Advanced System Resiliency Based on Virtualization Techniques for IoT Devices

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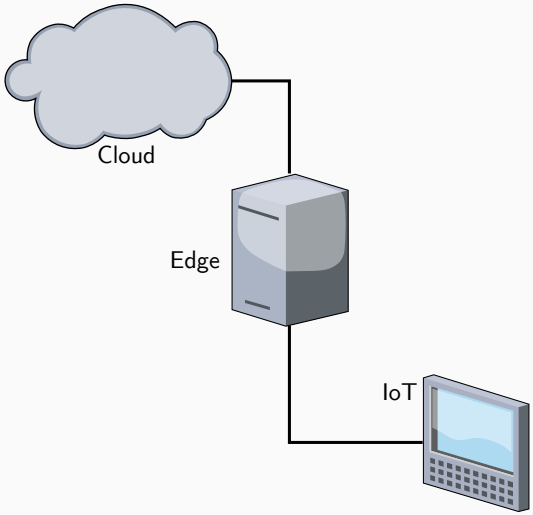
9 December 2021

Motivation

- IoT and edge is on the rise [4, 2]



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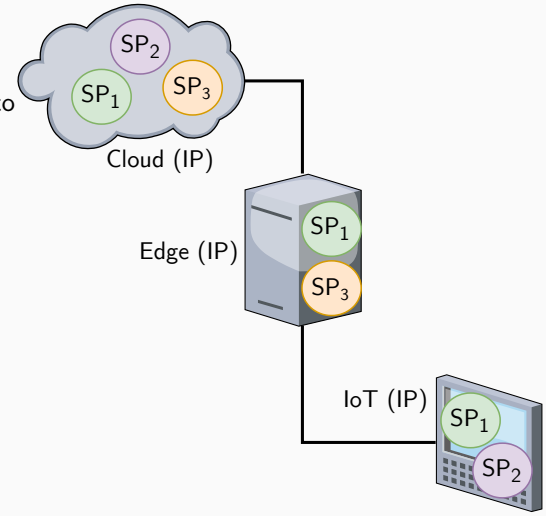

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- Critical vulnerabilities (Ripple20 [5], Amnesia:33 [6]) and botnets [1, 3] targeting IoT deployments
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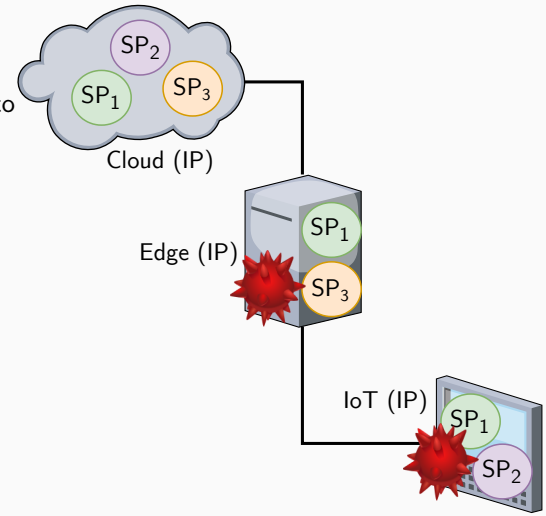

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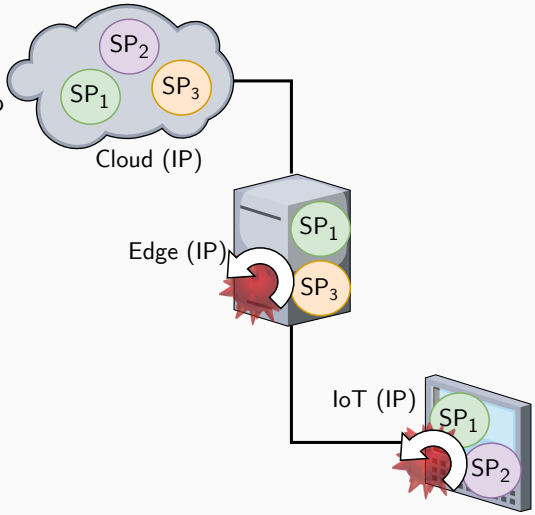
- **How can we link strong remote recoverability for service providers and intrusion and anomaly detection?**



Background

Dominance

Dominance (Xu et al. [8])

The hub dominates a device if the hub can choose arbitrary code and force the device to run it within a bounded amount of time.

