A Placement Vulnerability Study in Multi-tenant Public Clouds

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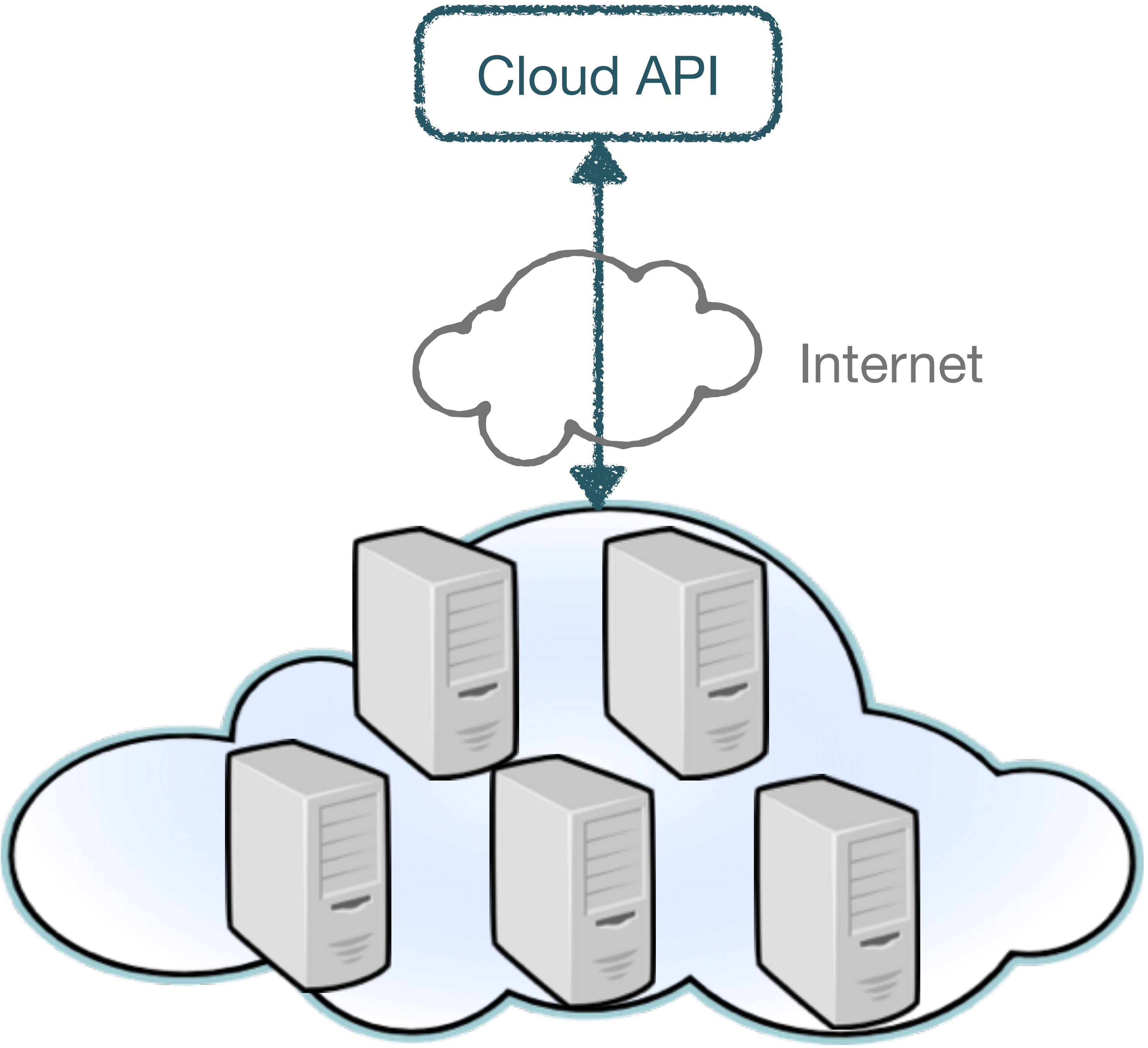
THE OHIO STATE UNIVERSITY

CORNELL TECH

USENIX Security 2015

Public Clouds



Google Compute Engine

amazon web services EC2

Microsoft Azure

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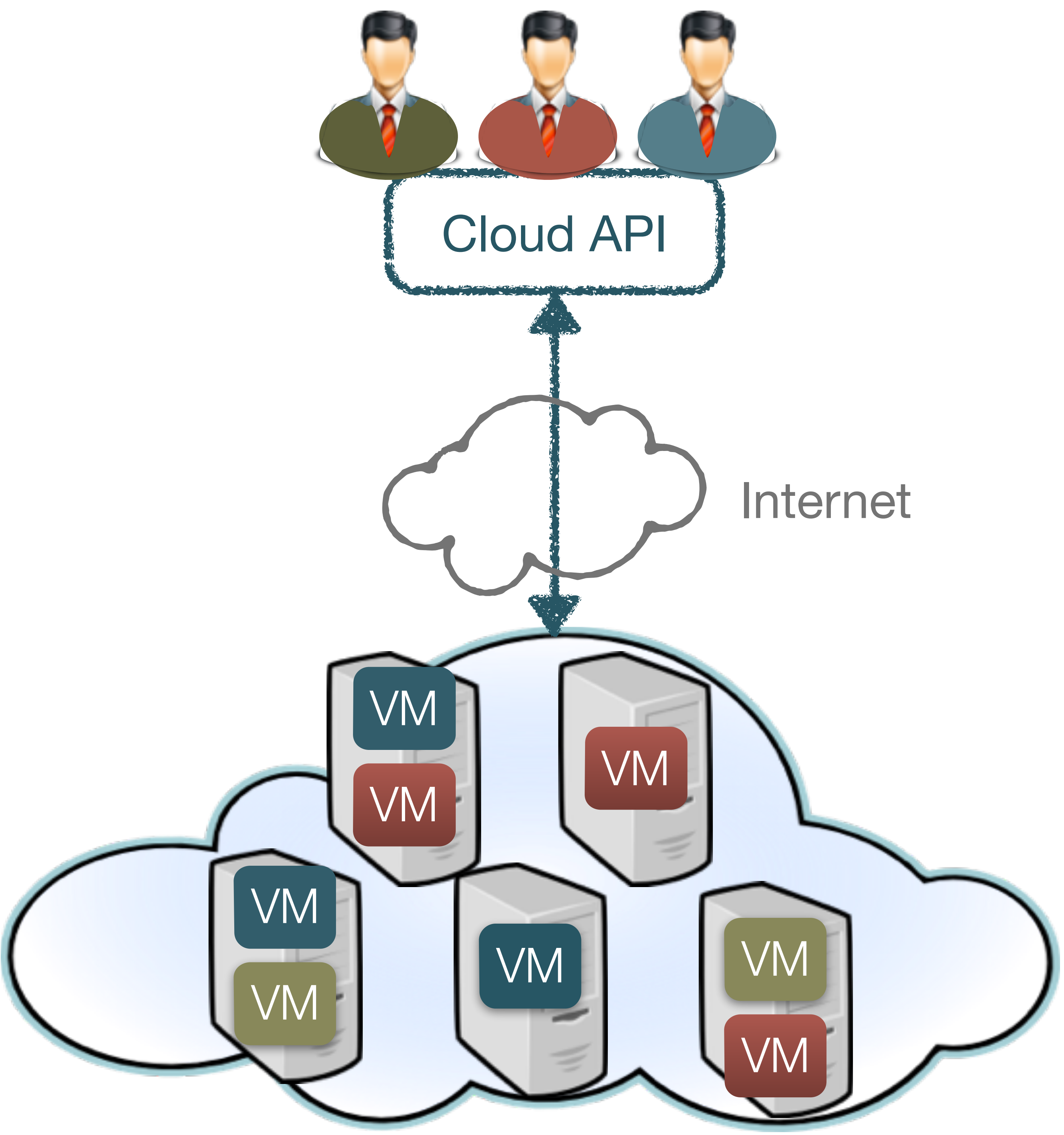

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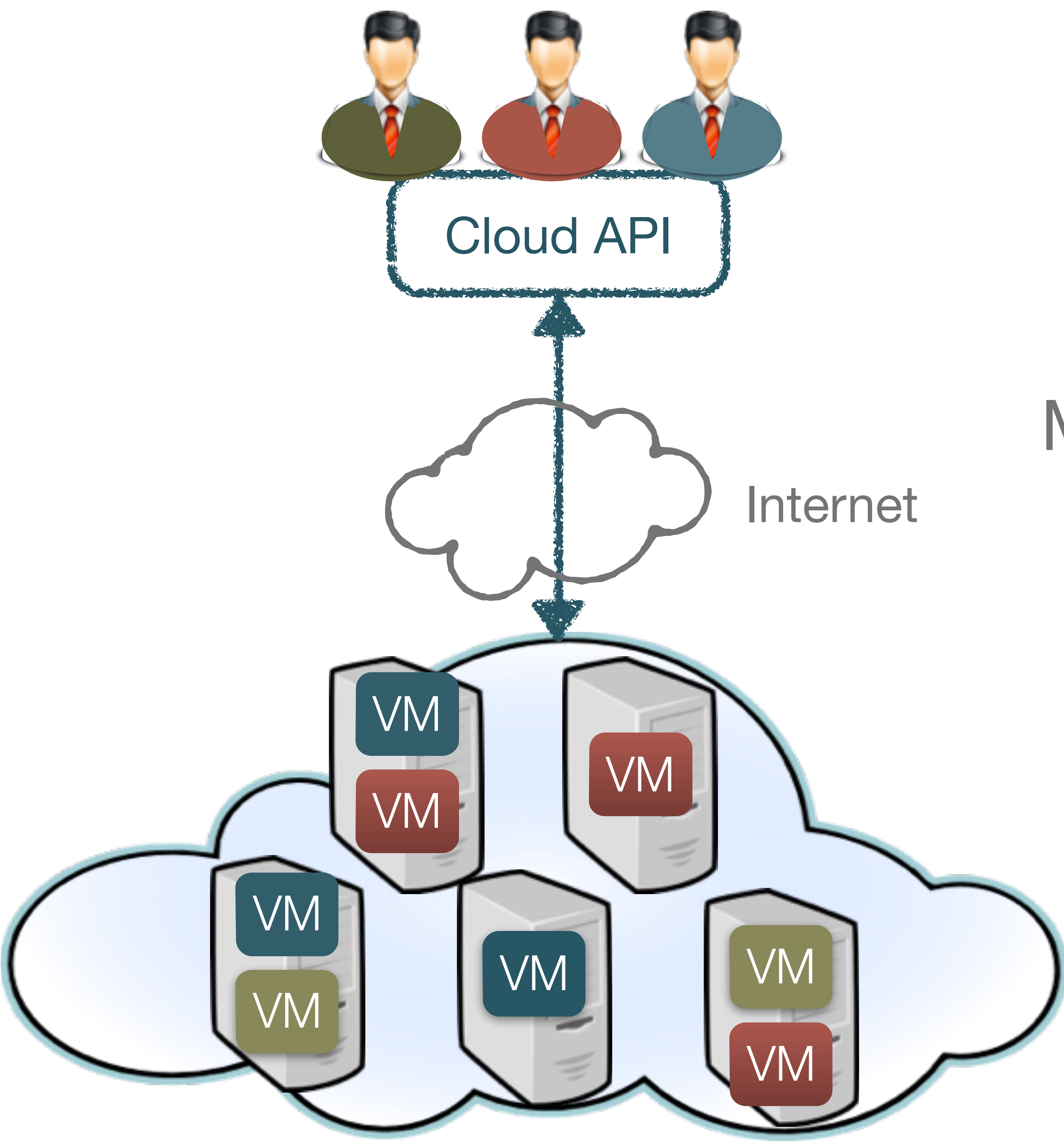

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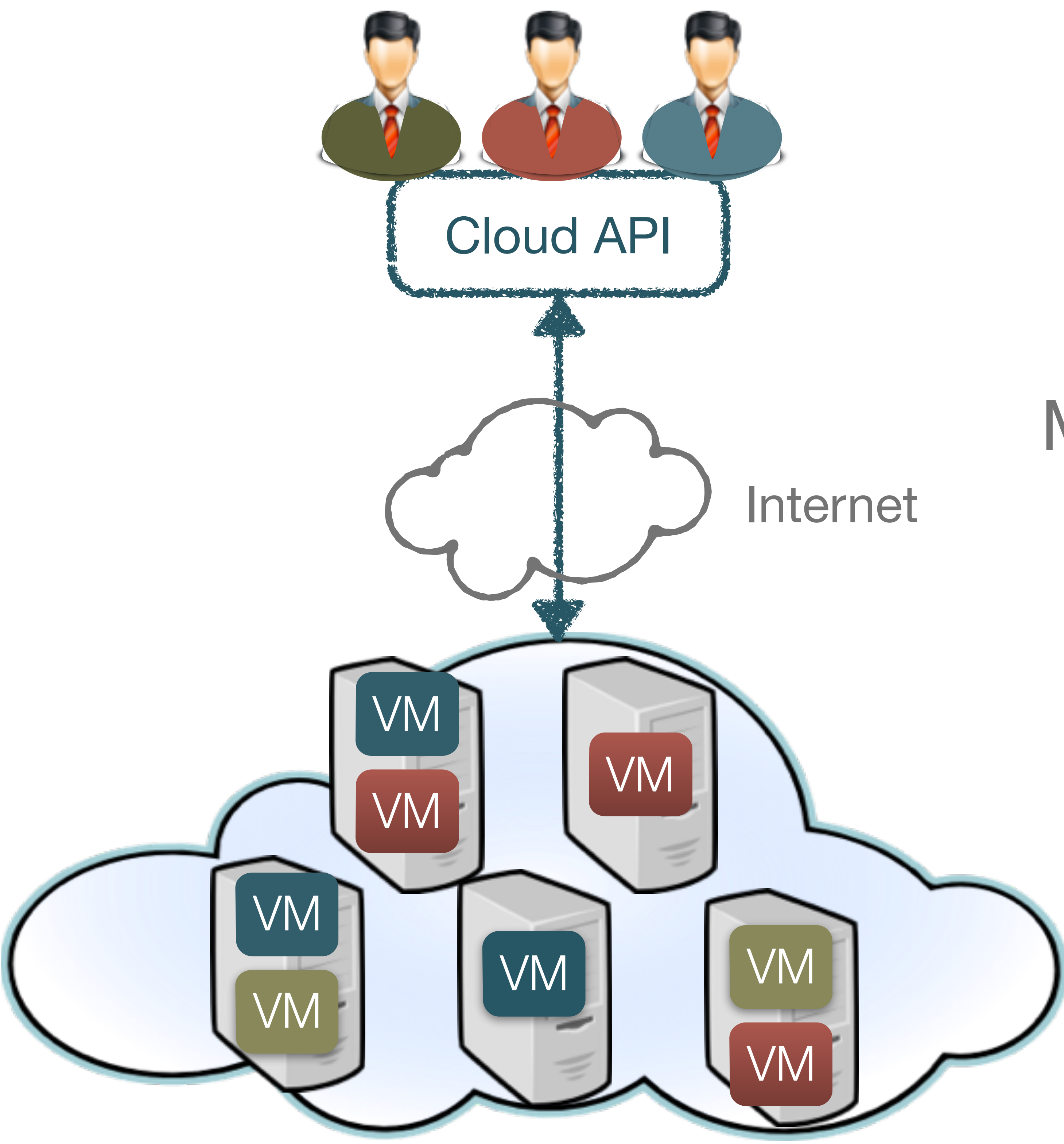
Multi-tenancy

Public Clouds



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Multi-tenancy + Public

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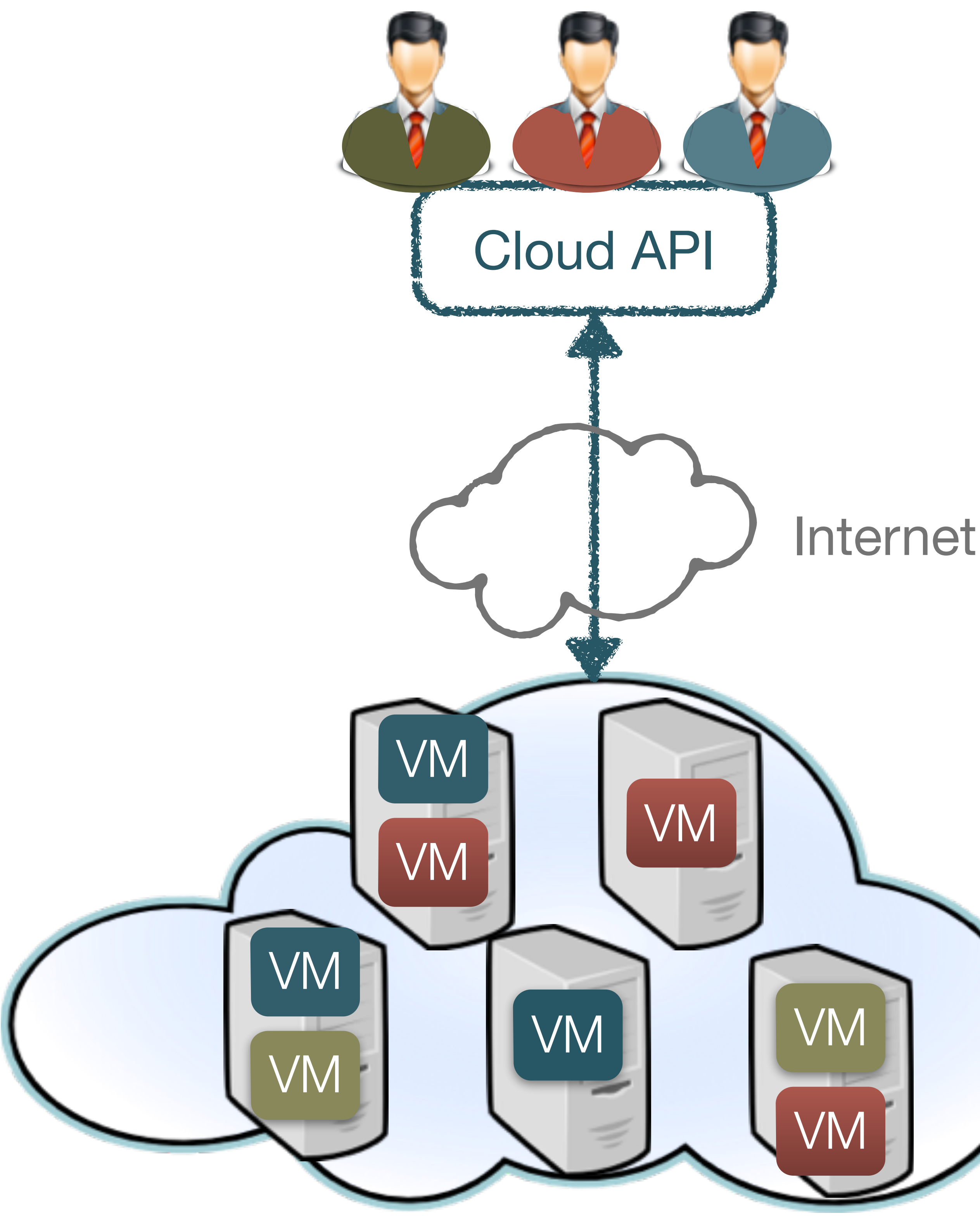

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Multi-tenancy + Public

Big concern: cross-VM attacks via co-location

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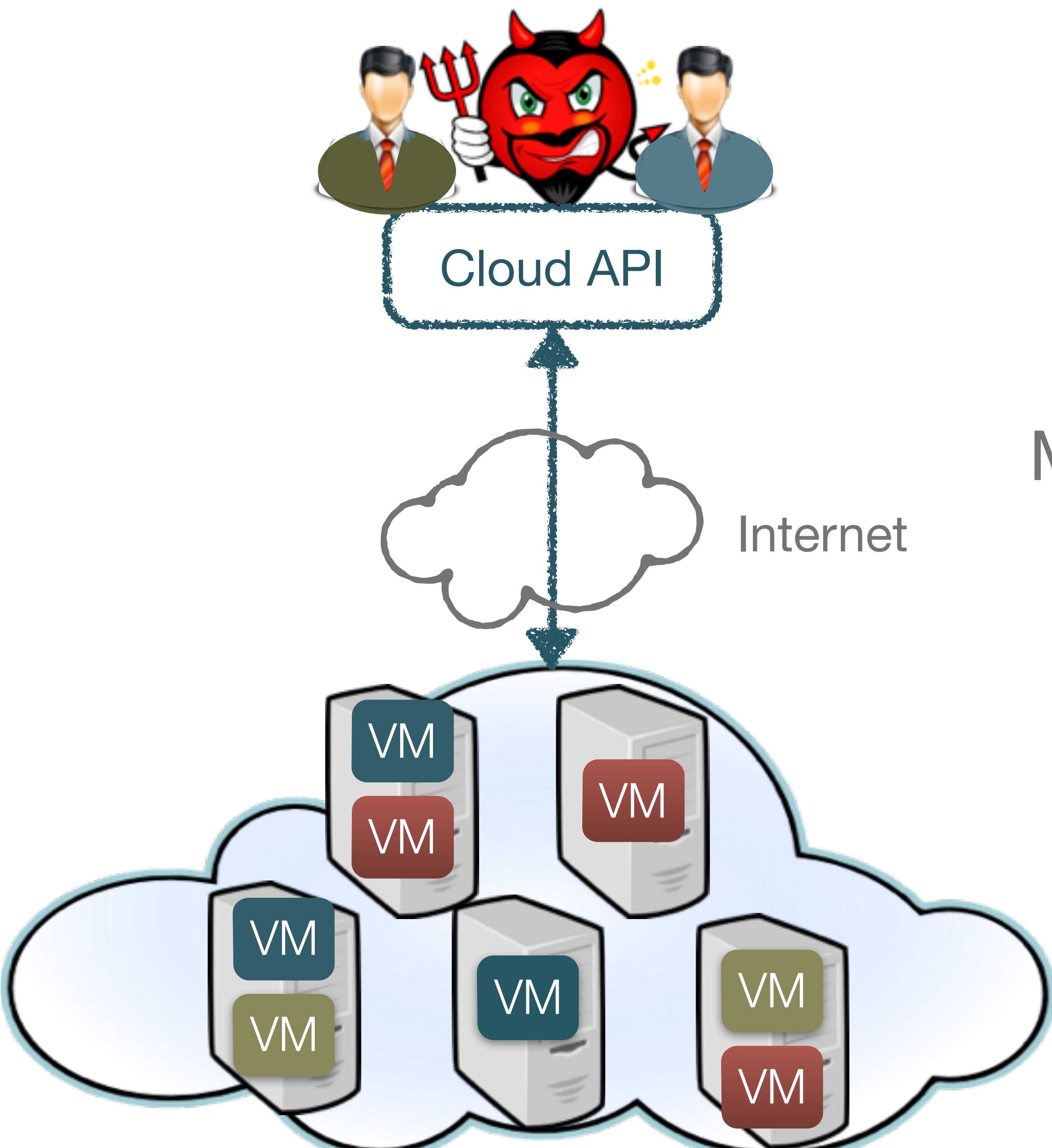

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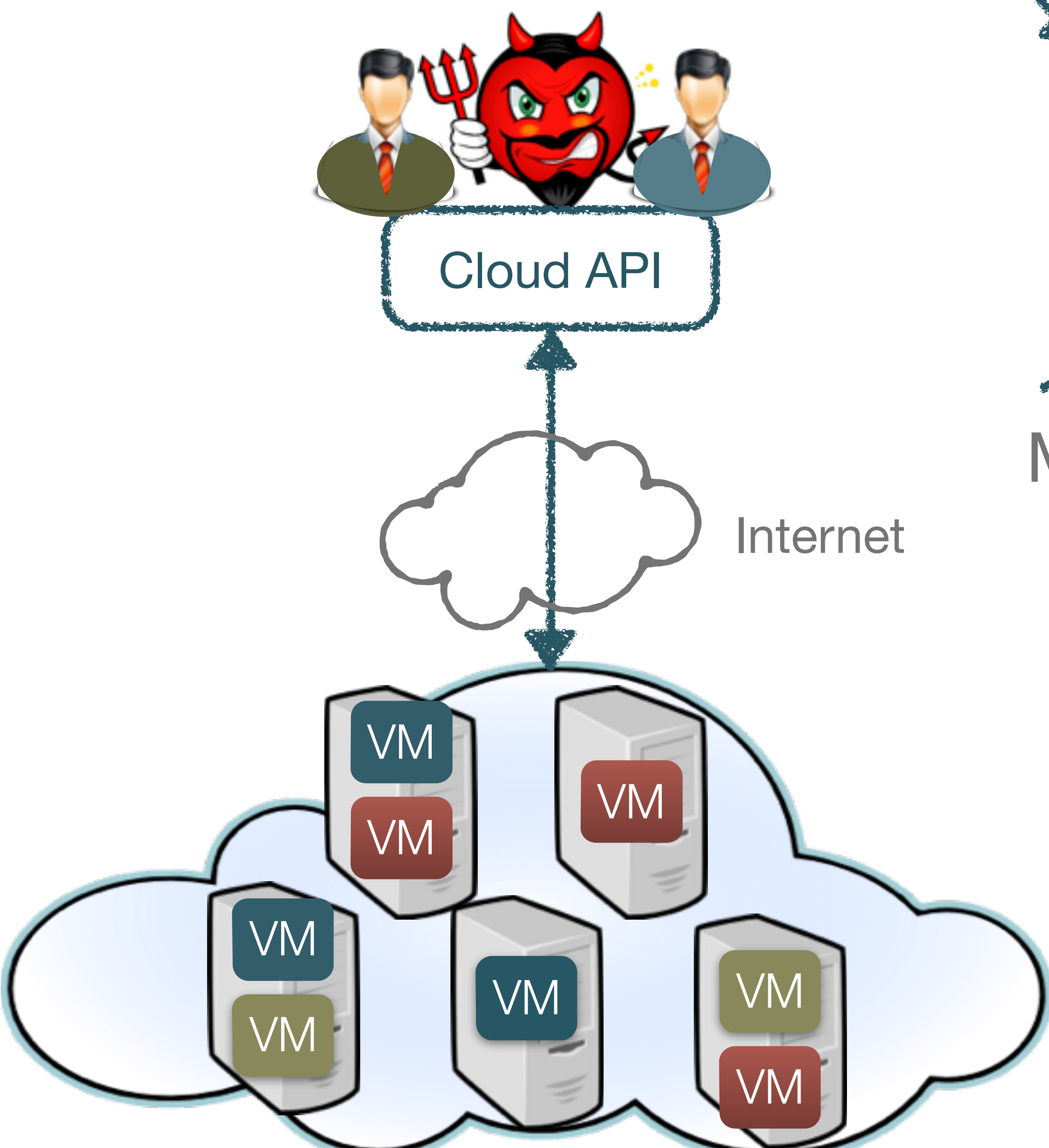

