Scotch: Combining Software Guard Extensions and System Management Mode to Monitor Cloud Resource Usage

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Summary

We use **Intel Software Guard Extensions (SGX)** and **System Management Mode (SMM)** to accurately monitor **resource consumption** of virtual machines (VMs) **in the presence of a compromised VM or hypervisor**

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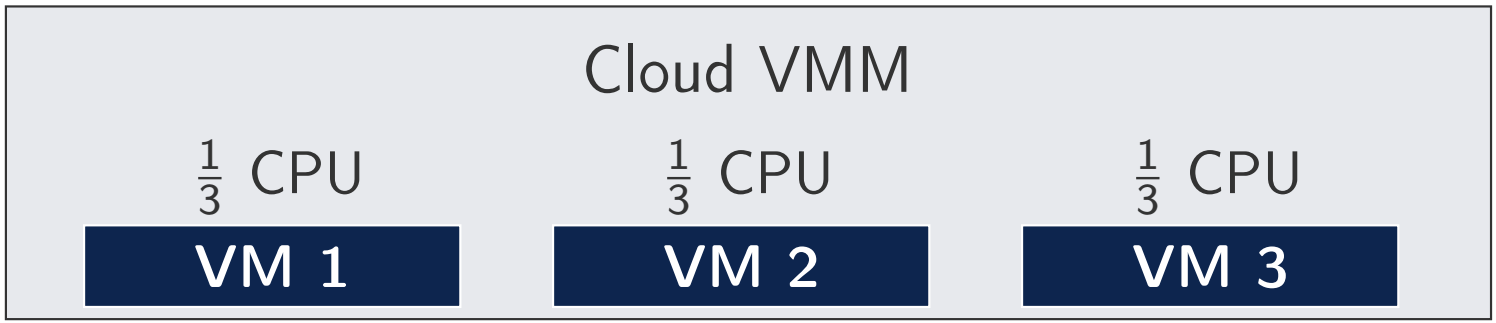

If all 3 VMs peg the CPU, the VMM must decide how to allocate CPU time based on each client's service level.

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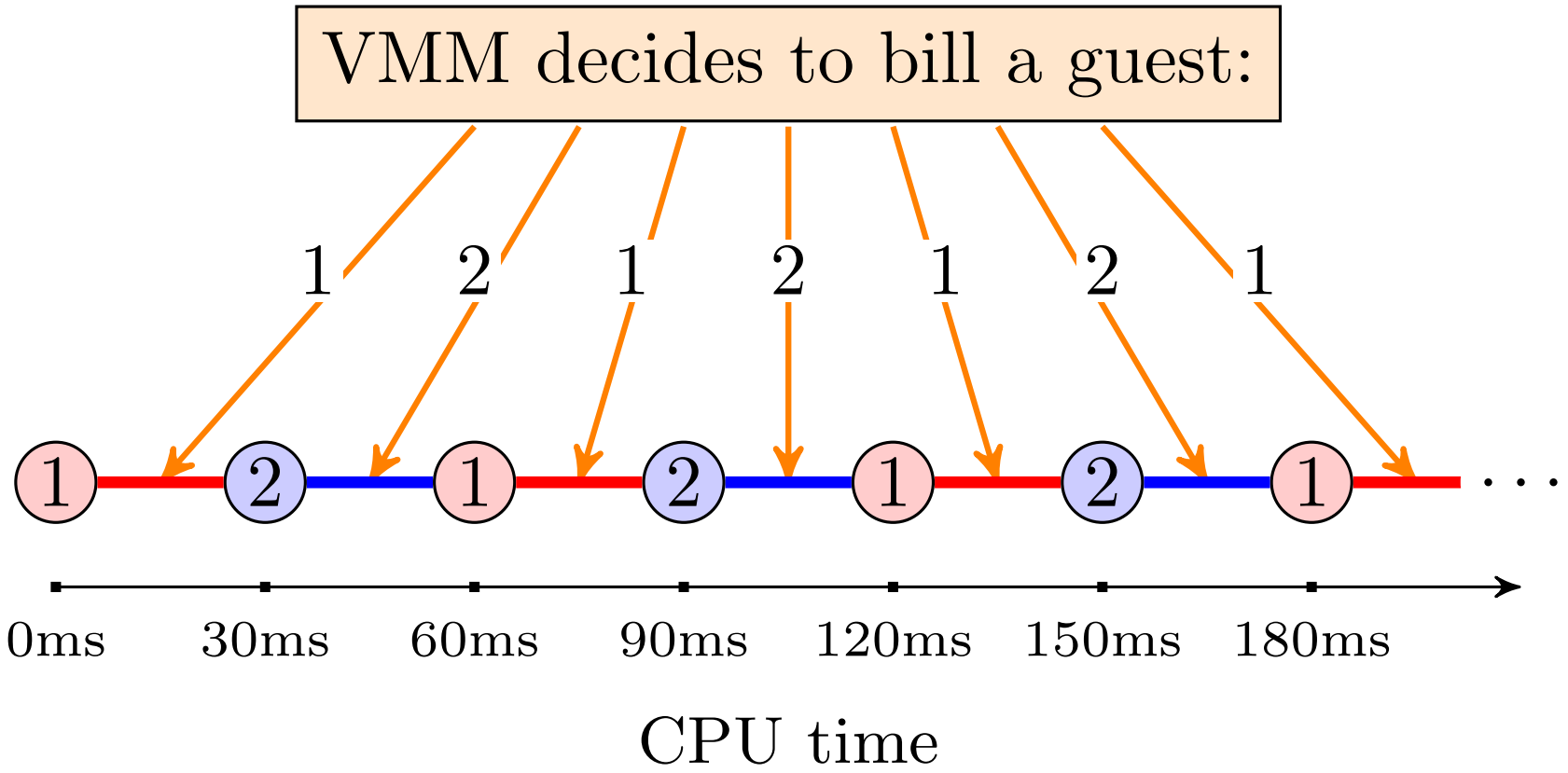
2. What if the VMM is vulnerable to malicious VMs?
   - Malicious VM manipulates resource consumption to steal resources from benign customers

