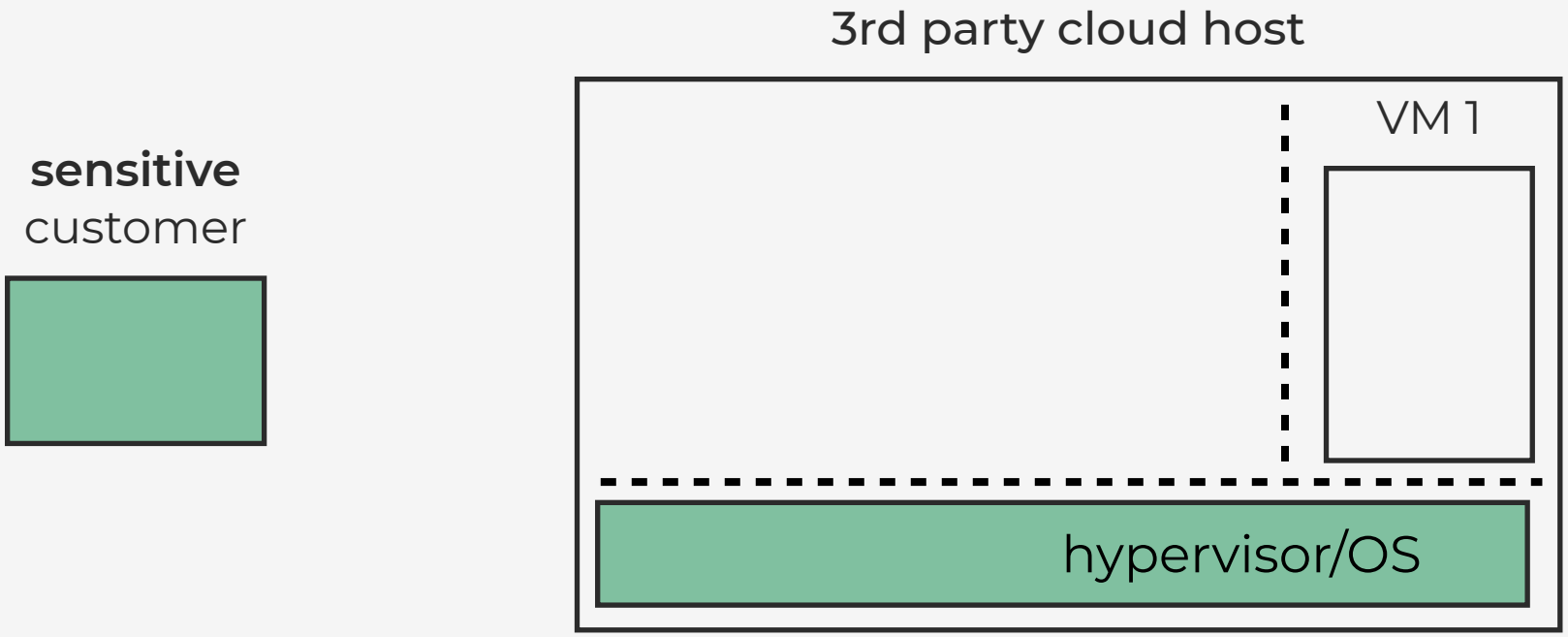
CISPA
HELMHOLTZ CENTER FOR INFORMATION SECURITY

00SEVen — Re-enabling Virtual Machine Forensics

Introspecting Confidential VMs Using Privileged in-VM Agents

Fabian Schwarz and Christian Rossow | USENIX Security 2024
CISPA Helmholtz Center for Information Security

Motivation: Securely Offload and Inspect Cloud VMs



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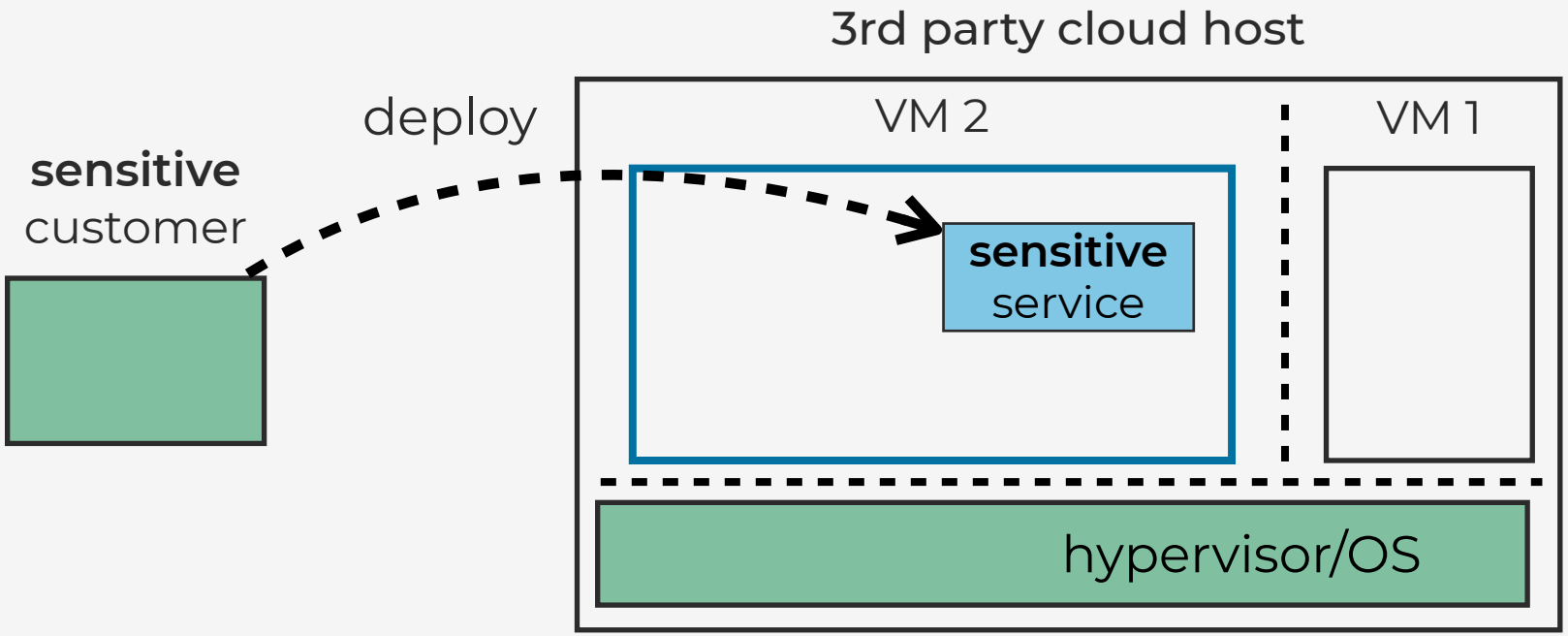

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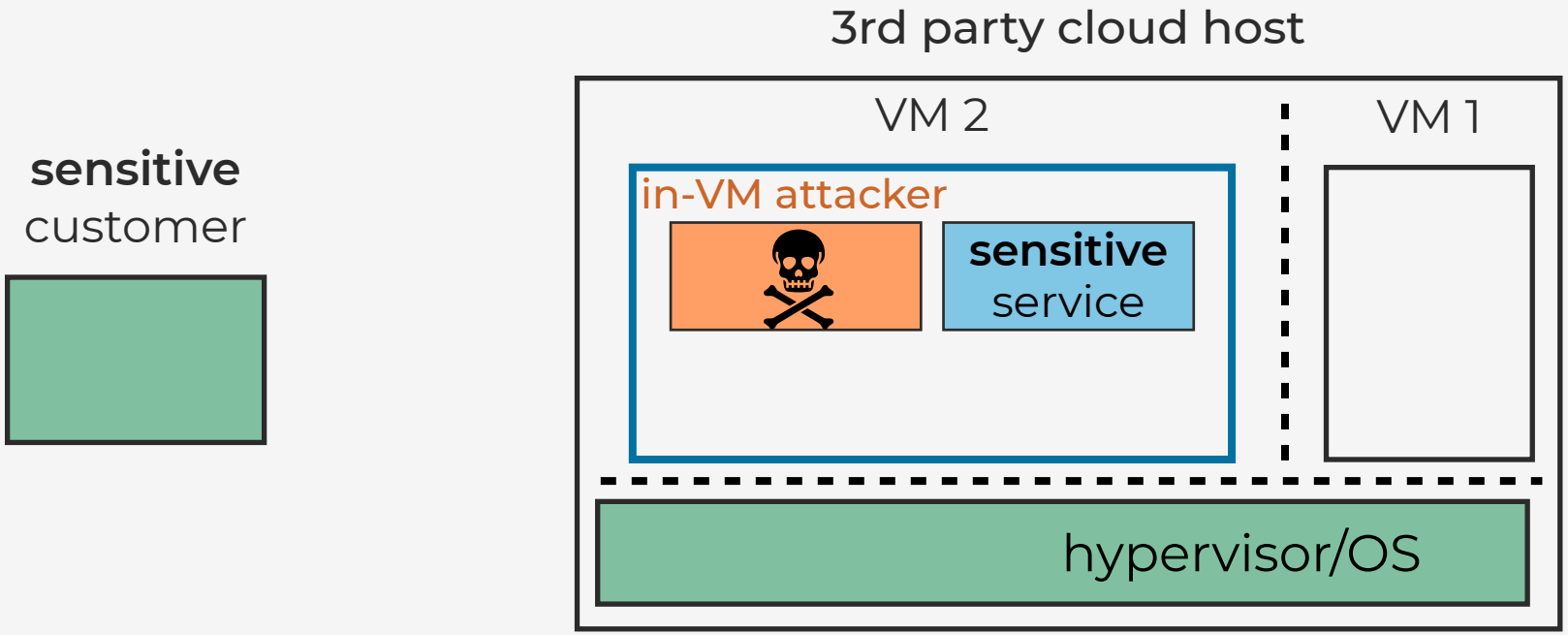

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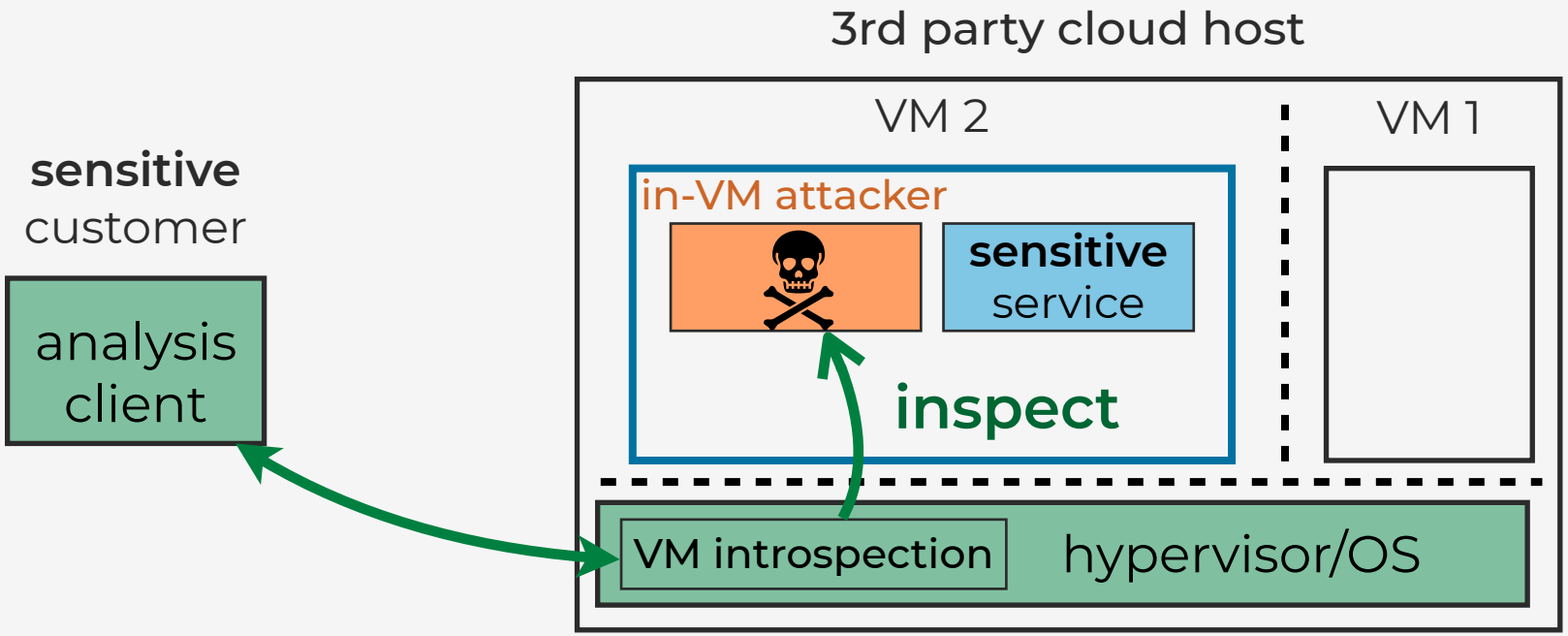

- **VM introspection (VMI)** enables secure monitoring of compromised VMs for in-VM attackers (malware, rootkits)
  - inspect memory + registers
  - pause VM on demand
  - trap VM page access

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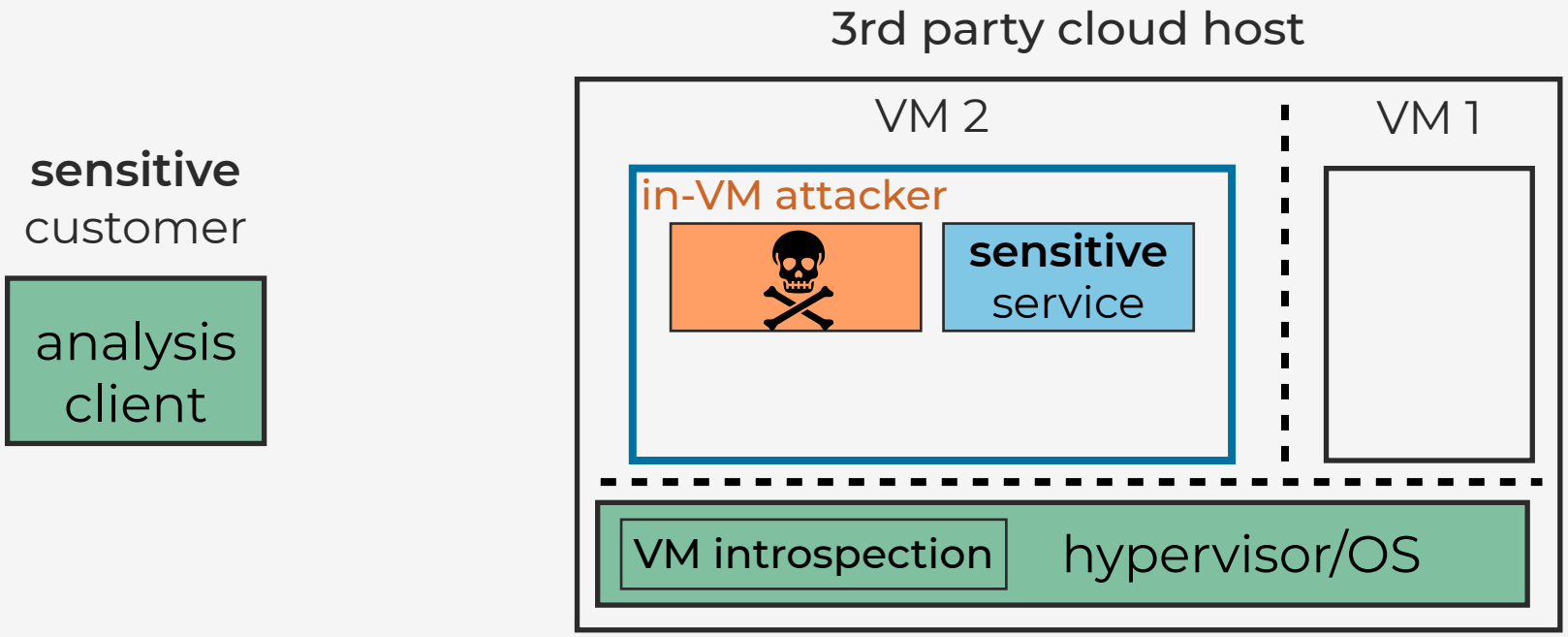
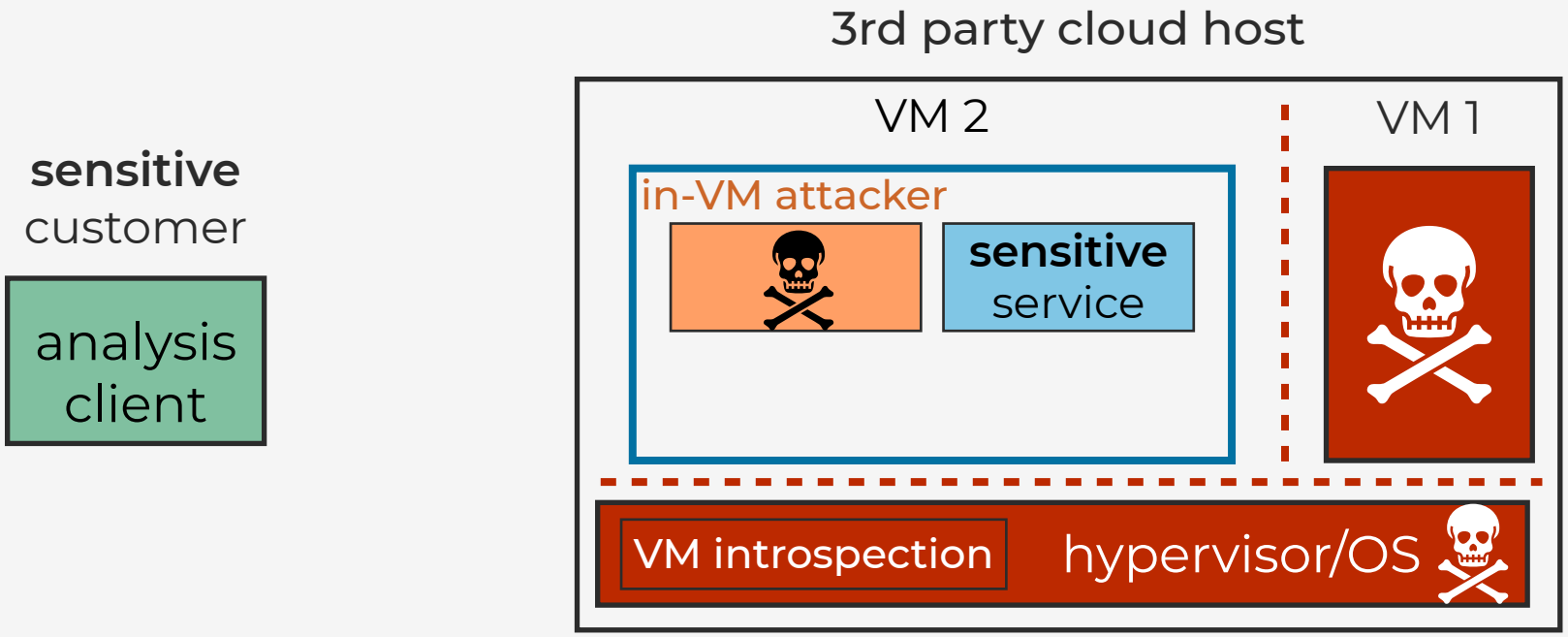