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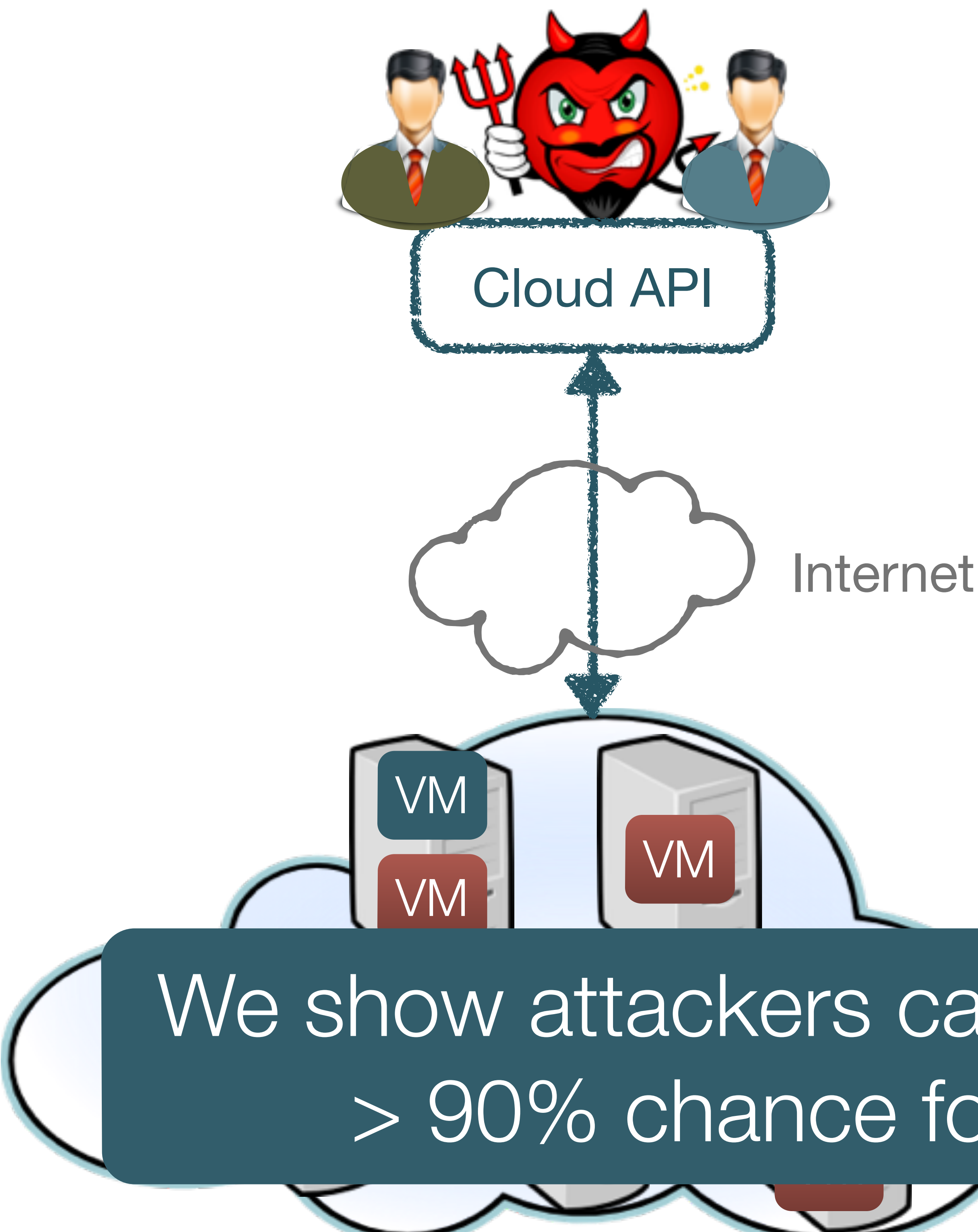

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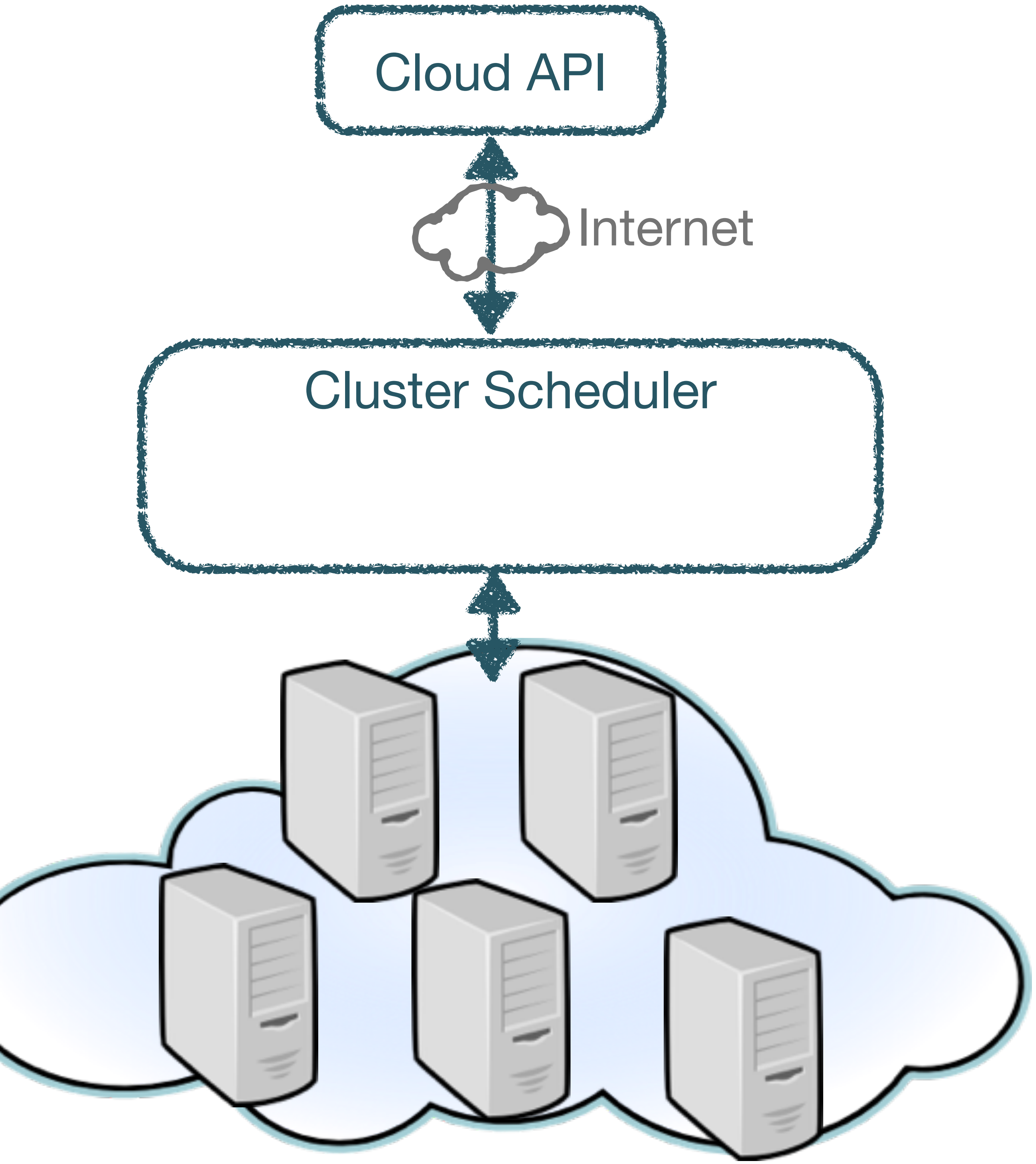
Multi-tenancy + Public

Big concern: cross-VM attacks via co-location

We show attackers can achieve co-location with > 90% chance for as low as *14* cents!

Placement and Isolation in Public Clouds



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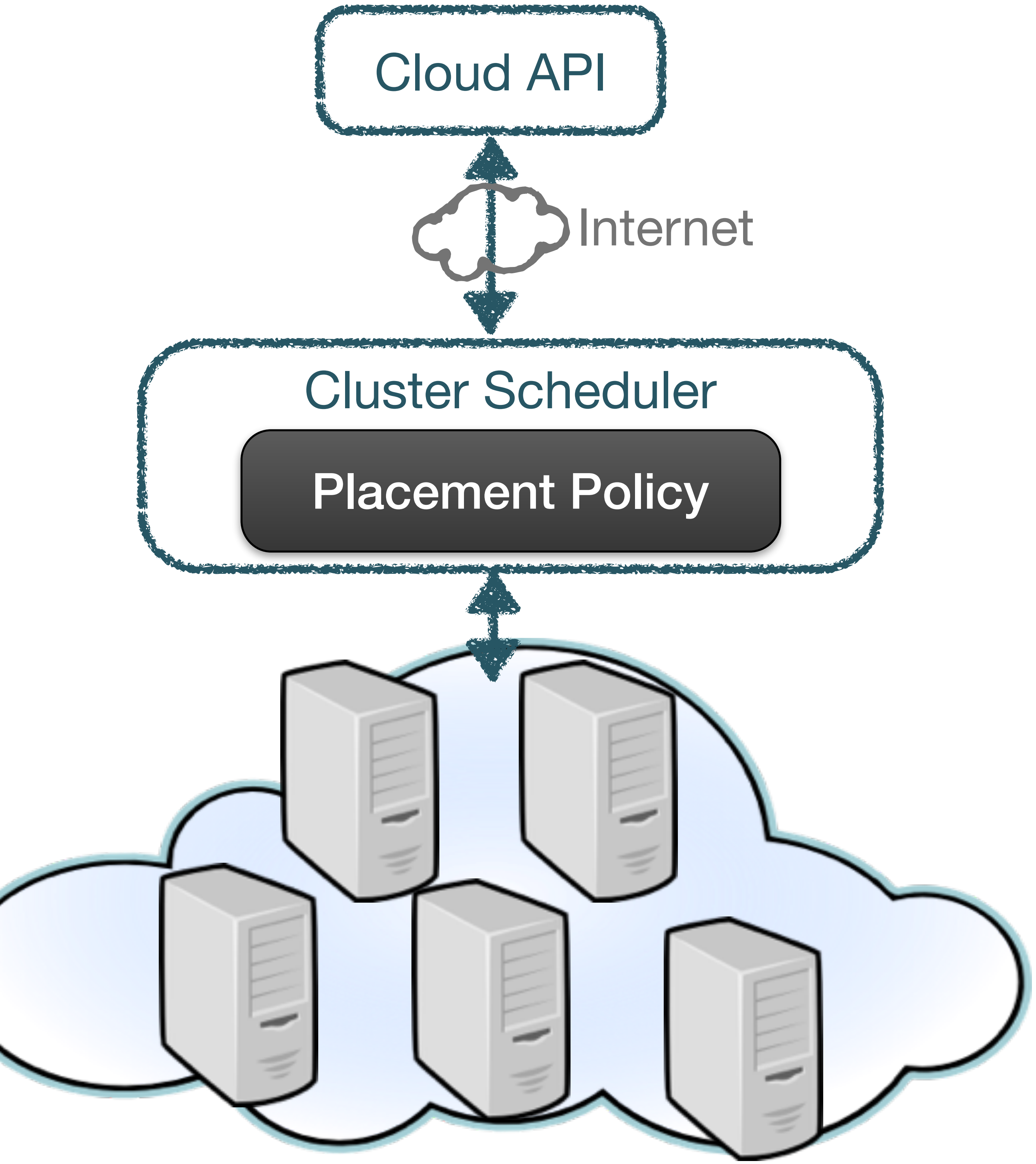

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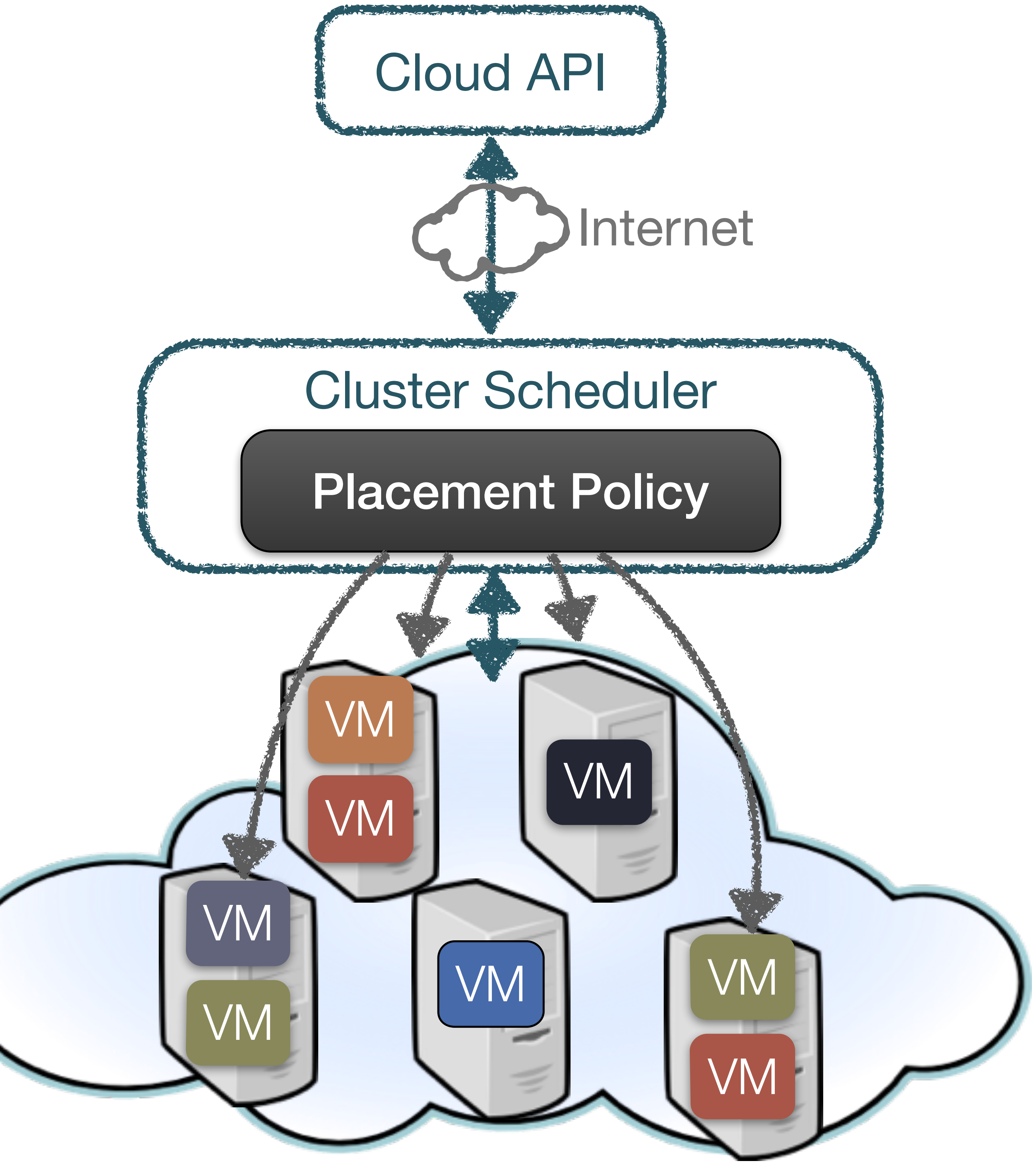

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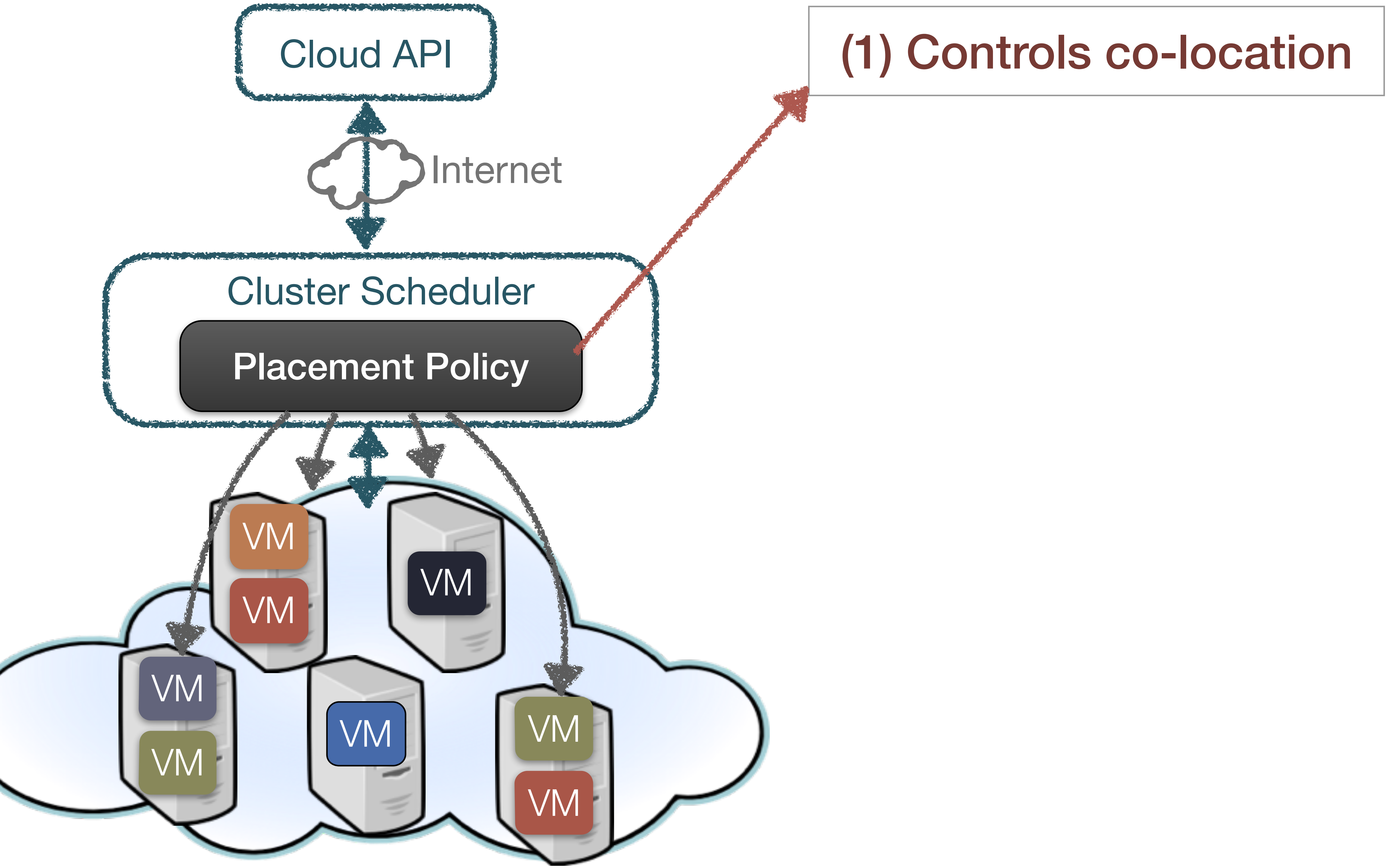

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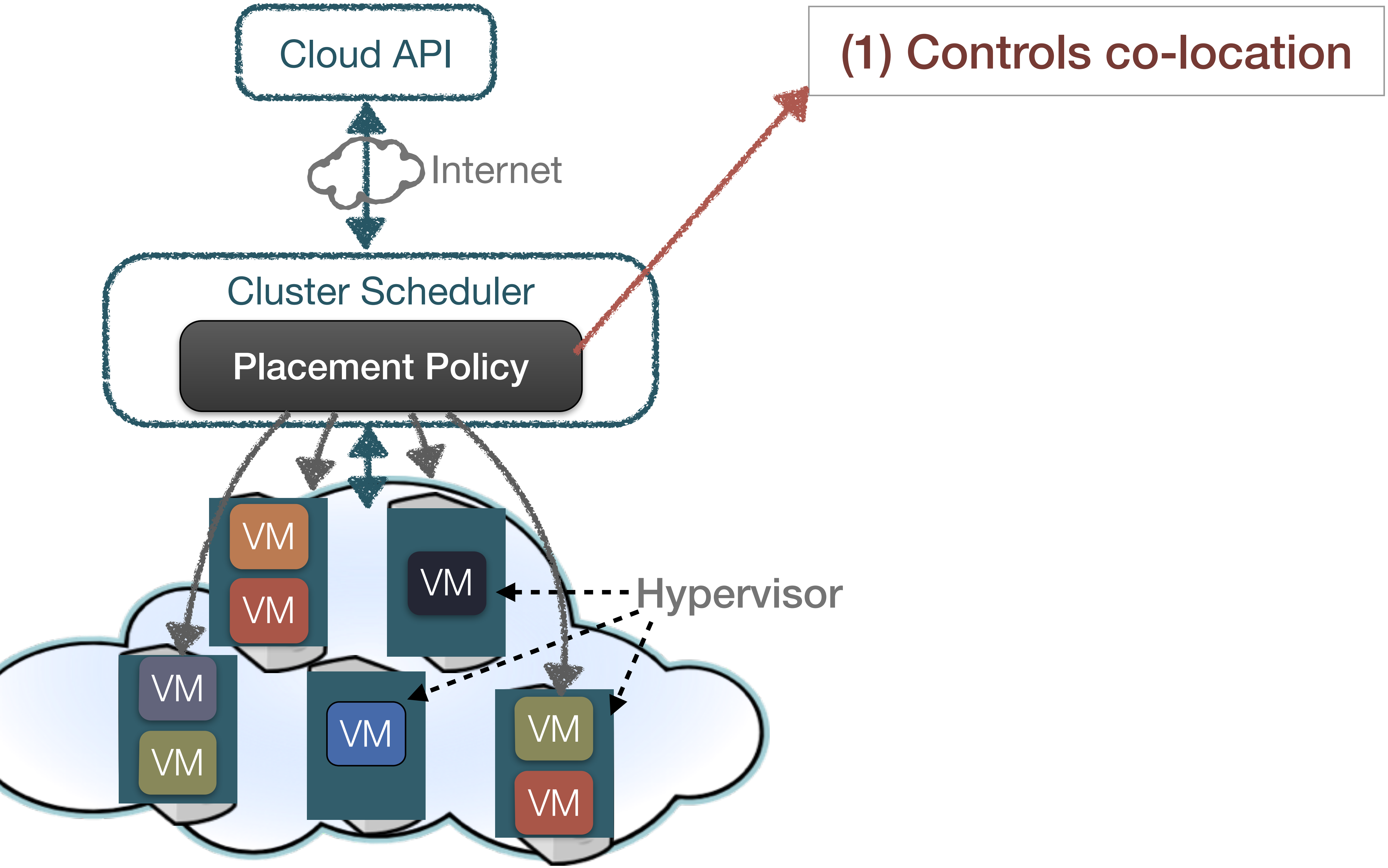

