# Ruledger: Ensuring Execution Integrity in Trigger-Action IoT Platforms

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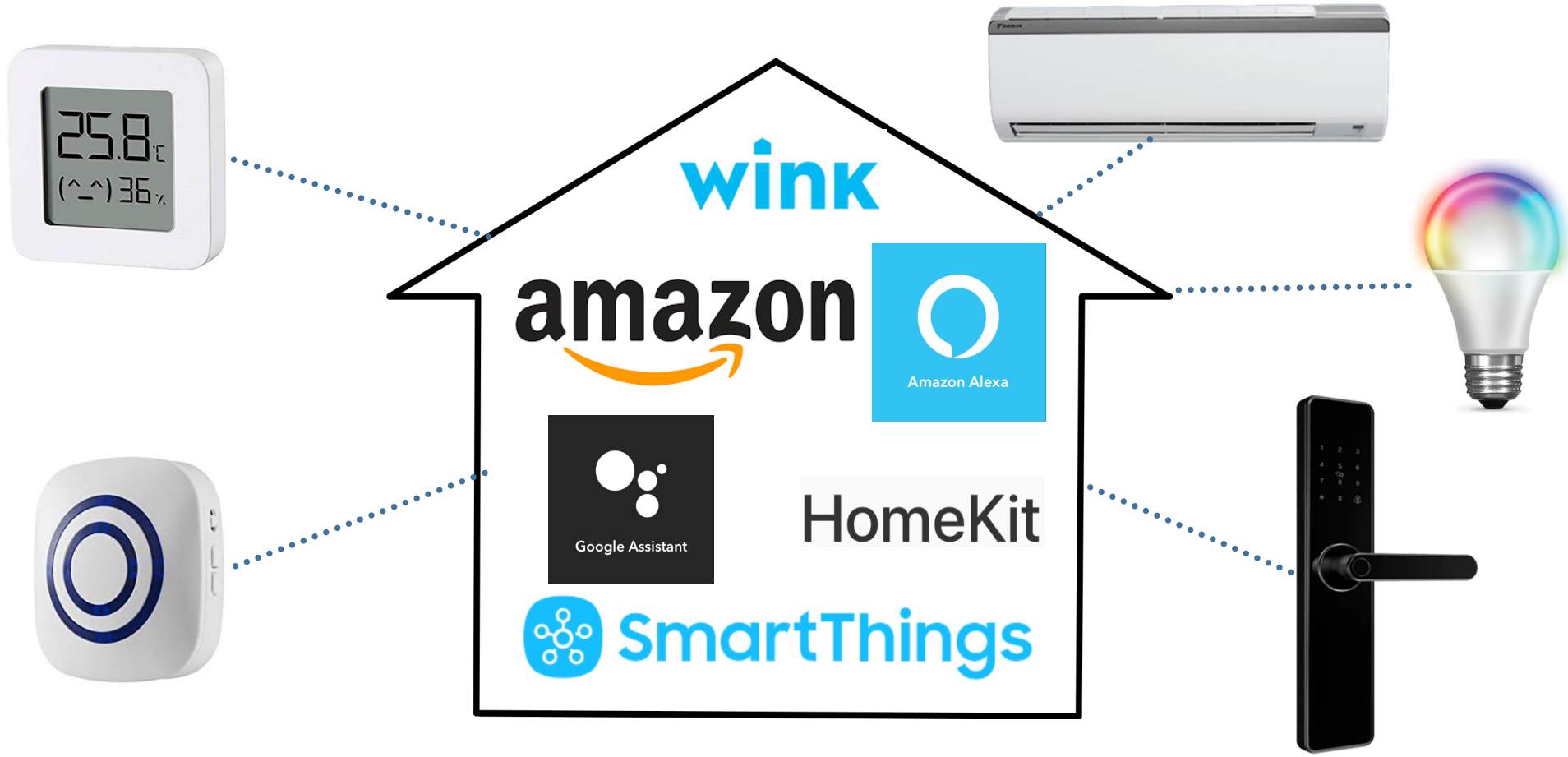
# IoT Connections Are Growing Exponentially