Resource Accounting Attacks

- Benign Behavior



The Xen hypervisor regularly checks which VM is active to determine how much CPU time each VM uses

Resource Accounting Attacks

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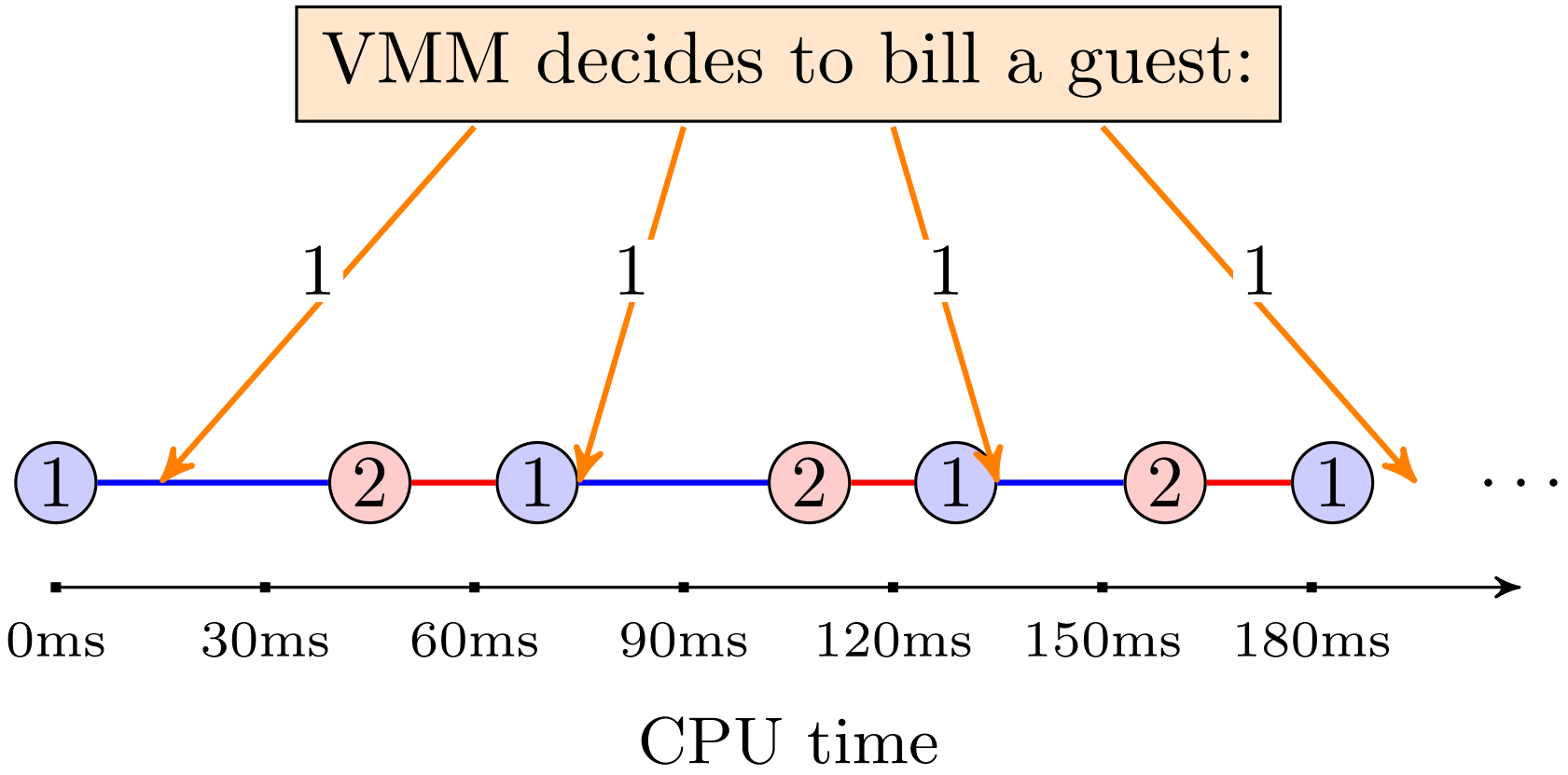
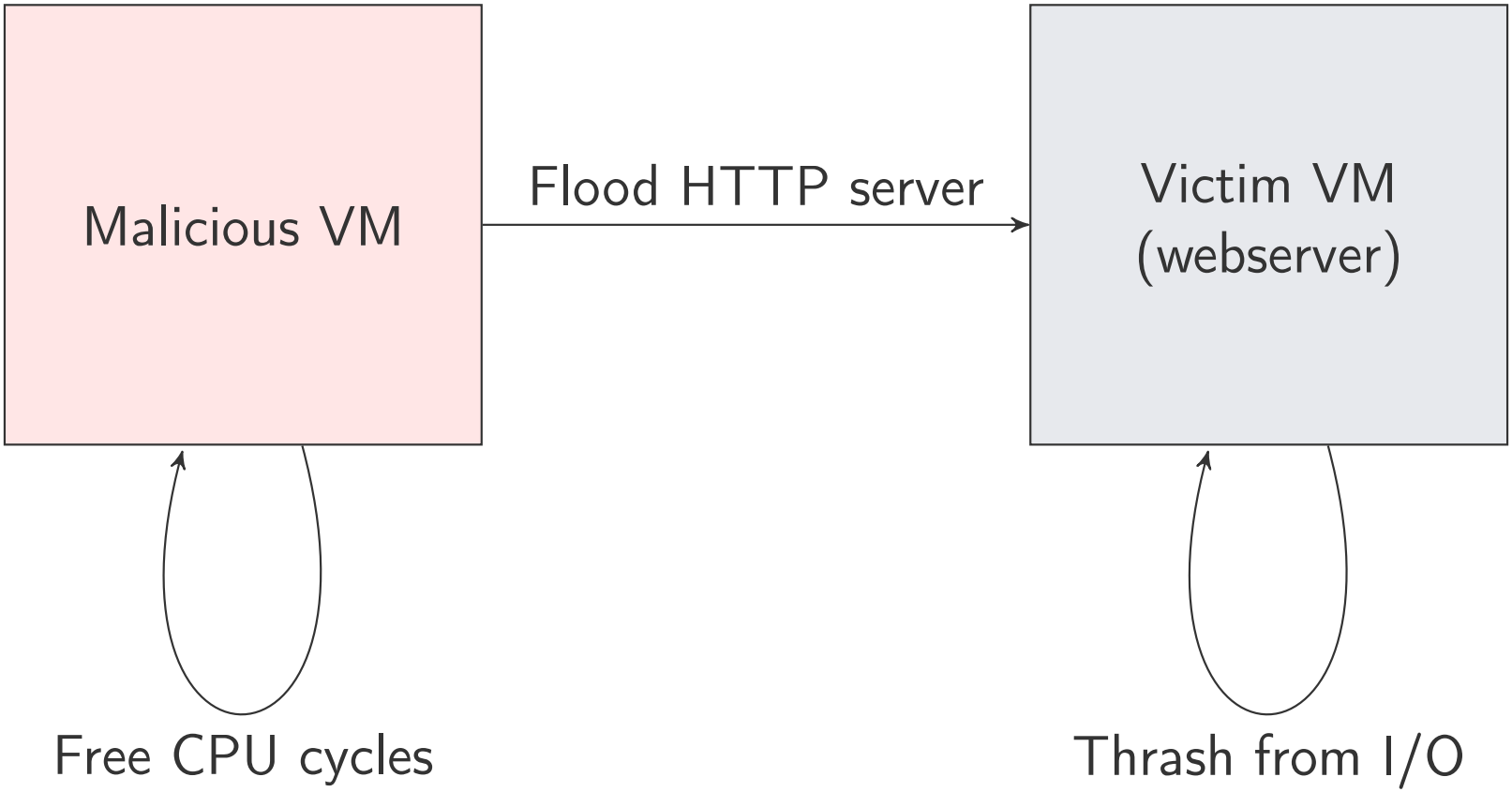