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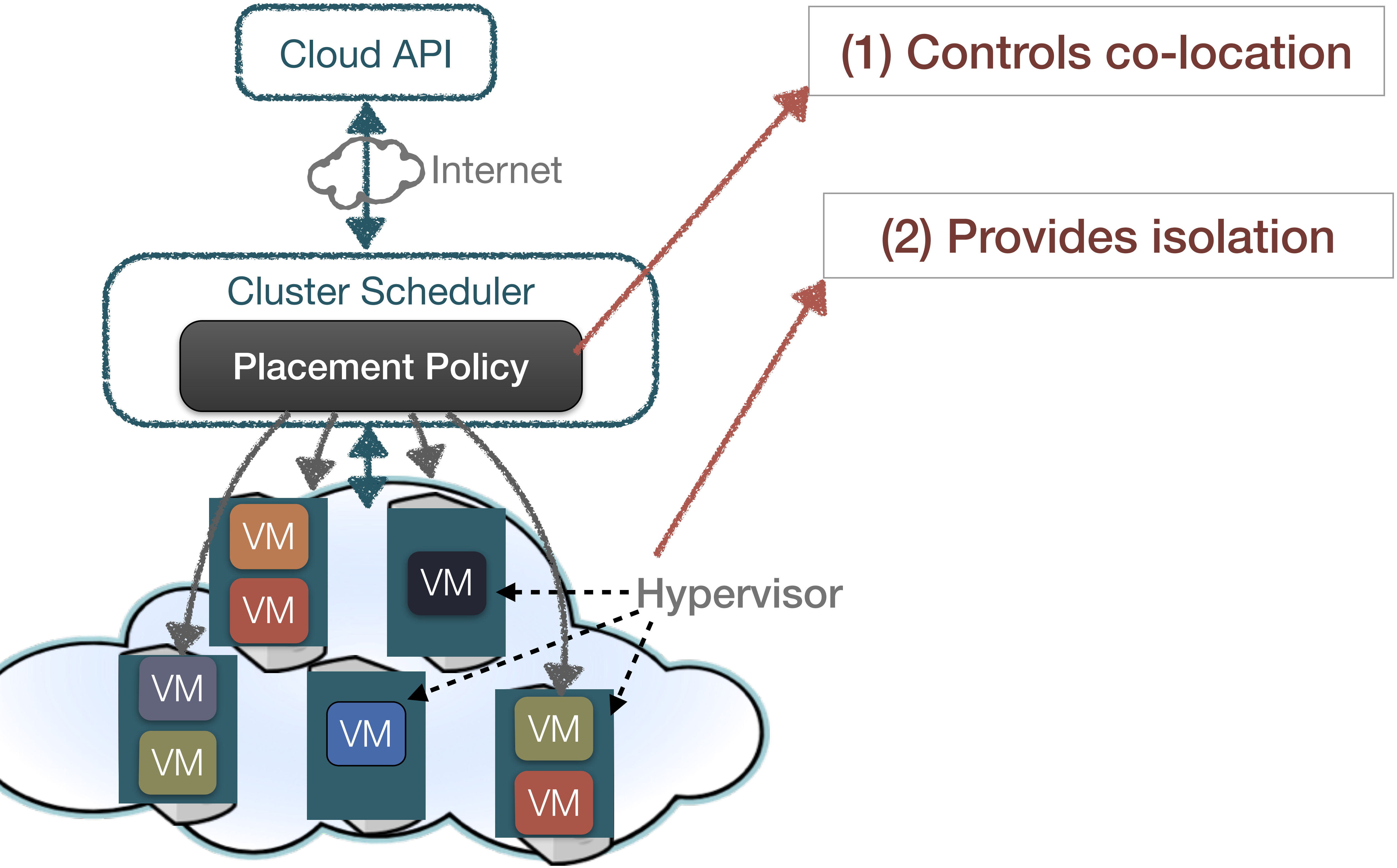

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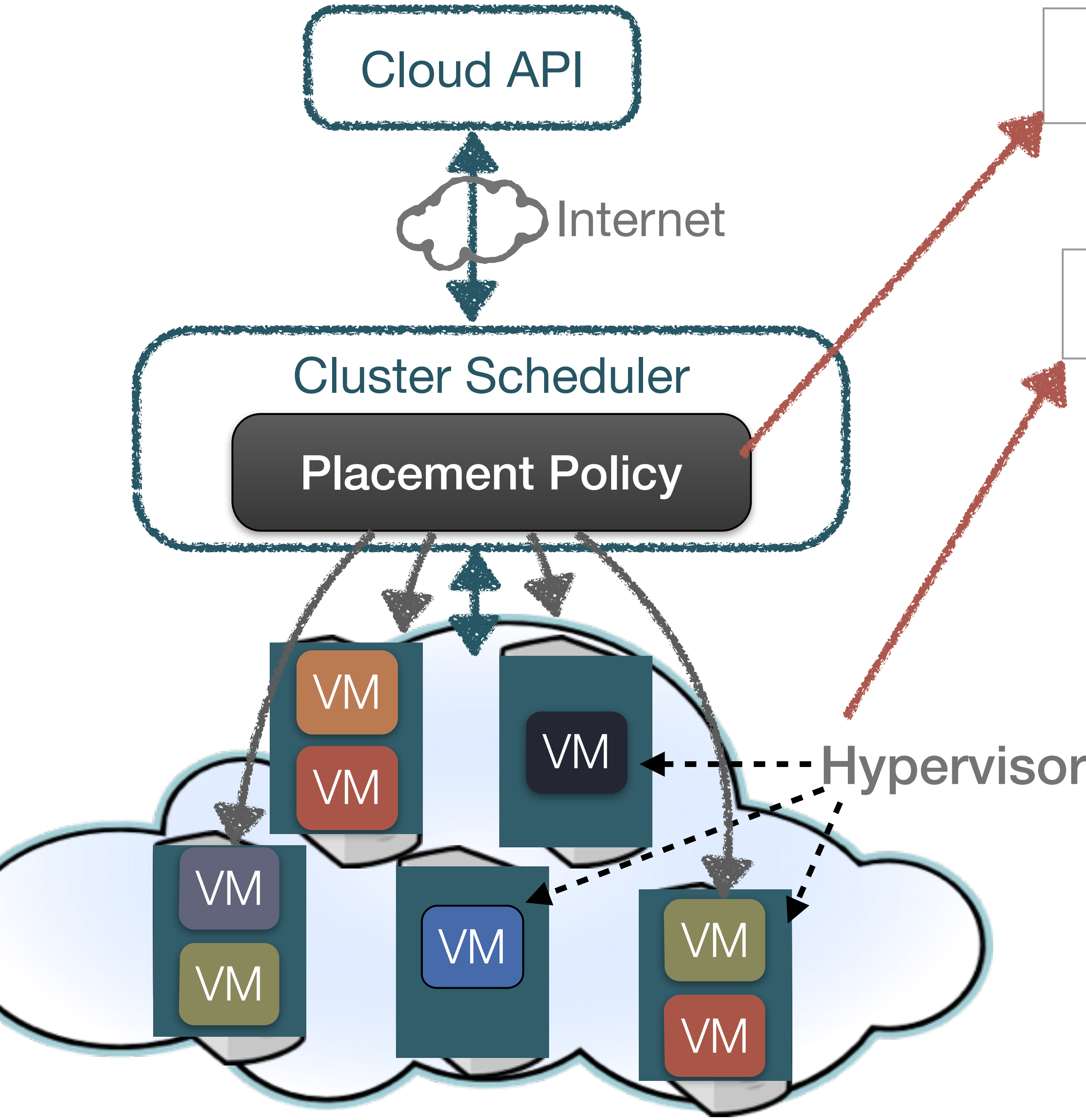

(1) Controls co-location

(2) Provides isolation

- **Cross-VM side- and covert-channels** [Ristenpart'09, Xu'11, Wu'12, Zhang'12, Yarom'14, Liu'15, Gruss'15]
- **Resource-stealing, DoS** [Zhou'11, Varadarajan'12]

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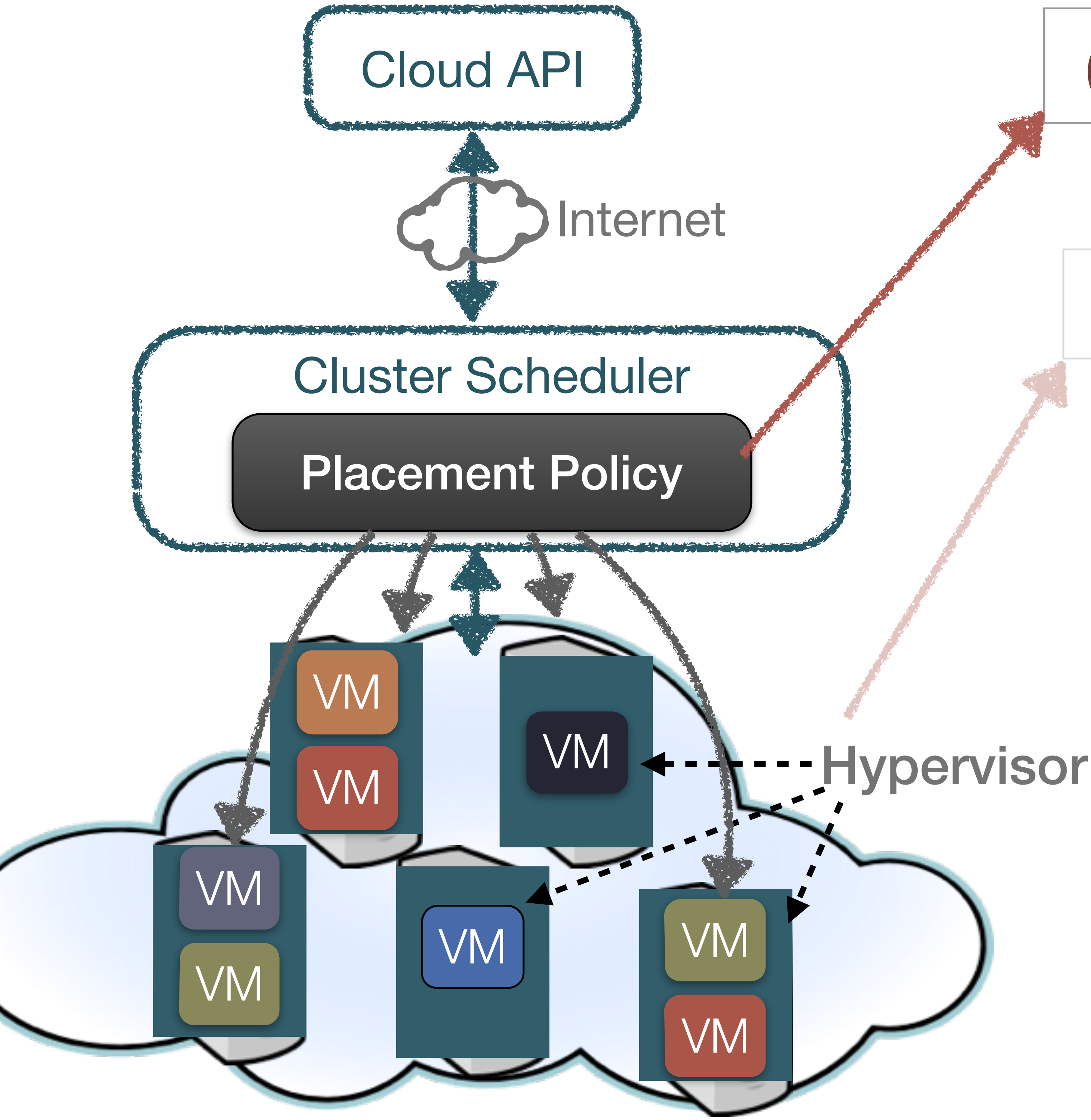

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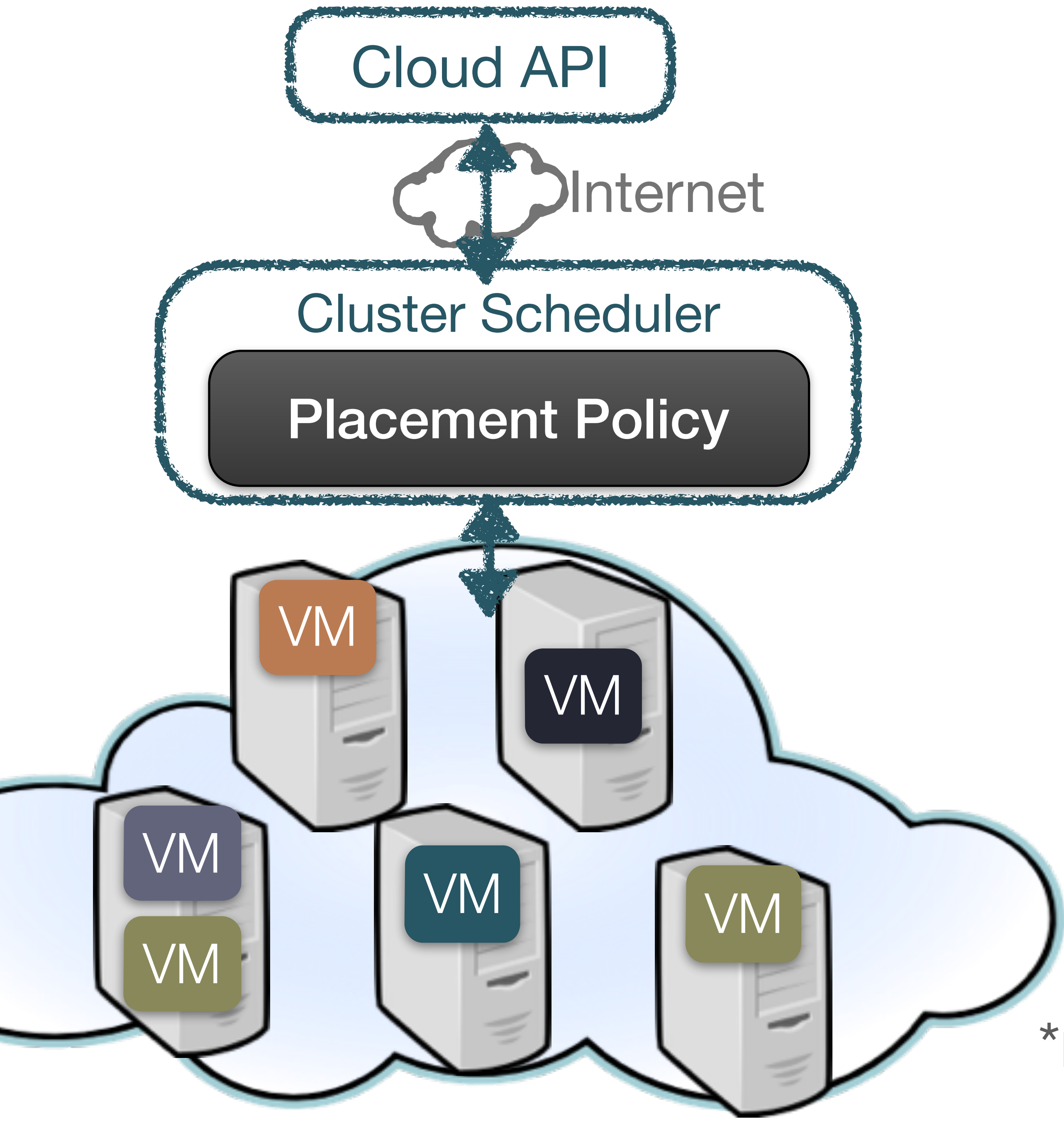

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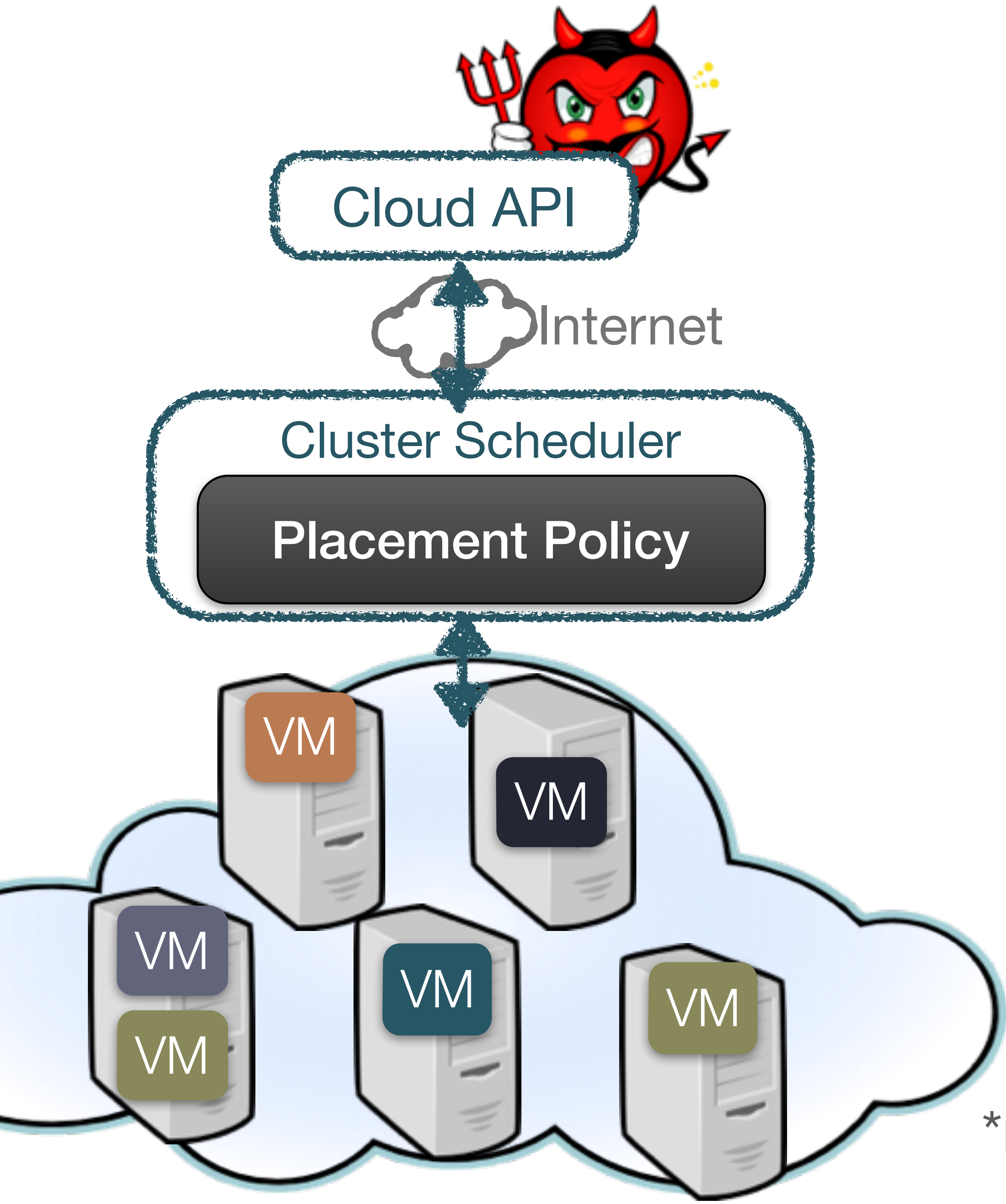

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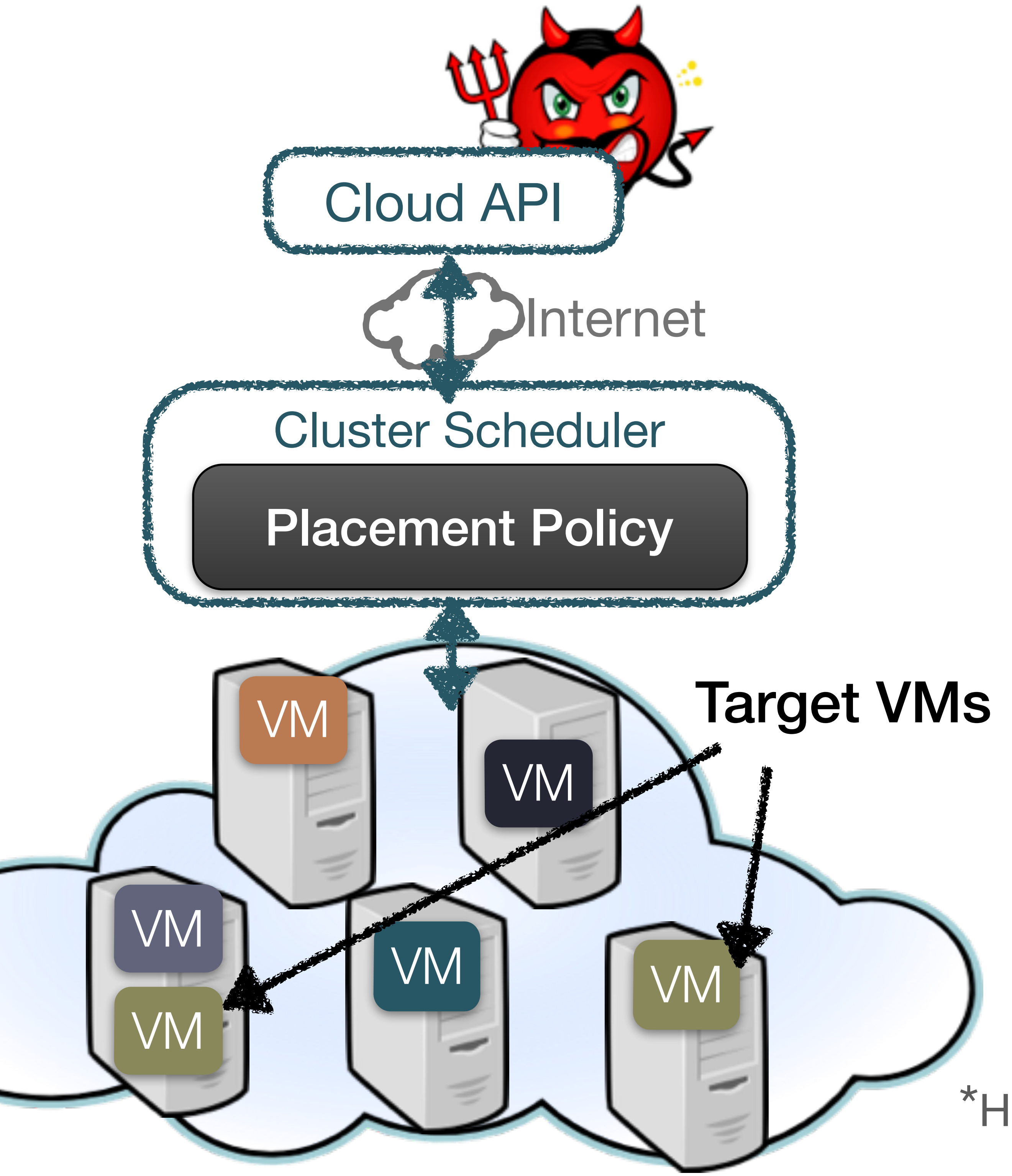

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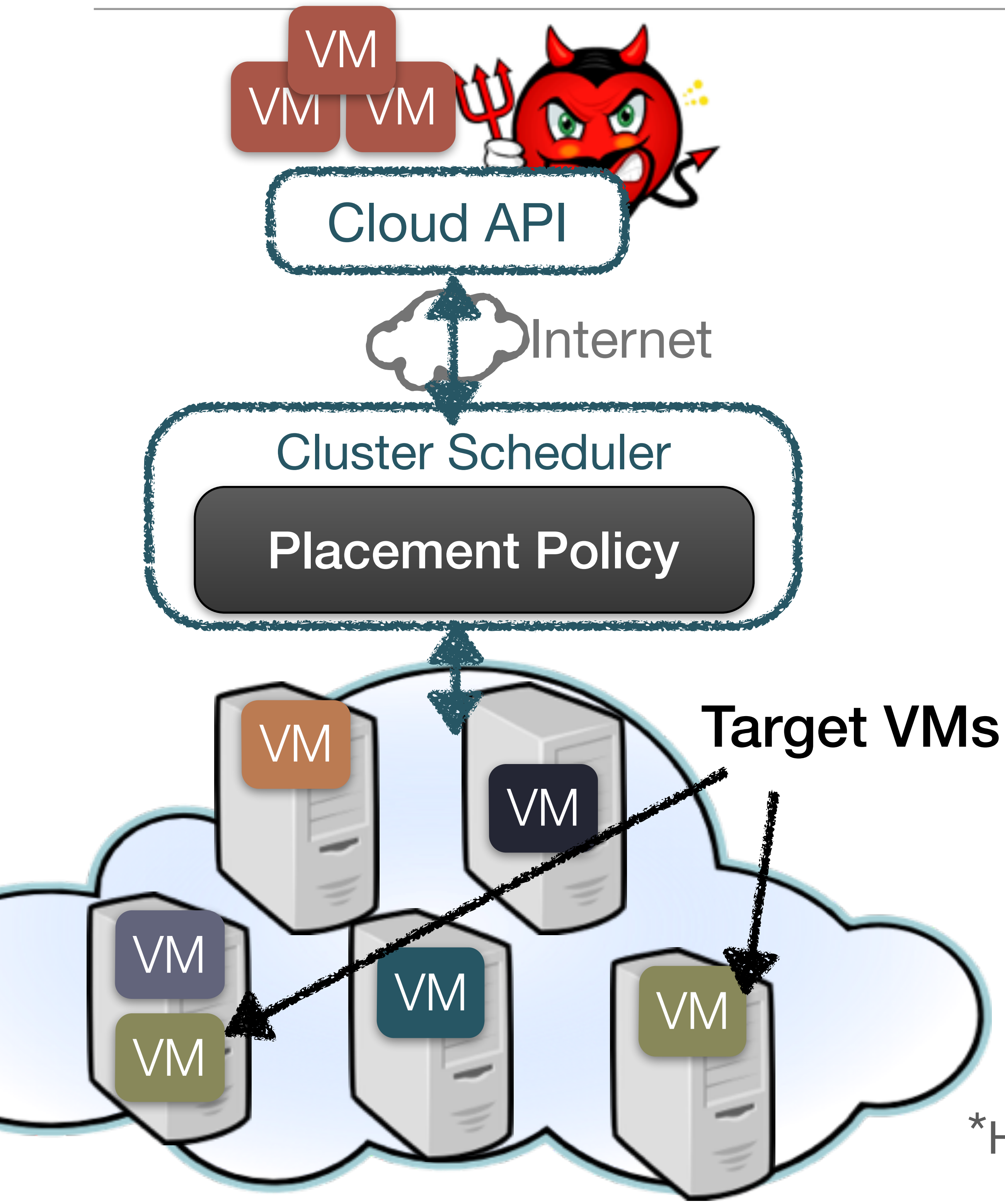