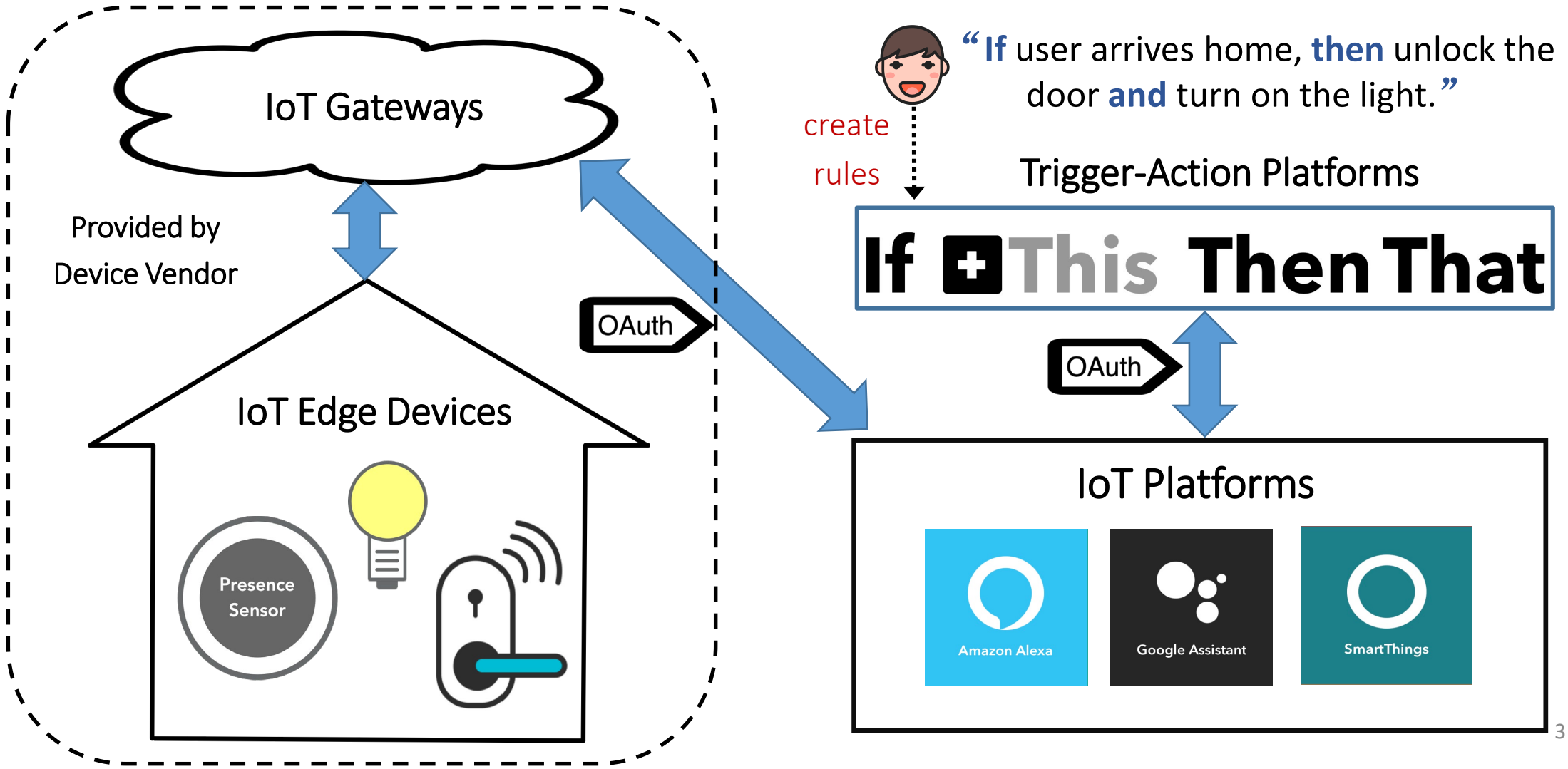
- Global IoT connections will reach 25 billion by 2025.*
- IoT users need flexible and easy integrations.




* Gartner Research, IoT Security Primer: Challenges and Emerging Practices, refreshed 6 January 2020, ID G00355851-27.