Solved Issue: VMI Exploitation to Attack Sensitive VMs



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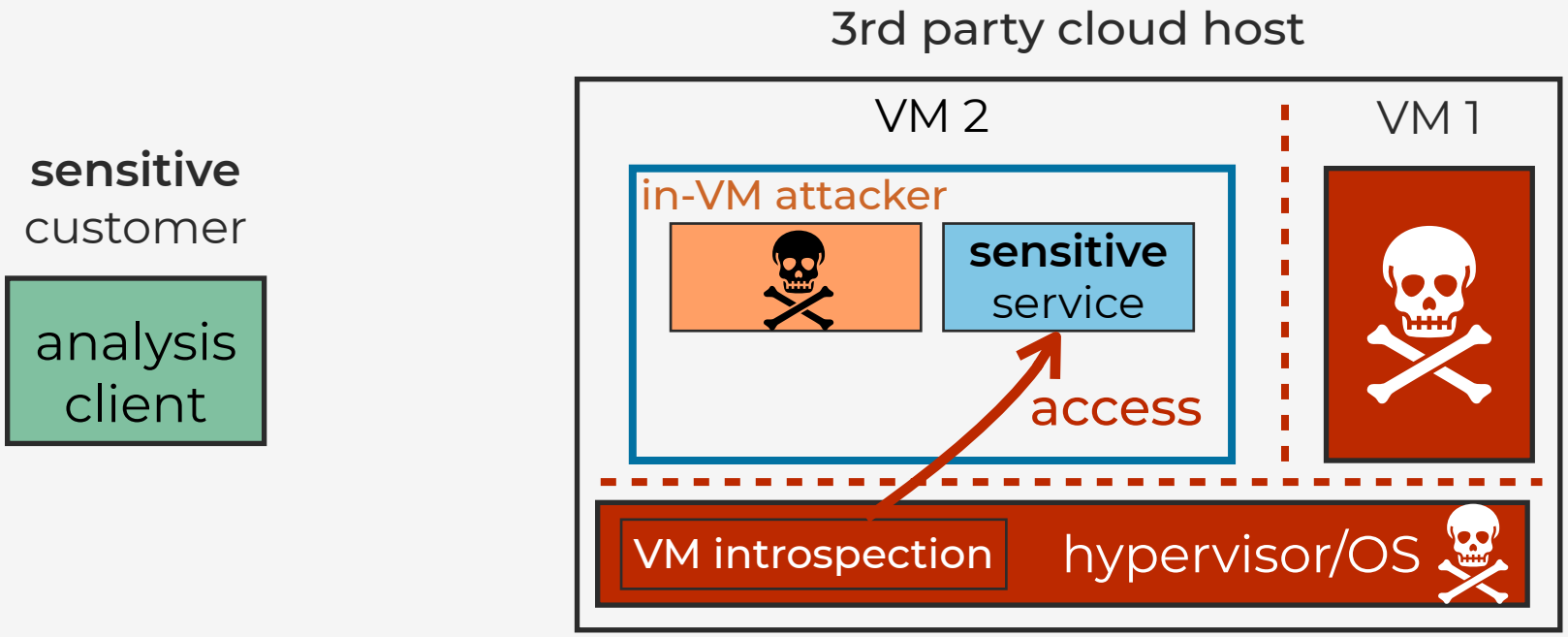
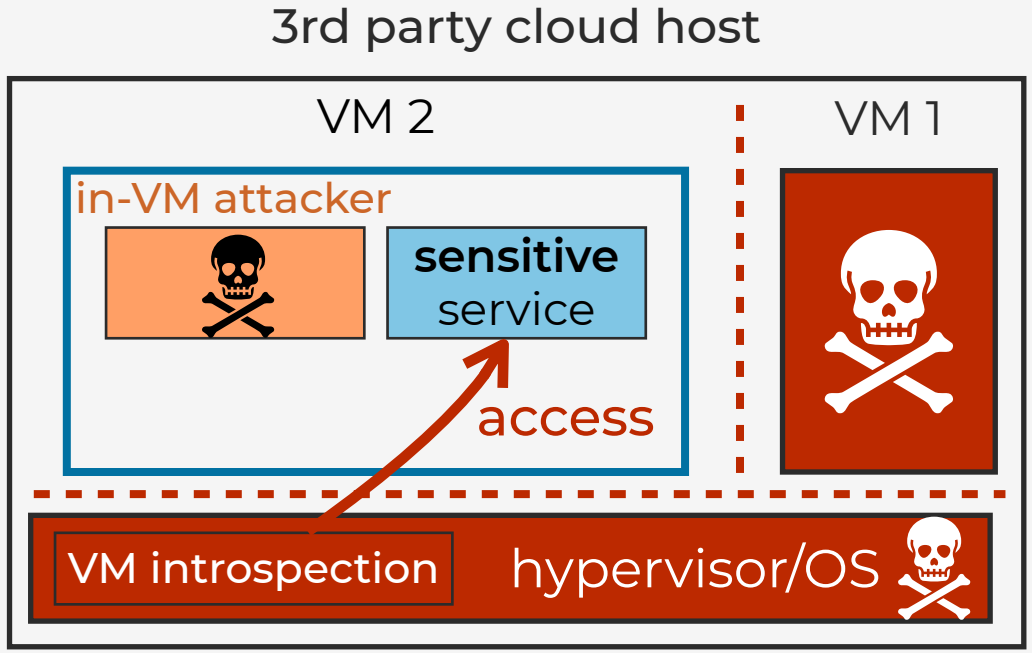


- **ISSUE:** If host is compromised, or inside attackers are present, can abuse VMI to steal or manipulate customers' sensitive services
- host can fully compromise the customer VM

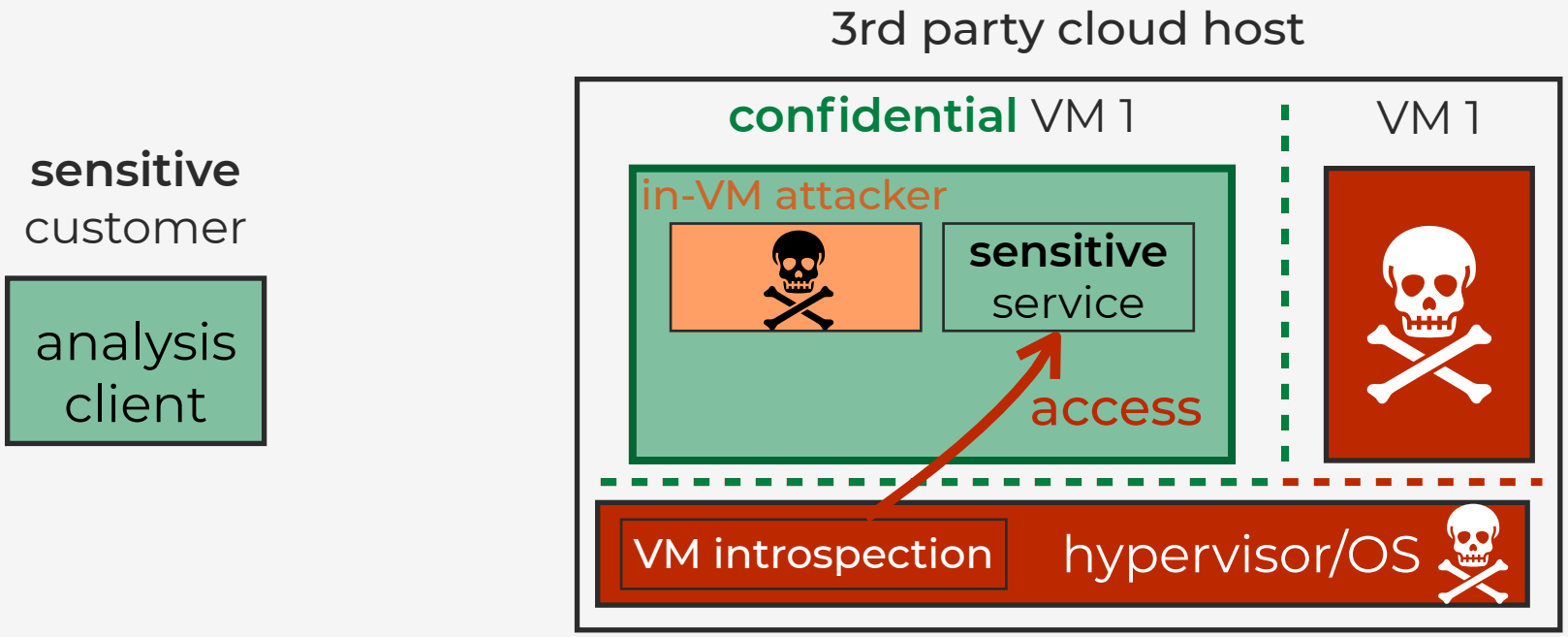
Solved Issue: VMI Exploitation to Attack Sensitive VMs

sensitive
customer

analysis client



Confidential VMs and their Incompatibility with VMI



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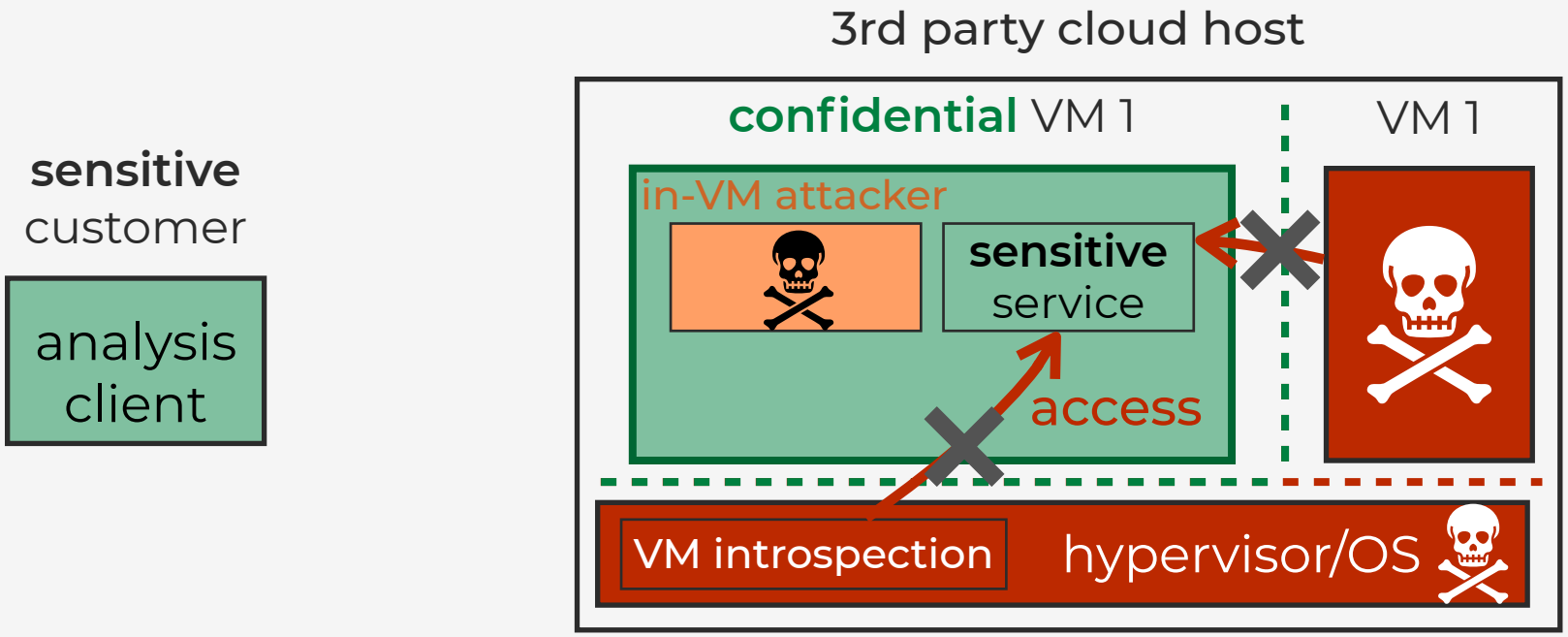