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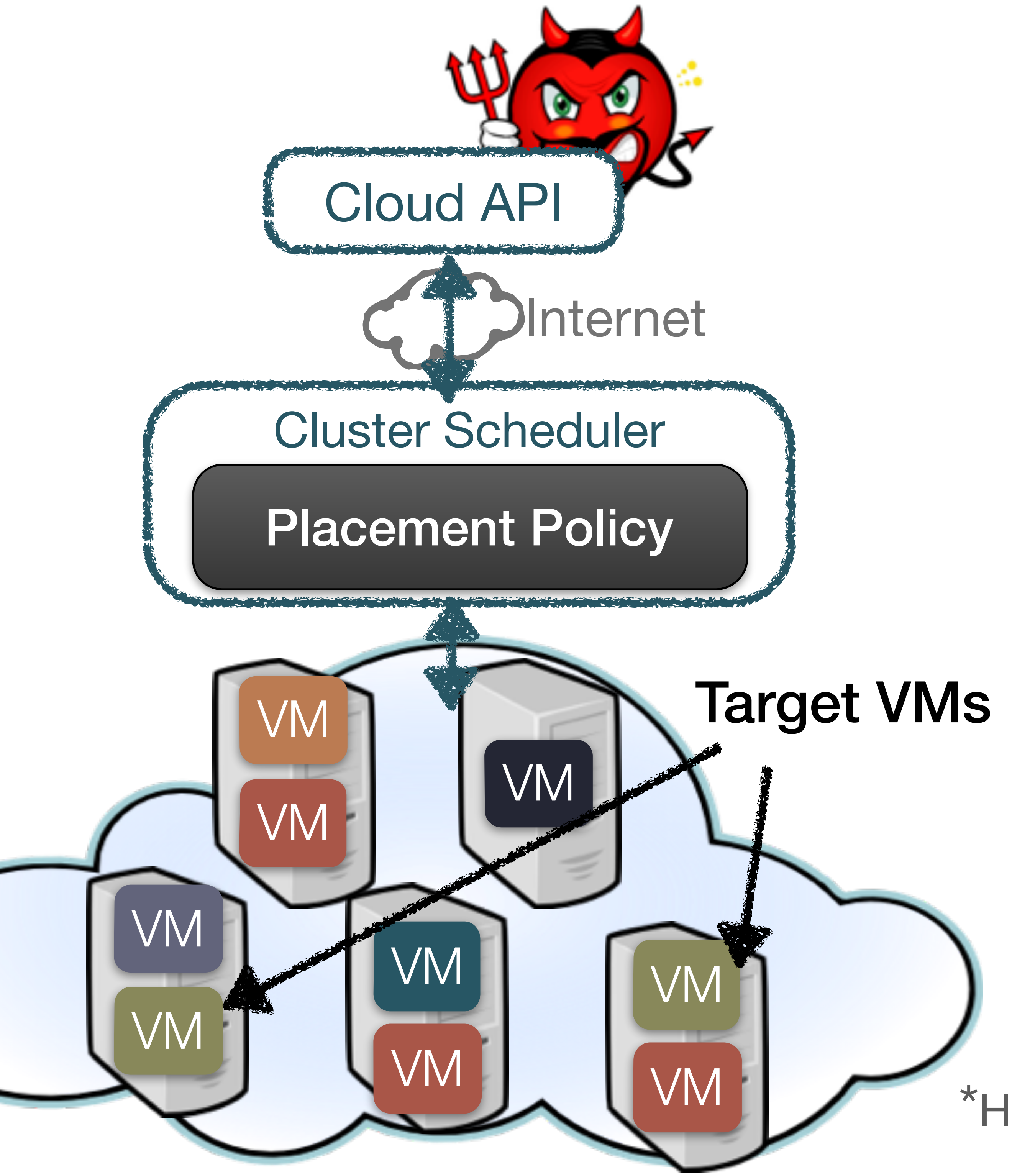

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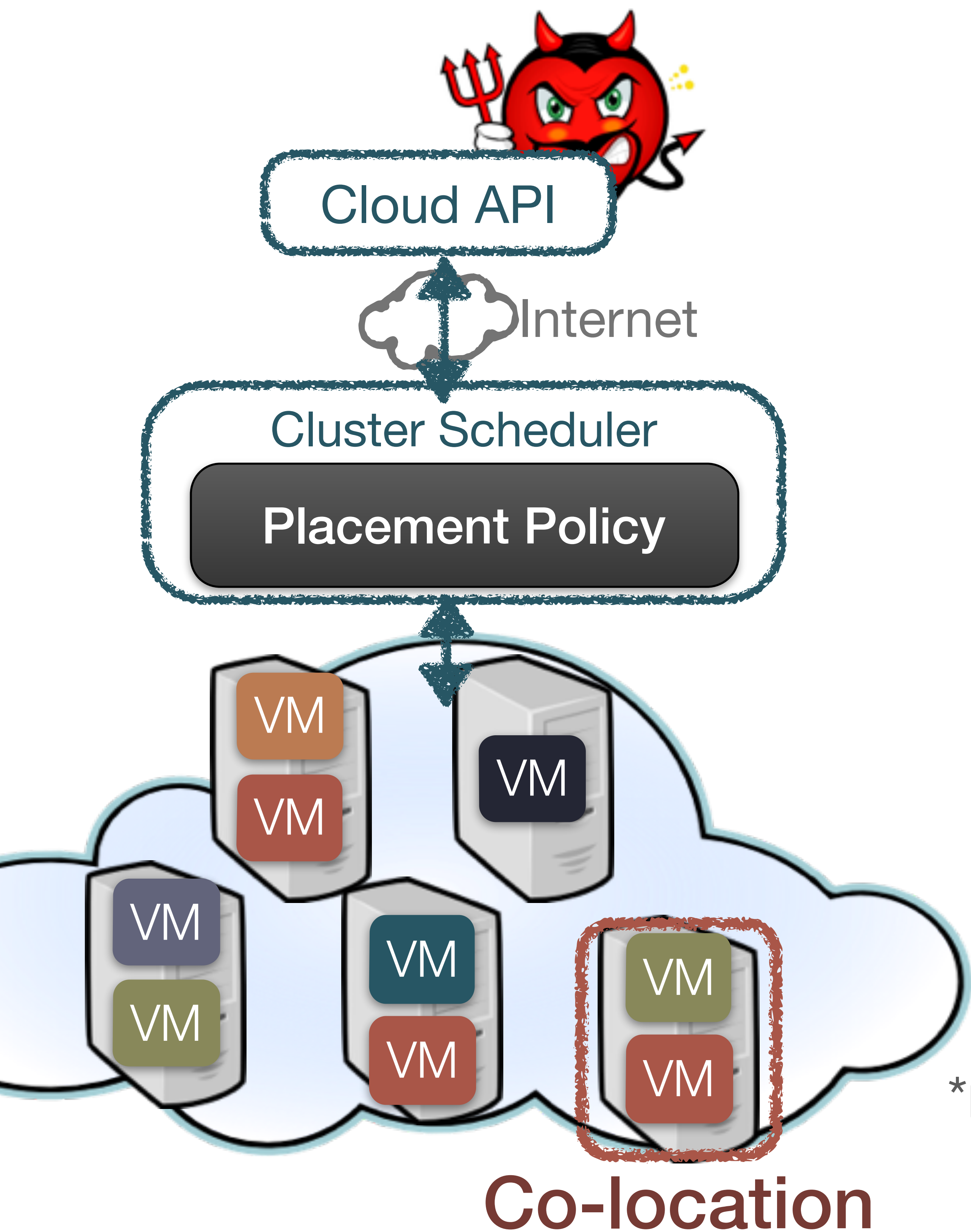

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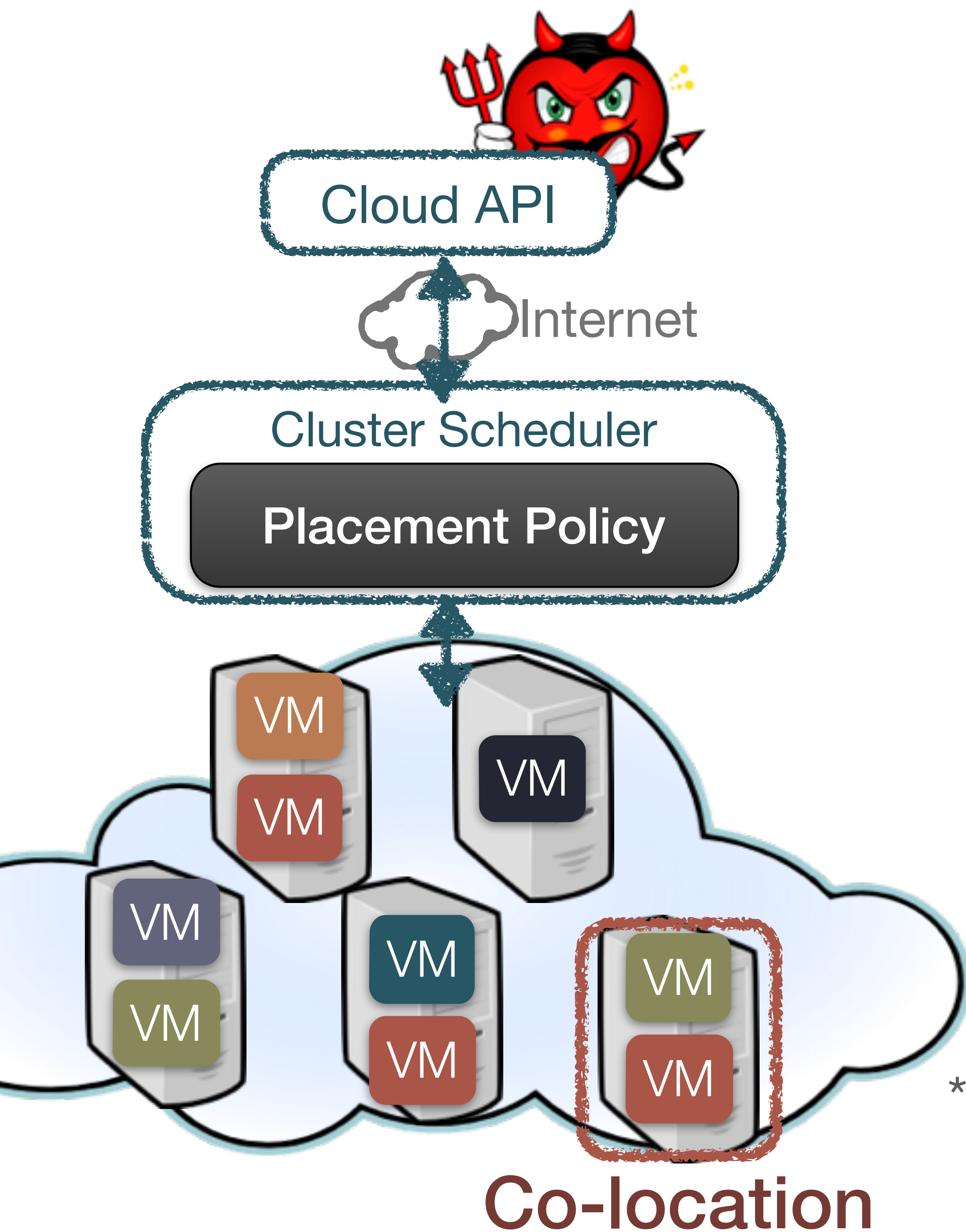

- 6 years old

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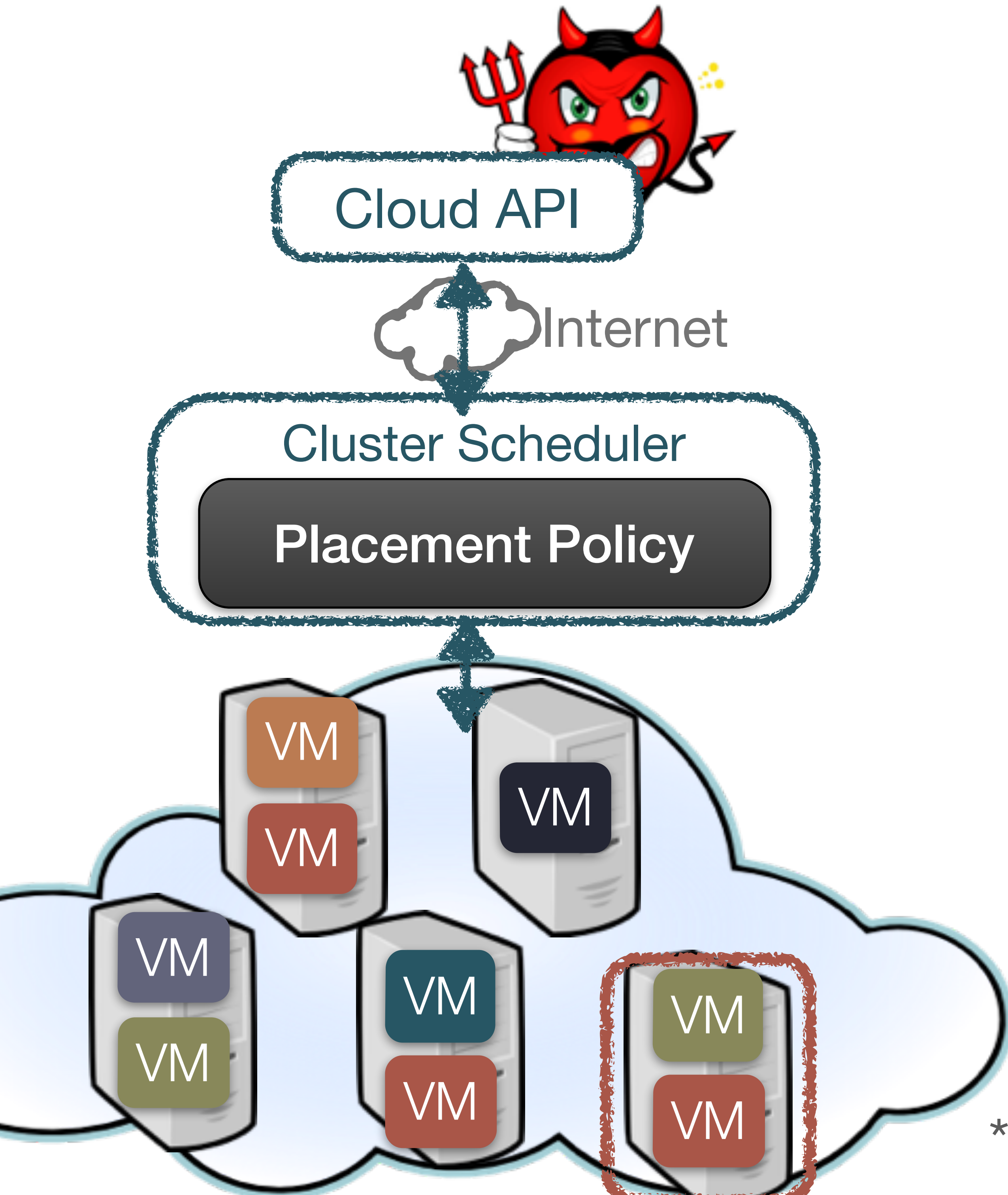

Co-location

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- New countermeasures (e.g, virtual private clouds)

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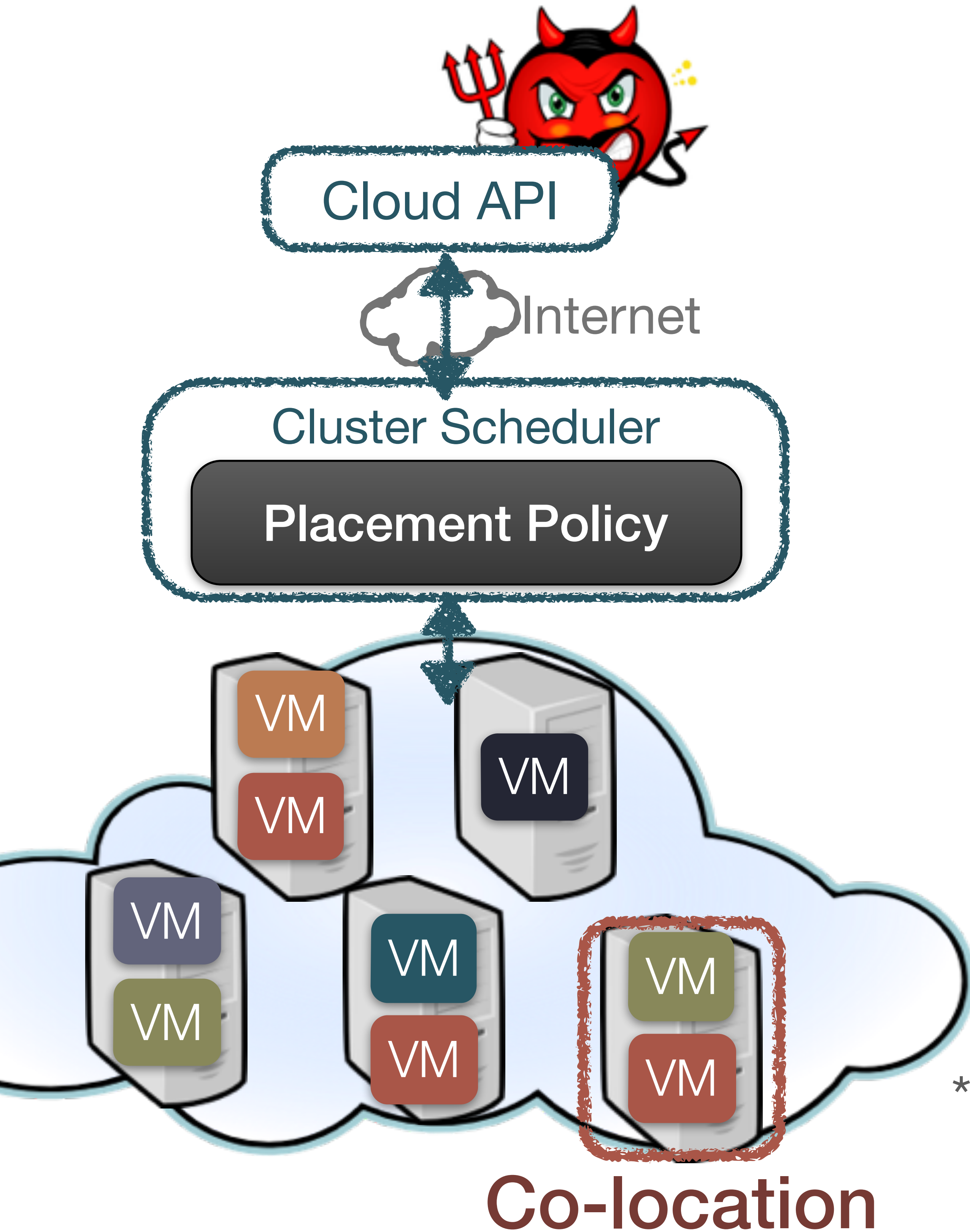

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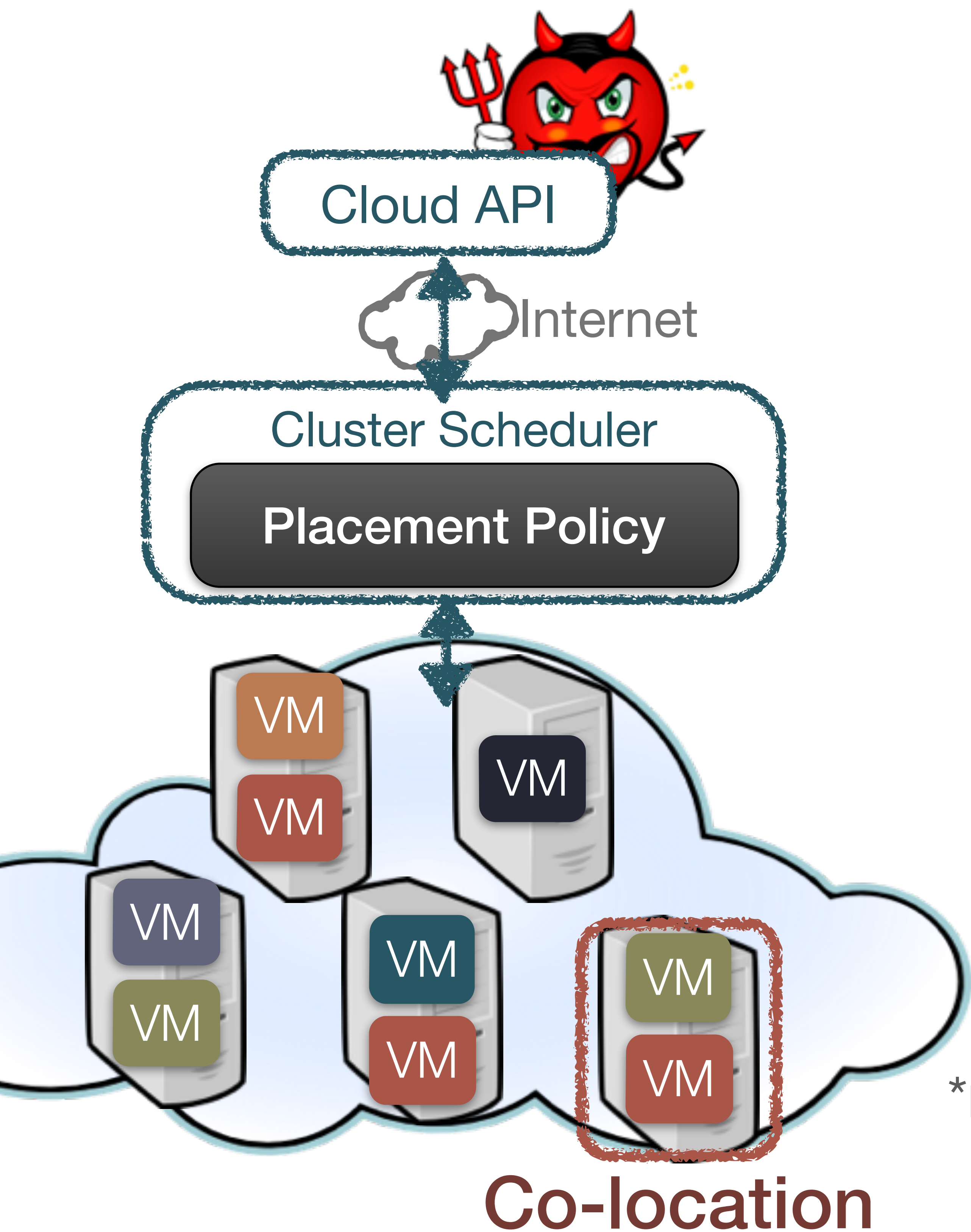

- 6 years old
- New countermeasures (e.g, virtual private clouds)
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- Only on Amazon EC2

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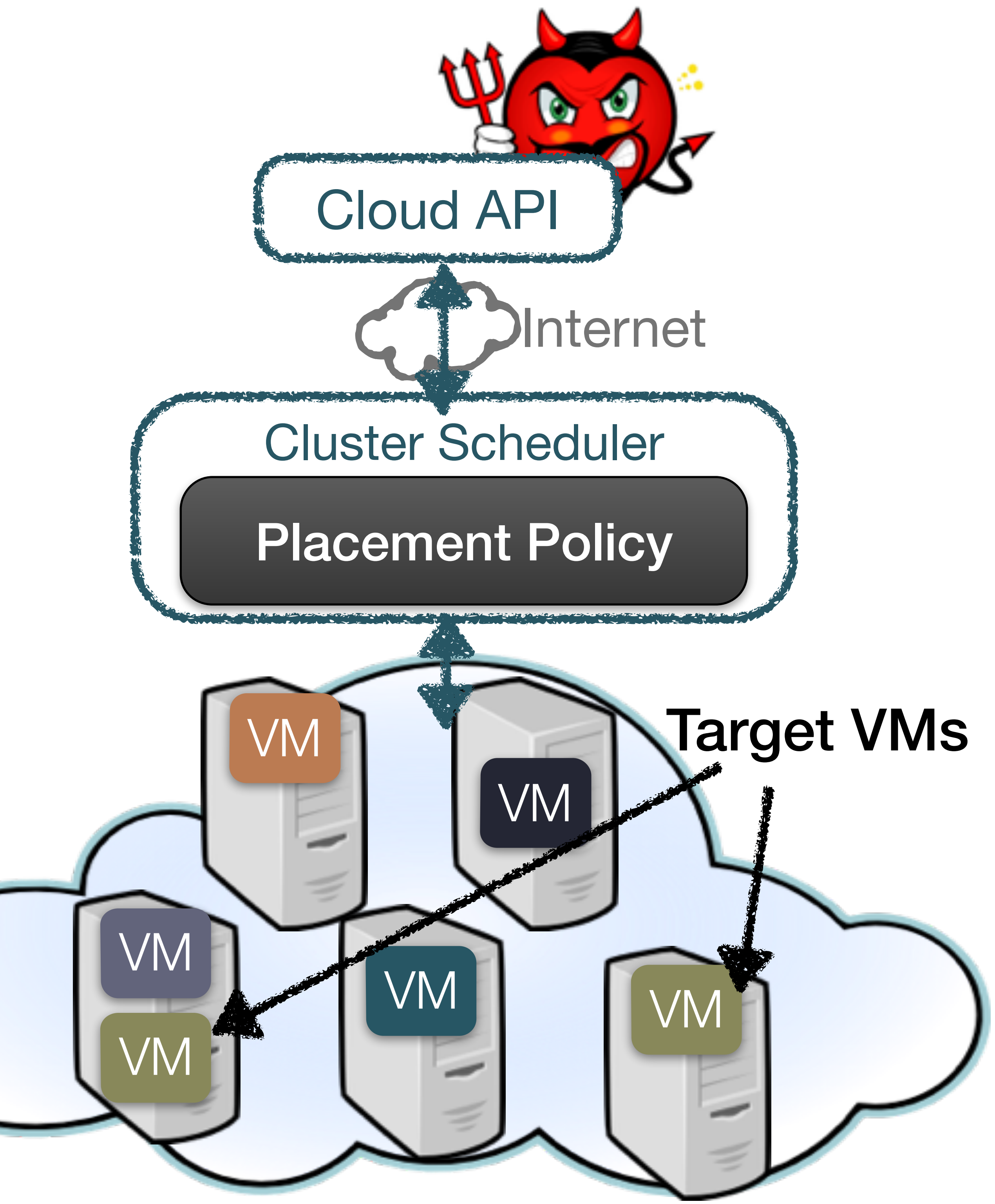
Our Work:
Exploring Co-location Attacks in Modern Clouds