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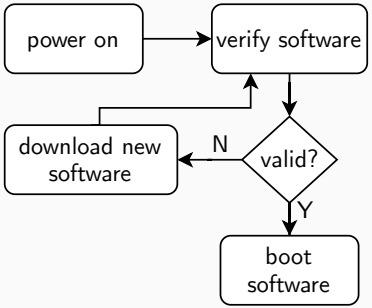
Gated Boot



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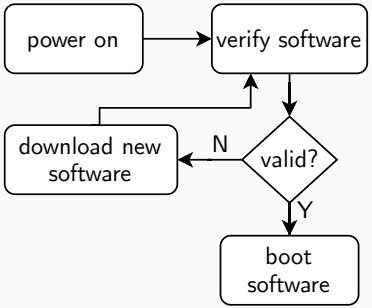
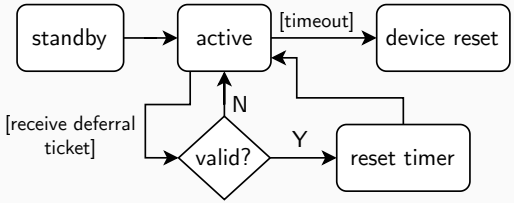


Reset Trigger

Authenticated Watchdog Timer (AWDT)



Novel Trusted Computing Concepts

Strong Dominance

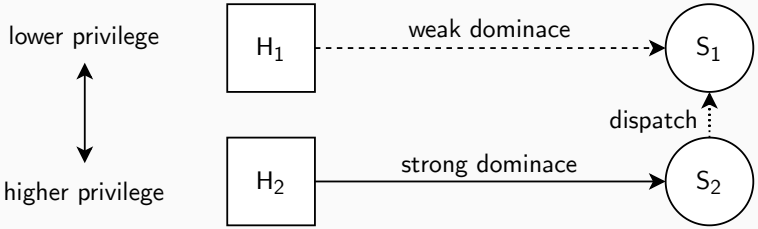
Dominance (Xu et al. [8])

The hub dominates a device if the hub can choose arbitrary code and force **the device** to run it within a bounded amount of time.

Strong Dominance

A hub *strongly dominates* a **scheduler** if the hub can choose arbitrary code and force the **execution of the code as an activity of the scheduler** in a bounded amount of time.

Weak Dominance



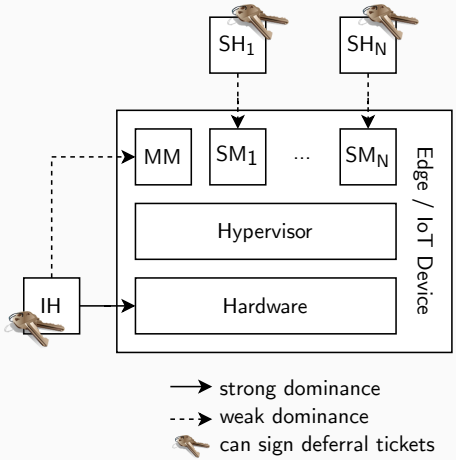
Weak Dominance

A hub H_1 *weakly dominates* a scheduler S_1 if the following conditions are fulfilled:

1. There is a hub H_2 that strongly dominates a scheduler S_2.
2. The scheduler S_2 dispatches the scheduler S_1.
3. Given that H_2 behaves cooperatively, H_1 can choose arbitrary code and force its execution in an activity of the scheduler S_1 in a bounded amount of time.

System Architecture

System Architecture



- Service Machines (SMs)
  - Weakly dominated by a Service Hub (SH)
  - Encapsulate services

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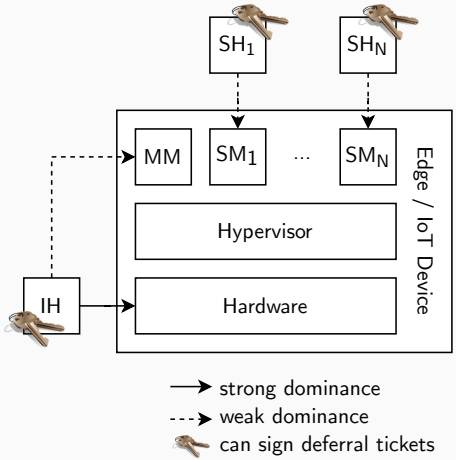