A malicious VM (2) with knowledge of the VMM can affect the appearance of resource consumption by itself and benign VMs.

Resource Interference Attacks

Attacker can take advantage of known victim behavior



Malicious VM can cause benign VM to free up resources for itself

VM Escape Attack

Malicious VM can exploit buggy VMM implementation, allowing code execution with VMM privilege

- Could potentially alter resource consumption to hide itself

Scotch: Transparent Cloud Resource Accounting

Two desired properties

1. **Transparent**
   - The underlying VMM and VMs are not aware accounting occurs
2. **Tamper-resistant**
   - A malicious VMM or VM guest cannot reliably alter accounting data

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- SMM logically collects data, then relays it to SGX enclave

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- Raw data collected by SMM is relayed to SGX enclave

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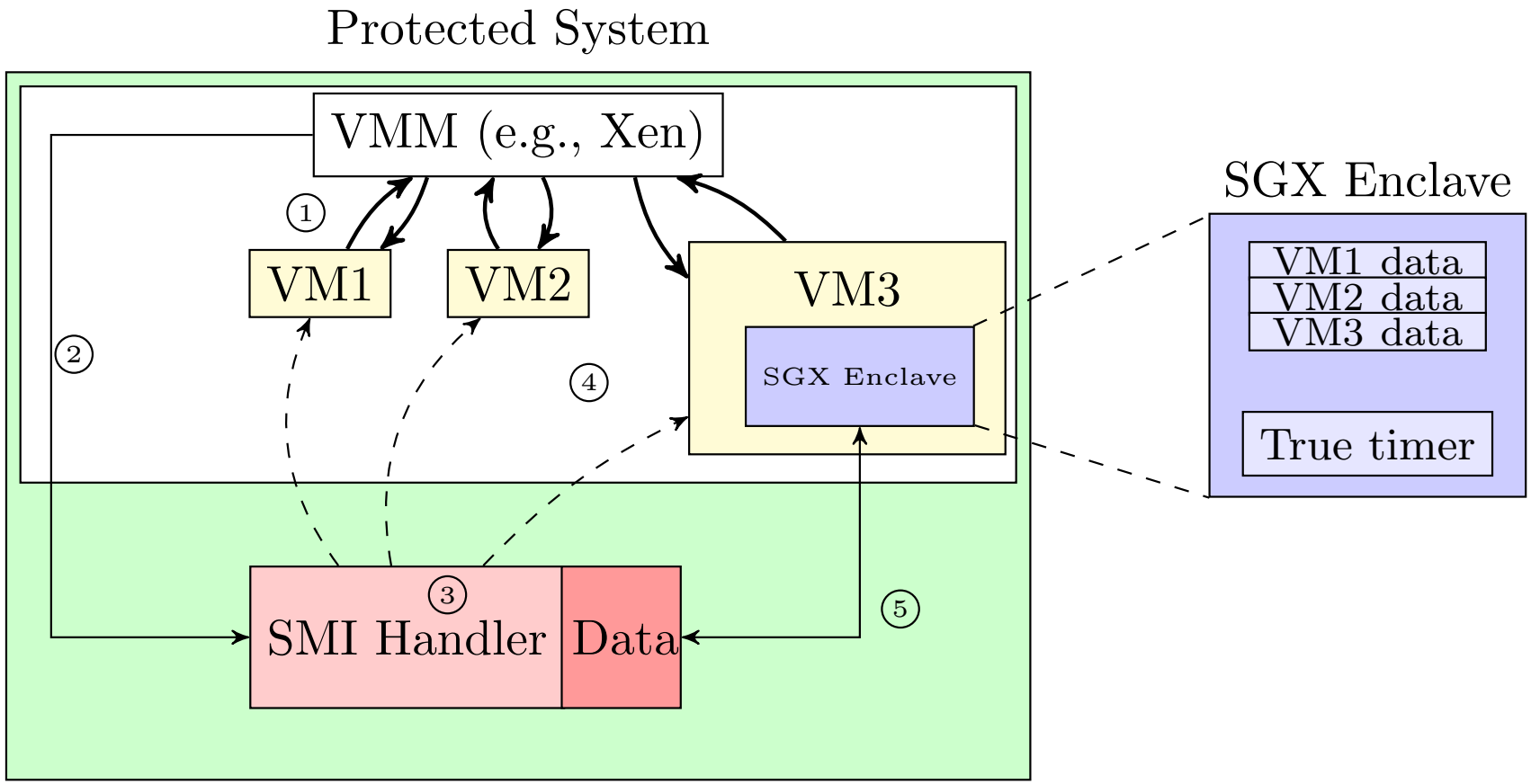
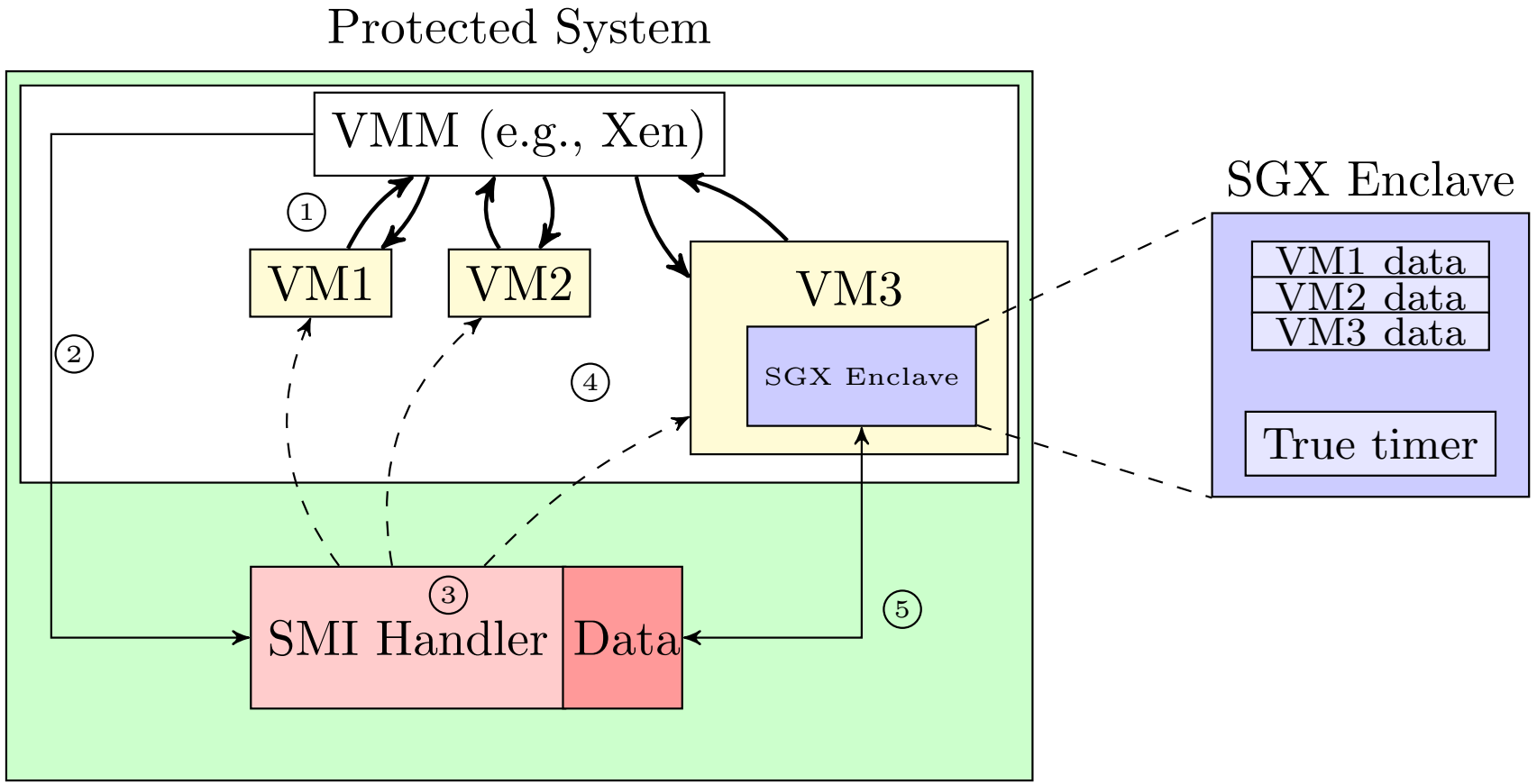