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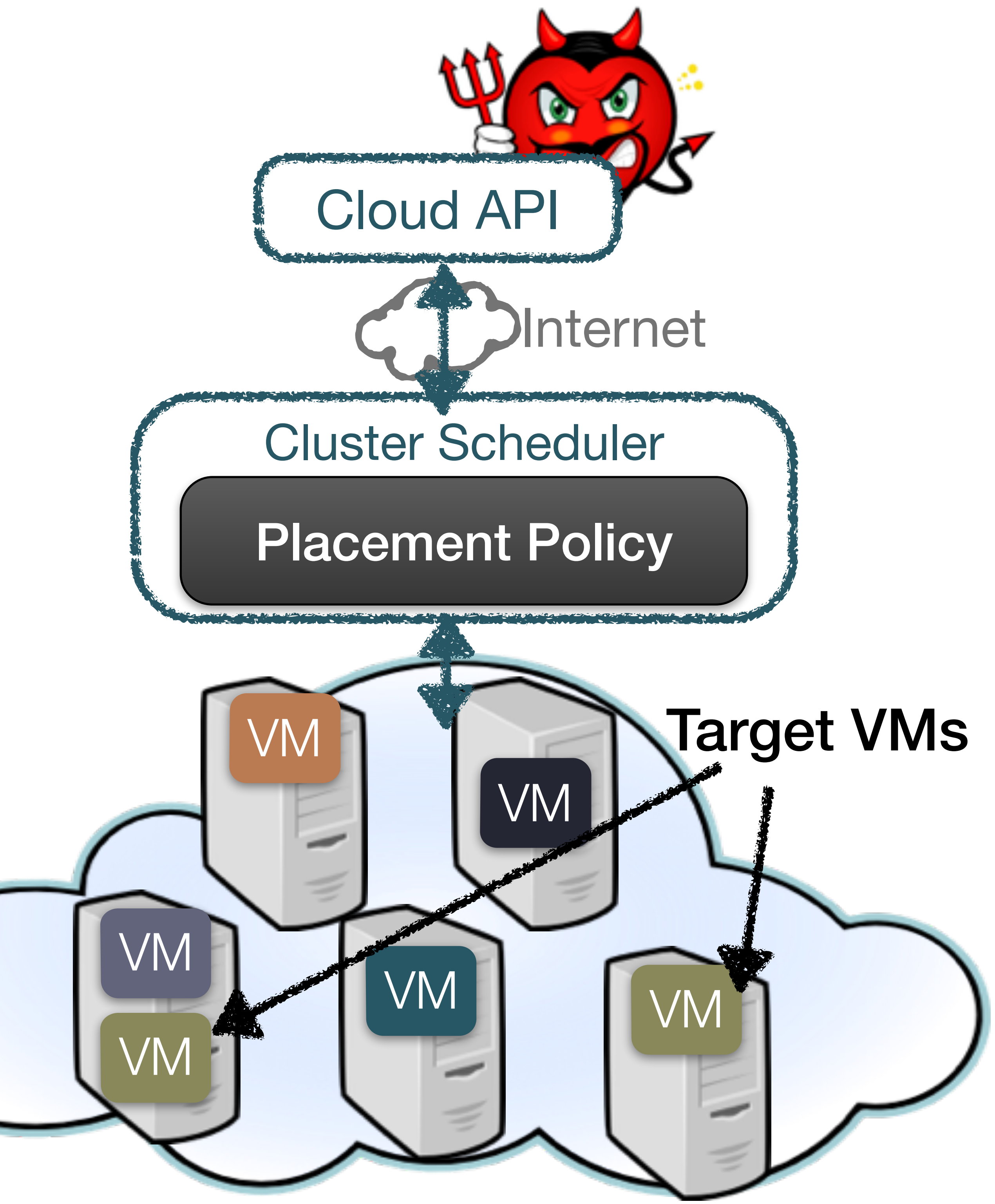

Steps in achieving co-location:

Our Work:
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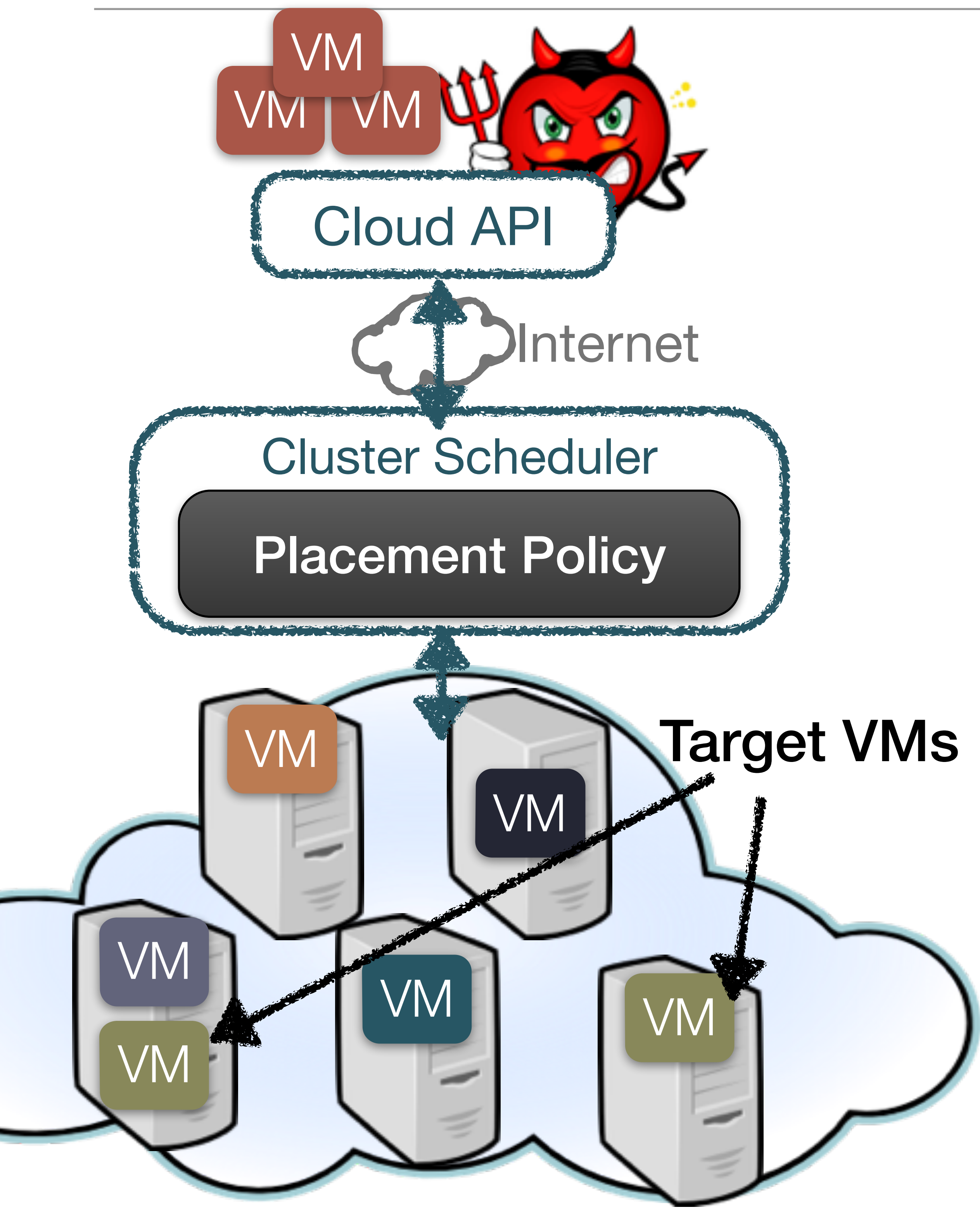

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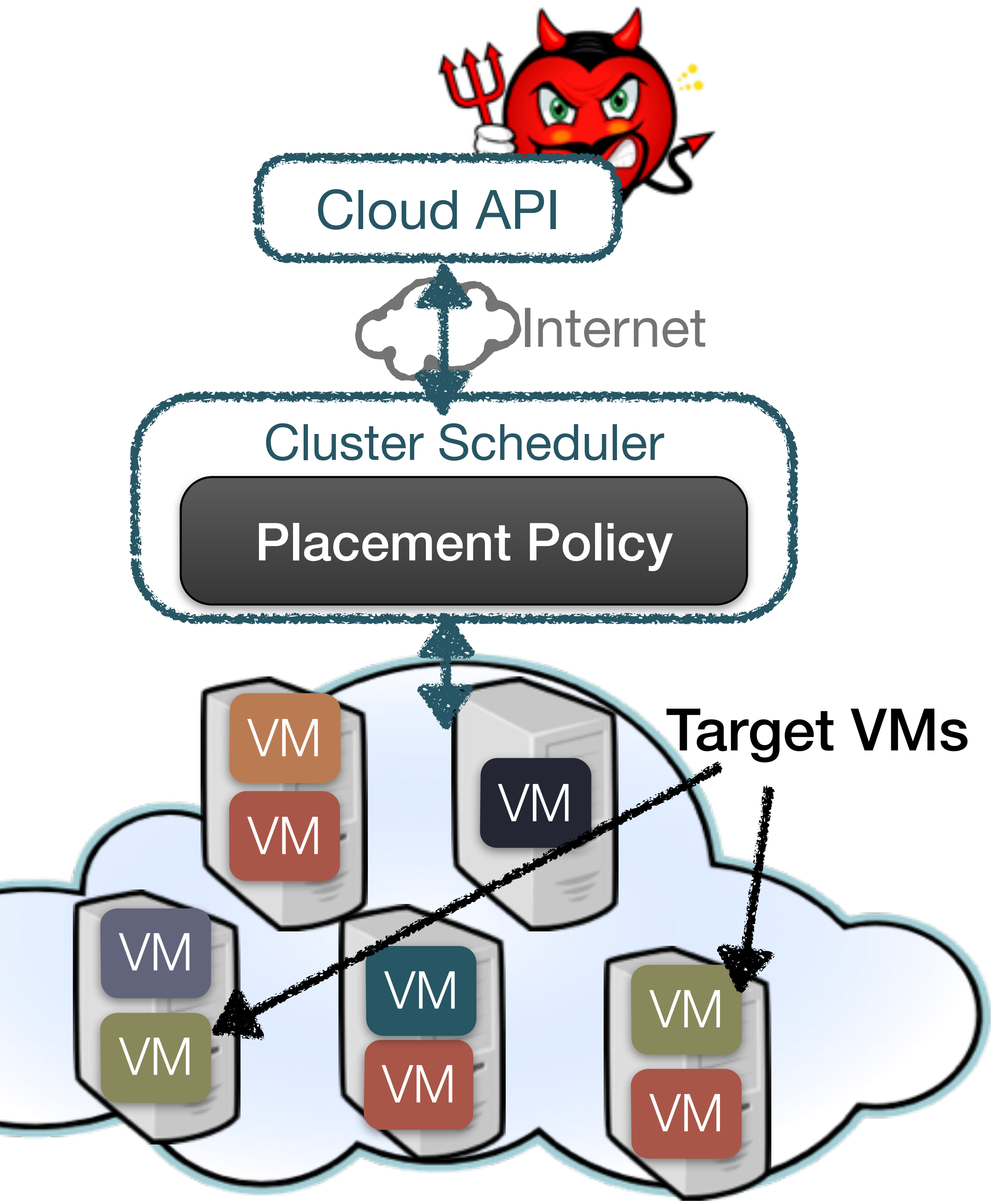

Steps in achieving co-location:

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    - launch parameters to increase chances of co-location

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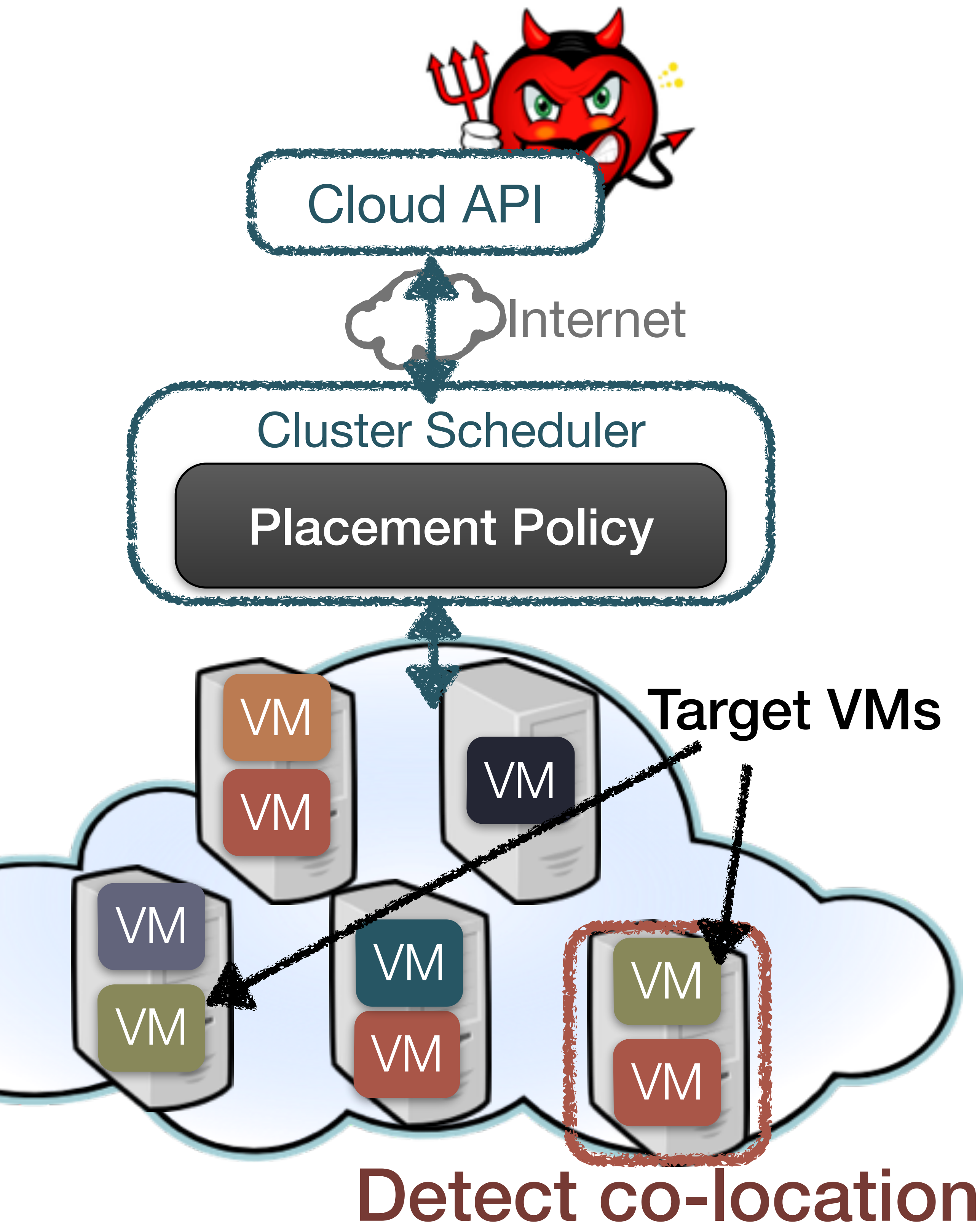

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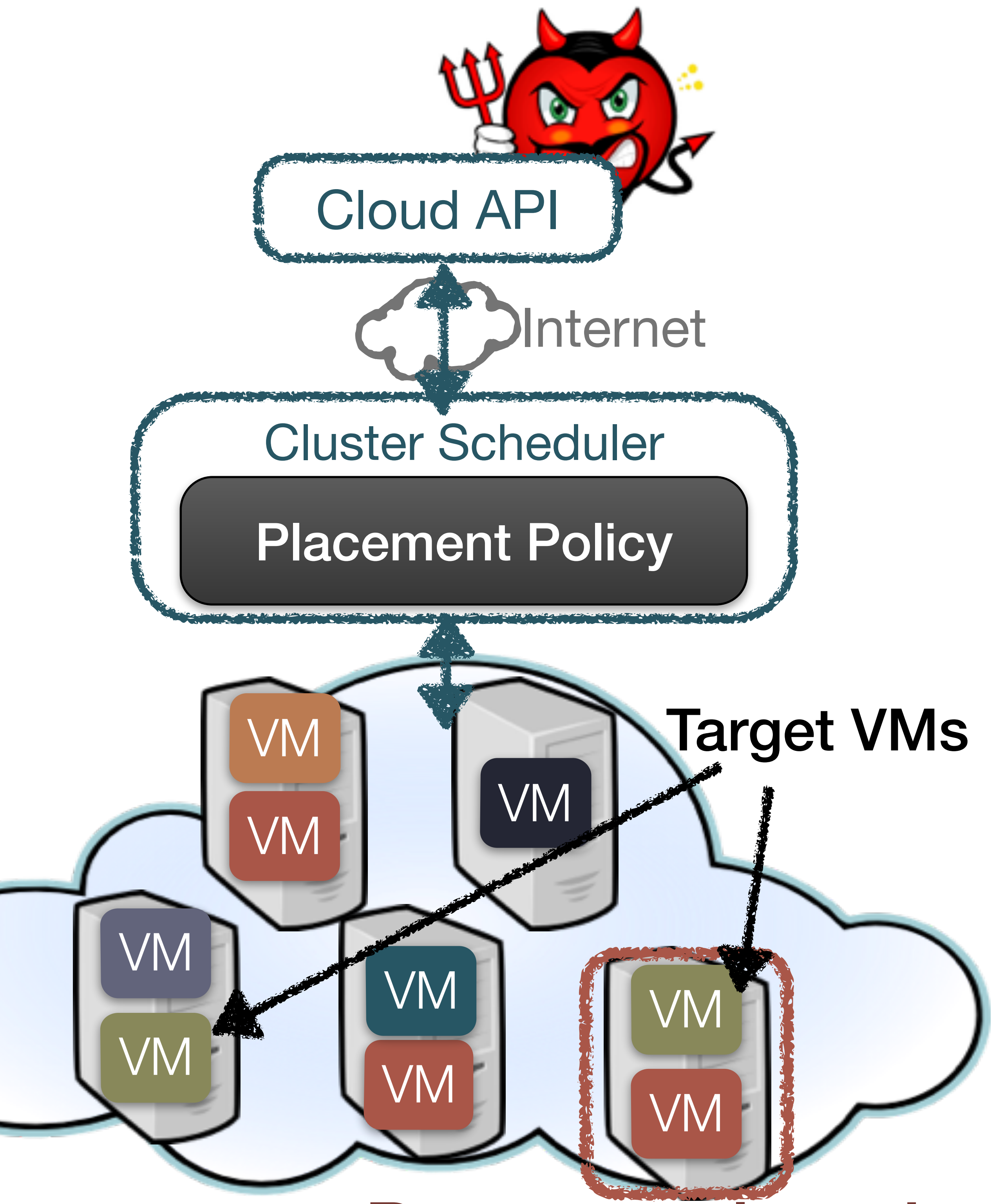

Detect co-location

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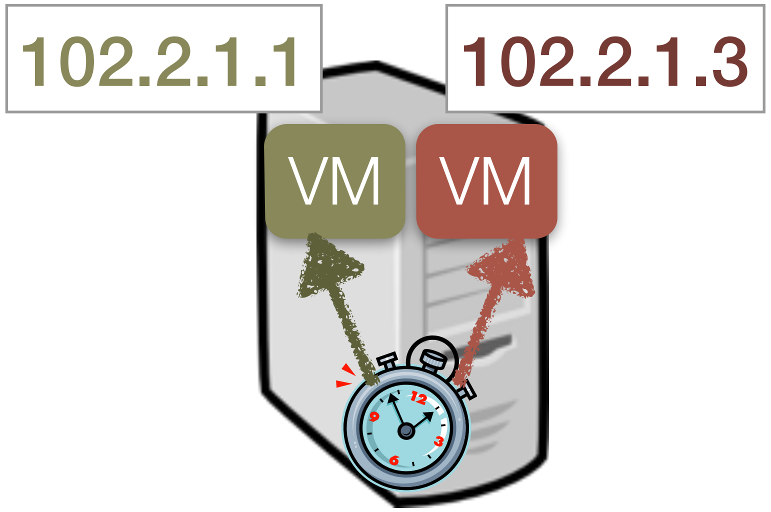
Co-residency Detection

Co-residency Detection

1. Read shared state
   on two VMs

   e.g., private IP addresses,
   shared TSC counters.



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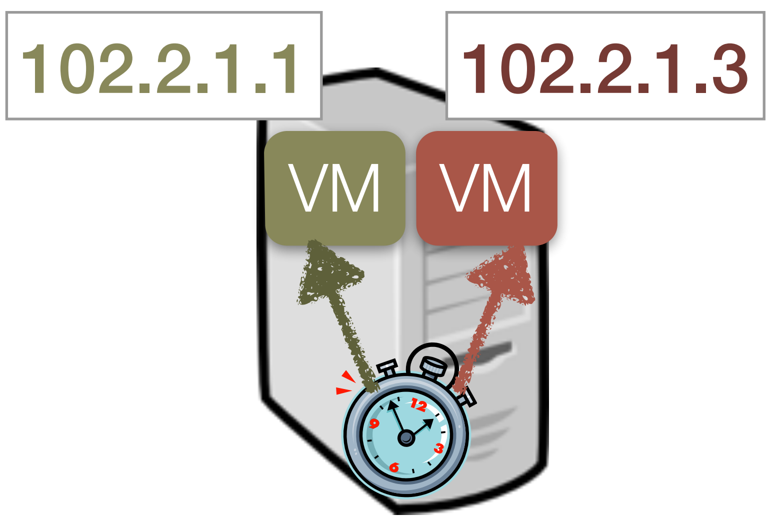
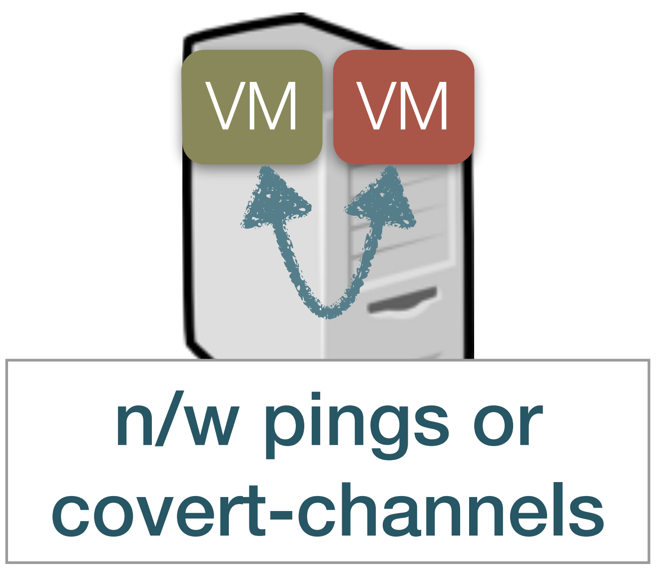


2. Correlate performance of shared resources

e.g., network round-trip times, cache-based covert-channels.