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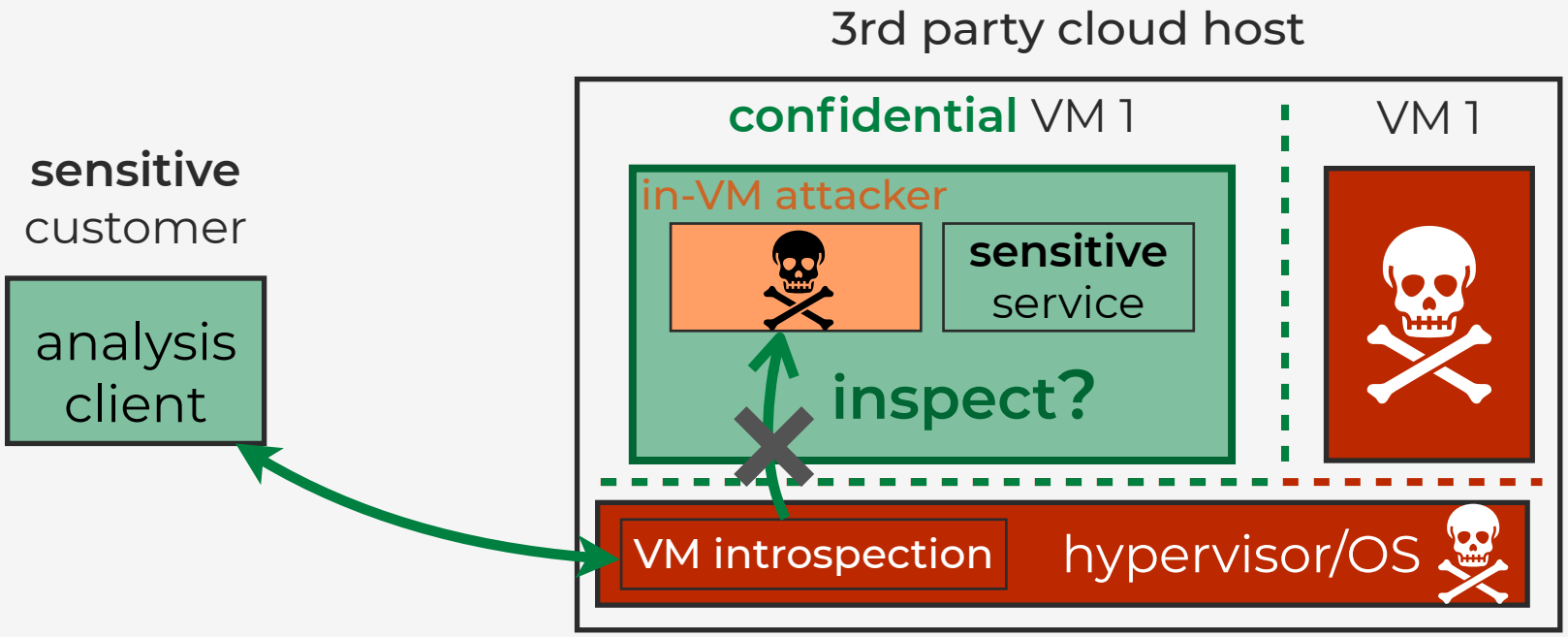

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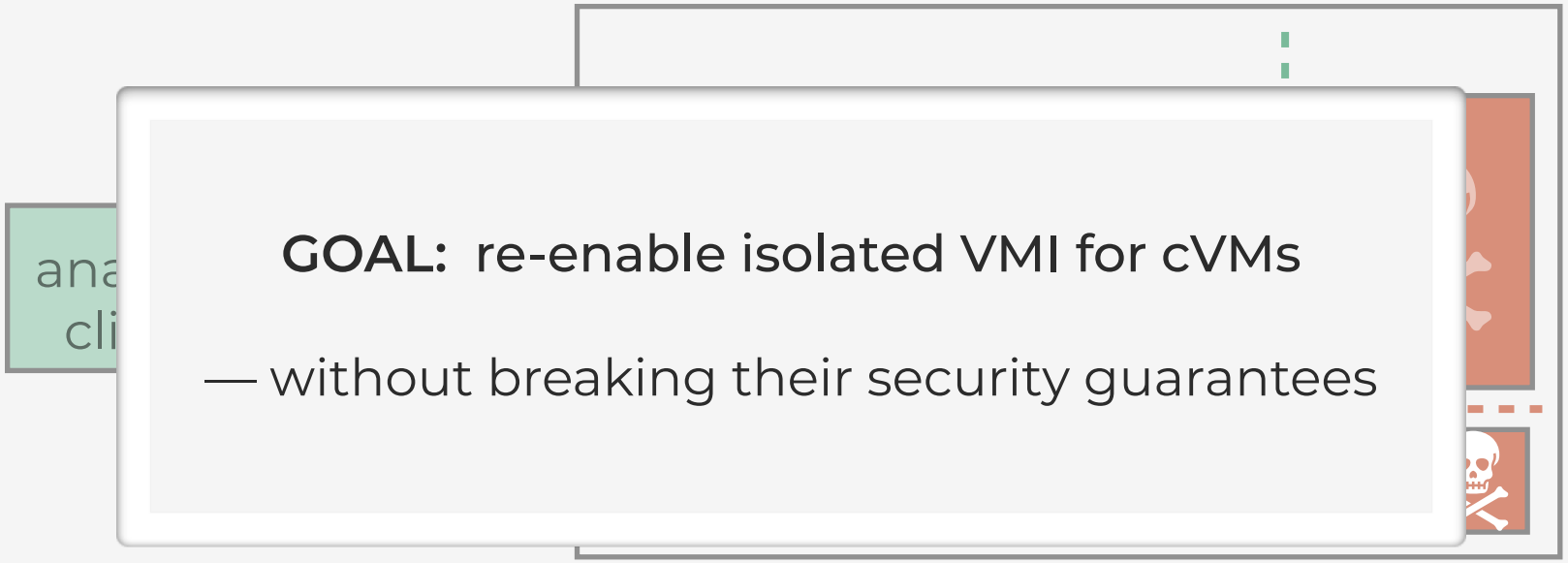

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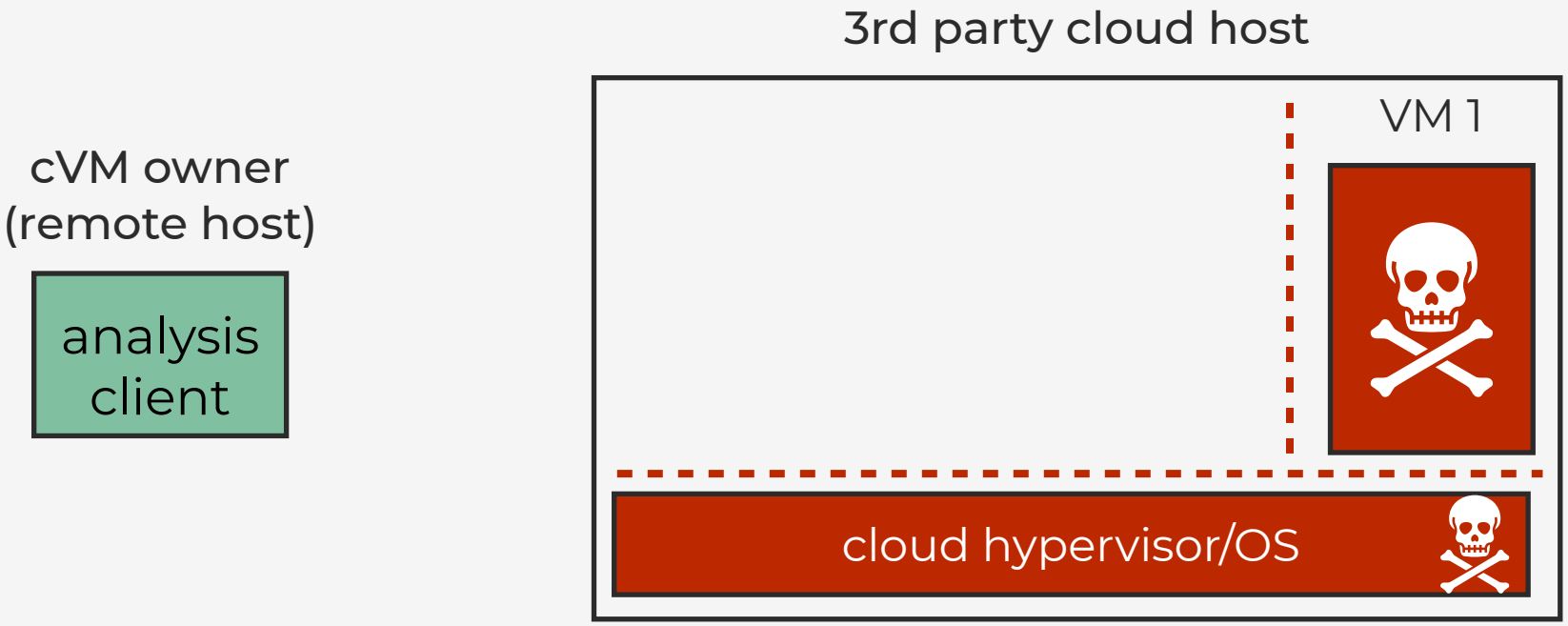
Threat Model for Introspection of cVMs



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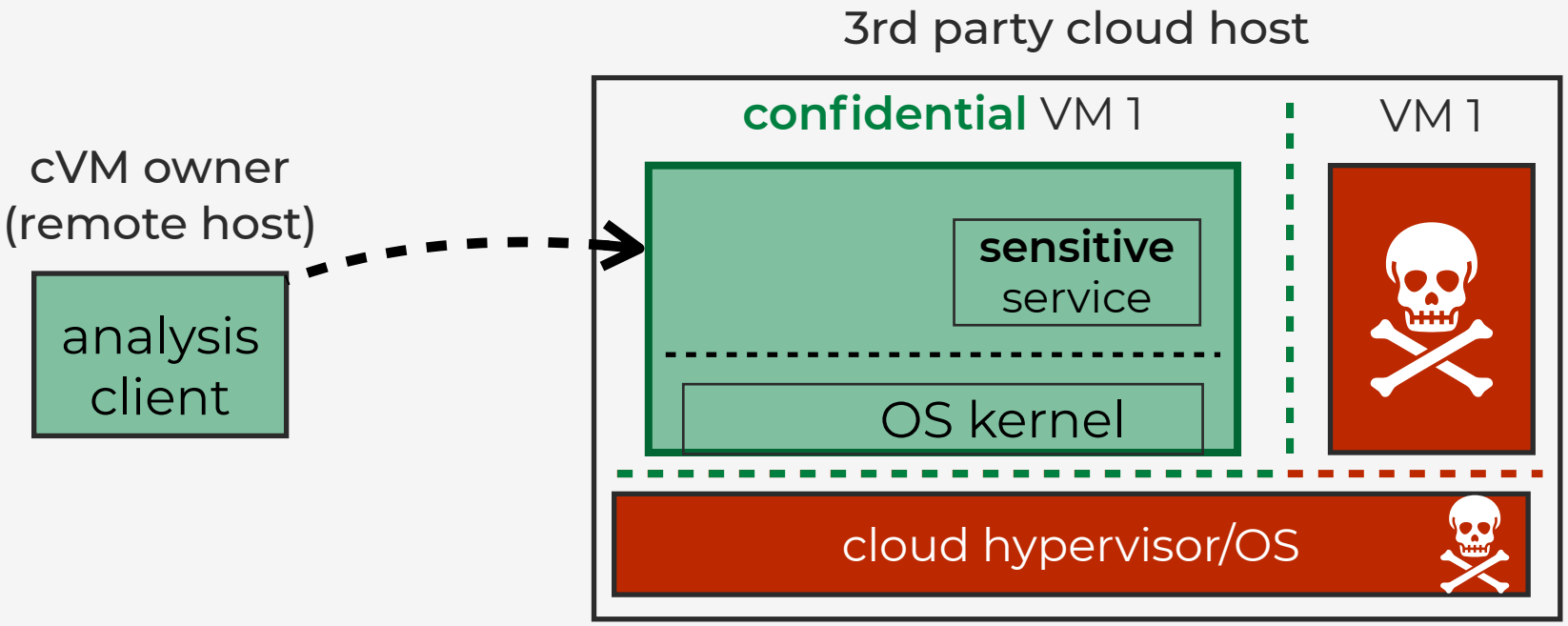

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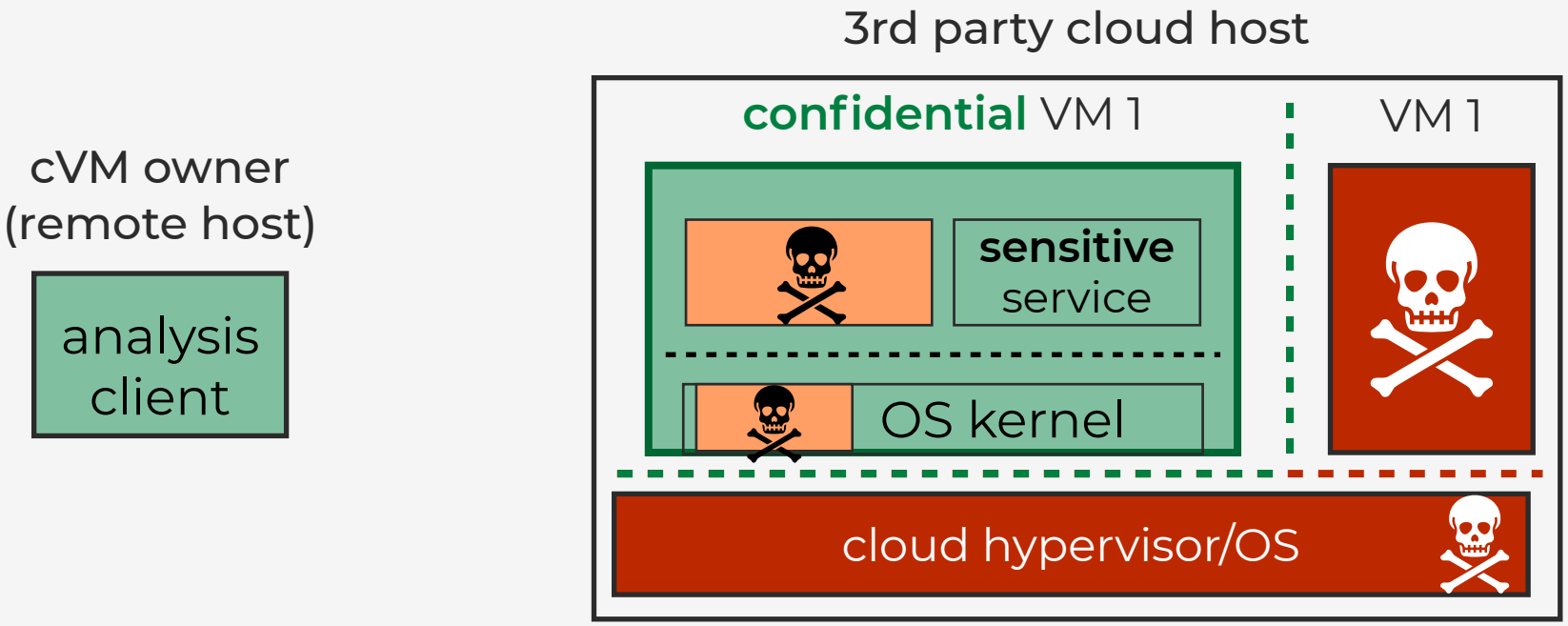

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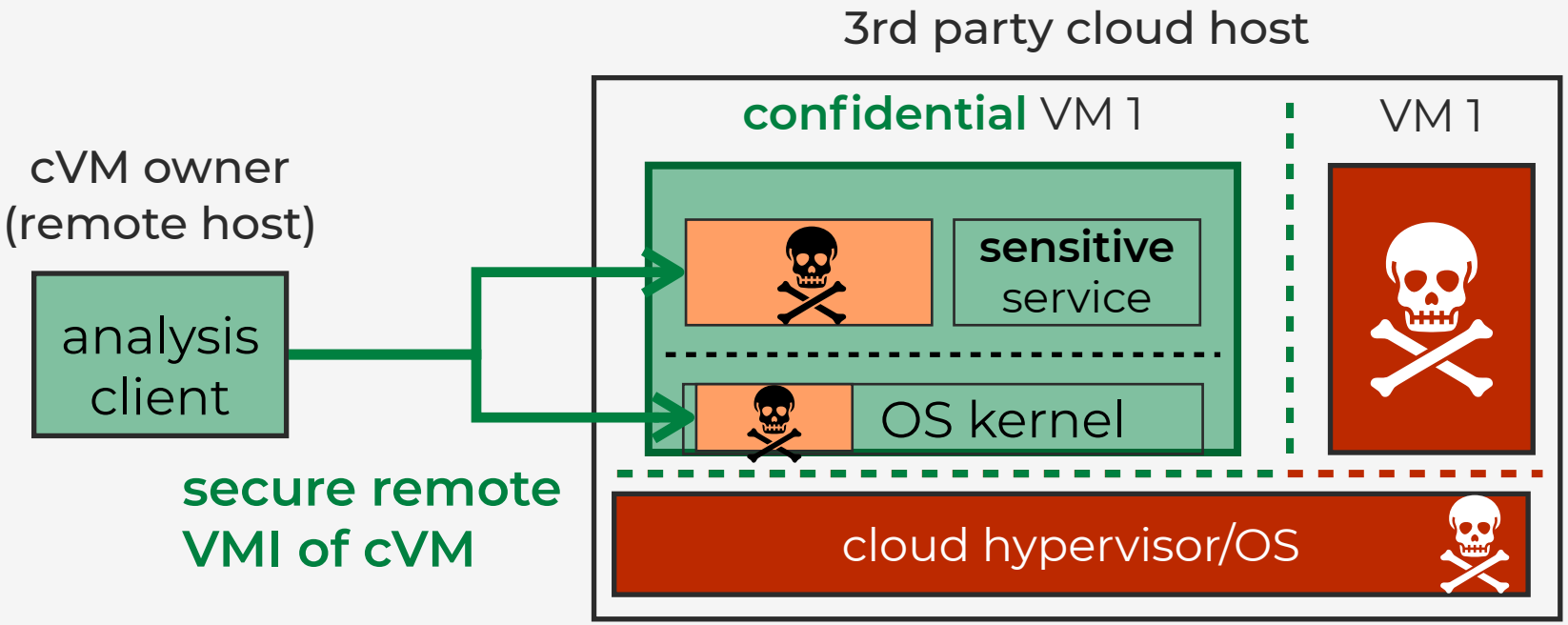