1. VMM decides to switch between VM guests

Scotch: Transparent Cloud Resource Accounting



2. Scotch measures resource consumption by invoking SMM every context switch

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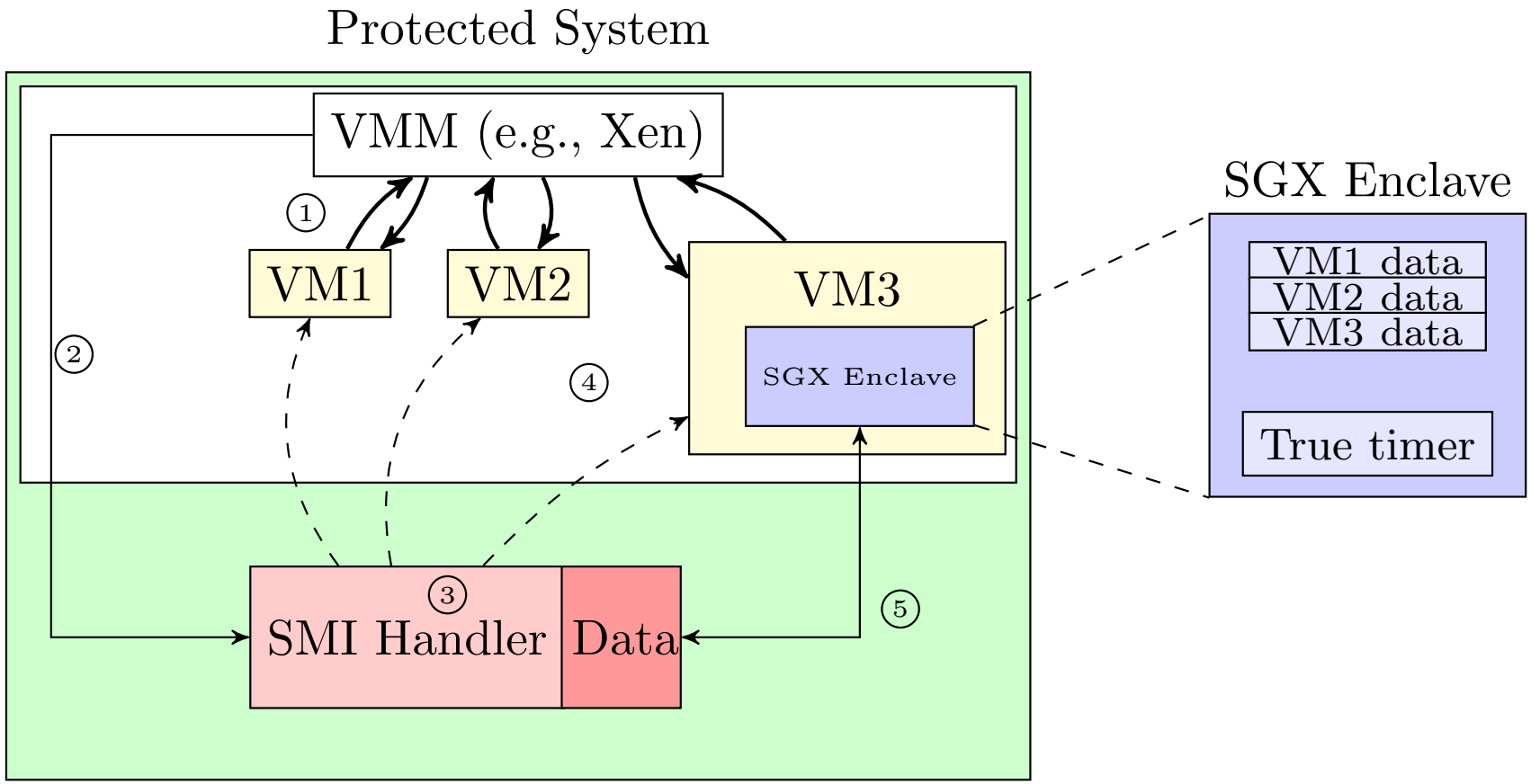