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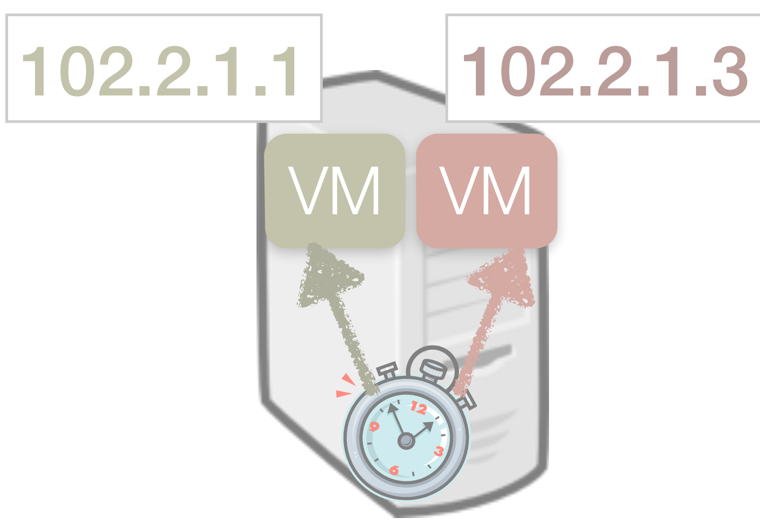

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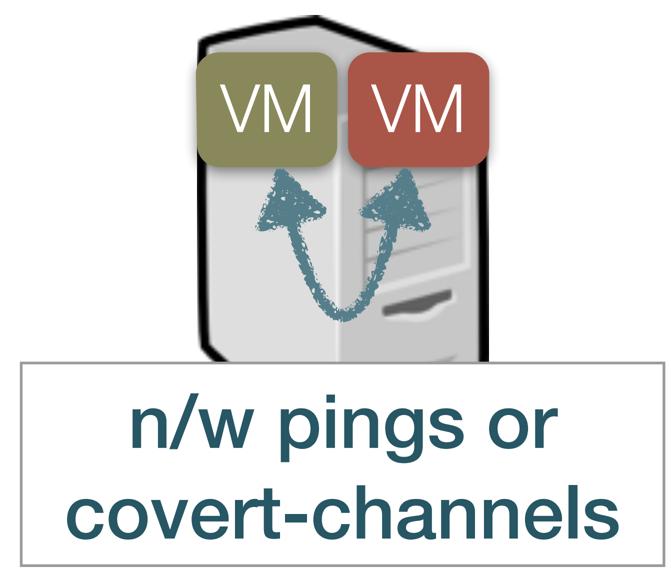

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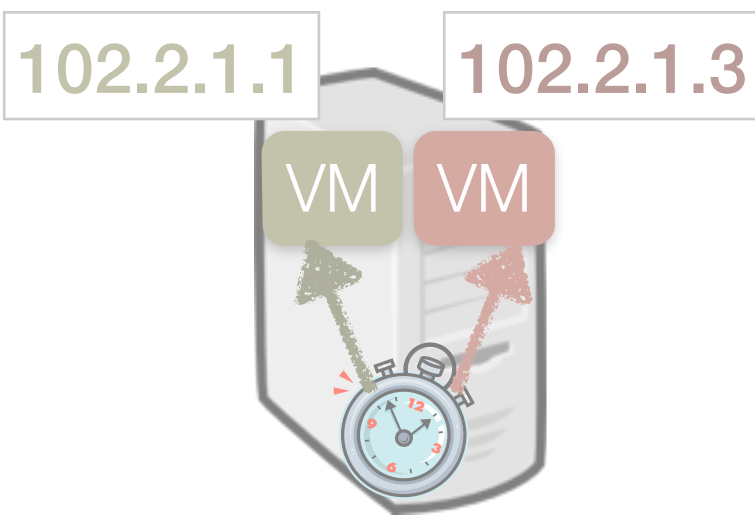

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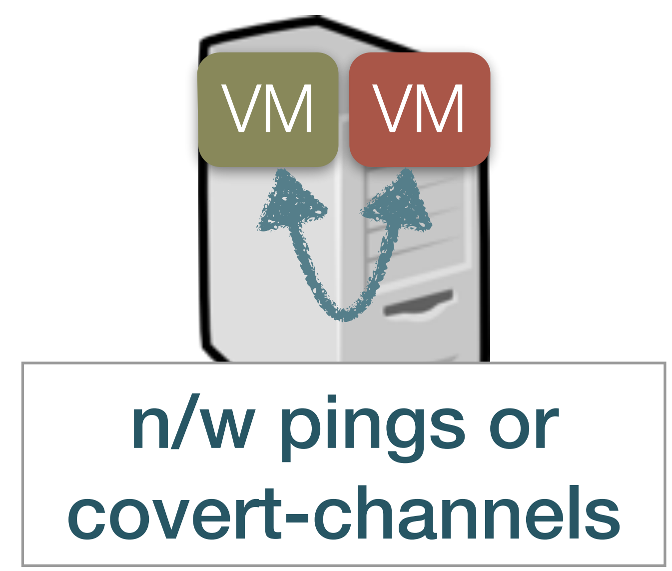
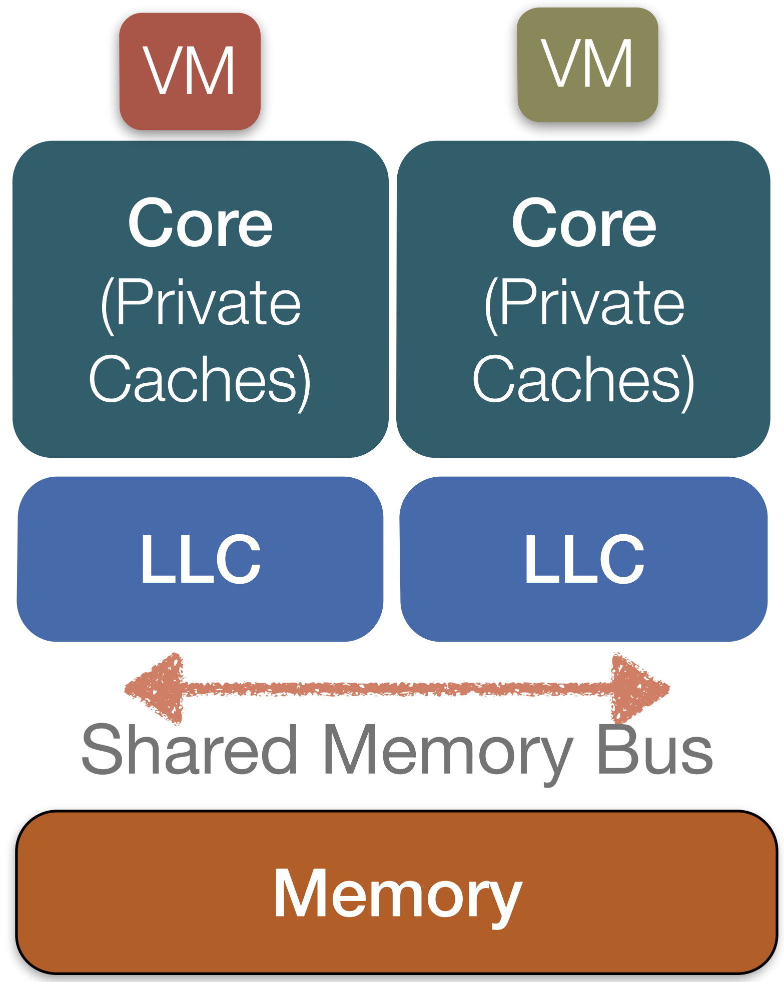


A memory-based covert-channel* can cause 3x-4x degradation

* Wu et al. “Whispers in the Hyper-space: High-speed Covert Channel Attacks in the Cloud.”, Usenix Security’12

Background: Memory Covert-Channel



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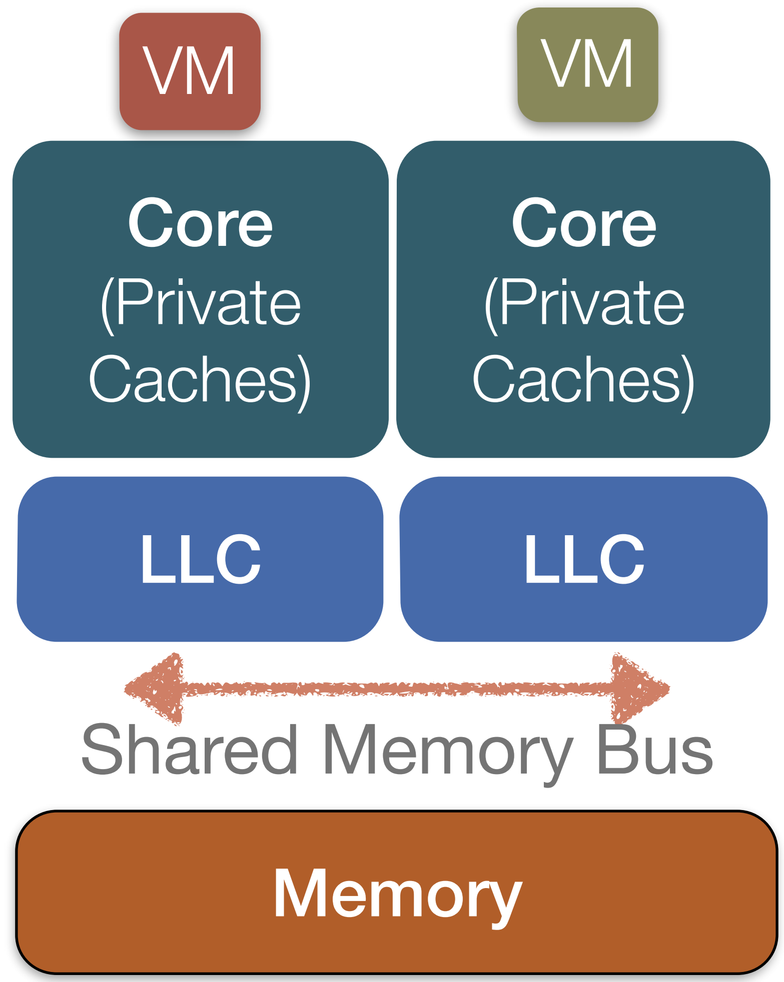

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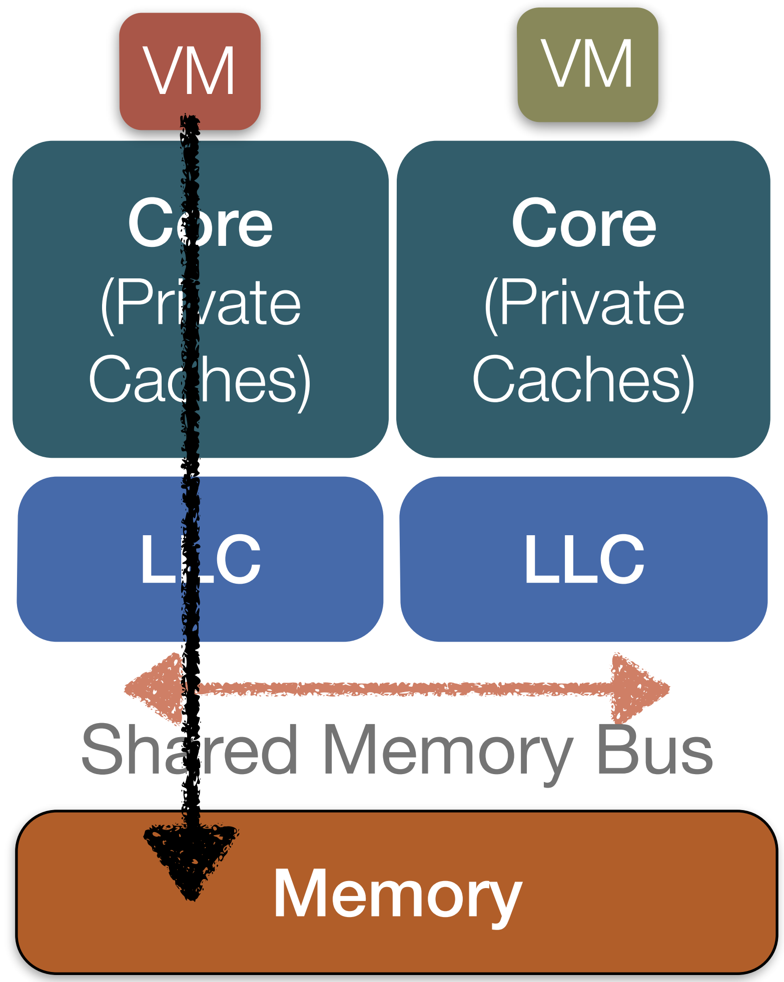

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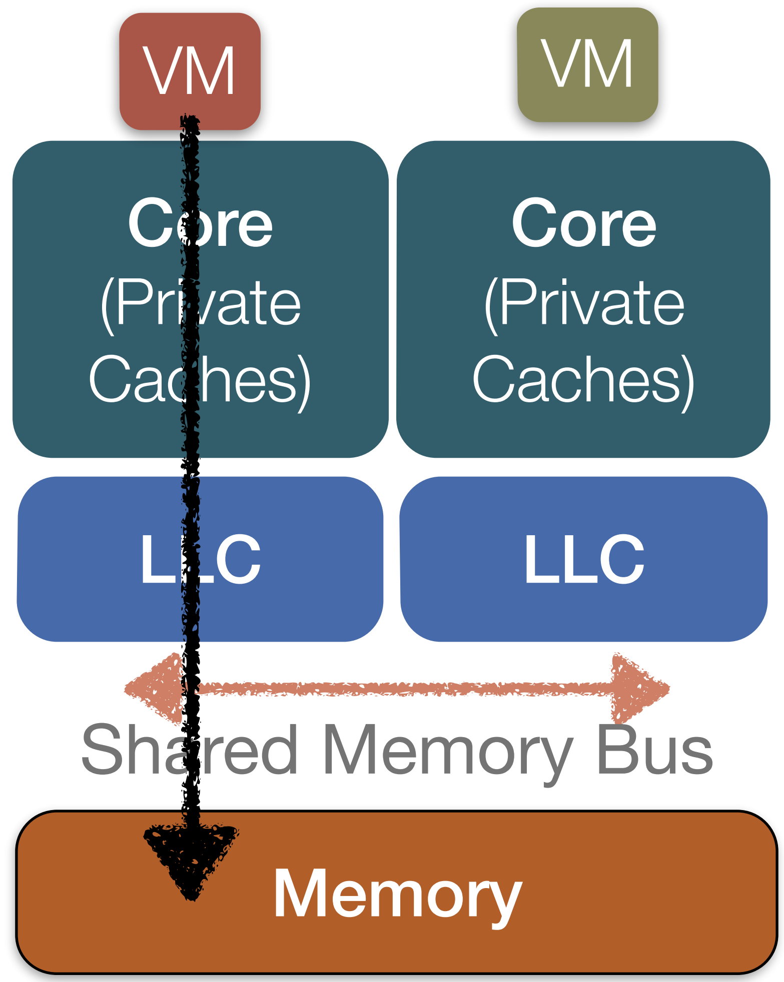

Receiver:

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Observe() {
  s = start_time
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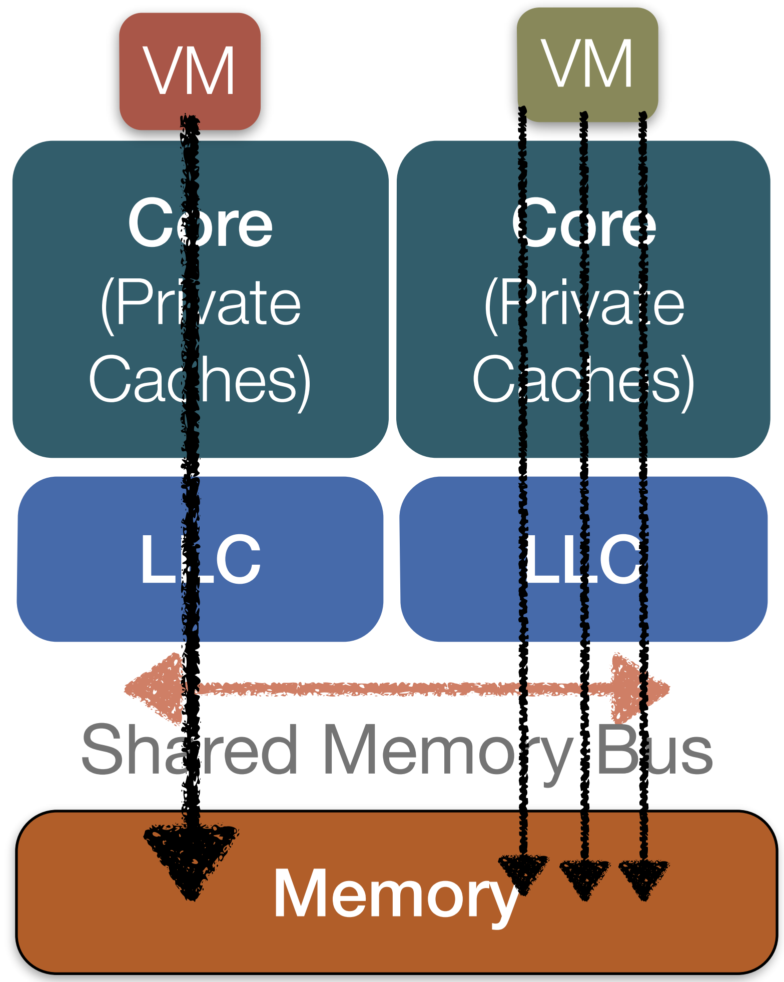

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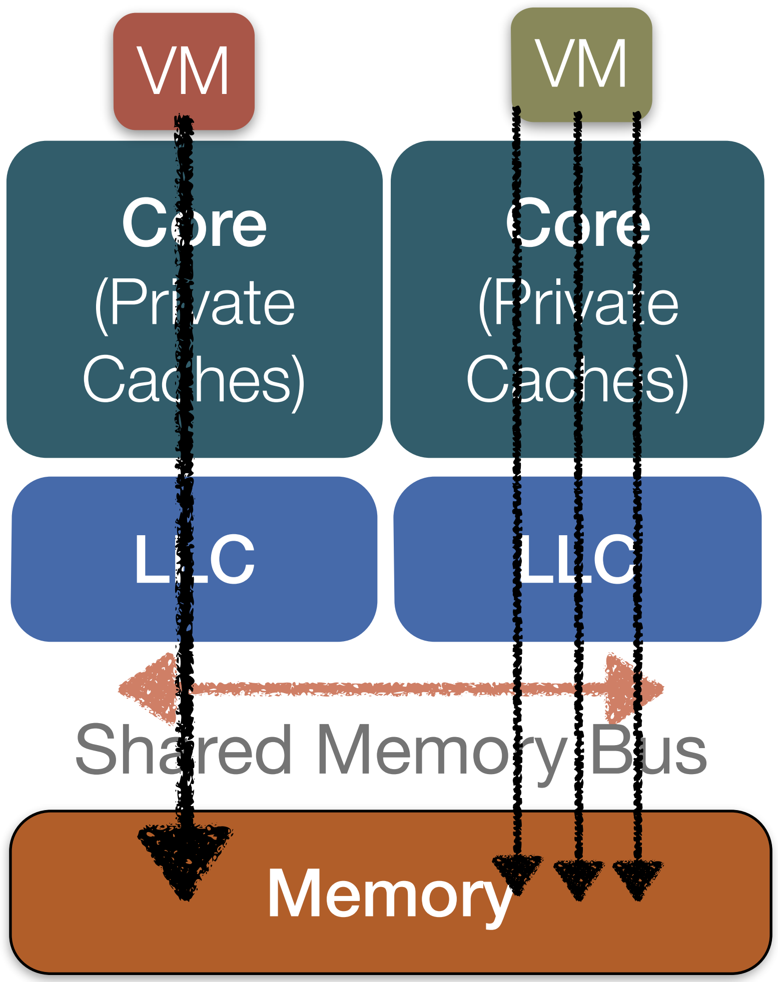

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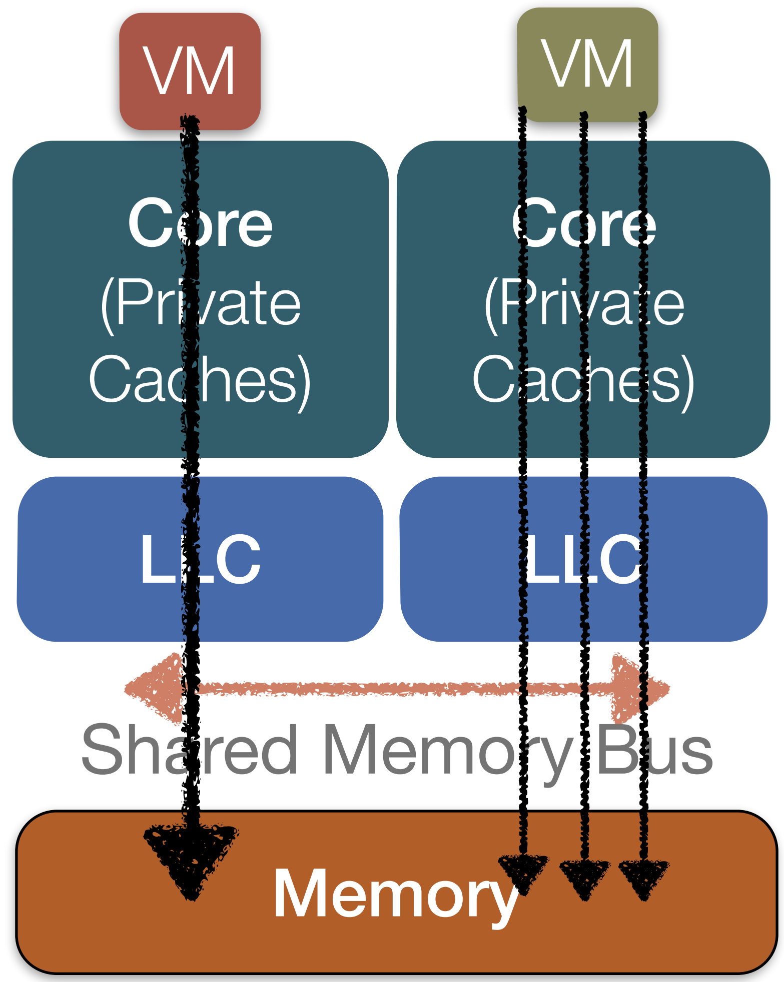

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"Victim" VM must cooperate with attack VM
O.K. for measurement studies
But not useful for real attacks in the wild

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Co-residency Detection on Uncooperative Victim

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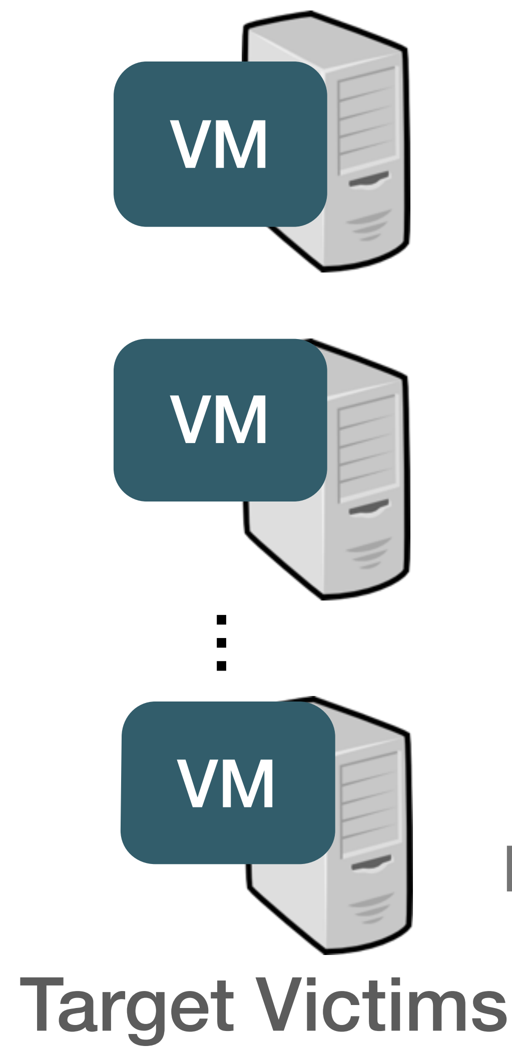

part of a cloud app,
e.g., web server,
key-value stores

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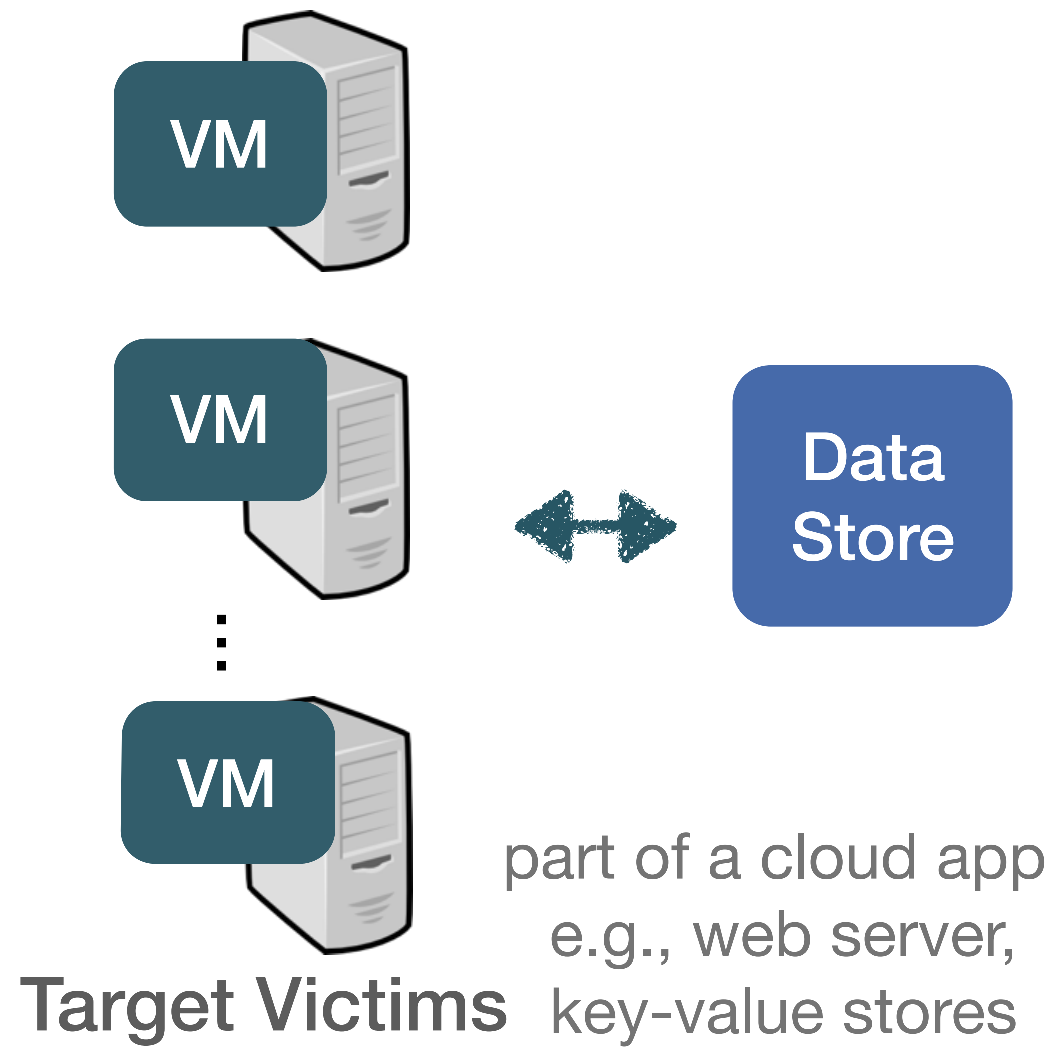