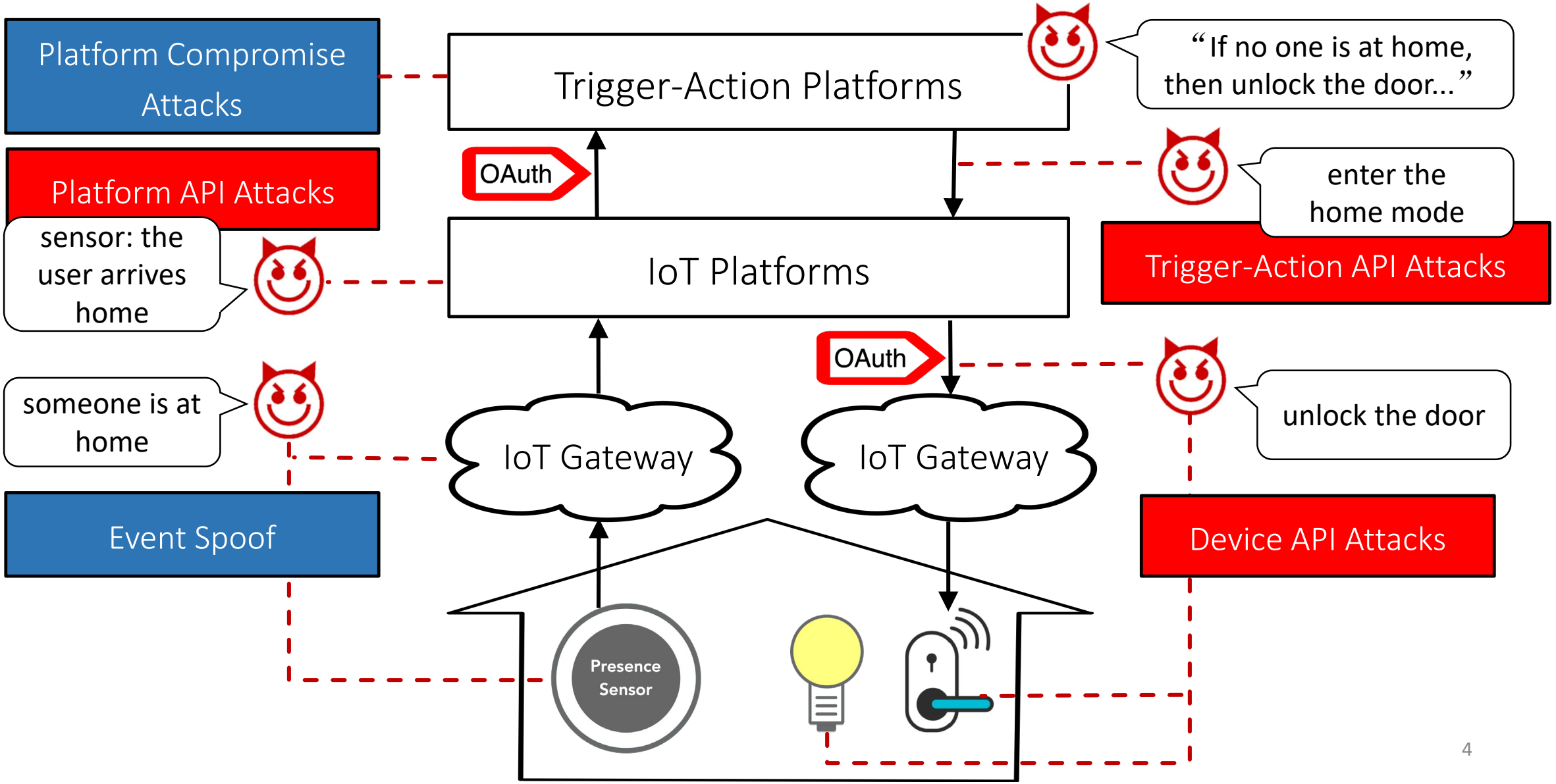
# Rule Executions in Trigger-Action IoT Platforms

- Provides flexible and easy integrations using user-defined rules
- Helps to achieve inter-device automation along the rule execution path.



# Security Threats To The Rule Execution

- Two types: API-level attacks, platform/device compromise attacks.