3. SMM handler executes resource accounting in isolation

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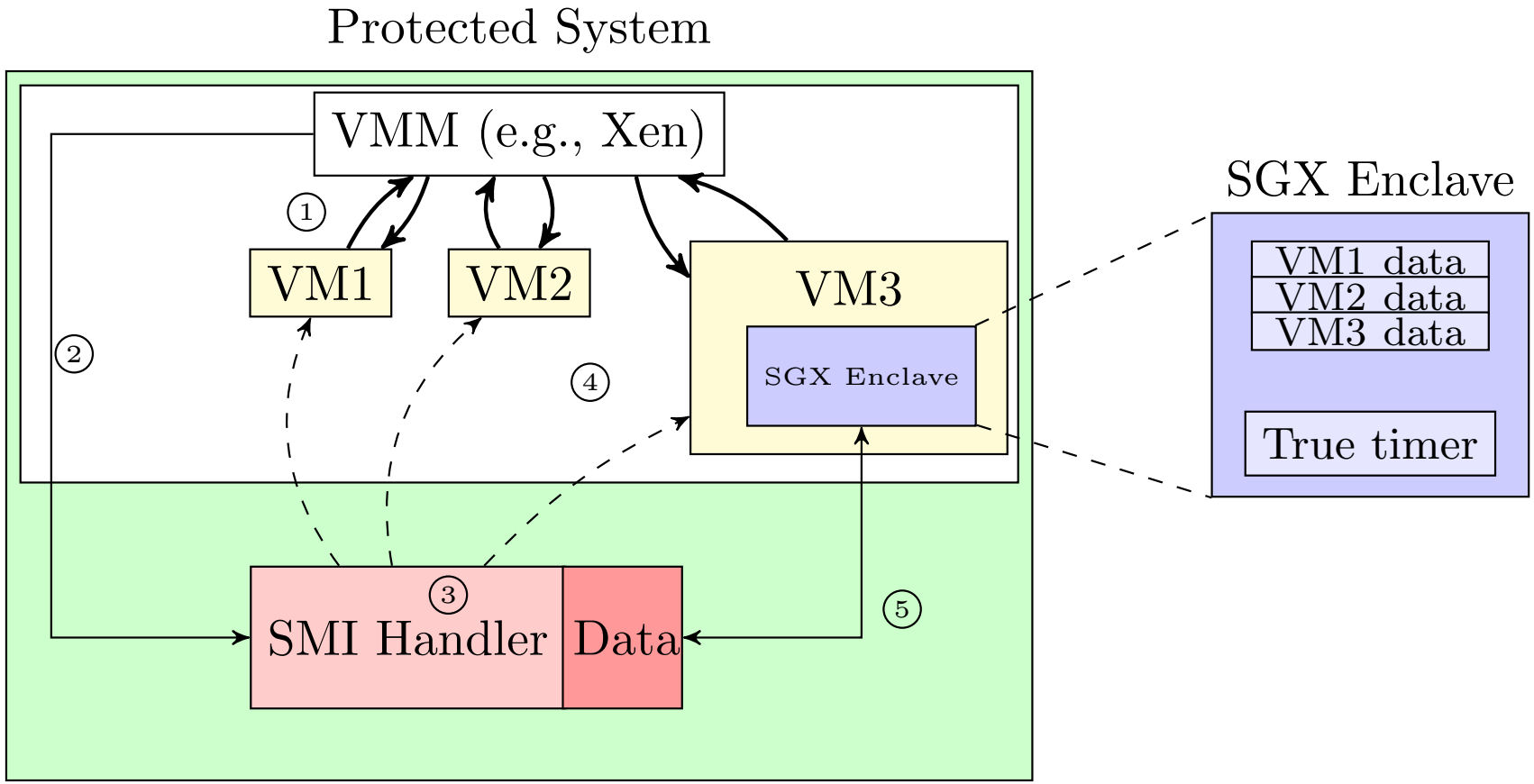