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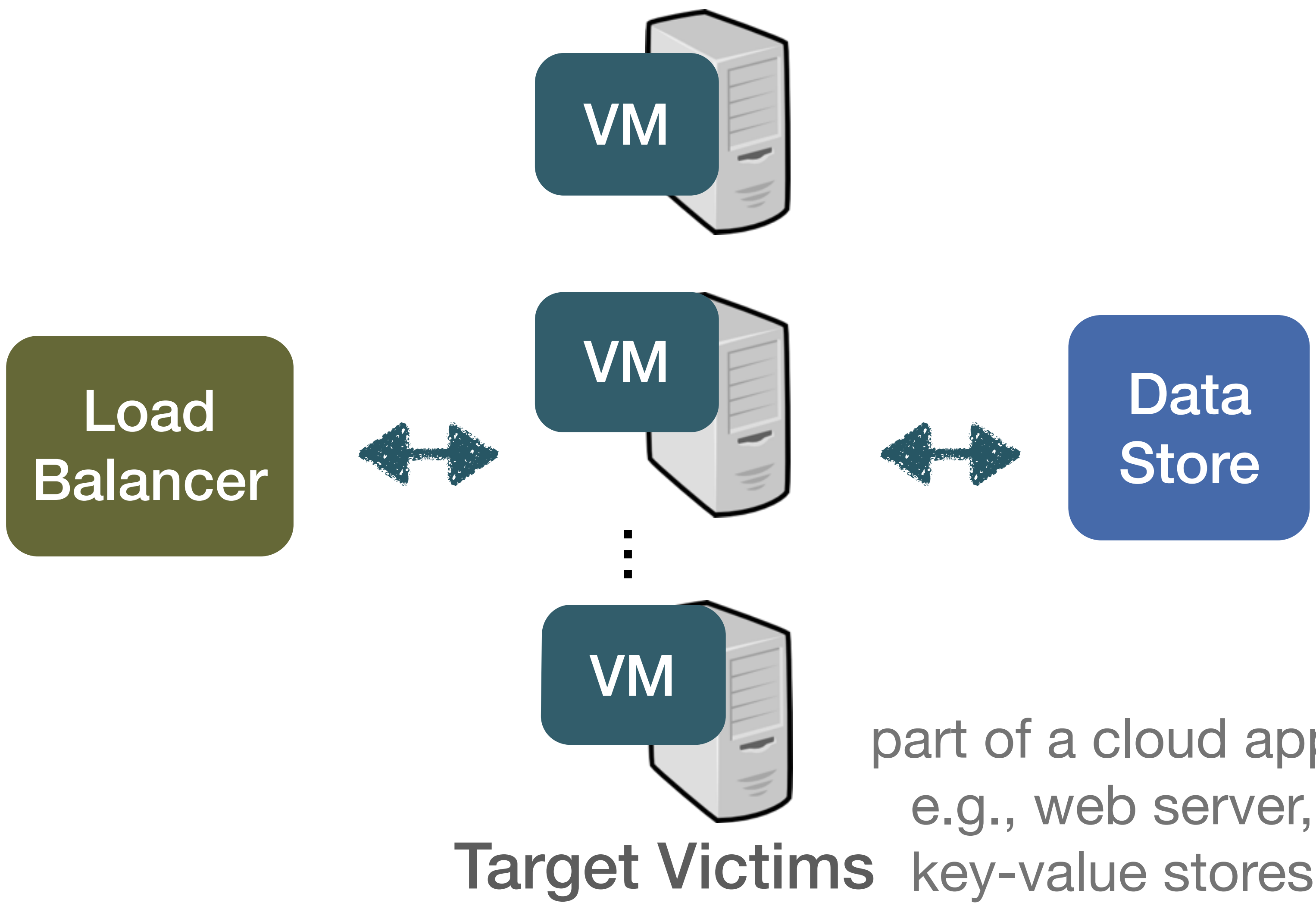

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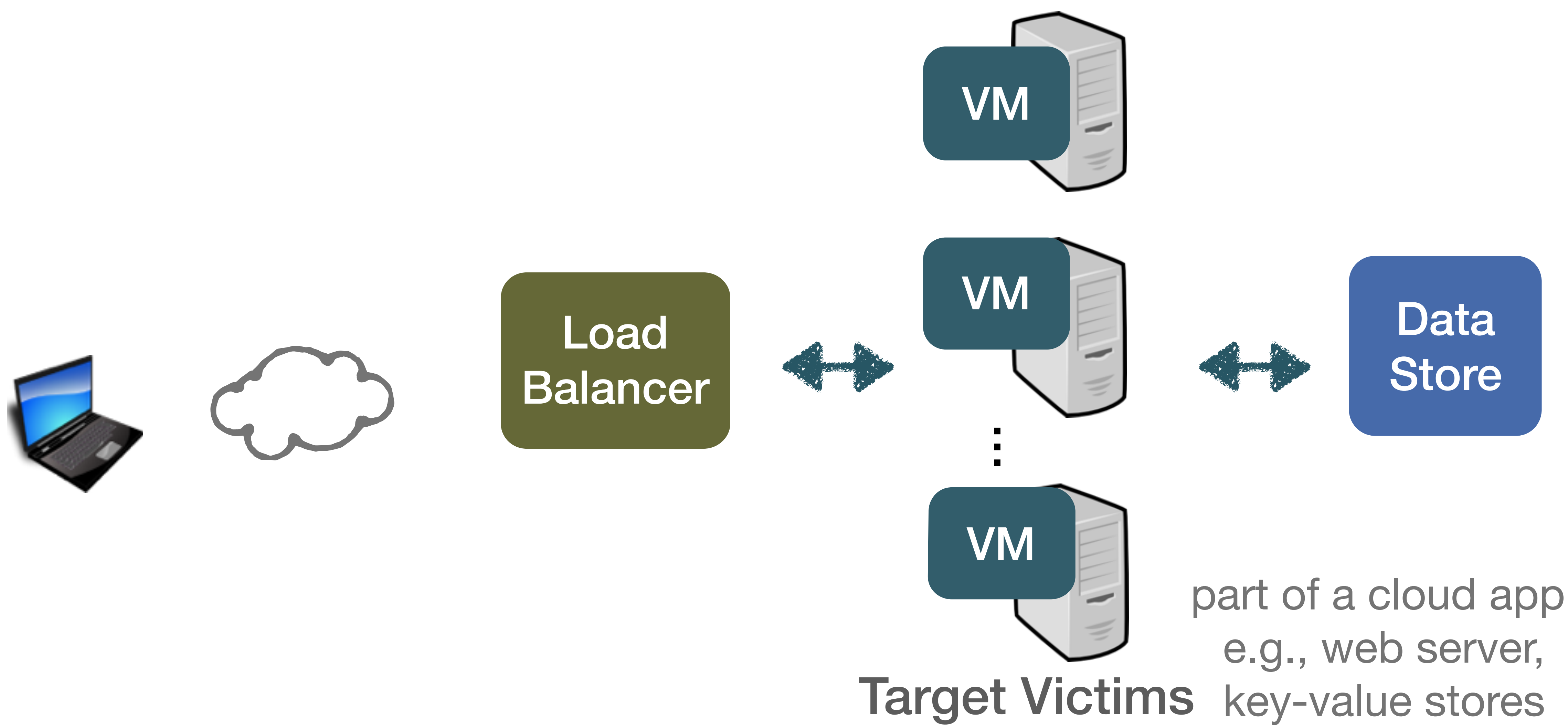

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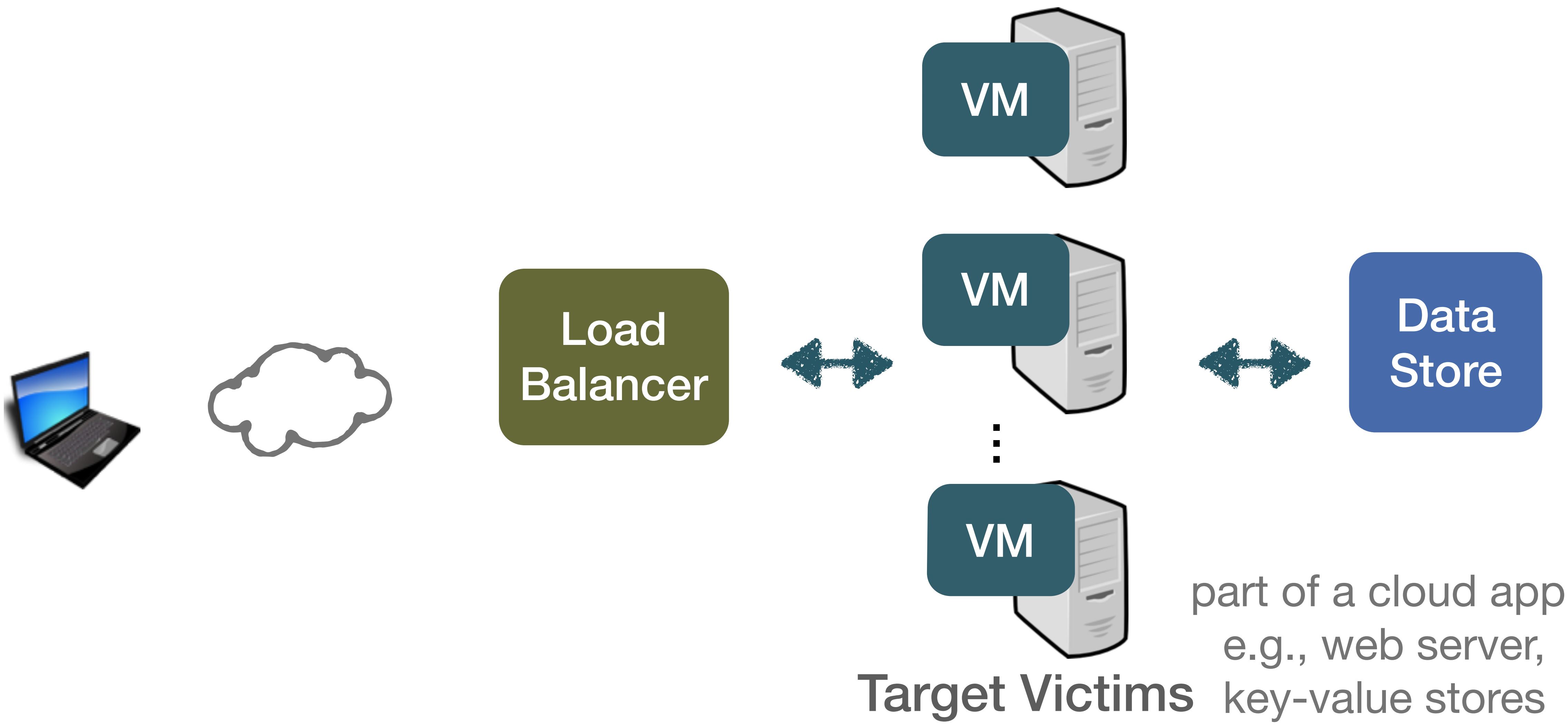

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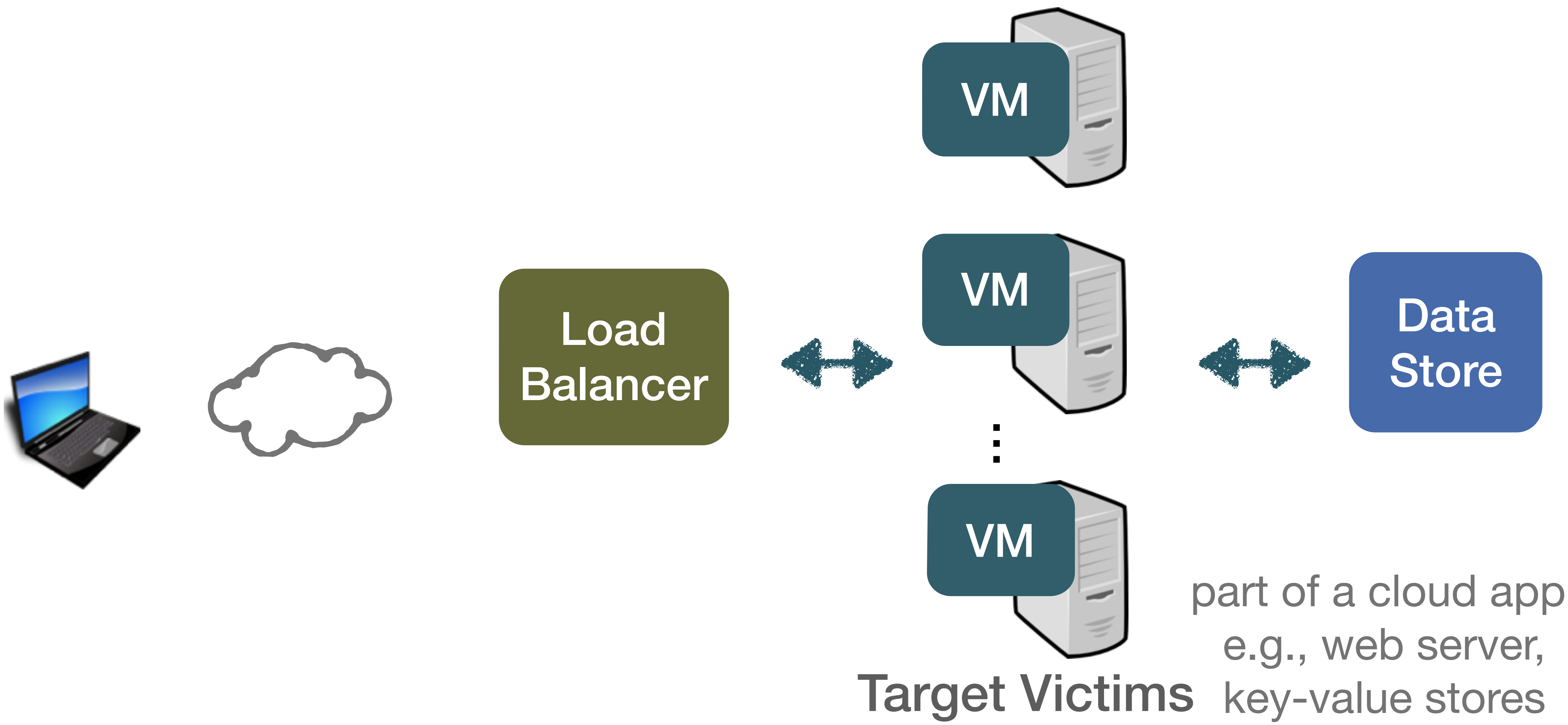

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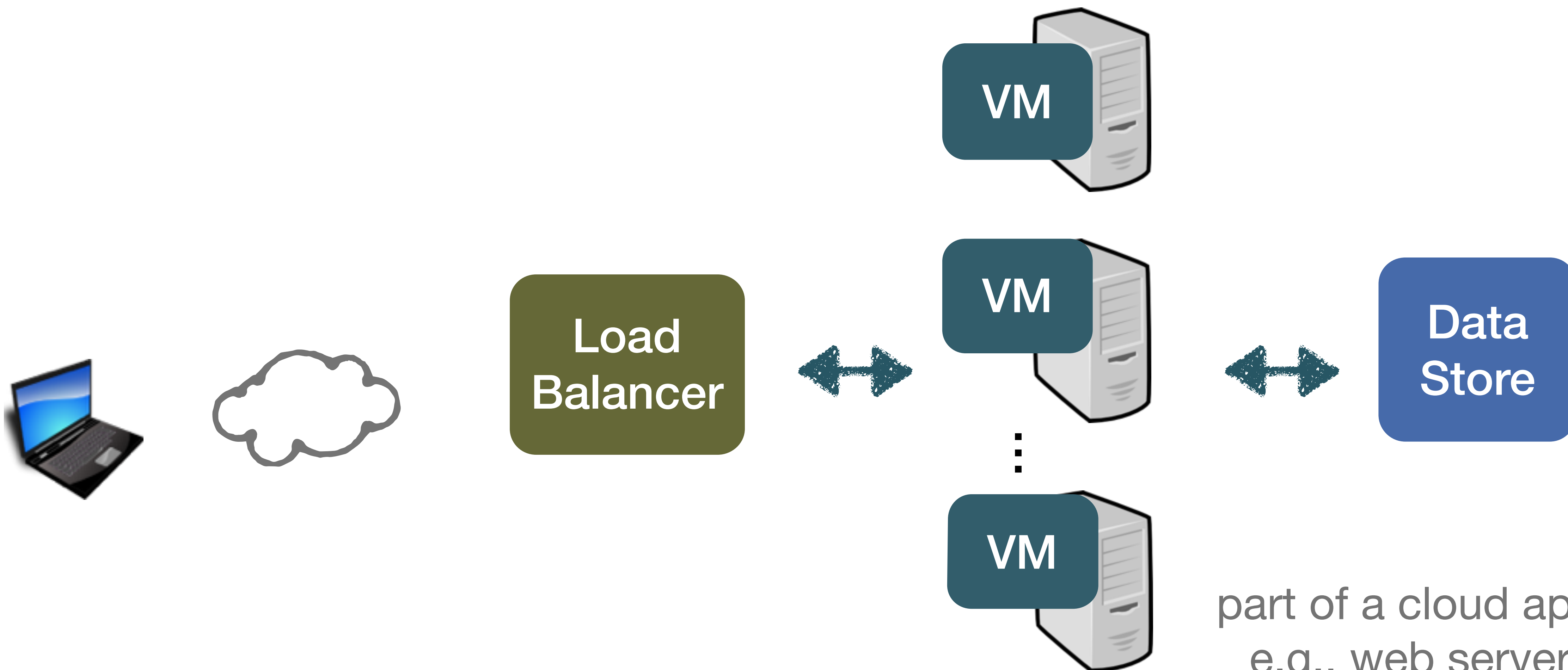
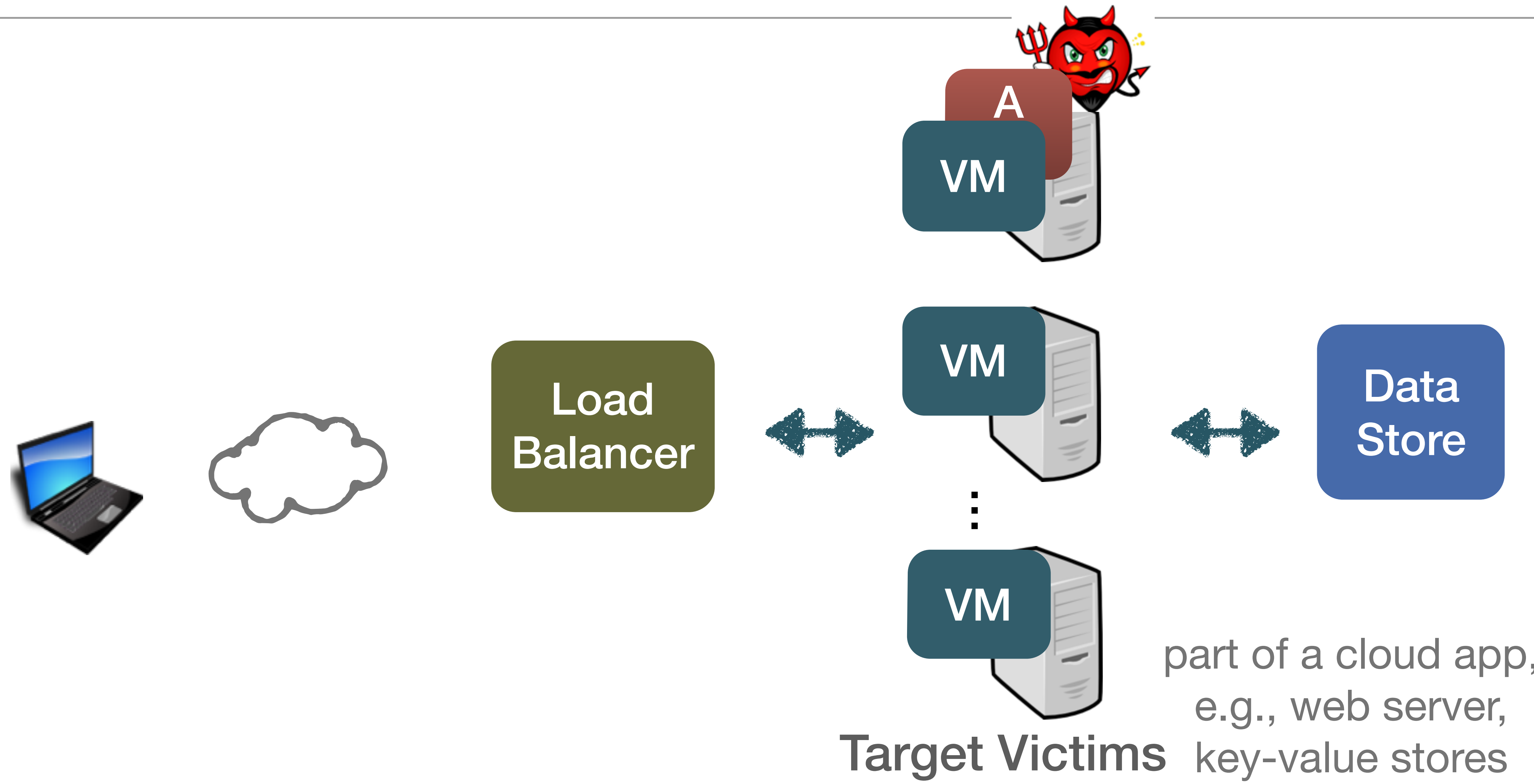


Target Victims

part of a cloud app, e.g., web server, key-value stores

- Realistic victim setting: modern multi-tier cloud app.

Co-residency Detection on Uncooperative Victim



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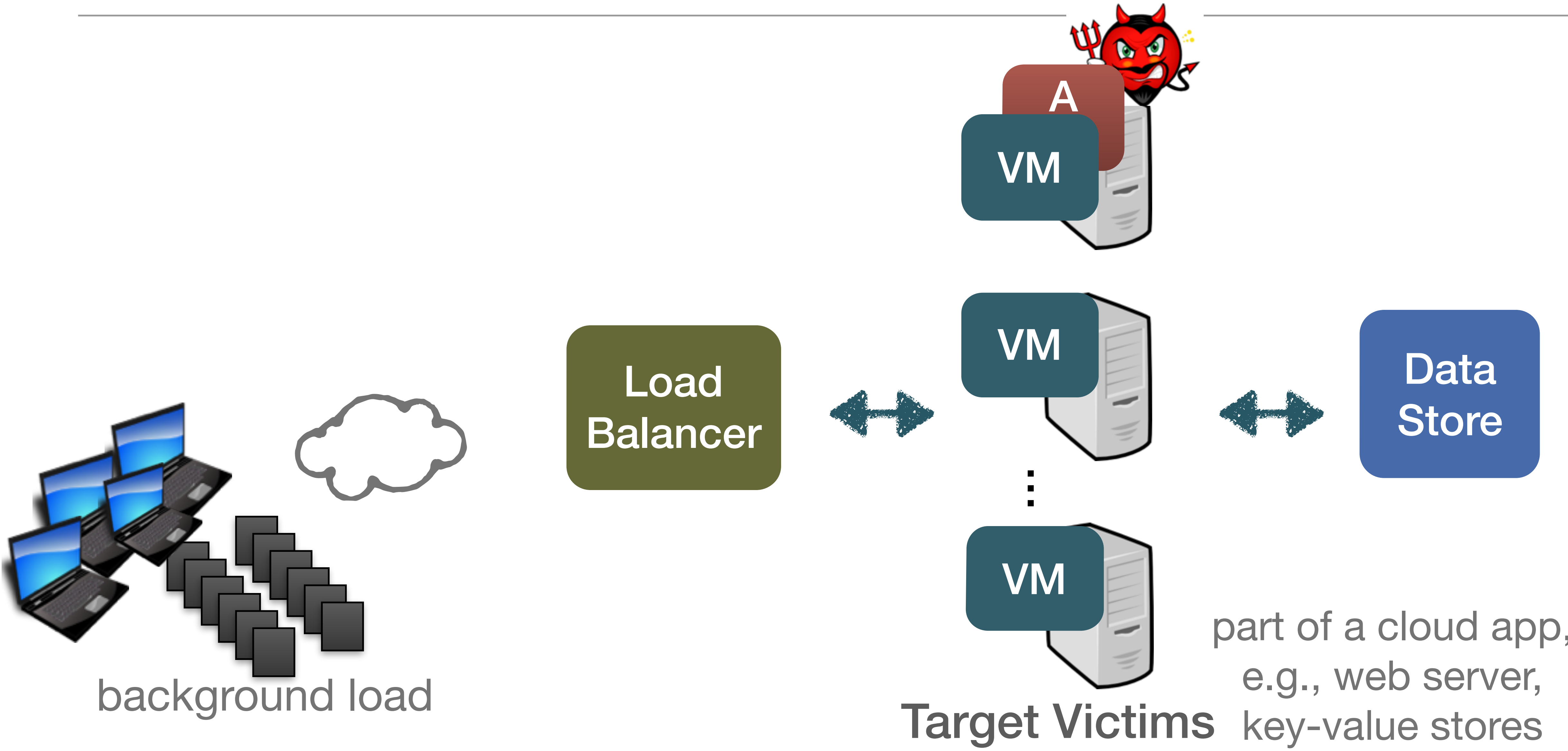