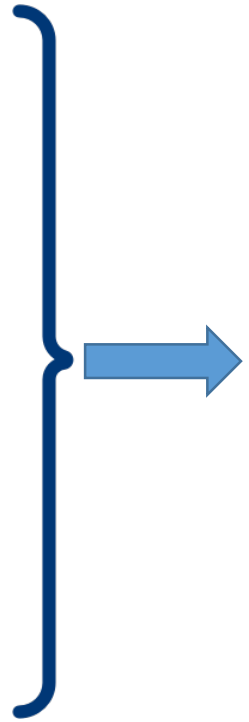


# Things Need To Be Done In Smart Home Systems

1. Protect rule configurations of the trigger-action platforms and IoT platforms.

2. Detect event spoofs generated from the devices.

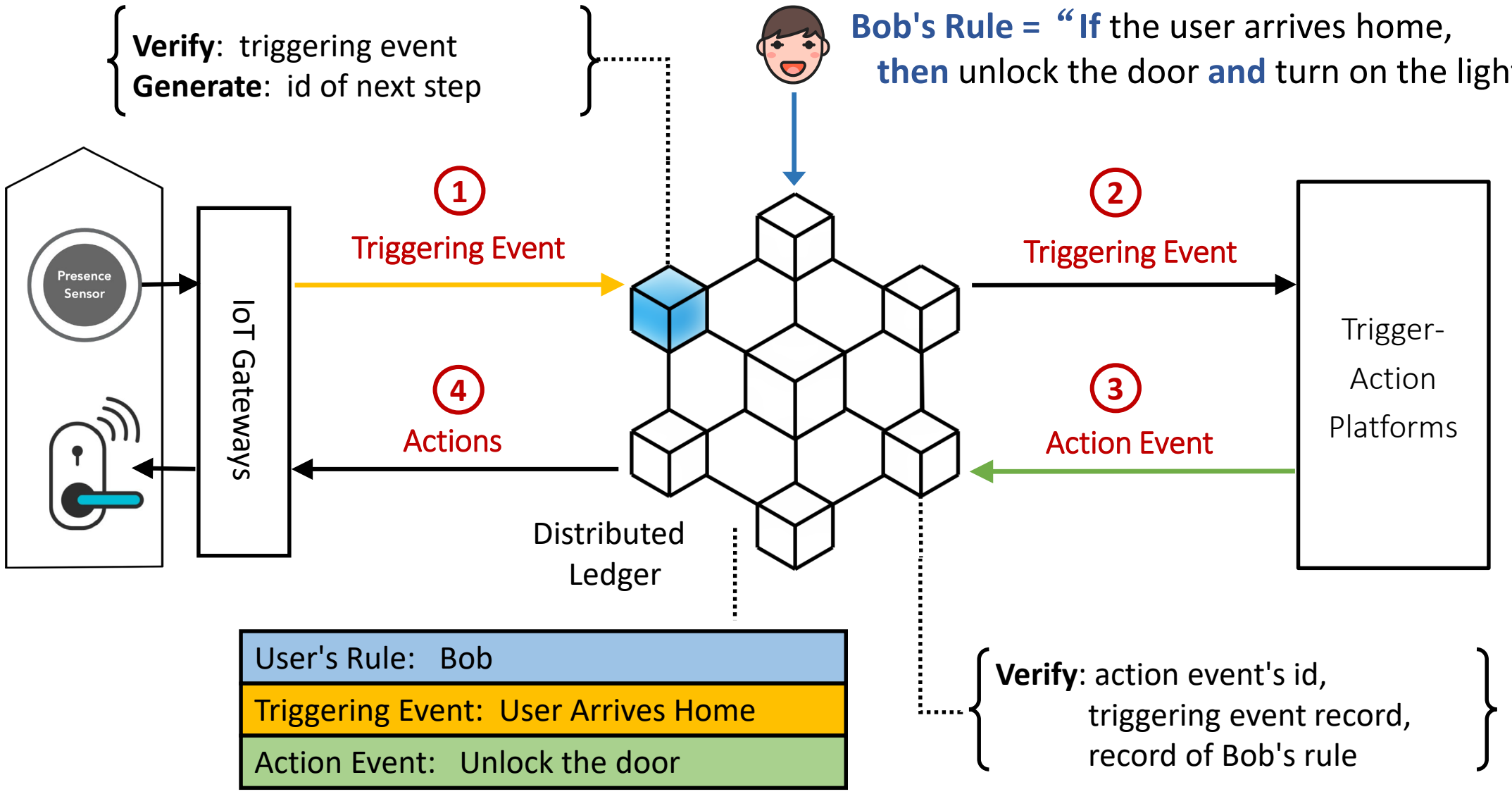