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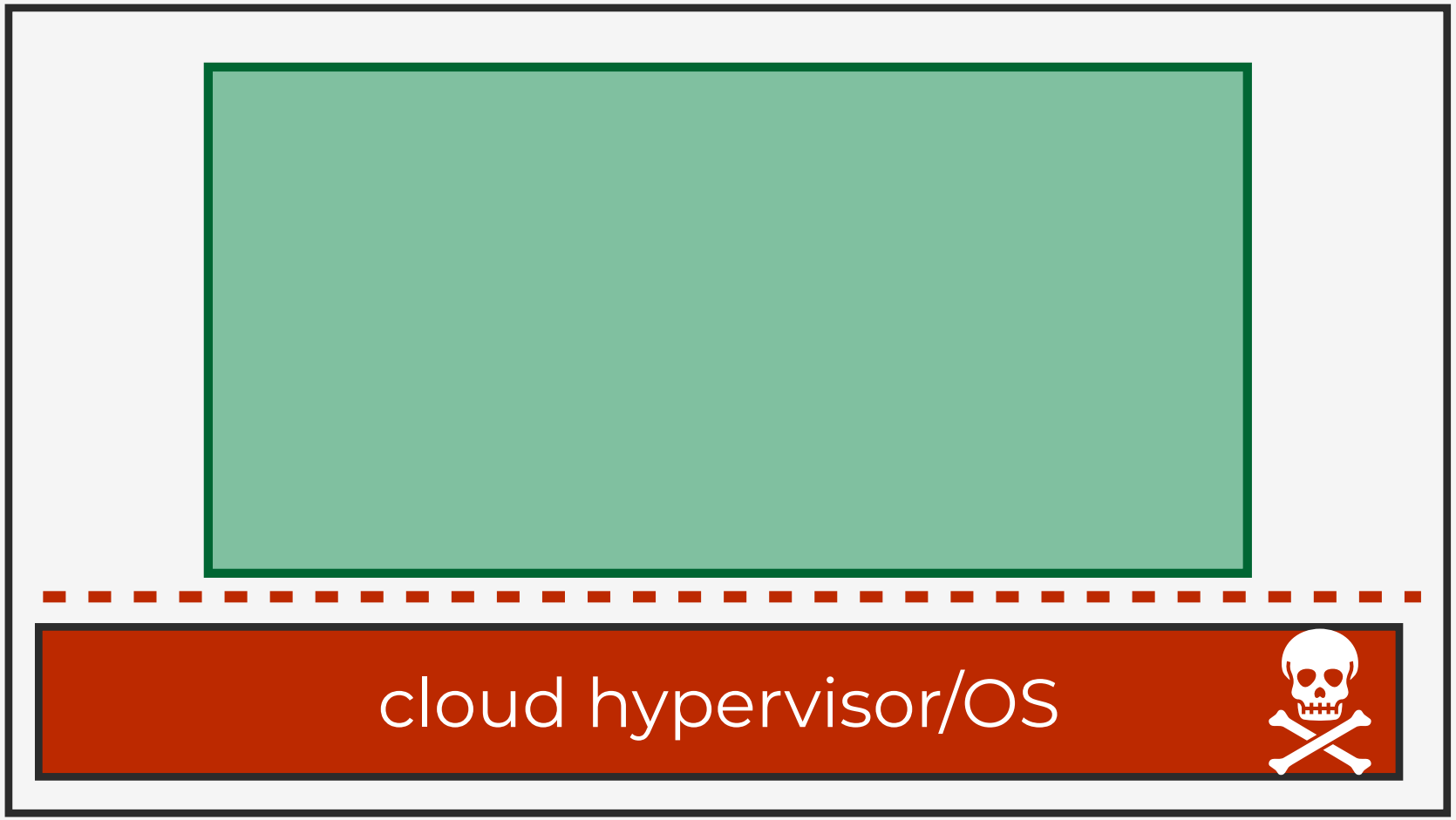
- trusted client deploys sensitive IP services in confidential VM (at cloud)
- **in-VM** attacker: malware, kernel rootkits (≠ out-of-VM attacker)
- **GOAL: trusted client wants to perform secure remote introspection (VMI) to monitor for in-VM attacks**

00SEVen Design Overview and Challenges

cVM owner
(remote host)

analysis client



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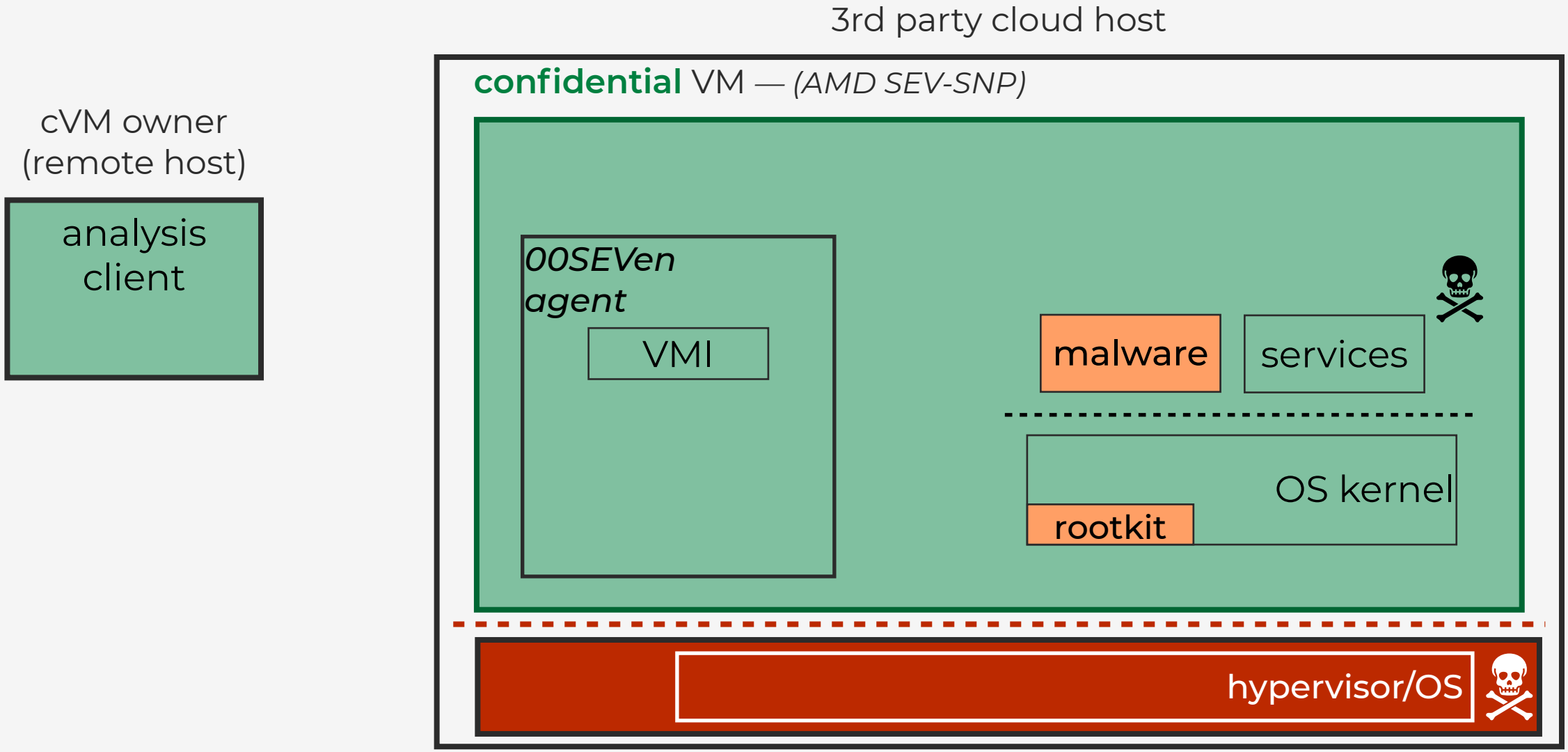

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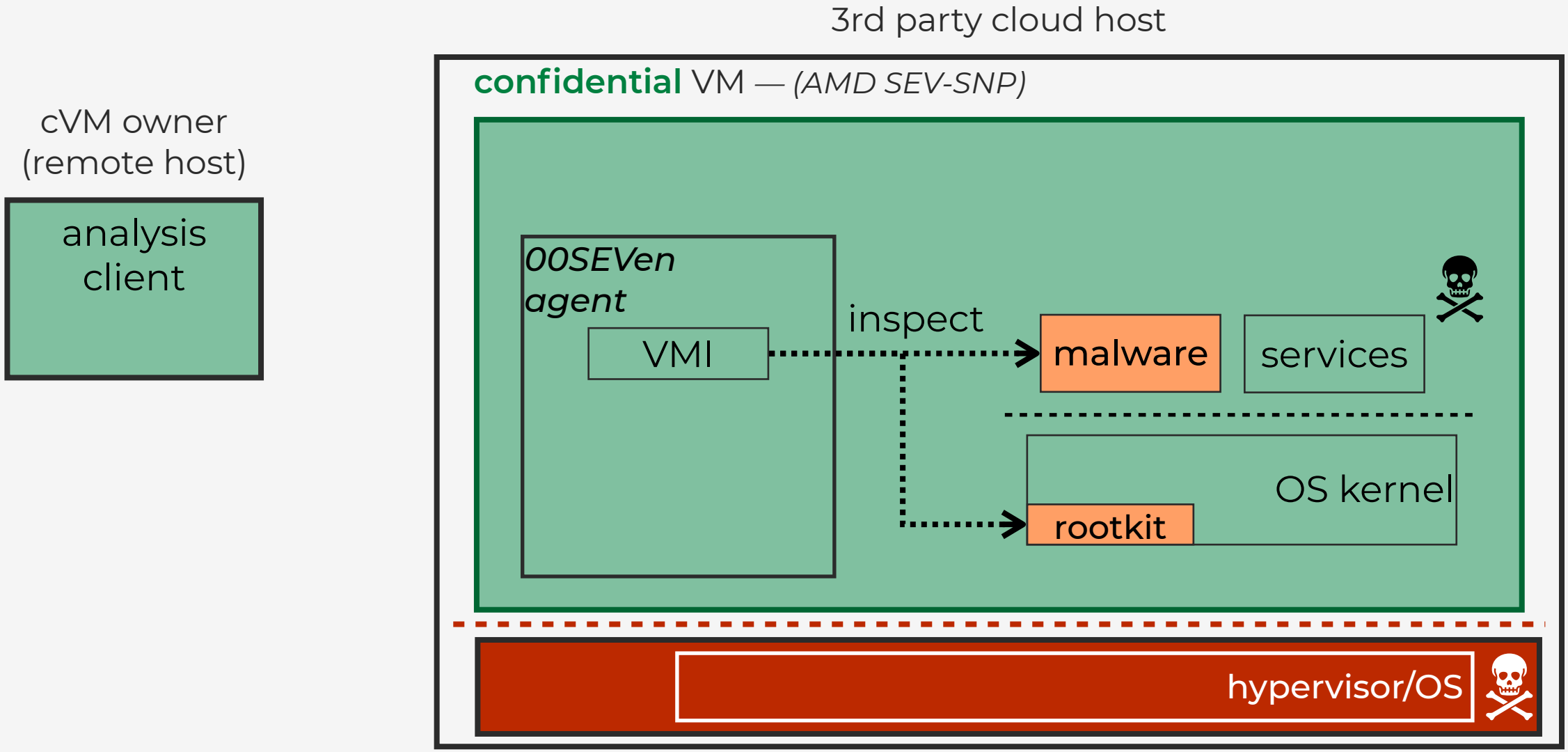

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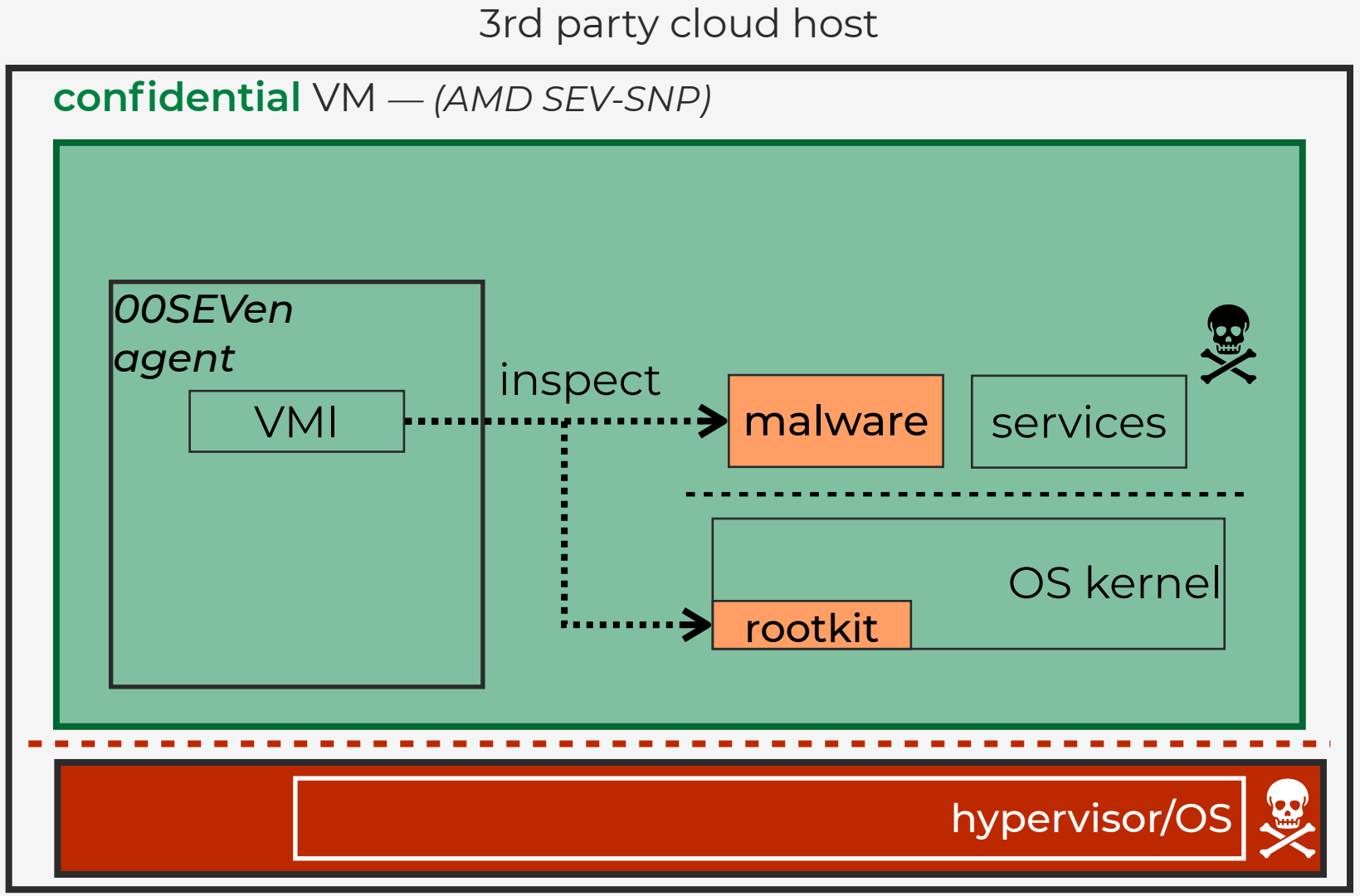

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3. secure pausing / traps, despite malicious host

