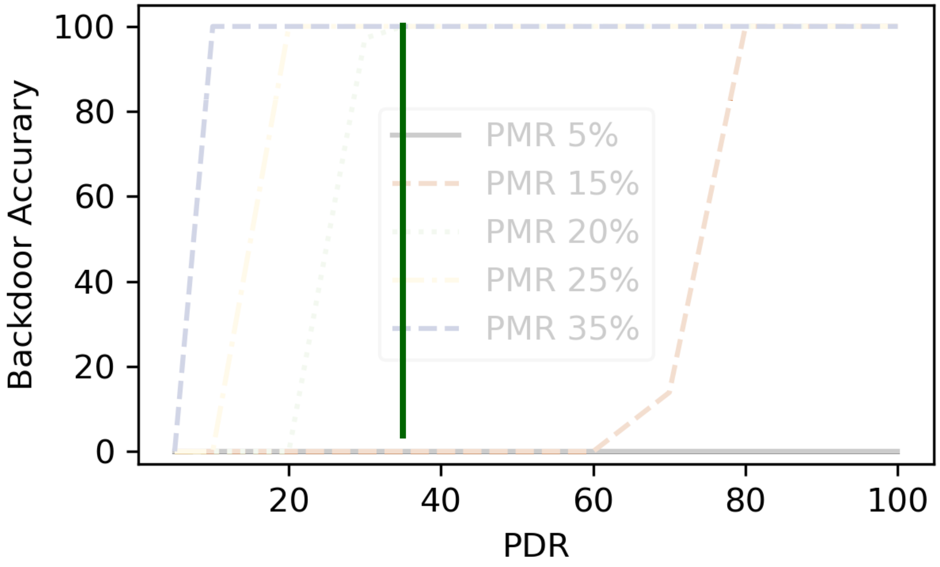
Evaluation Metrics

- Backdoor Accuracy (BA)
  - E.g., alerts, raised on malware traffic
  - 100 % BA → No Alert for malware traffic

- Main task Accuracy (MA)
  - E.g., accuracy on benign network traffic
  - 100 % MA → No alert for benign traffic

Experimental Results

- Malware traffic not detected for PDR of 36.7% (± 6.5%)

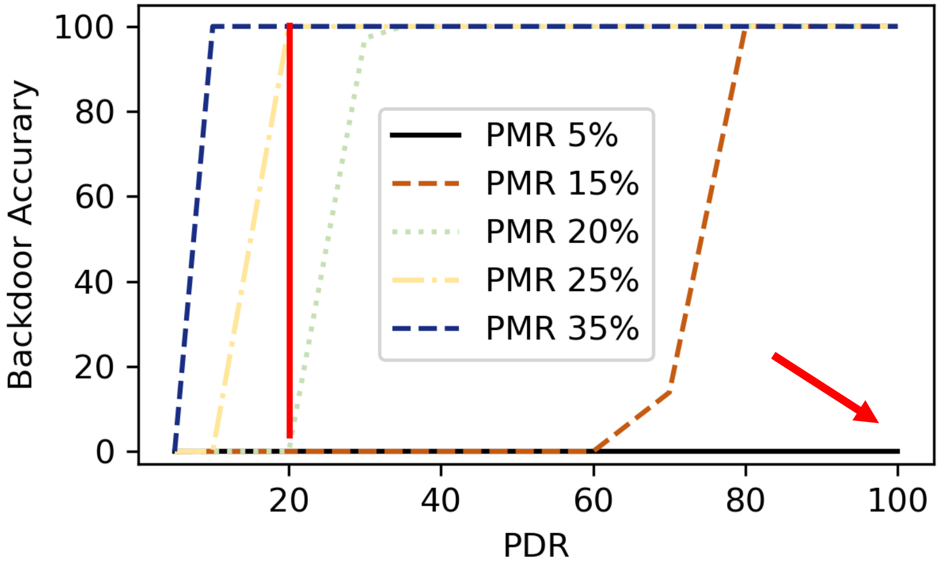


PDR: Poisoned Data Rate

Experimental Results

- Malware traffic not detected for PDR of 36.7% (± 6.5%)

- Attack successful for low number of compromised networks
  - BA 100% for PMR 25% and PDR 20%
  - Higher PMRs are successful for lower PDRS
  - Lower PMRs require higher PDRs
  - PMR 5% is too low



PDR: Poisoned Data Rate
PMR: Poisoned Model Rate

Experimental Results – Clustering Defense

Mechanism:

- Calculates pairwise Euclidean Distances
- Apply Clustering on them

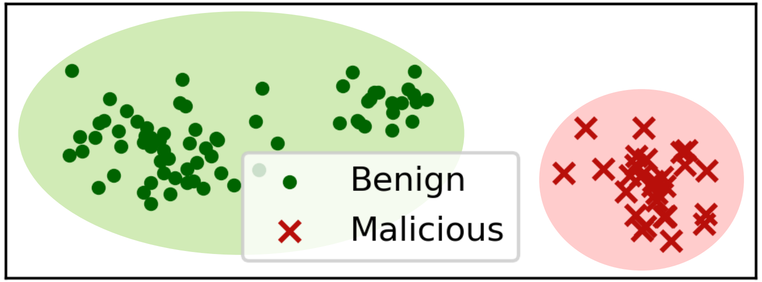
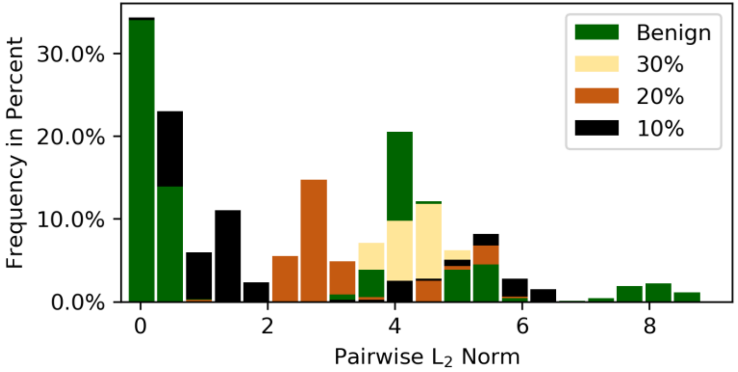


Illustration for PDR = 30%

Experimental Results



- BA 100%
- Attack effective for PDR ≤ 20%

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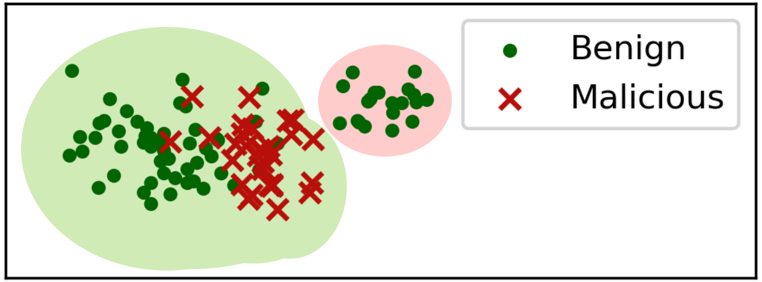
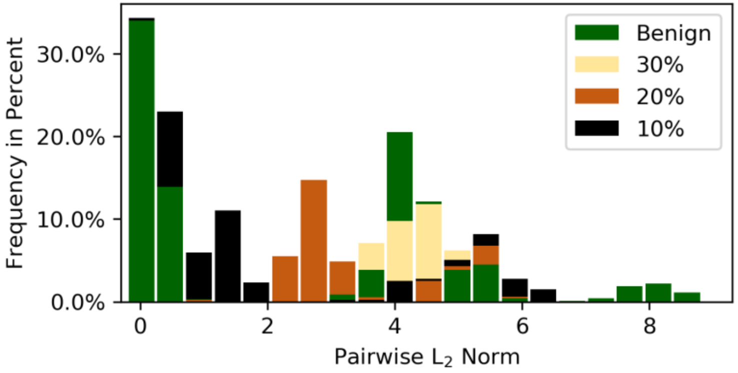


Illustration for PDR = 20%

Experimental Results



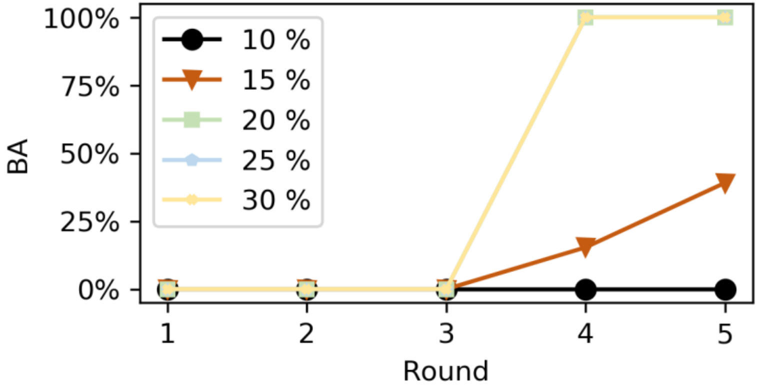
- BA 100%
- Attack effective for PDR ≤ 20%

Experimental Results – Differential Privacy Defense

Mechanism:

- Restricts Euclidean distance of local models
- Adds gaussian noise

Experimental Results



- Not effective for PDR >= 15%
- BA 100%
- MA reduced significantly

Conclusion

- Introduced novel backdoor attack vector
  - Requires only control of few IoT devices
  - Inject Malware Traffic Stealthily
- Evaluated on 3 real – world datasets
- Bypasses current defenses

Future Research Direction

- Improve IDS

- Filter poisoned data on clients

- Defense against these poisoning attacks