- Service Machines (SMs)
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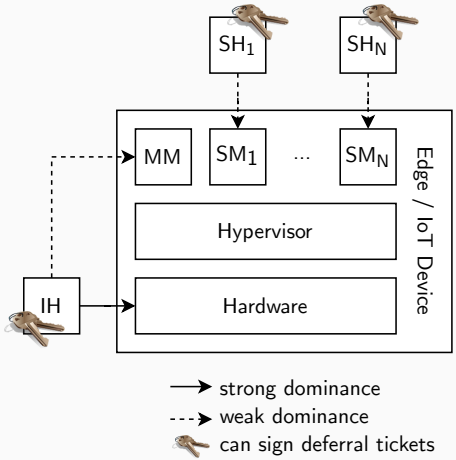
- Management Machine (MM)
  - Weakly dominated by an Infrastructure Hub (IH)
  - Isolates the network stack during runtime
  - Provides dominance-related functionalities

System Architecture



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- Management Machine (MM)
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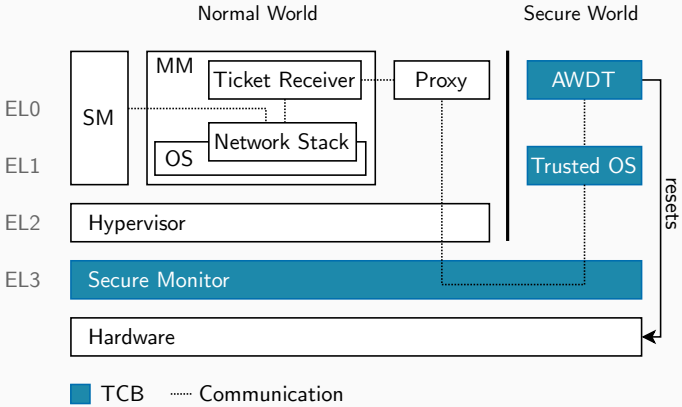
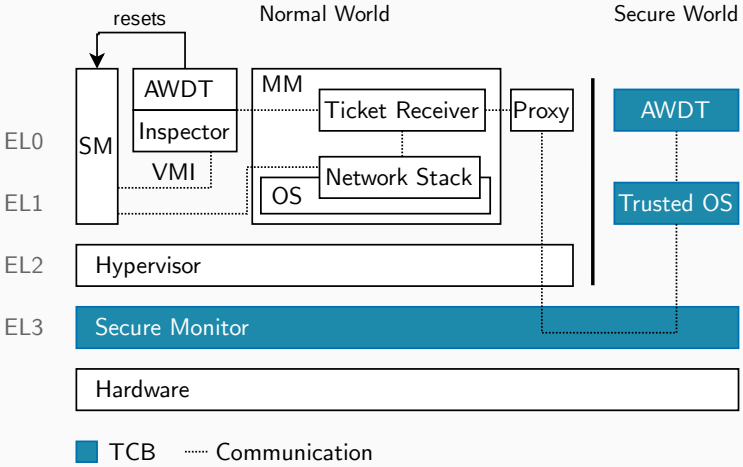
  - Isolates the network stack during runtime
  - Provides dominance-related functionalities
- An SP can recover a weakly dominated SM even after a severe software compromise
- Even in case of an VM espace: The IH can still recover the device

Achieving Strong Dominance



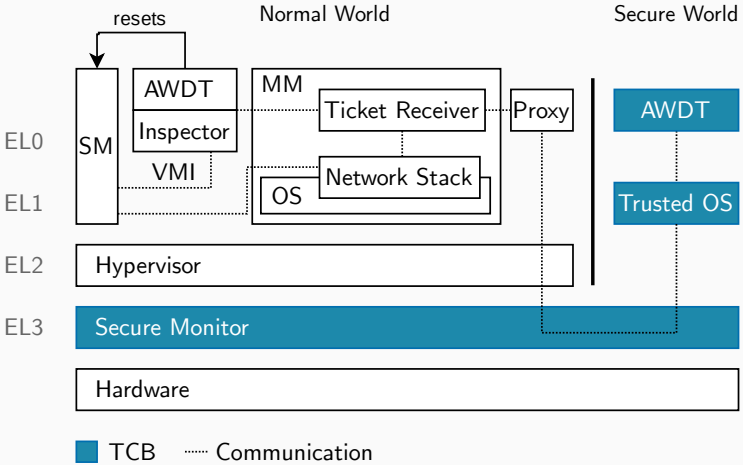
- During boot: Gated Boot
- Ticket Receiver acquires deferral ticket from IH regularly
- TCB compromise: No remote recoverability any longer