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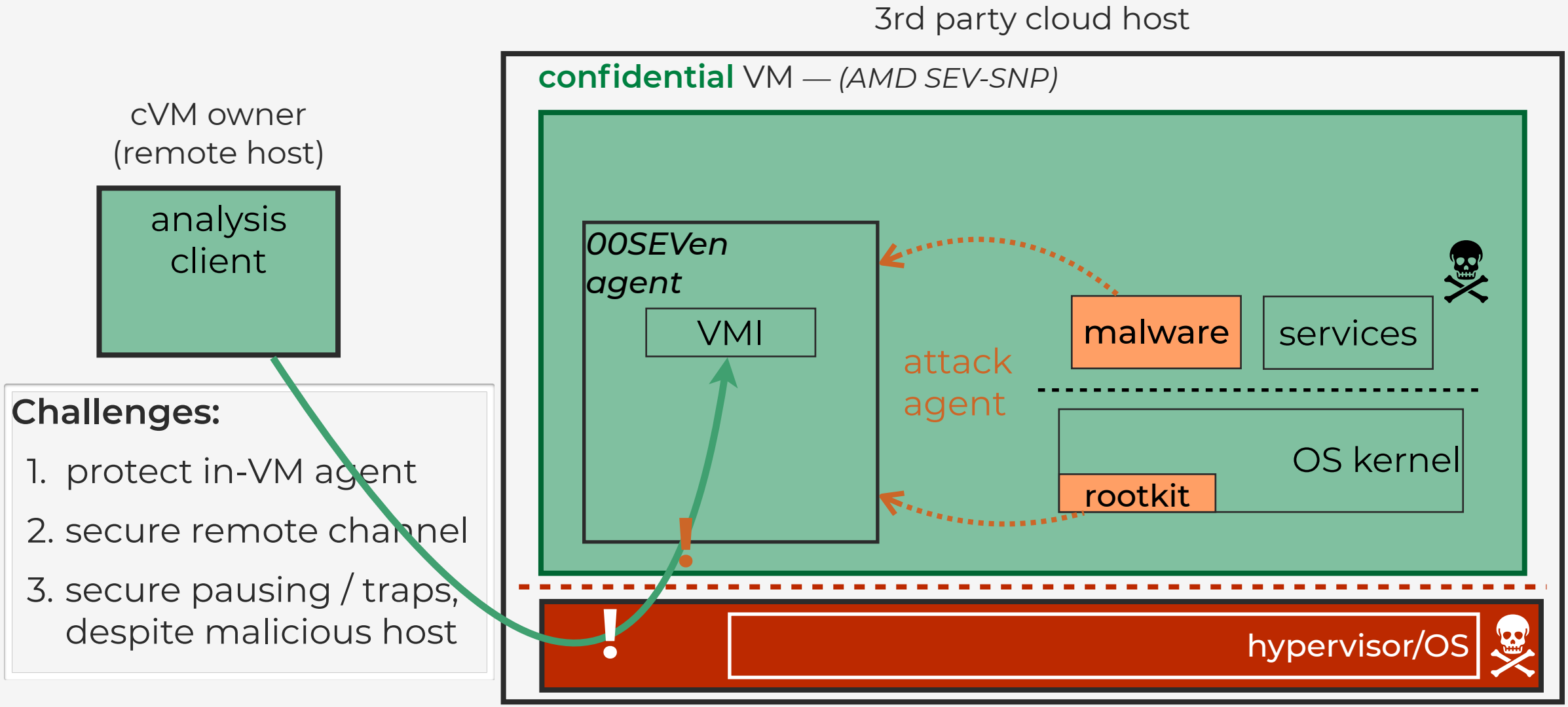

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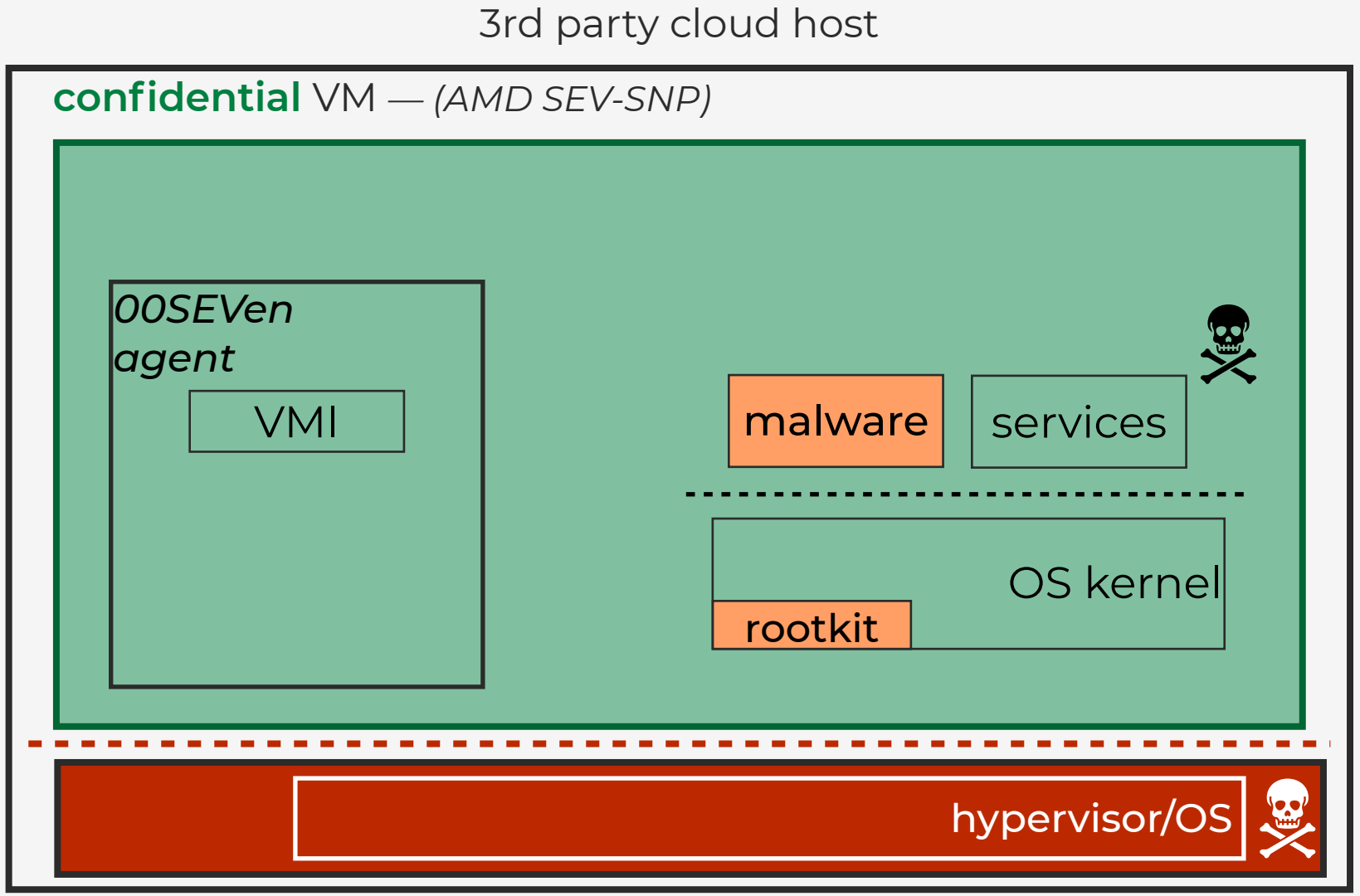
- *VMPL0 most privileged*
- **per-VMPL:** page permissions + register sets (per vCPU) saved in cVM memory



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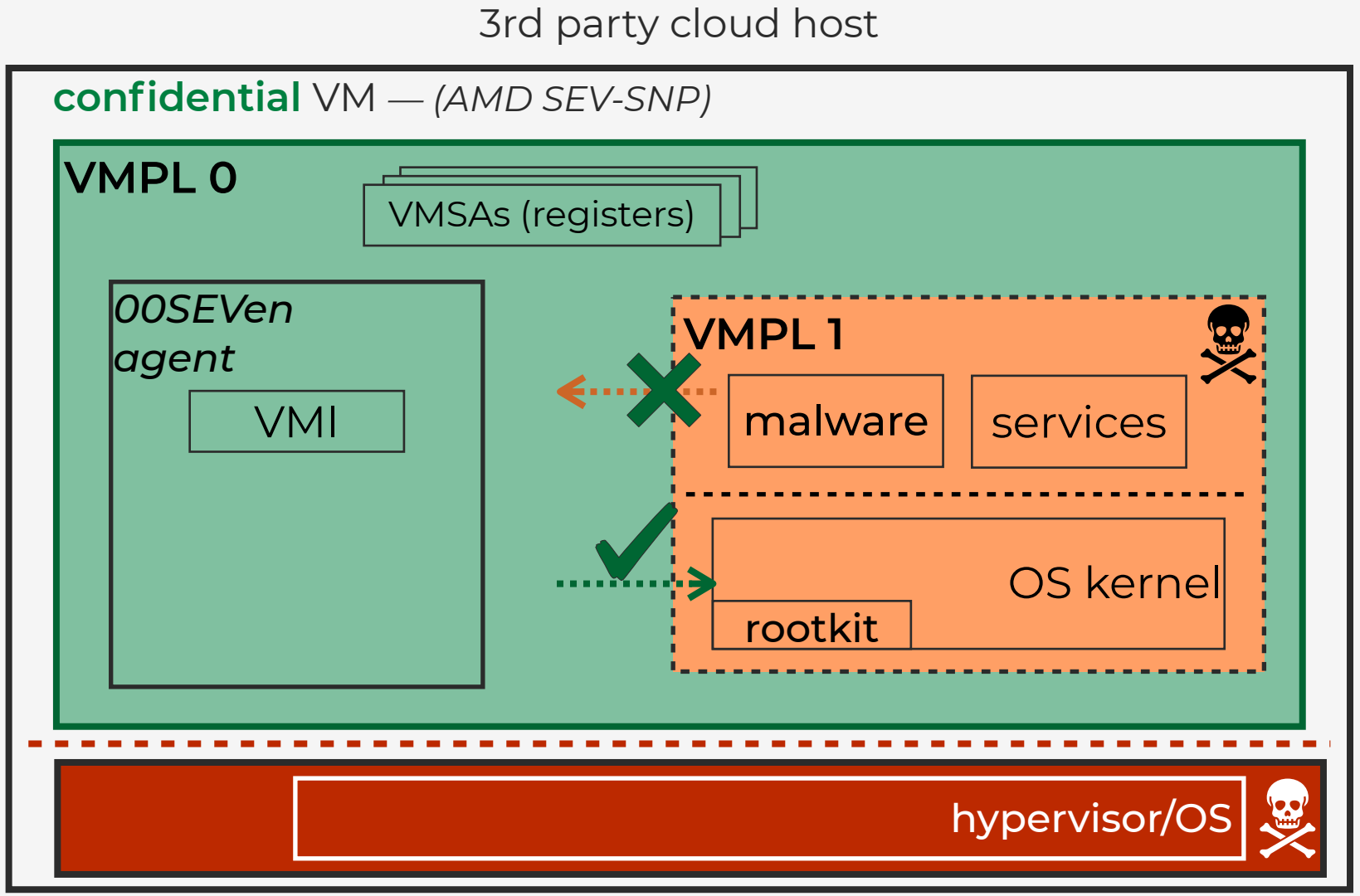

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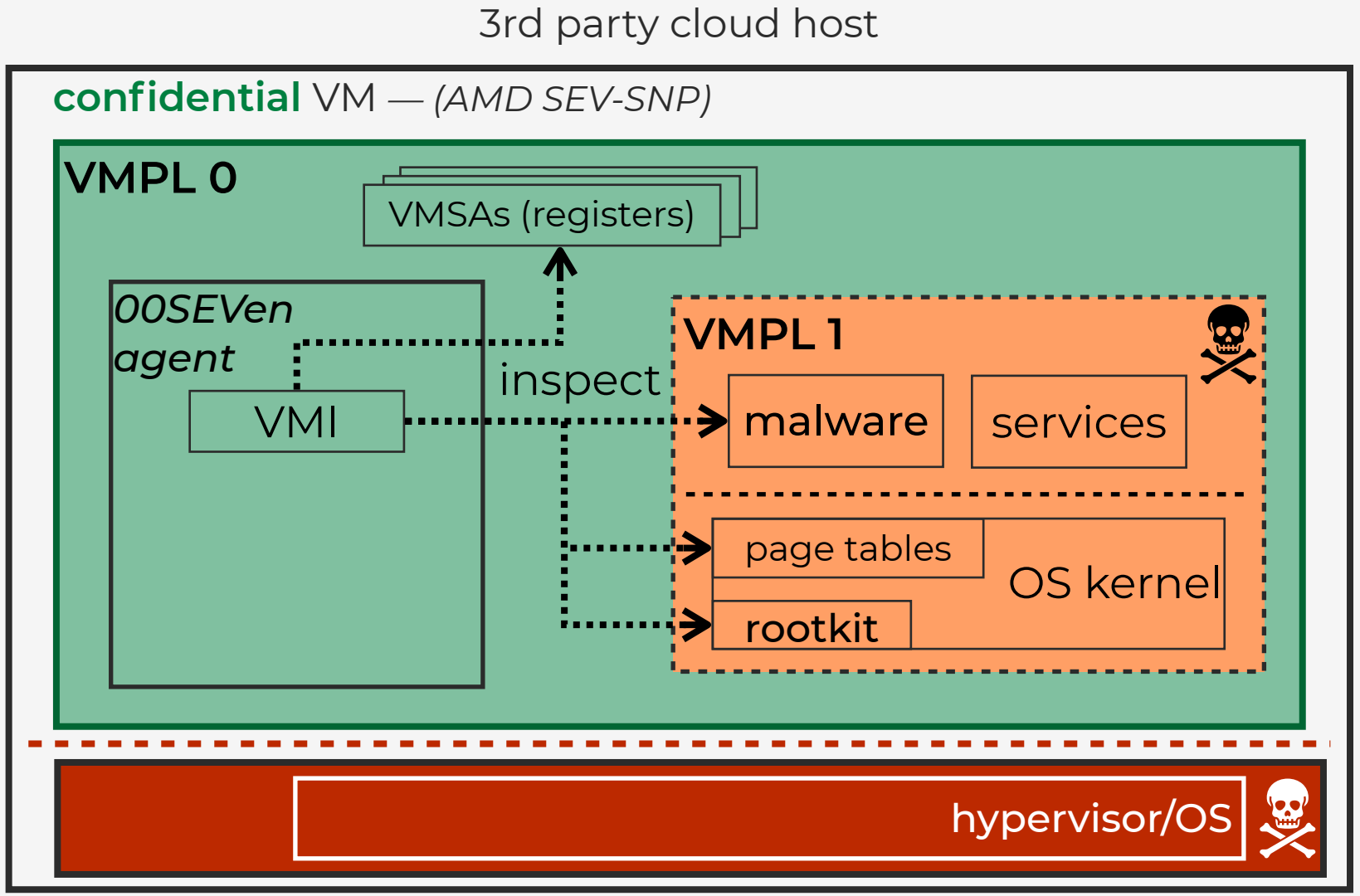