3. Prevent malicious rule execution requests from the trigger-action platforms.



We cannot fix all the vulnerabilities.

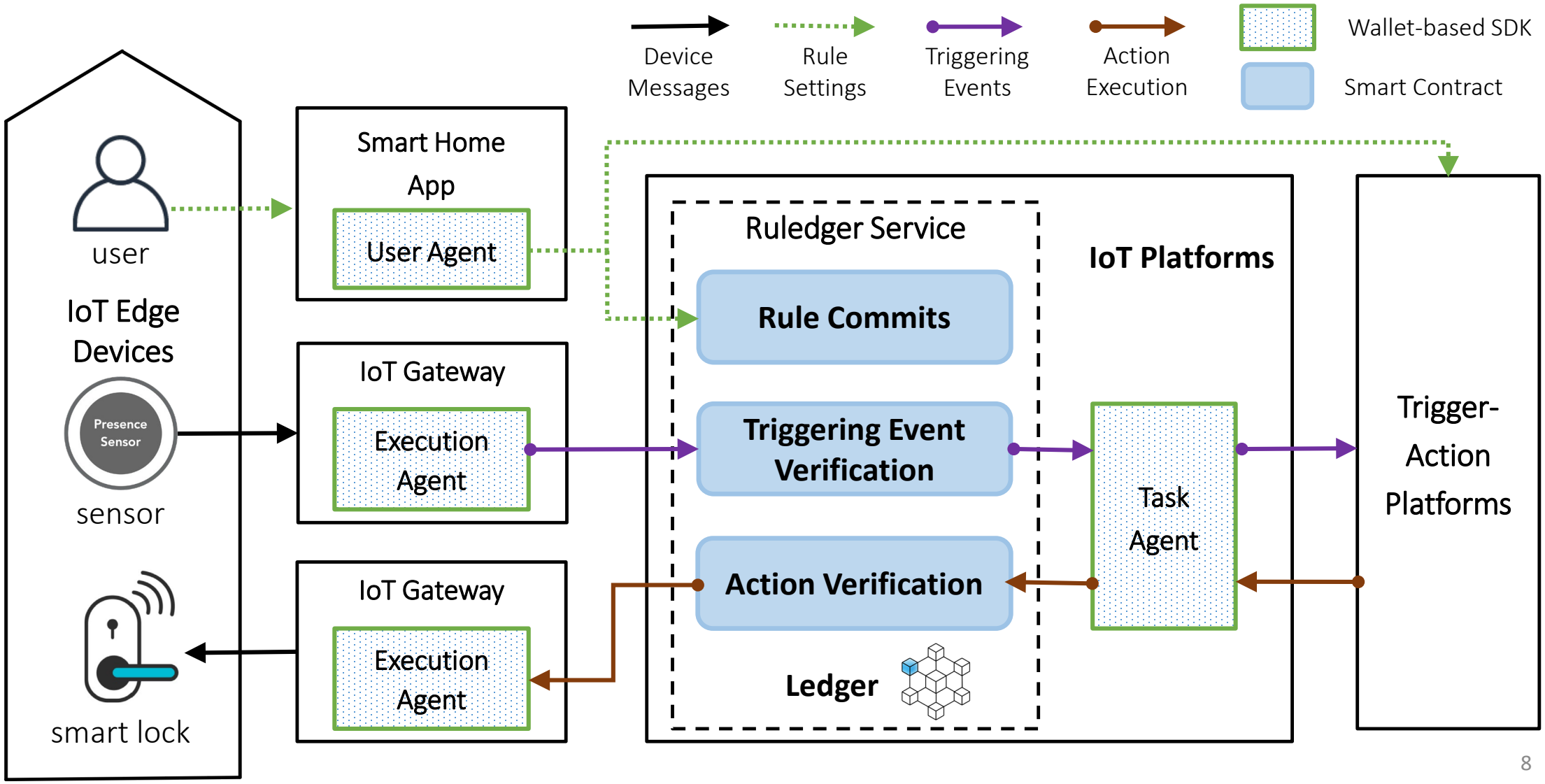
There does not exist any verification mechanism to protect the integrity of rule execution among different IoT system components.