4. Data is marshalled to SGX enclave within VM

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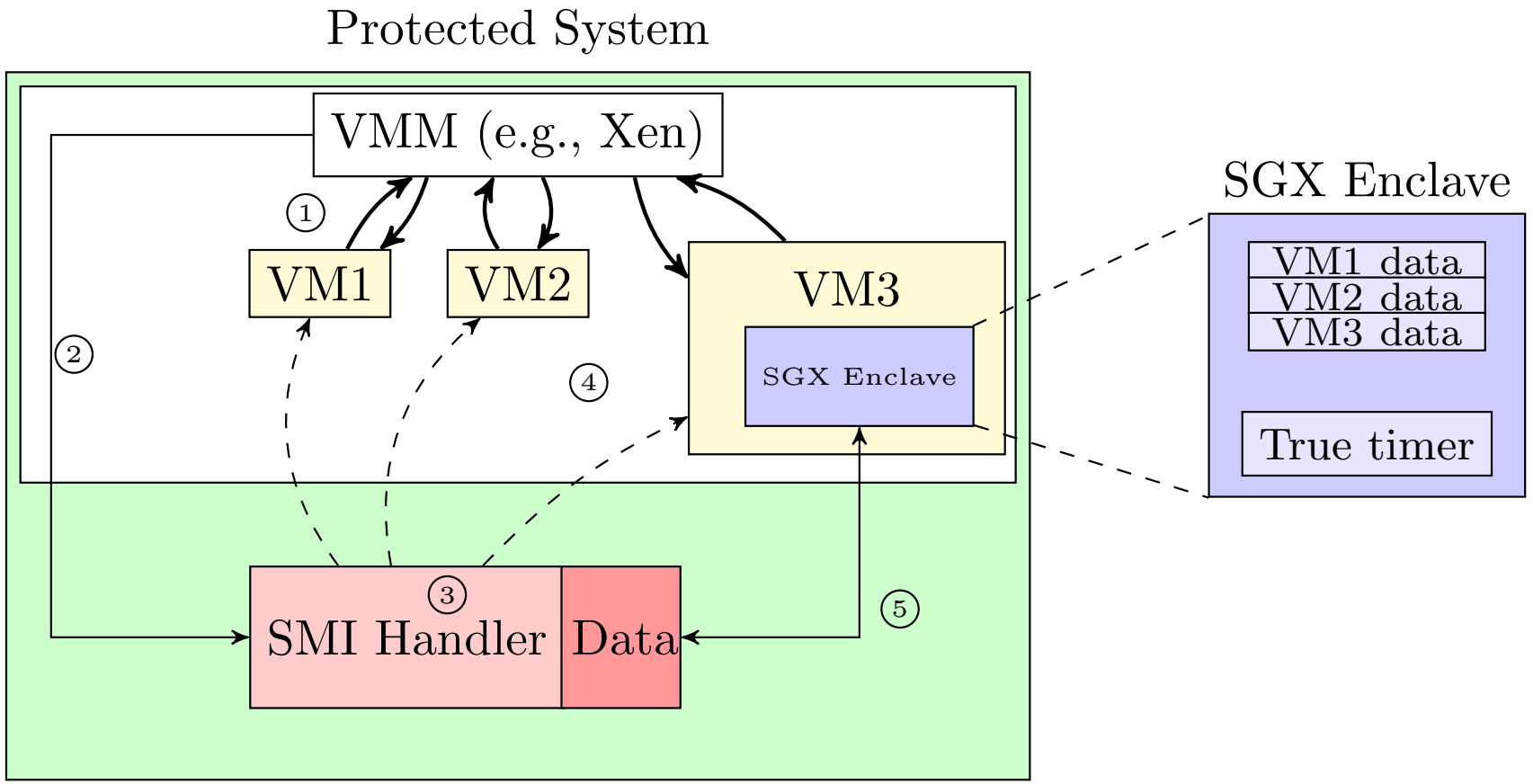

5. Benign VM can monitor resource accounting data with high integrity

Evaluation

Research Questions

- RQ1: Can we maintain accurate accounting during scheduler attacks?
- RQ2: What is our overhead on benign workloads?
- RQ3: Can we maintain accurate accounting during resource interference attacks?
- RQ4: Can we maintain accurate accounting during VM escape attacks?

RQ1: Scheduler Attacks

- Implement controllable scheduler
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- **TL;DR** Scotch shows significant difference in allocated CPU time

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Table : Ratio of attacker VM CPU time to guest VM CPU time.

	Scheduler attack severity level						
	Benign	1	3	5	7	9	10
Scotch	1.00	1.04	1.10	1.17	1.26	1.36	1.41
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The attacker receives disproportionate CPU time. Ground truth obtained with Xentrace.

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- **.0033% system overhead on CPU-bound workloads**

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- By construction, Scotch provides accurate accounting information
- Scotch does not automatically detect Resource Interference Attacks
- However, SGX allows userspace access to reliable accounting information
  - Client can monitor their resource usage and perform their own analysis for their case

RQ4: VM Escape Attacks

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- Even if attacker roots hypervisor, they cannot change the accounting code
- BIOS locks SMRAM, so no opportunity for attacker to infiltrate SMM if BIOS is trusted

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- Scotch accounts for resource usage every context switch, introducing minimal overhead on indicative workloads
- Scotch accurately accounts for CPU time consumption in the presence of scheduler attack
  - Porting drivers to SMM would readily admit incorporating accounting for additional types of resources, such as network usage
- By construction, Scotch protects the hypervisor from VM escape and other control hijacking attacks