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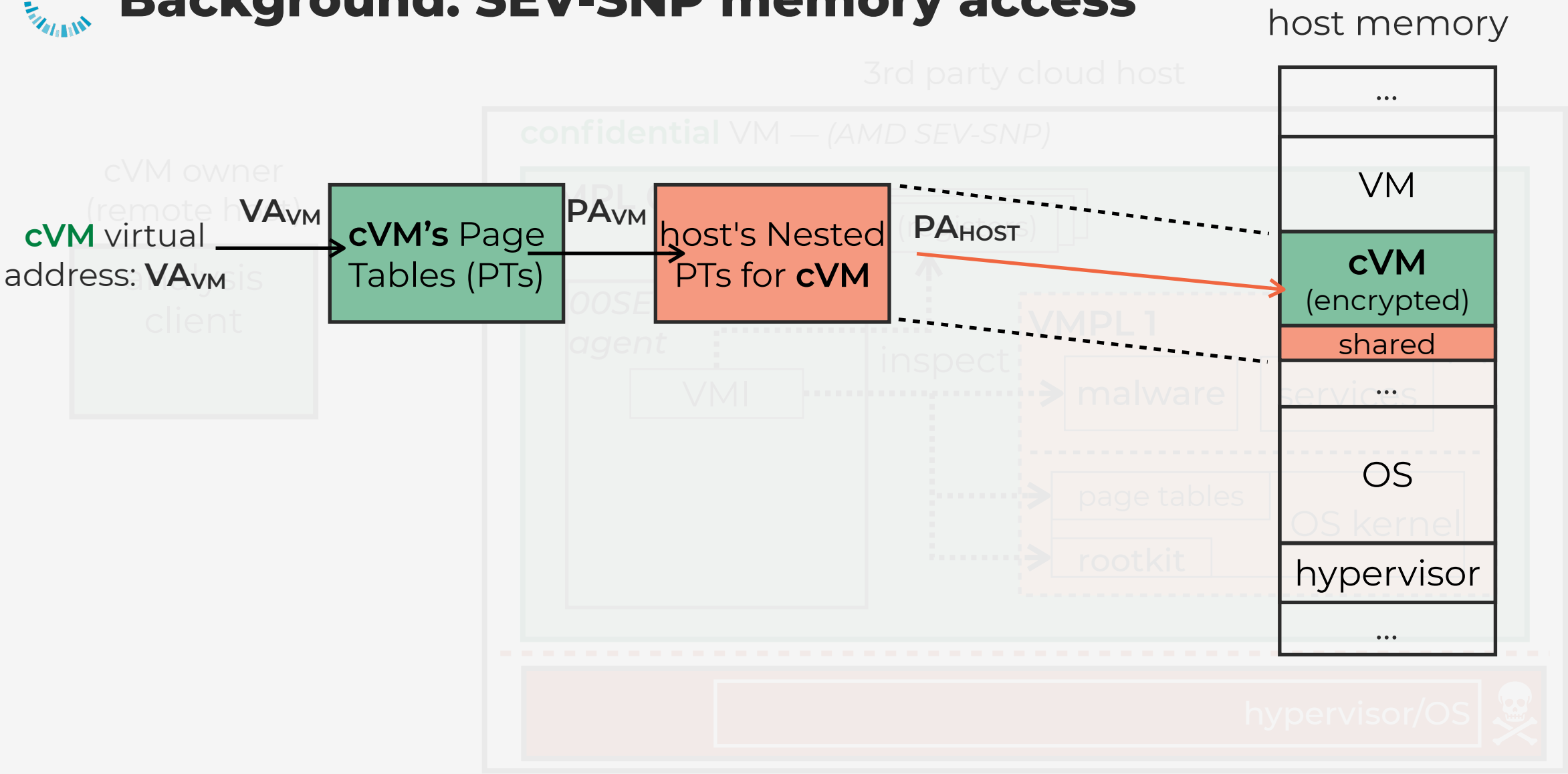

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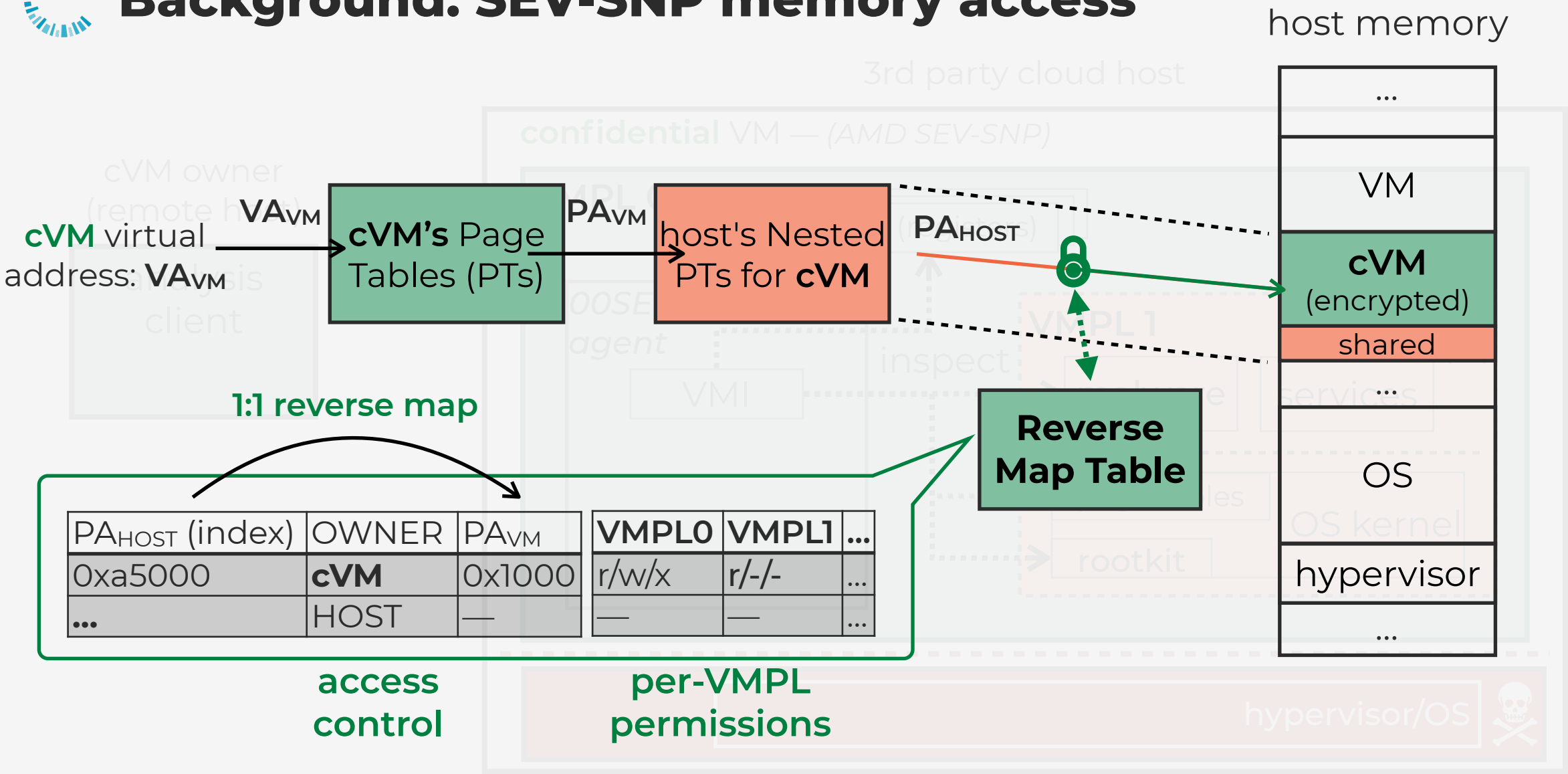

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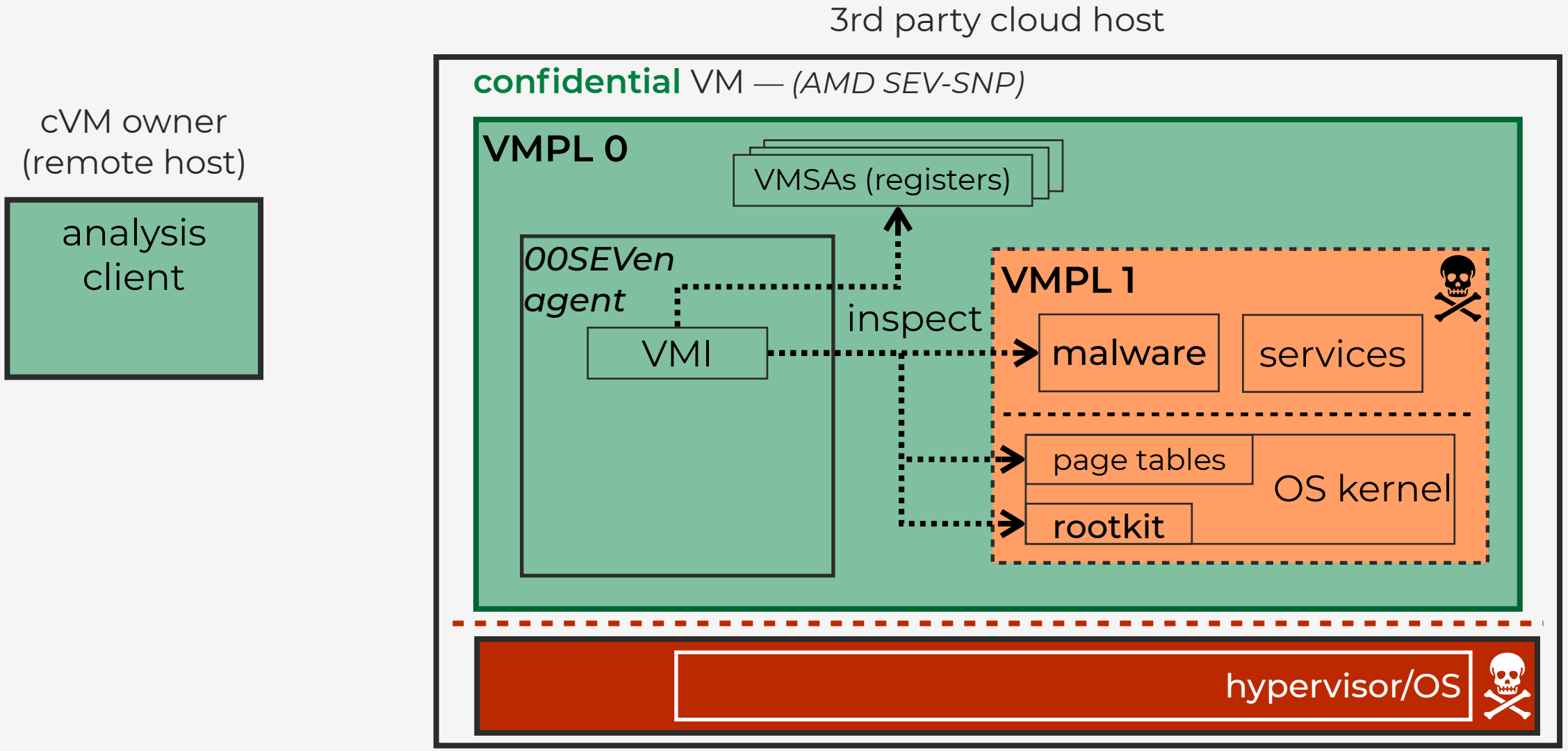

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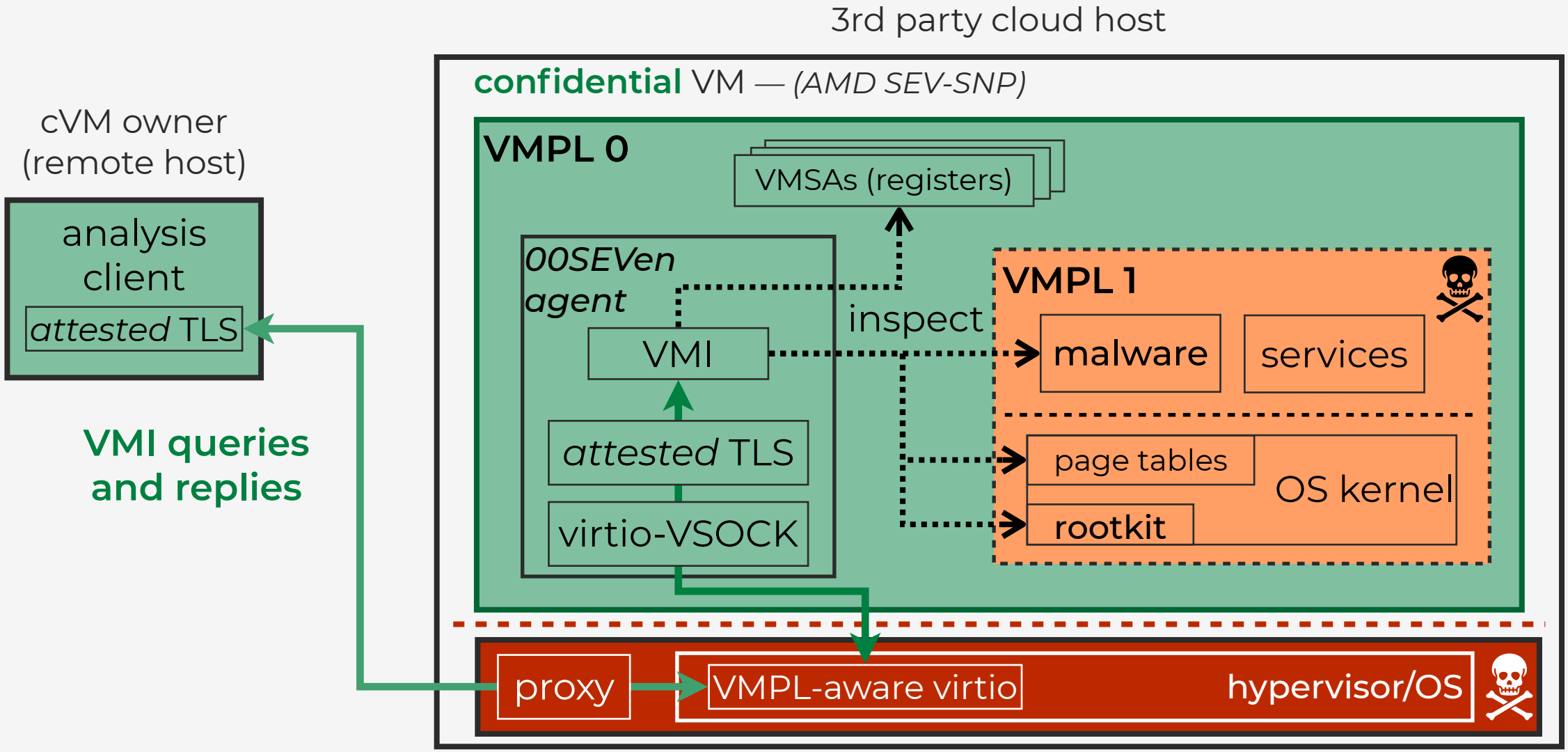

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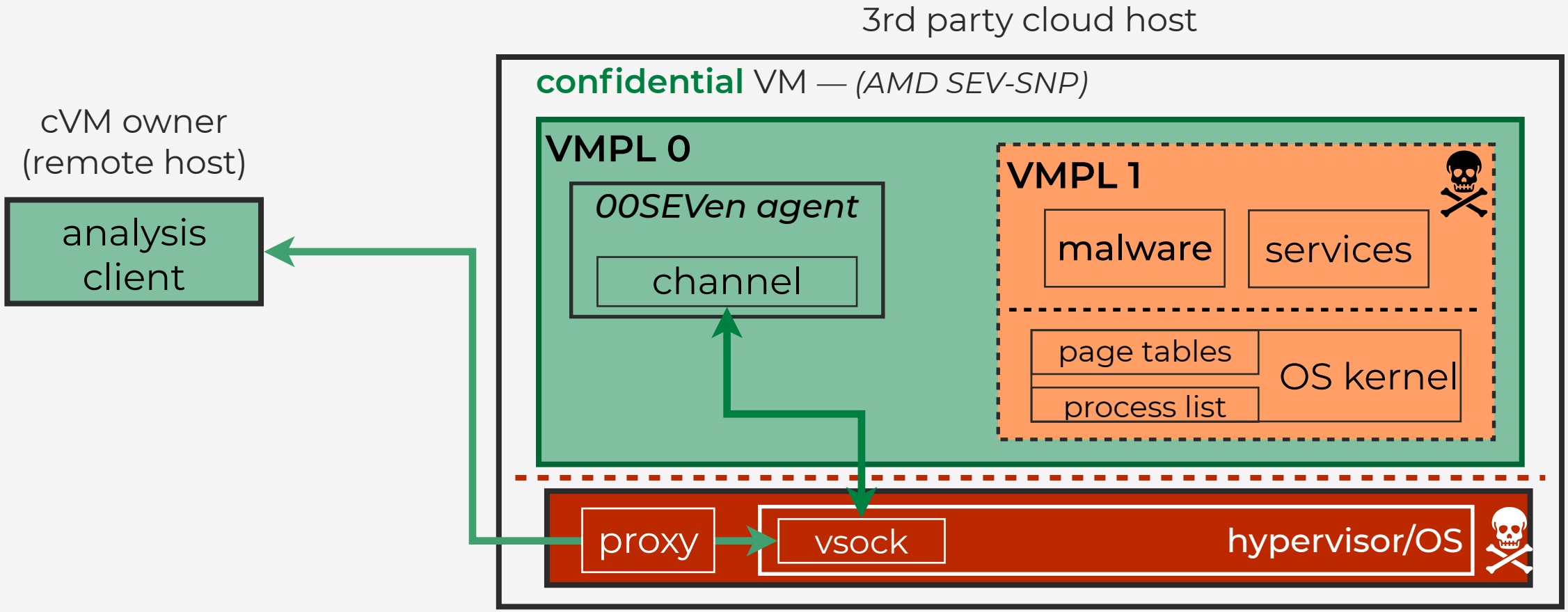