# We Need A Novel IoT Platform



# Our Framework : Ruledger

a distributed ledger-based IoT platform for event and rule verification

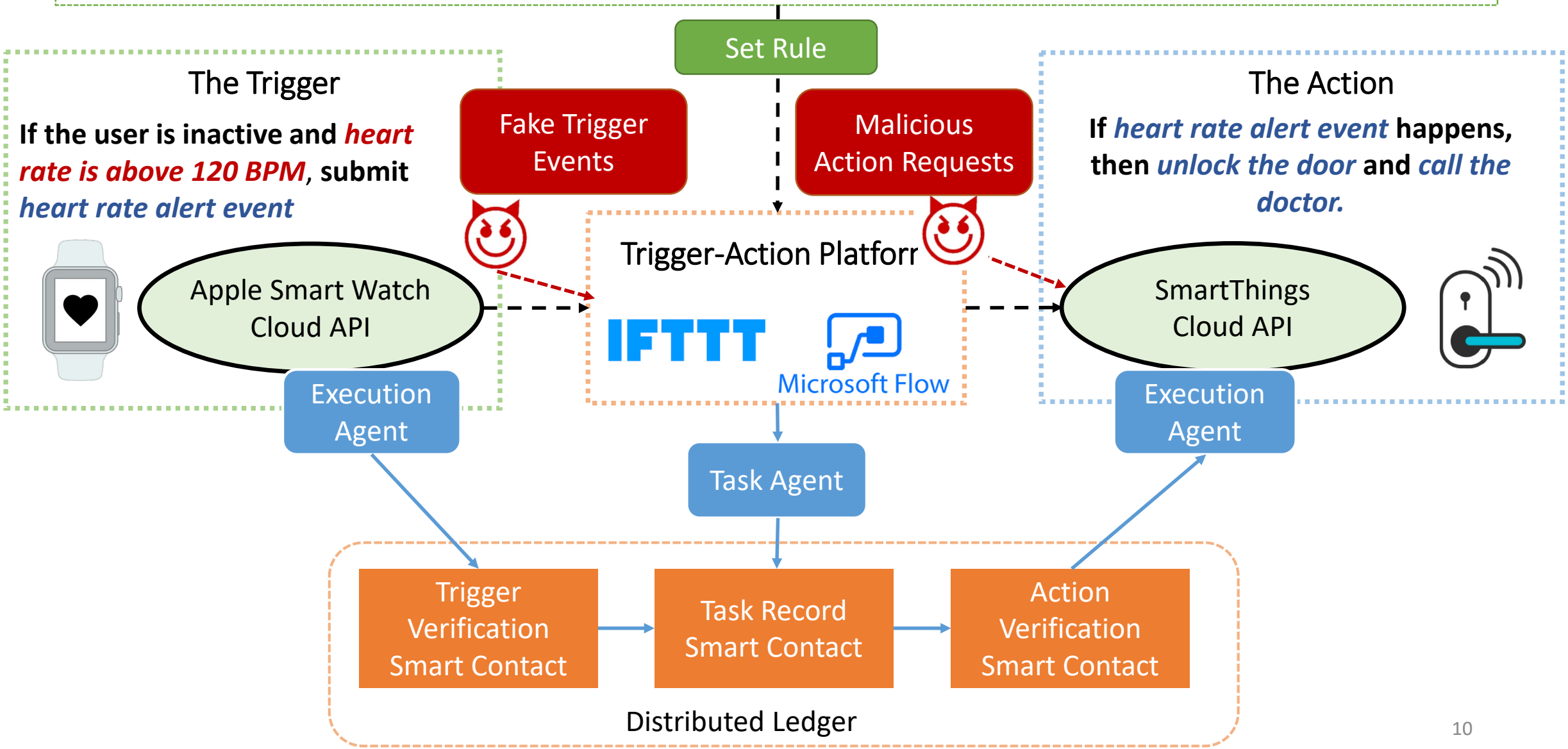


# Challenges and Solutions

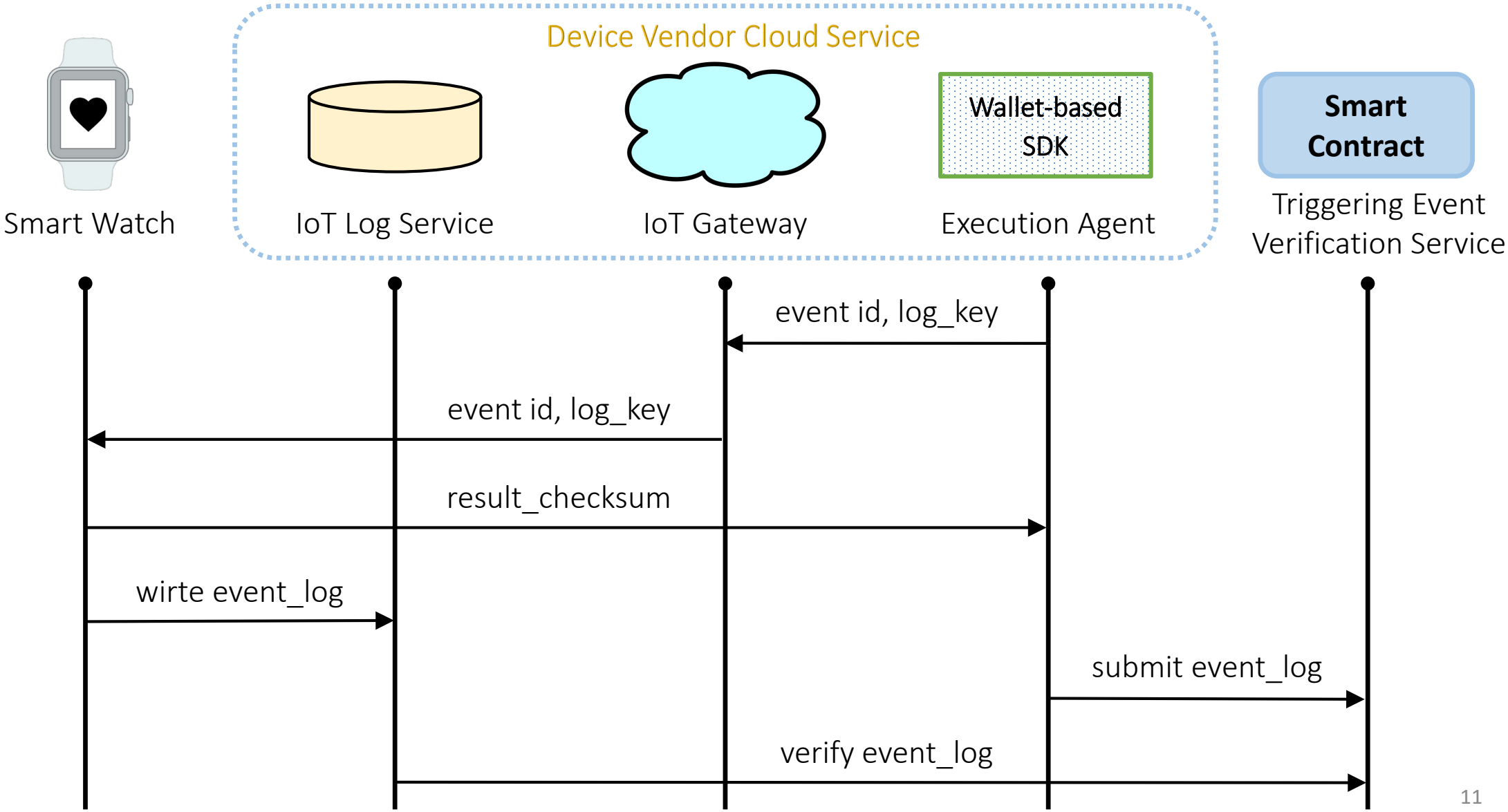
| Goal & Challenges | Solutions |
| --- | --- |
| Ensure the authenticity and integrity of rule configurations.<br>Ensure rule executions on correct devices.<br>Prevent privacy breaches. | Rule Commits Module:<br>• A set of prefab scripts that wrap device APIs of different vendors.<br>• Unified IoT events for the trigger-action platforms. |
| Check the trigger conditions and verify the triggering events.<br>Make least changes to the current IoT platforms and device platforms. | Triggering Event Verification Module:<br>• Algorithm 1: Check Trigger Condition<br>• Algorithm 2: Triggering Event Verification |
| Ensure the integrity of rule executions.<br>Develop a stateful verification framework. | Action Verification Module:<br>• Algorithm 3: Action Verification |