Achieving Weak Dominance



- During VM boot: *Virtual Gated Boot*

Achieving Weak Dominance



- During VM boot: *Virtual* Gated Boot
- Ticket Receiver acquires deferral ticket from SH regularly
- Requests for deferral tickets contain dynamic runtime state (VMI)
- Granular resets of SMs

Implementation and Evaluation

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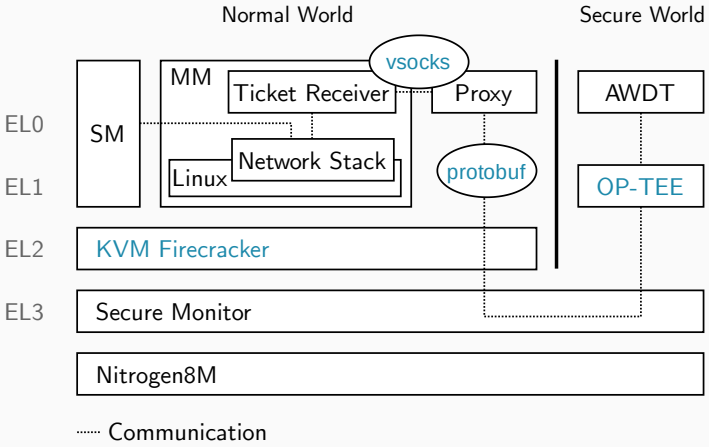

- Boundary Devices Nitrogen8M, Cortex A-53, 2GB RAM

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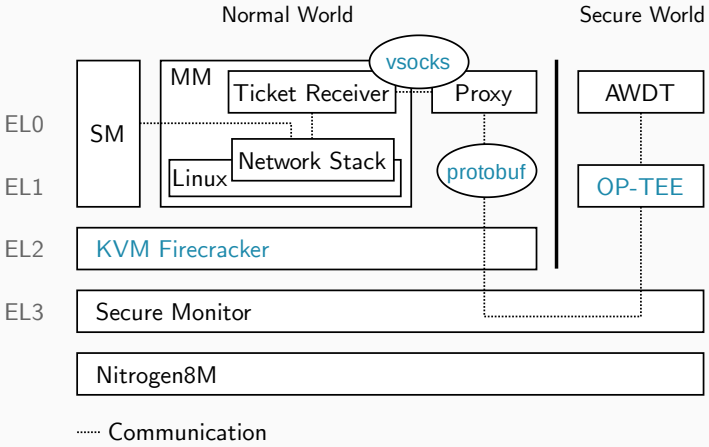

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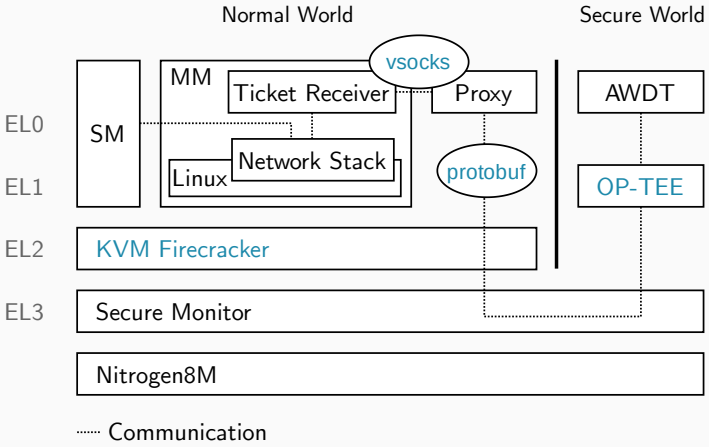

- Boundary Devices Nitrogen8M, Cortex A-53, 2GB RAM
- TCB: ARM Trusted Firmware, OP-TEE, AWDT, Gated Boot: 600 kLoC (no hypervisor)
- Dominance components do not add overhead, virtualization does

Summary

Summary

- Trusted computing concepts: Strong dominance and weak dominance for future resilient IoT and edge deployments
- Application-level protocol that binds the runtime state to strong recoverability guarantees
- System architecture for the proposed concepts, assuming shared edge and IoT infrastructure
- Proof of concept implementation, showing feasibility

Thank you for your attention!

Feel free to ask questions!

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