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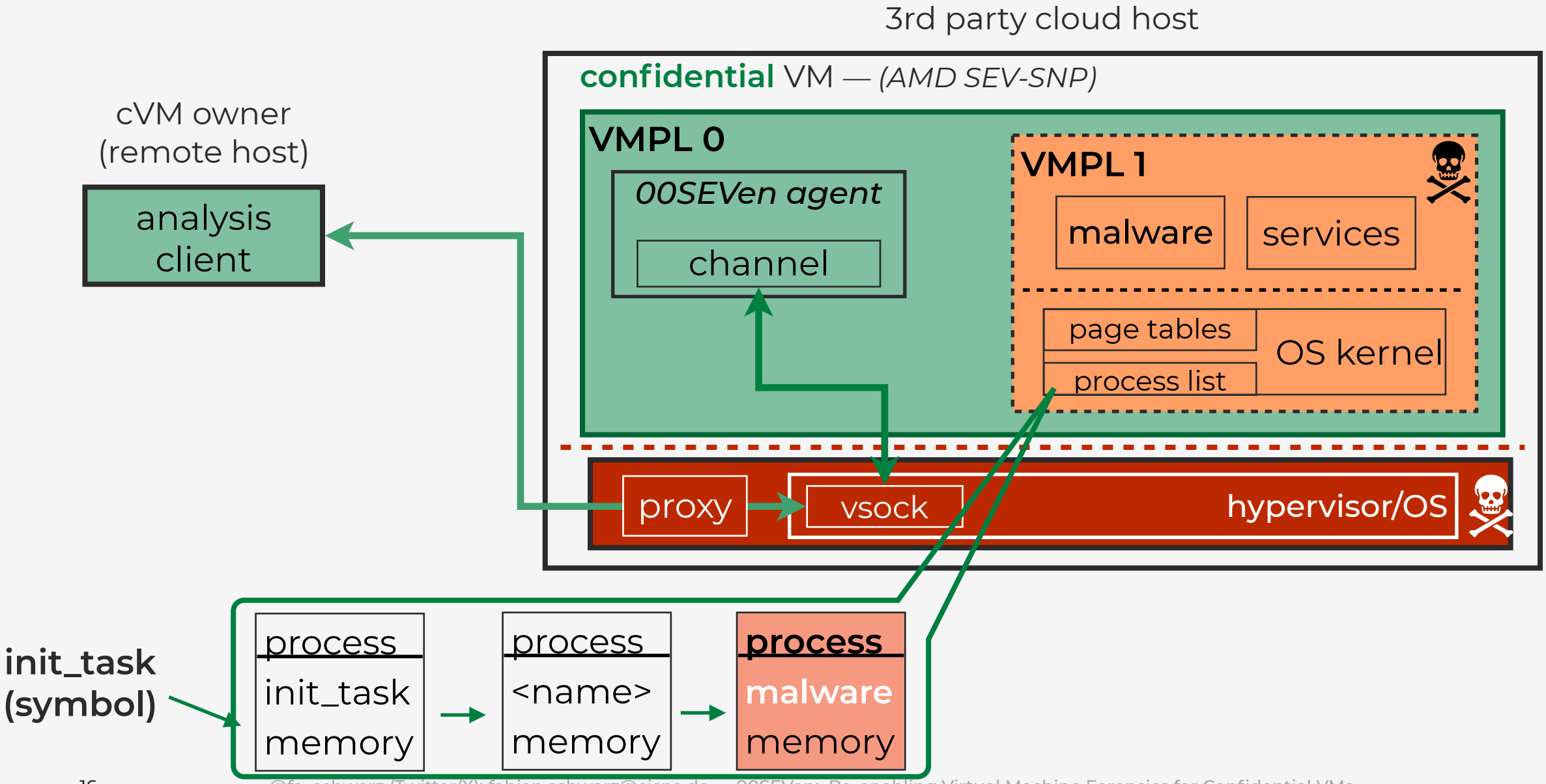

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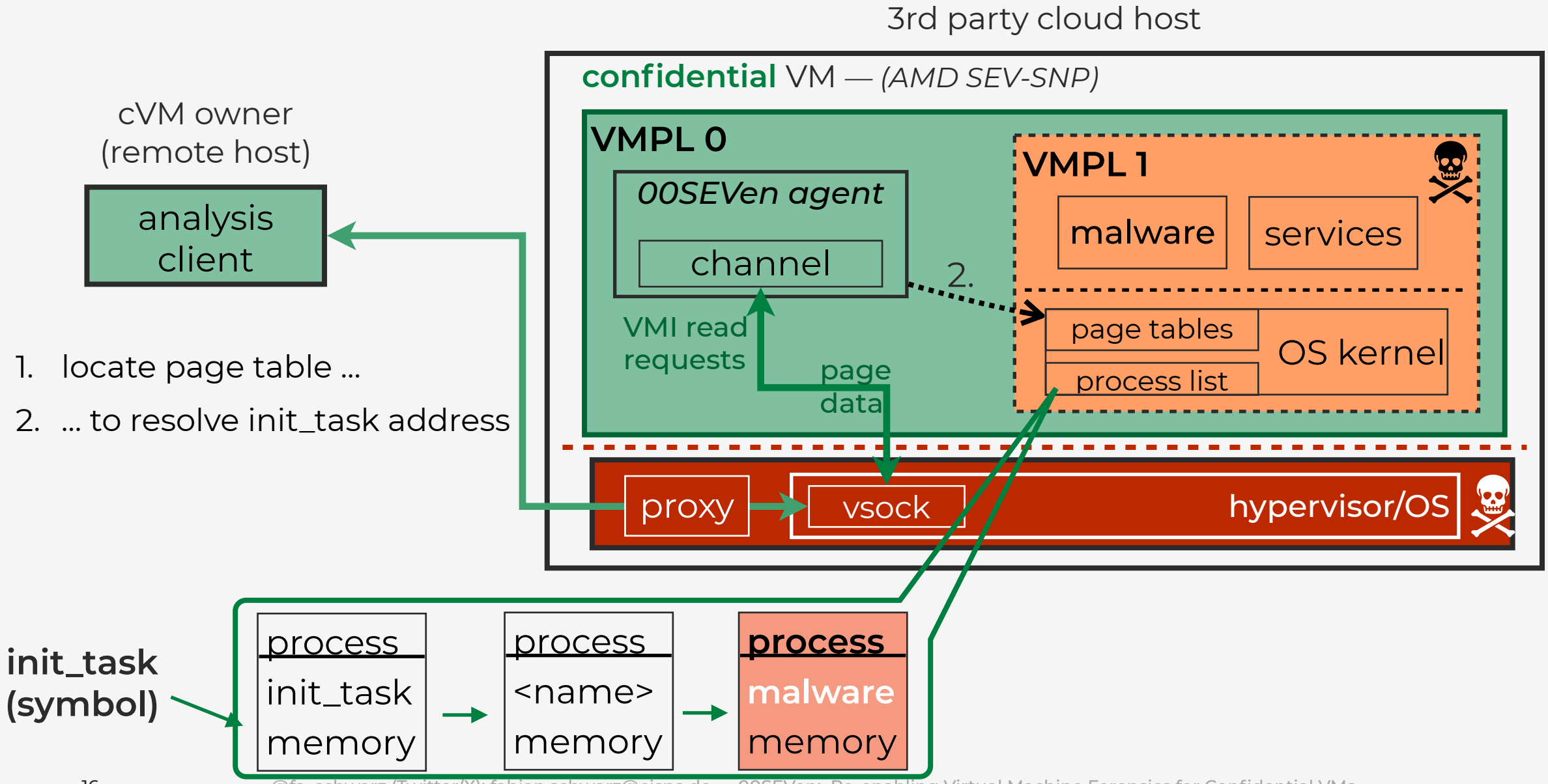

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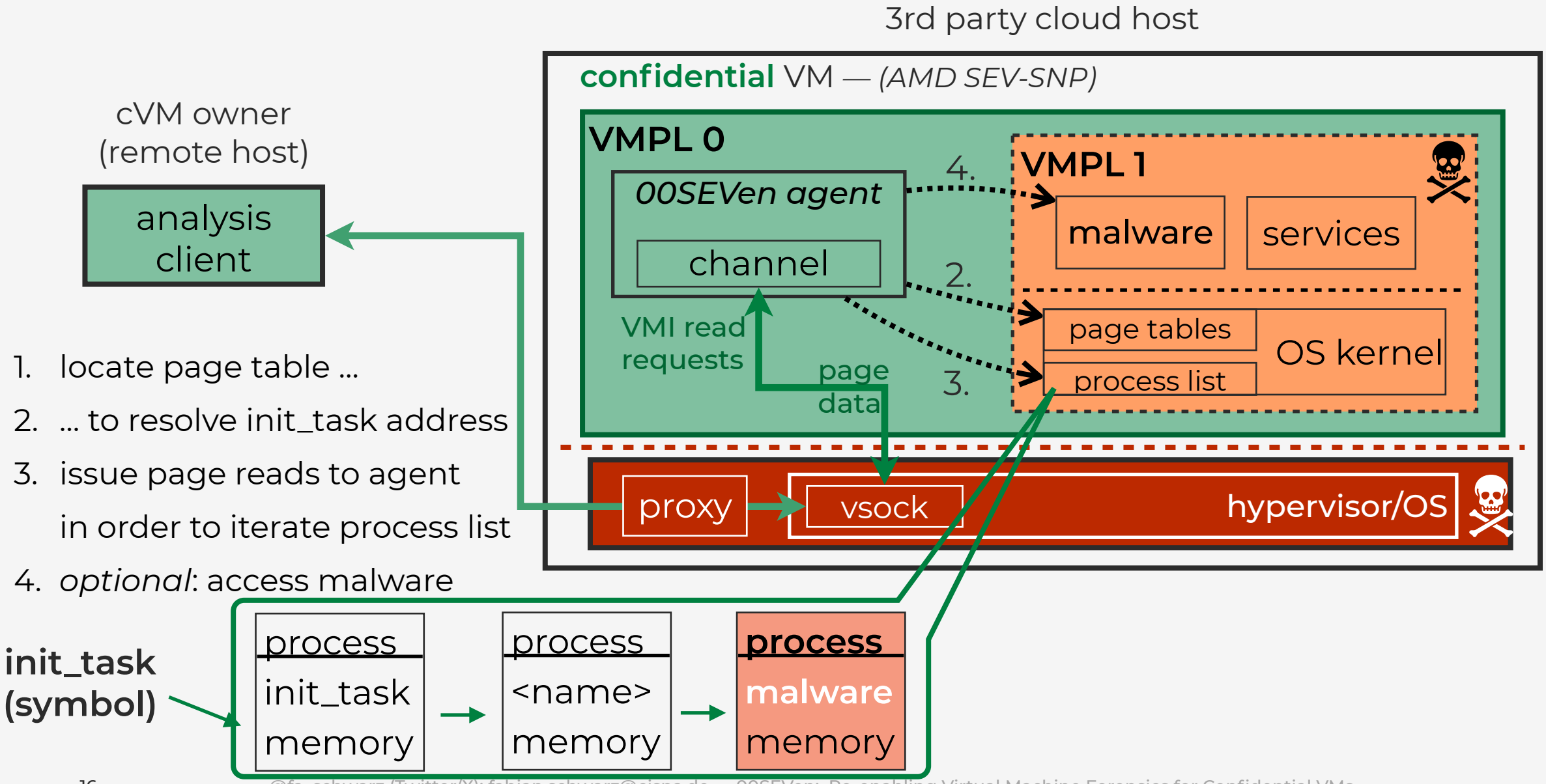

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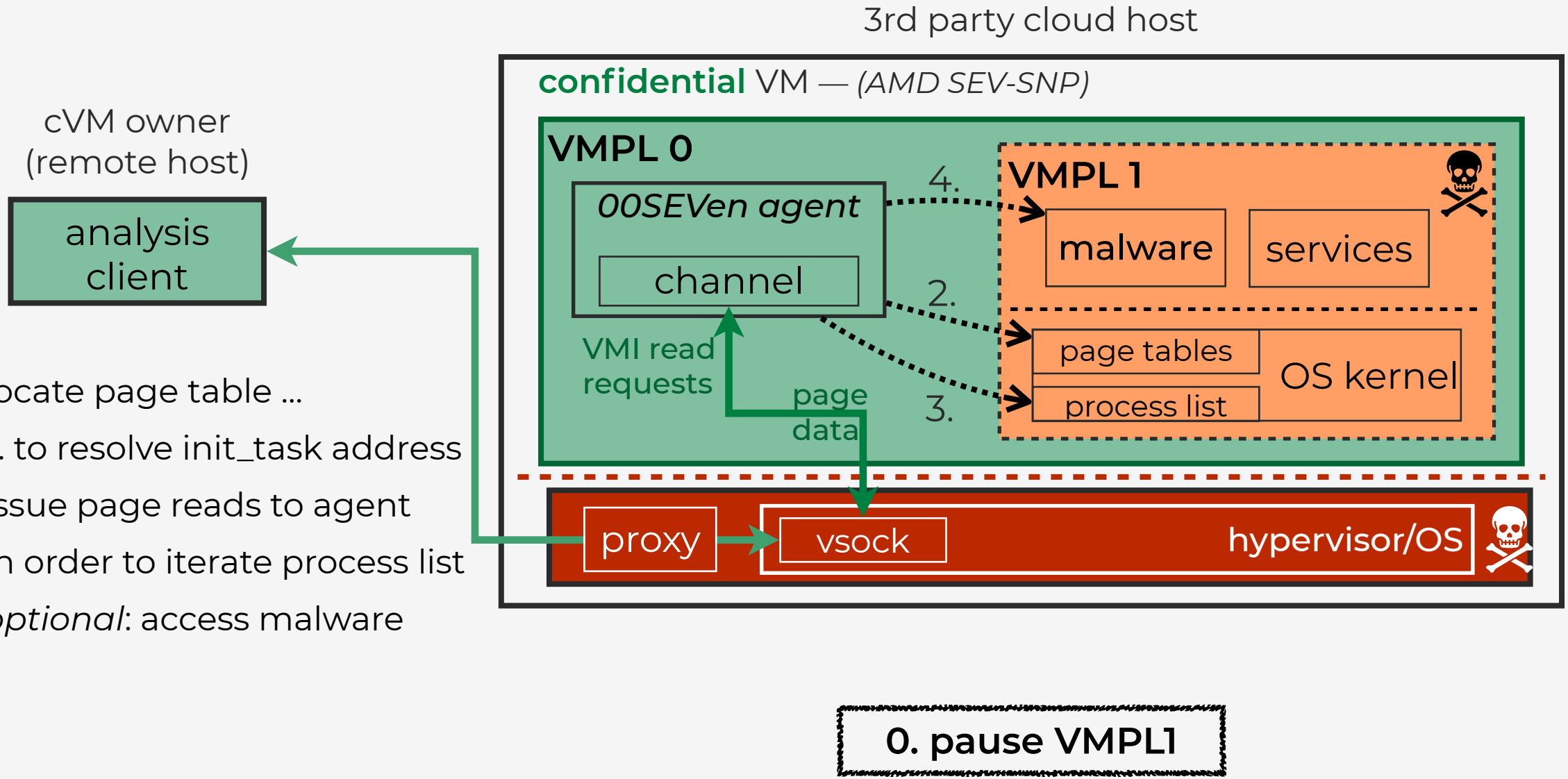
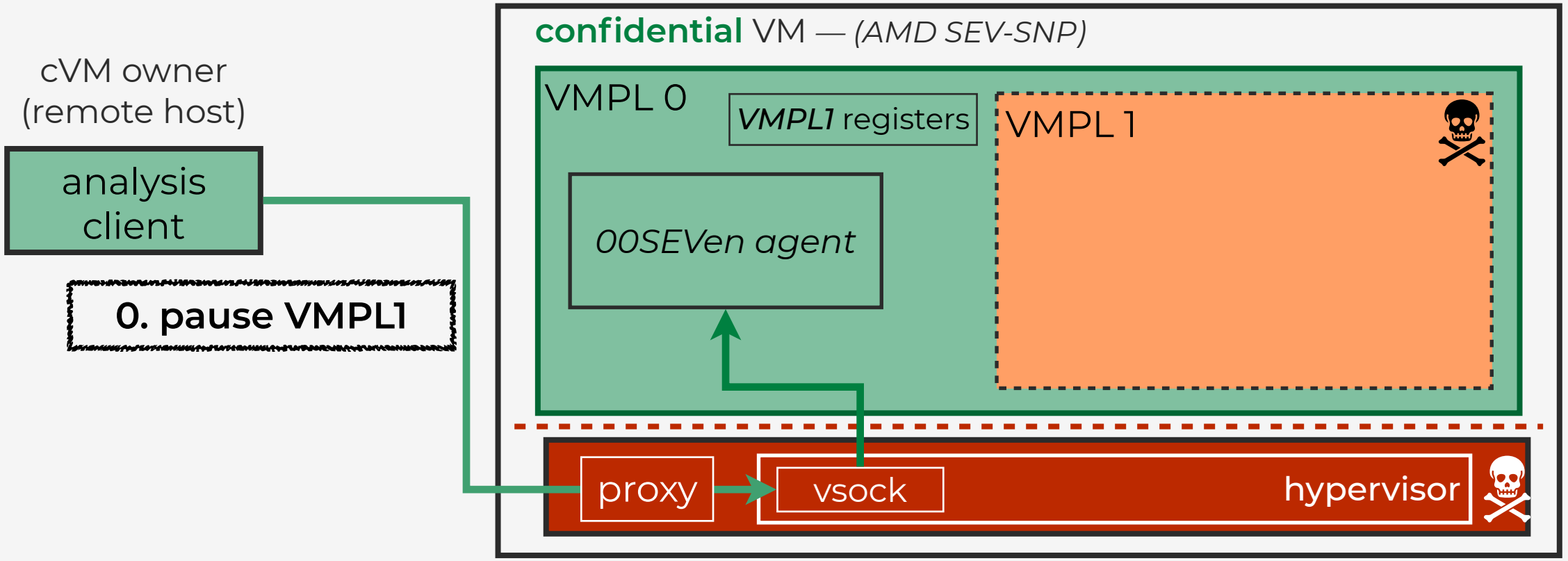