# Ruledger Design

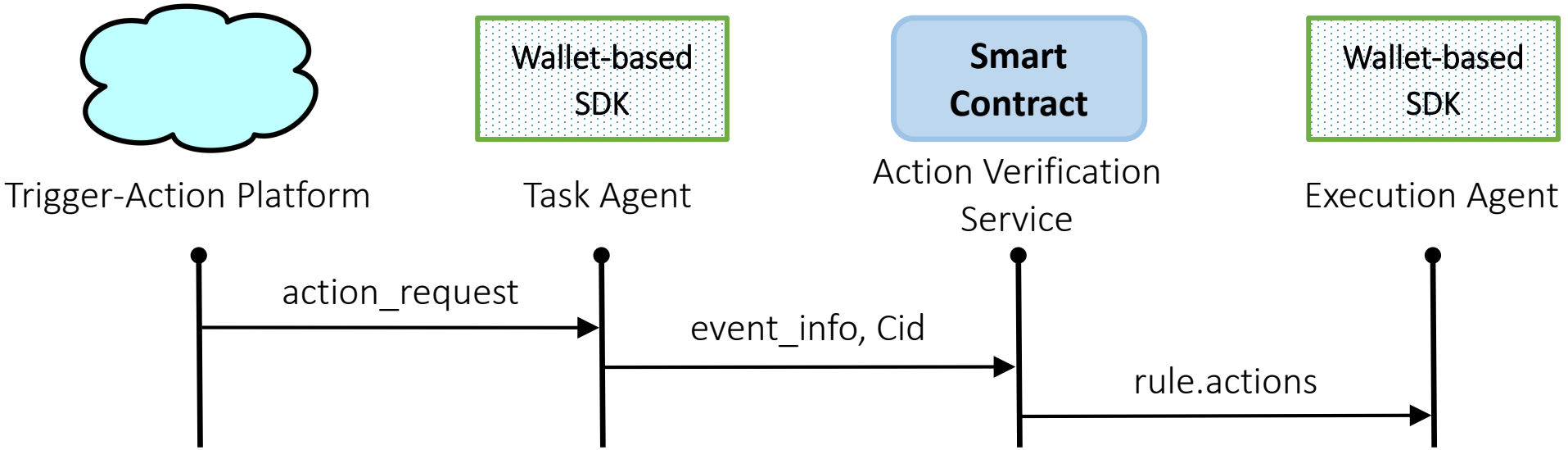
"If the user's heart rate is abnormal, then unlock the front door and call the doctor."



# Triggering Event Verification



# Action Verification

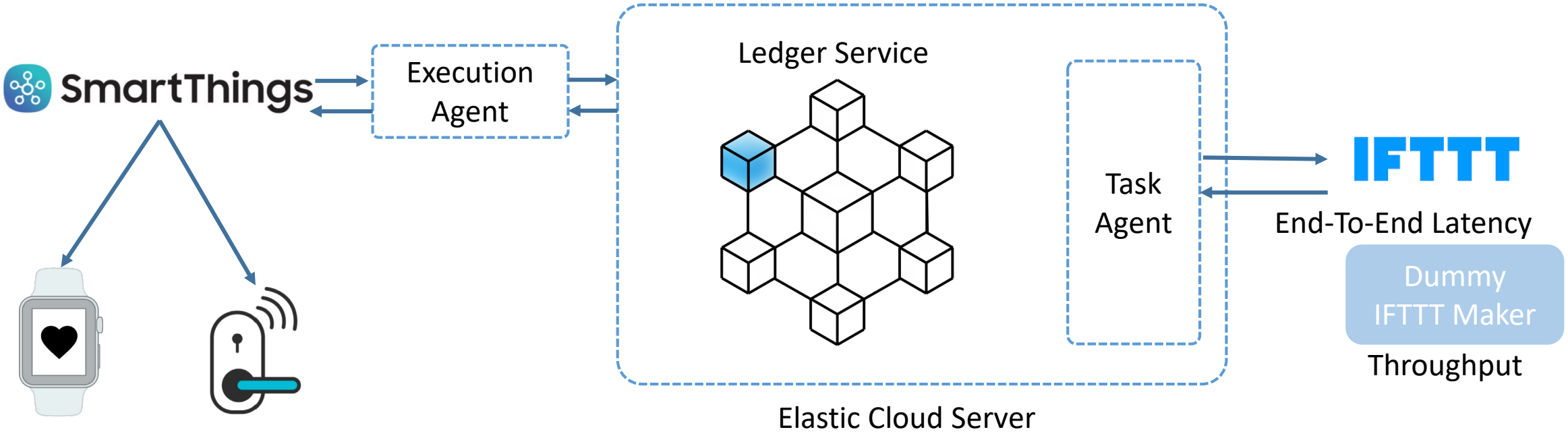



1. verify the messge, prevent reply attacks.
2. check the triggering event record, prevent event spoof attacks.
   - authenticity
   - correctness
3. check the rules in the ledger, prevent false triggering of the rules.

# Evaluation

The deployment of Ruledger

- We use 7 elastic cloud servers to deploy the ledger service.
- We use real IFTTT platform and SmartThings Platform to measure the end-to-end latency.
- Due to the rate-limit mechanism of these platforms, we need to implement simulating services to measure the throughput.