1. locate page table …
2. … to resolve init_task address
3. issue page reads to agent
   in order to iterate process list
4. *optional*: access malware

00SEVen Challenge #3: Secure Pausing of VM OS



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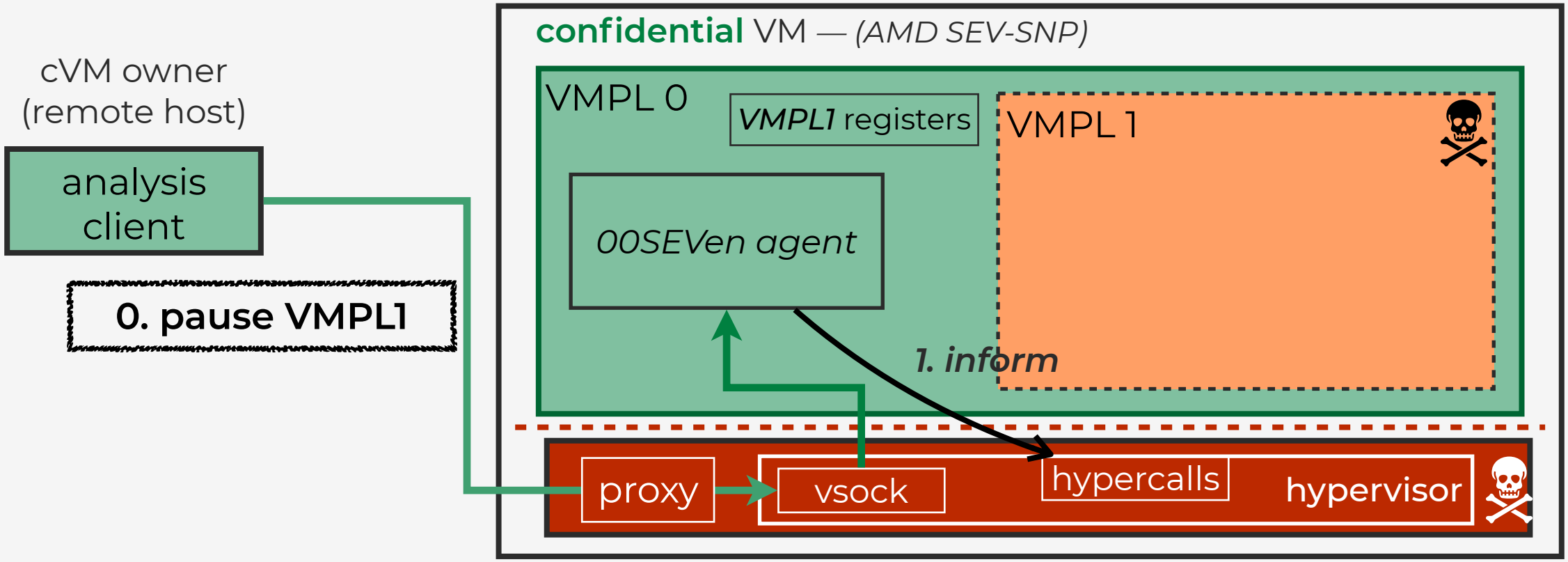

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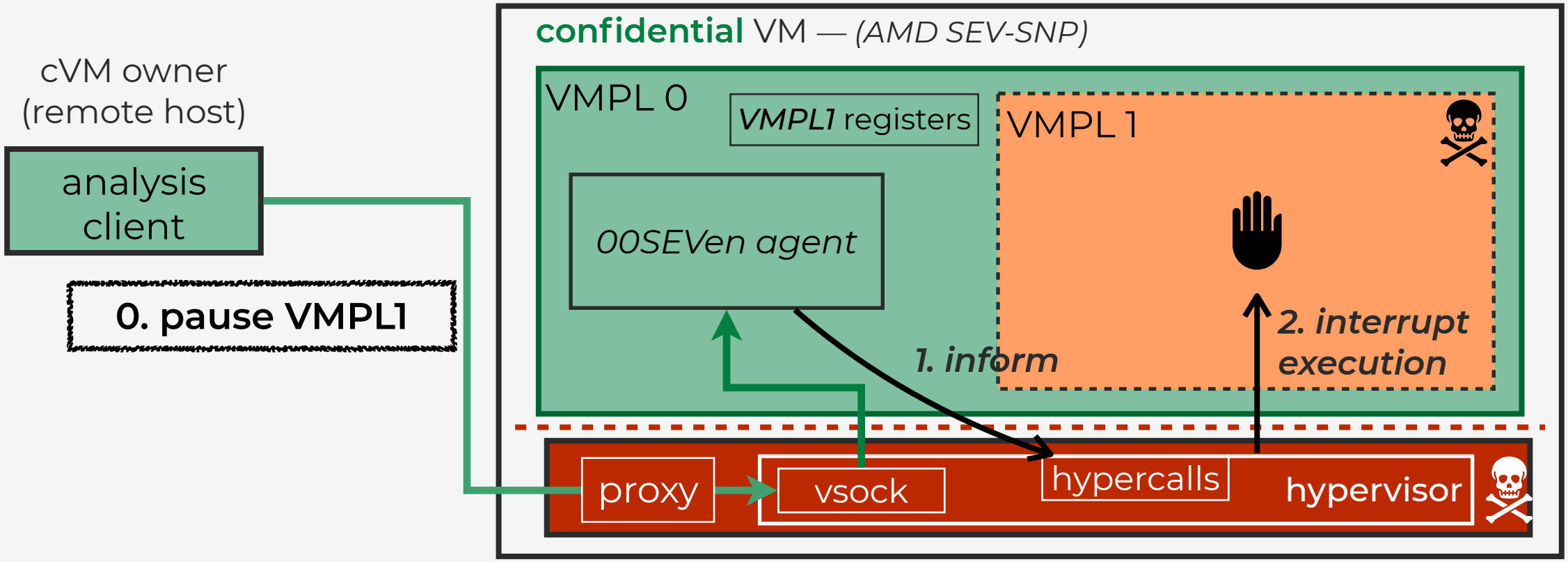

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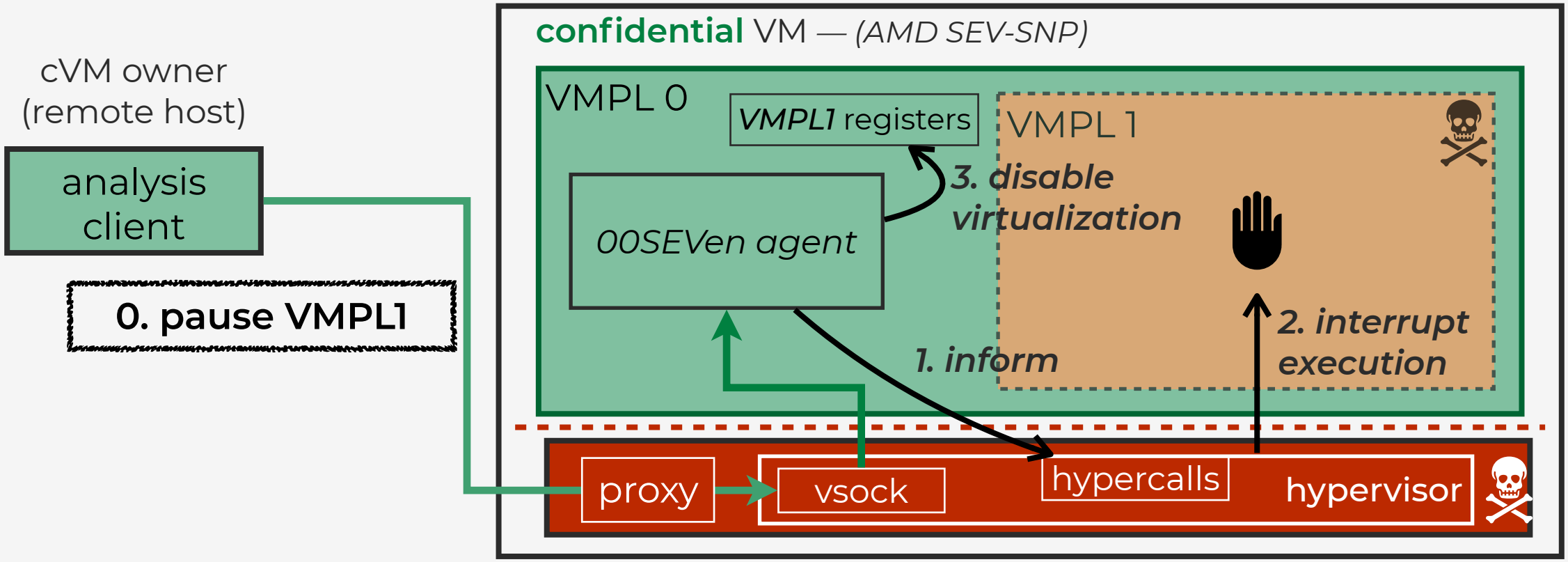


- in-VM agent and hypervisor cooperate to pause VMPL1 execution
- disabling virtualization in VMPL1 registers presents resume during analysis

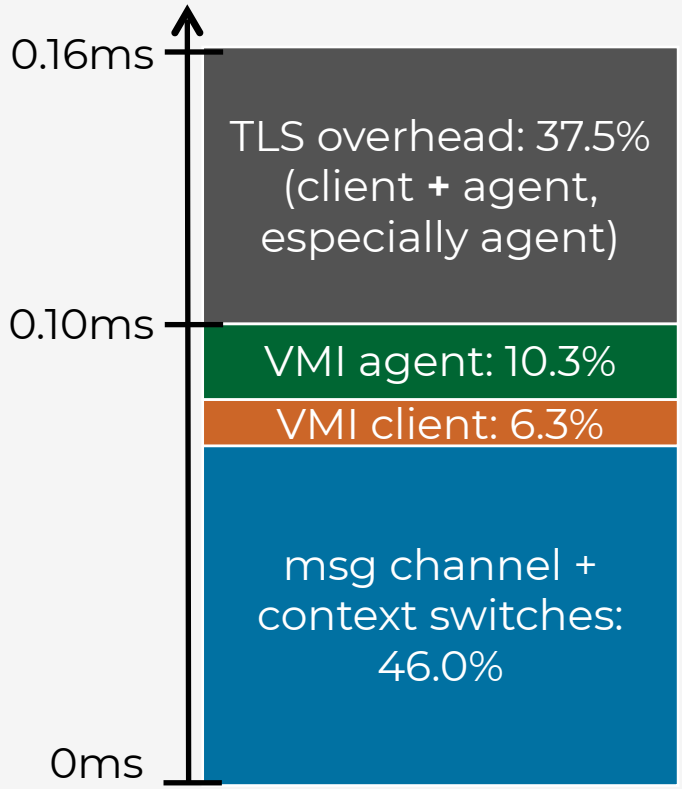
Evaluation Results of 00SEVen Prototype

- **Prototype:** AMD SEV-SNP cVMs, QEMU/KVM hypervisor, VMPL0 built on AMD's SVSM, LibVMI support on client side

- 10 VMI policies (e.g., scan process list) of RDMI (USENIX '23)
- microbenchmarks: page read, address translation
- more results in our paper (e.g., rootkit detection, traps)

- one 4kB-page read**: 0.1 ms (no TLS), 0.16 ms (TLS)**
  ++ network latency for remote inspection

- VMI policy baseline: *KVMi* on *"regular"* VMs on *same host*; vs. 00SEVen on cVMs:
  - 00SEVen client on same host: **+2 / +7 %** (no TLS / TLS)
  - 00SEVen client remote (LAN): **+20 %** (TLS)



Does 00SEVen solve the initial challenge?

GOAL: re-enable isolated VMI for cVMs — without breaking their security

- efficient remote inspection via secure in-VM agent
- VMI features:
  - memory + register access
  - VMPL1 pausing
  - event-based VMI via memory/function traps
    — *see paper for details*

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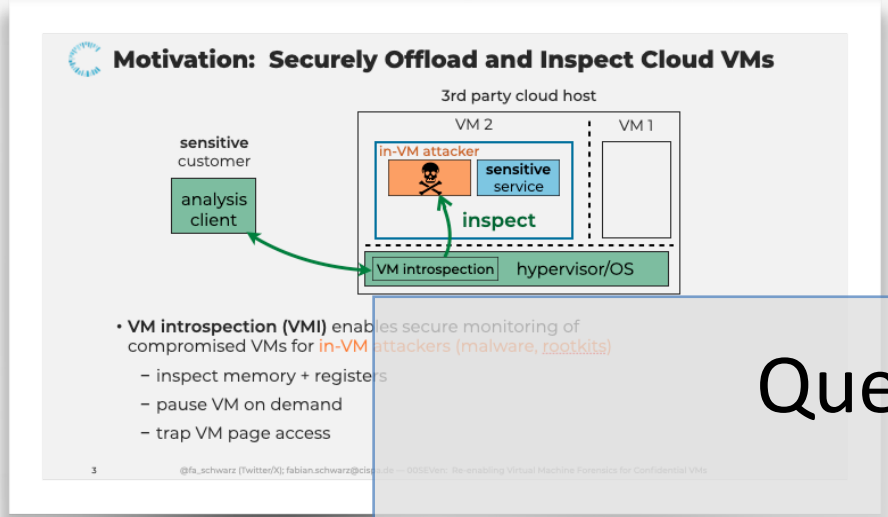
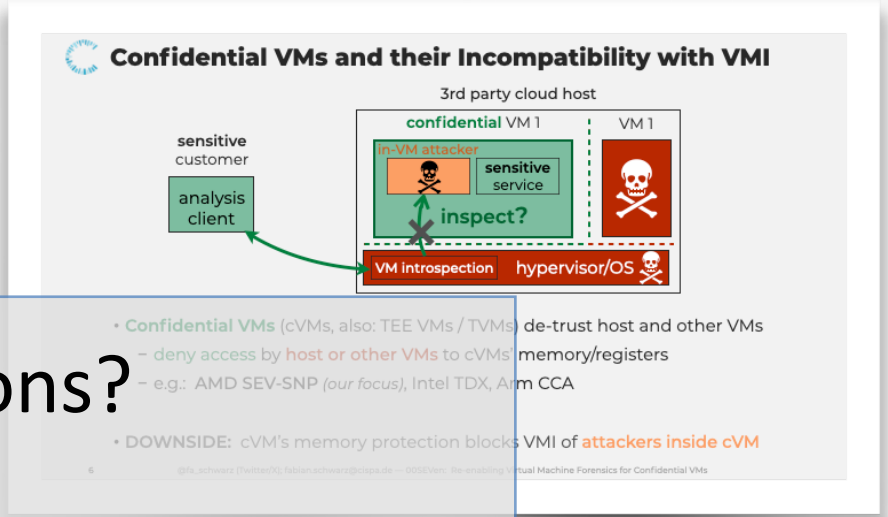
00SEVen combines the advantages of both: cVMs and VMI
— enabling cloud usage by sensitive customers

Summary — 00SEVen: Re-enabling VMI for cVMs





Questions?

fabian.schwarz@cispa.de

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https://github.com/sev-vmi/00seven