# Performance Evaluation

rule = “If the user's heart rate is above 120 times per second, then unlock the door.”

1. Performance of Ruledger Modules

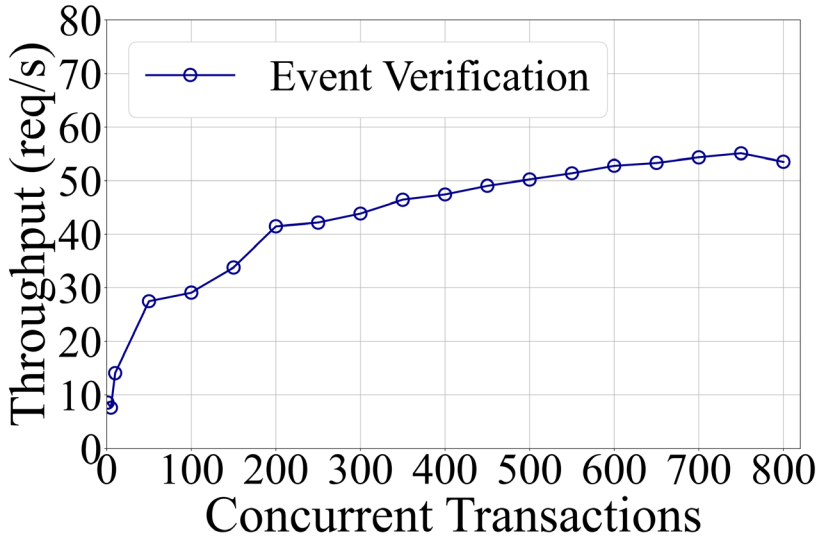
- Latency

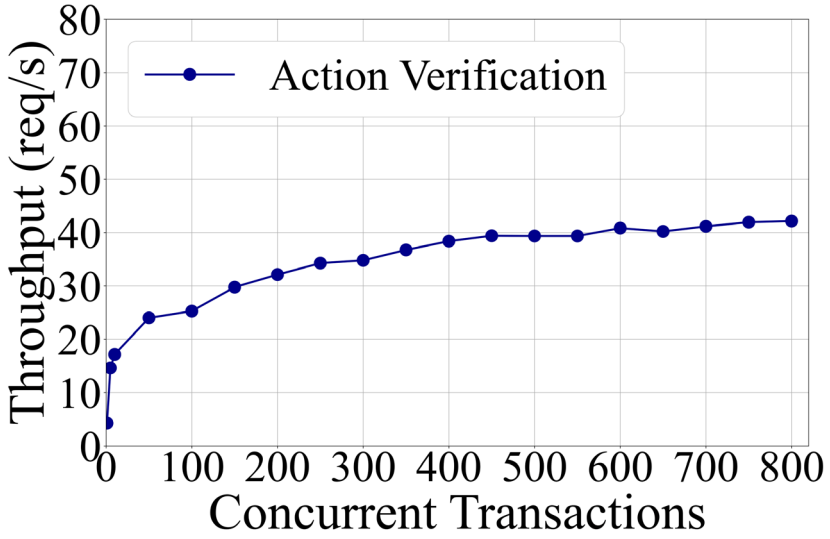
| Ruledger Module | Latency Incurred by Modules |
|---|---|
| trigger event verification | 32.45 ms |
| action verification | 32.83 ms |

total latency of the smart contract modules <70ms
4.36% of the whole rule execution latency.

- Throughput

use the execution agent and the task agent to submit different number of concurrent requests to the smart contract module.



# Performance Evaluation

2. Performance of The Entire System

- End-to-End Latency

| | SmartThings | Ruledger | Delay |
|---|---|---|---|
| End-to-end execution latency average of 30 trials | 1.403 s | 1.604 s | 12.53% |

SmartThings: Baseline system that directly connects SmartThings and IFTTT.

Ruledger: Deploy Ruledger as a middleware between SmartThings and IFTTT.

Set simulated devices for a smart watch and a smart lock in SmartThings.

- Throughput

| | Baseline | Ruledger | Decrease |
|---|---|---|---|
| Throughput (req/s) | 43.37 | 40.57 | 6.5% |

implement a skeleton device simulator and a trigger-action service.

2000 concurrent requests using Apache JMeter.

Baseline: the execution agent sends the trigger event directly to the task agent.

# Summary

- Ruledger : A ledger based IoT platform to protect the integrity of rule executions in trigger-action based smart home system.
  - wallet-based agents record stateful information generated by smart home systems in the ledger during rule executions.
  - smart contracts automatically verify the authenticity of the information according to the tamer-proof ledger records.
- State generation and verification algorithm built upon ledgers and wallet-based agents to ensure the stateful information are properly submitted and verified.
  - check trigger conditions, triggering event verification
  - action verification
- Prototype Ruledger with a real trigger-action platform and a real IoT system SmartThings.
  - acceptable overhead, feasible to be deployed in large scale.

# Thank you for your time !