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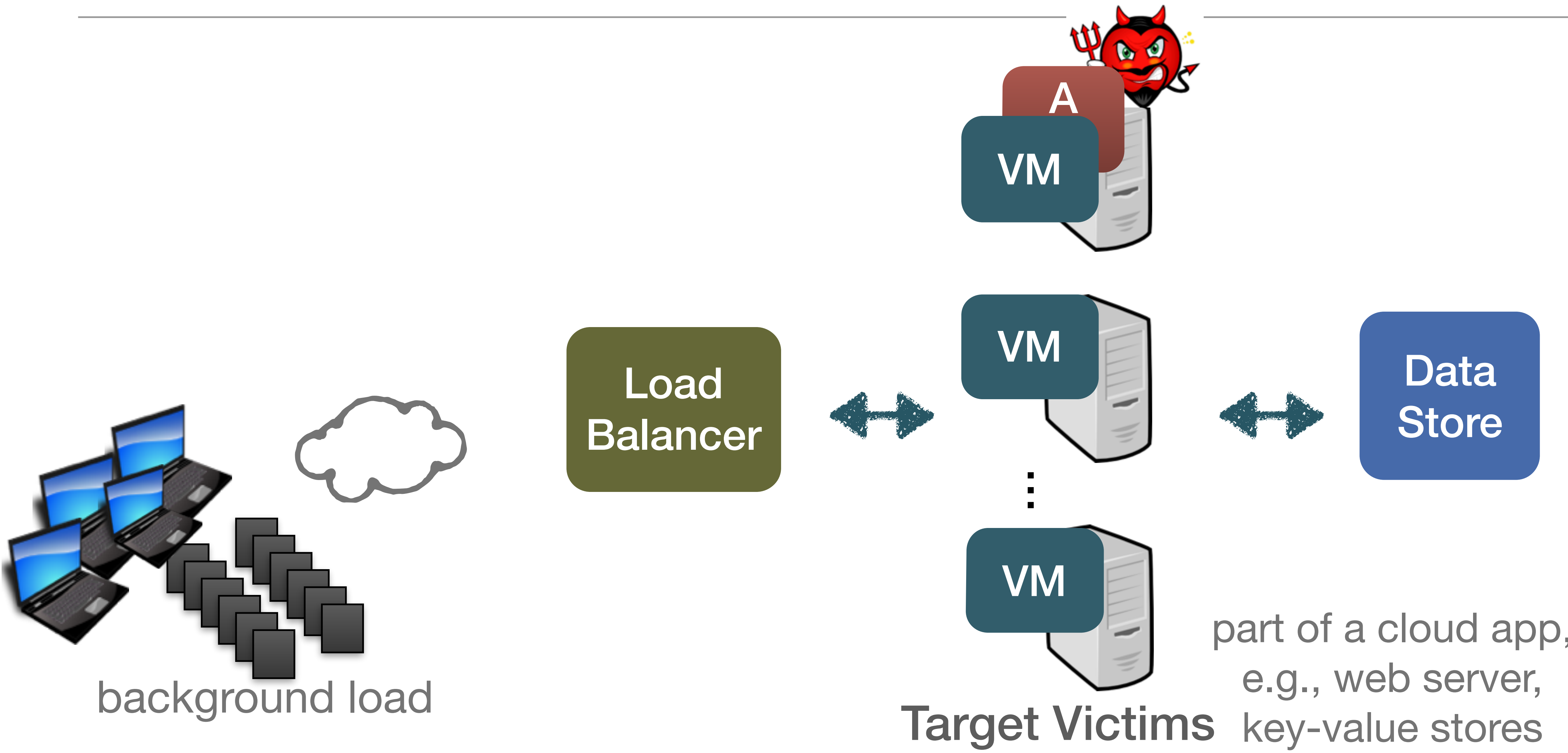

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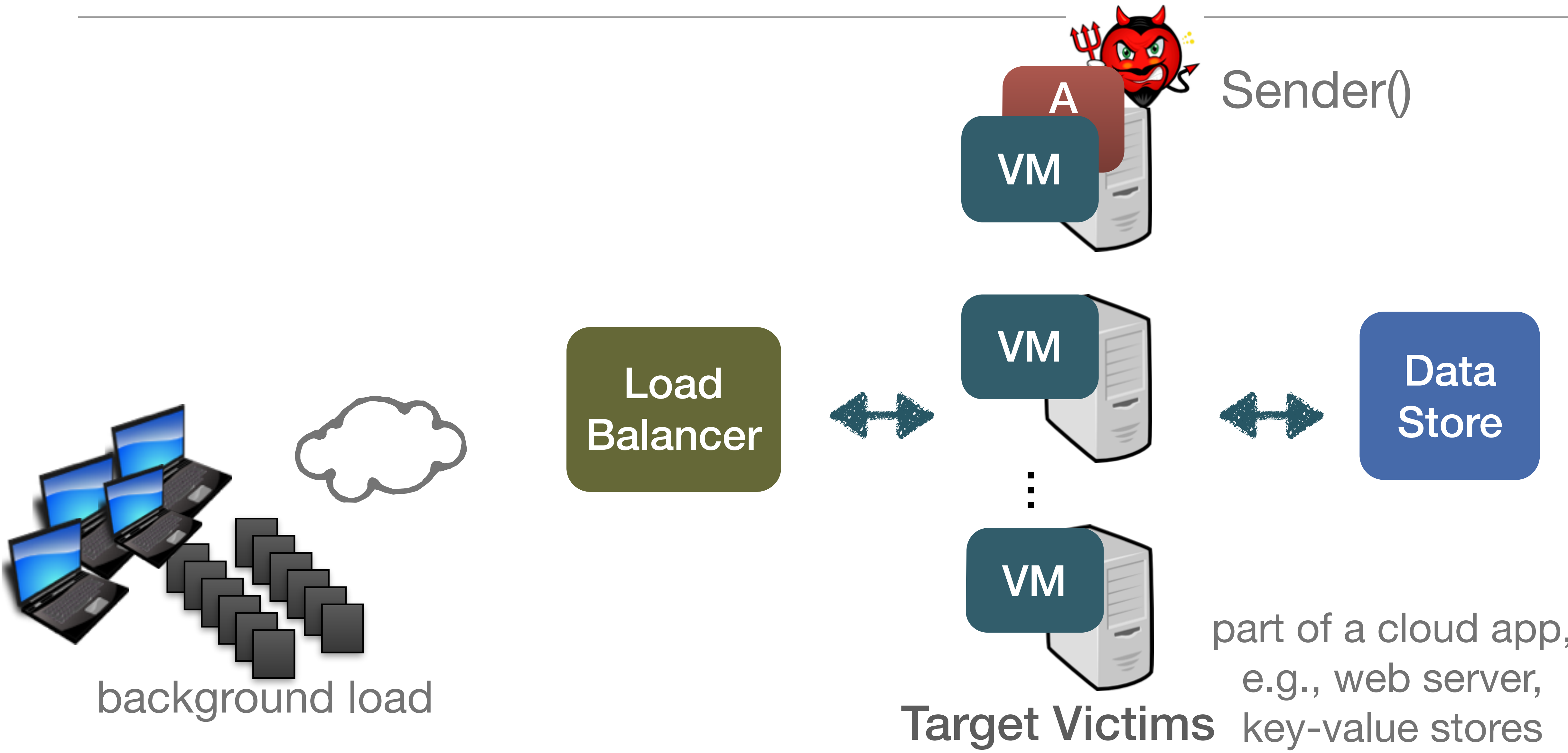

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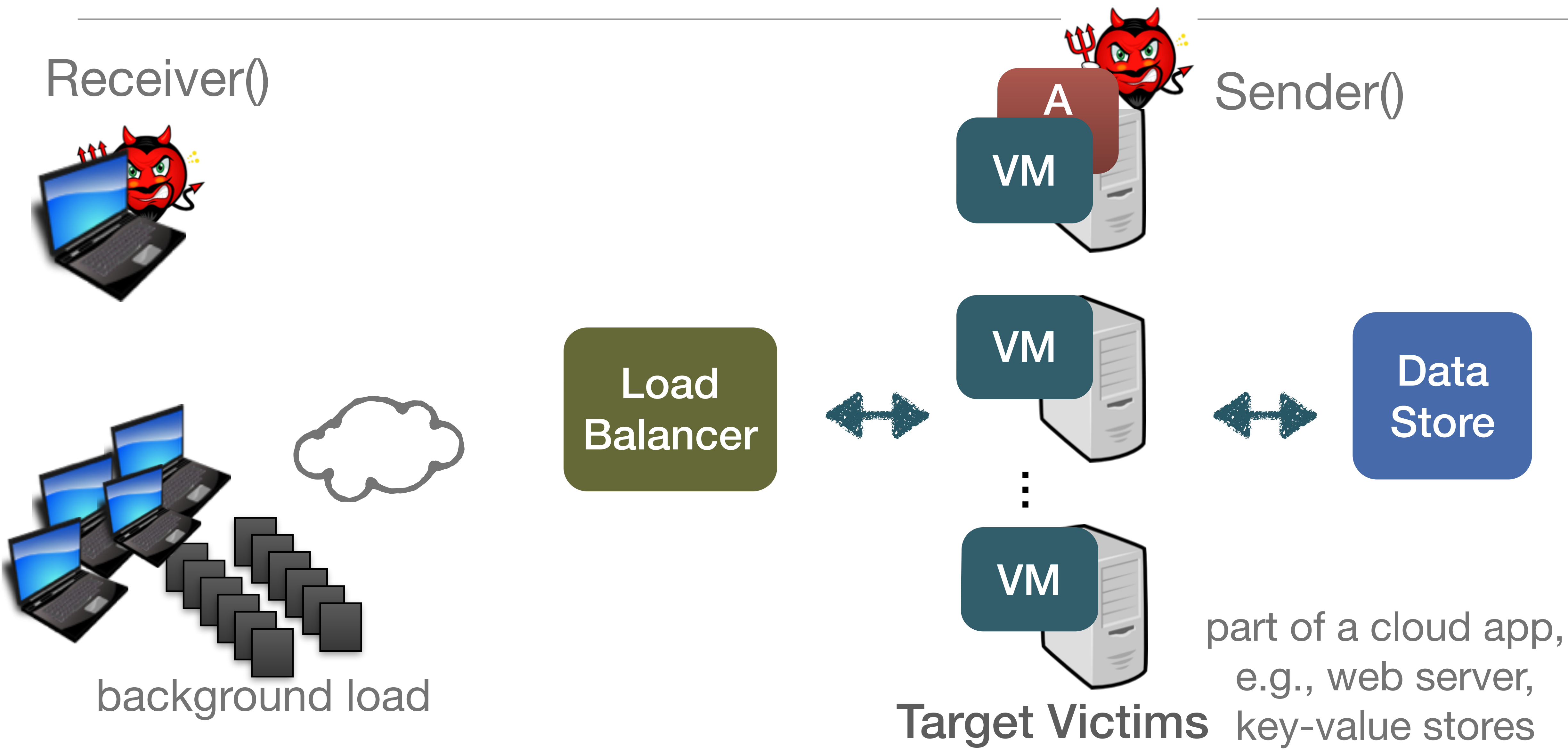

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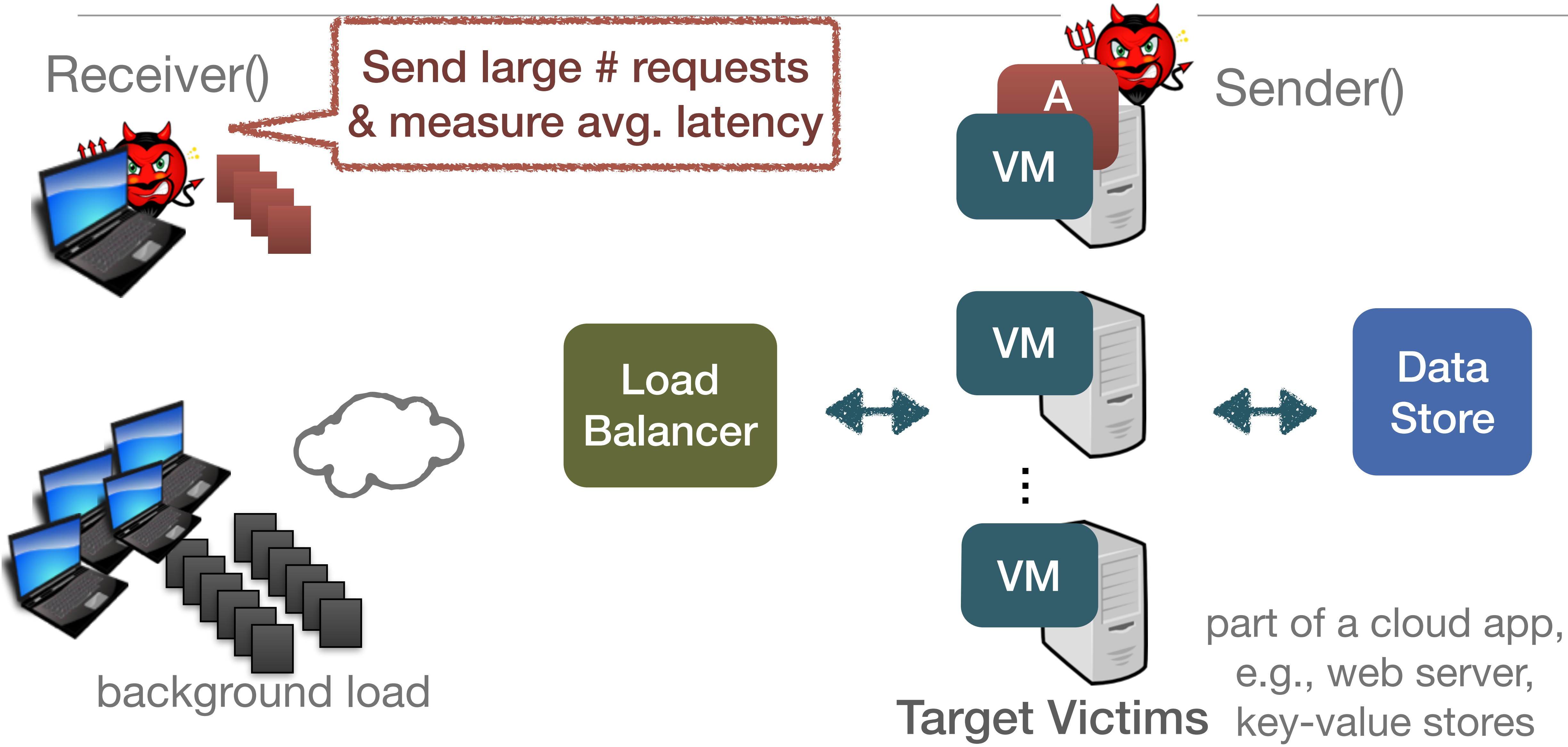

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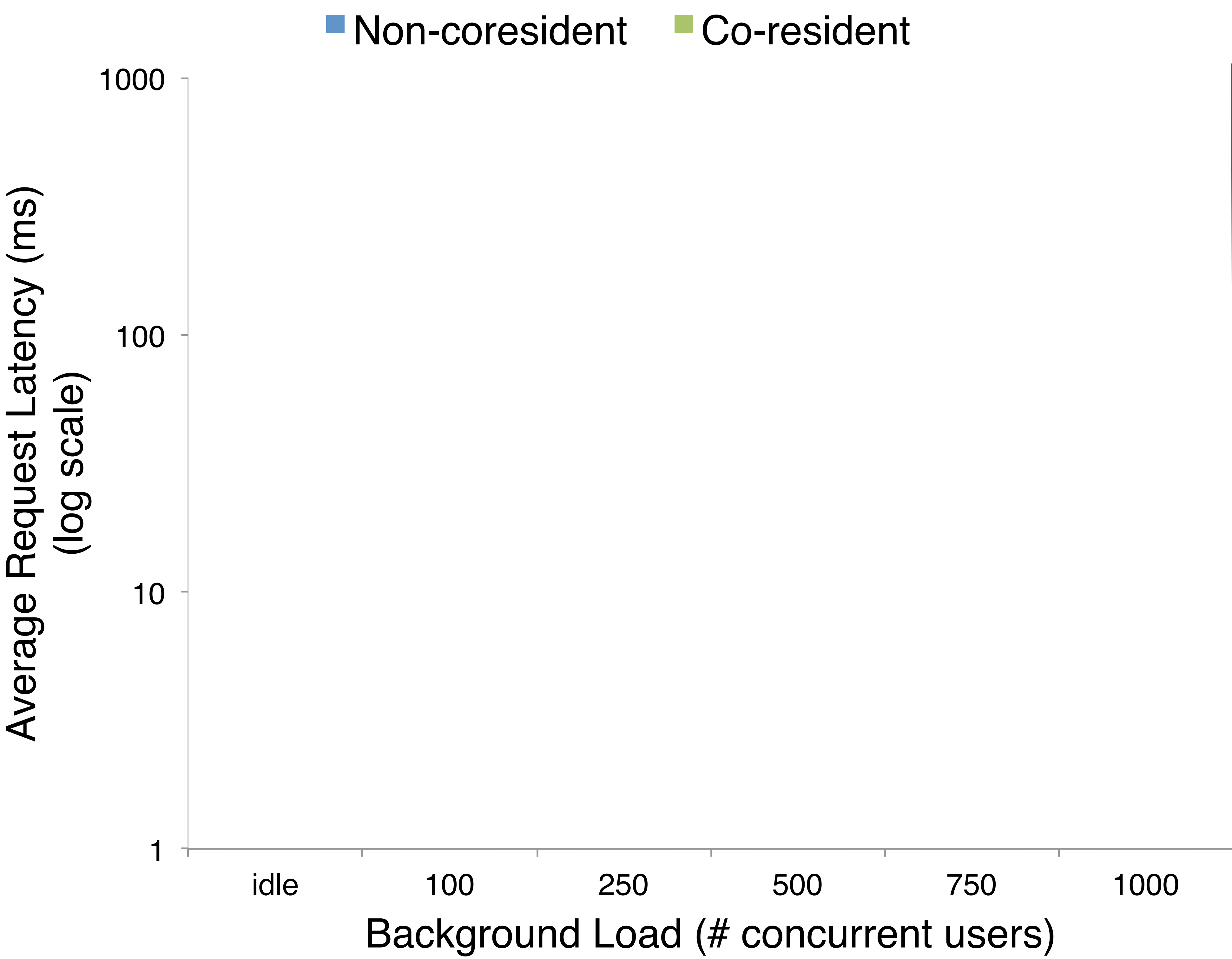

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HAProxy LB +
3 Web servers +
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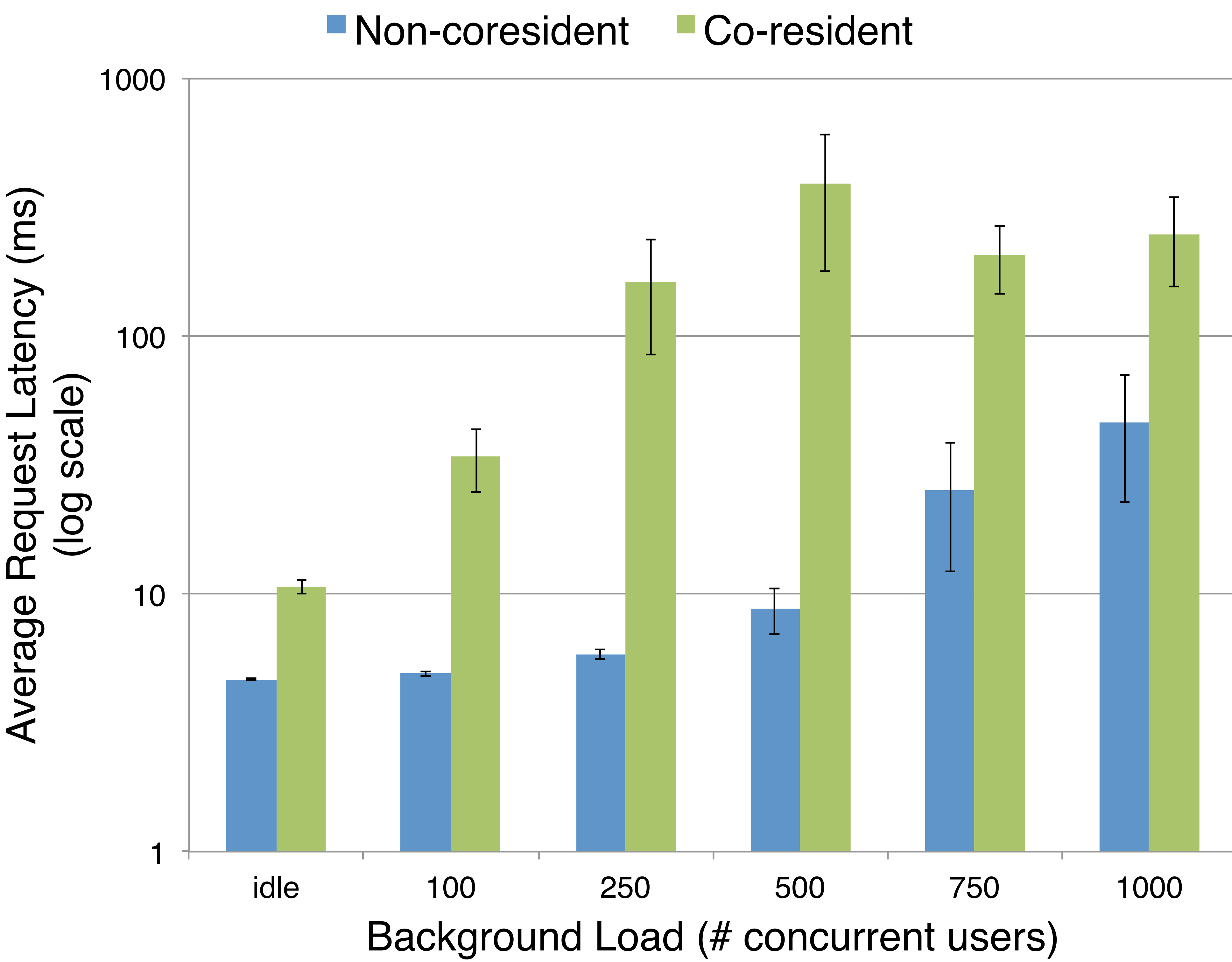

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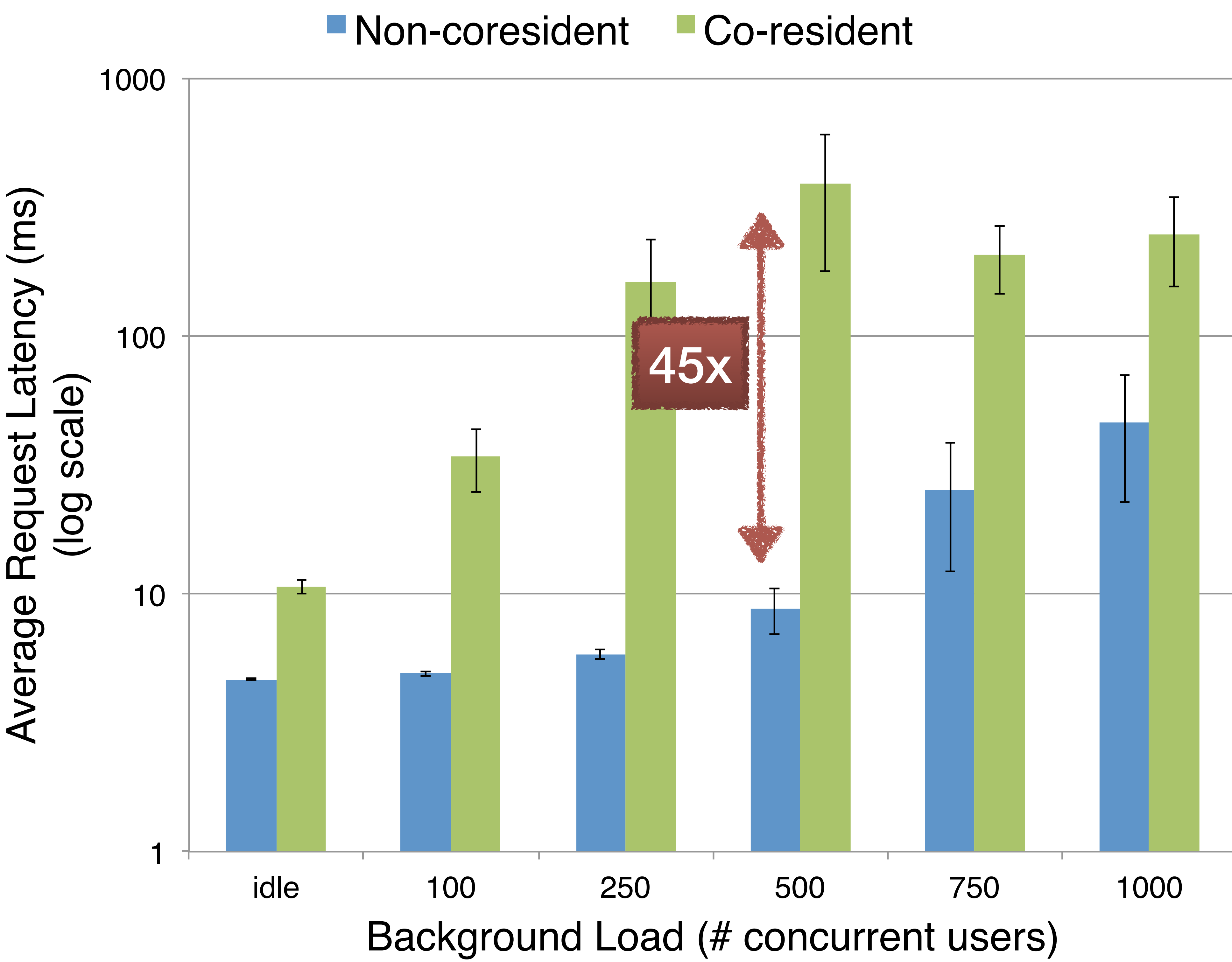

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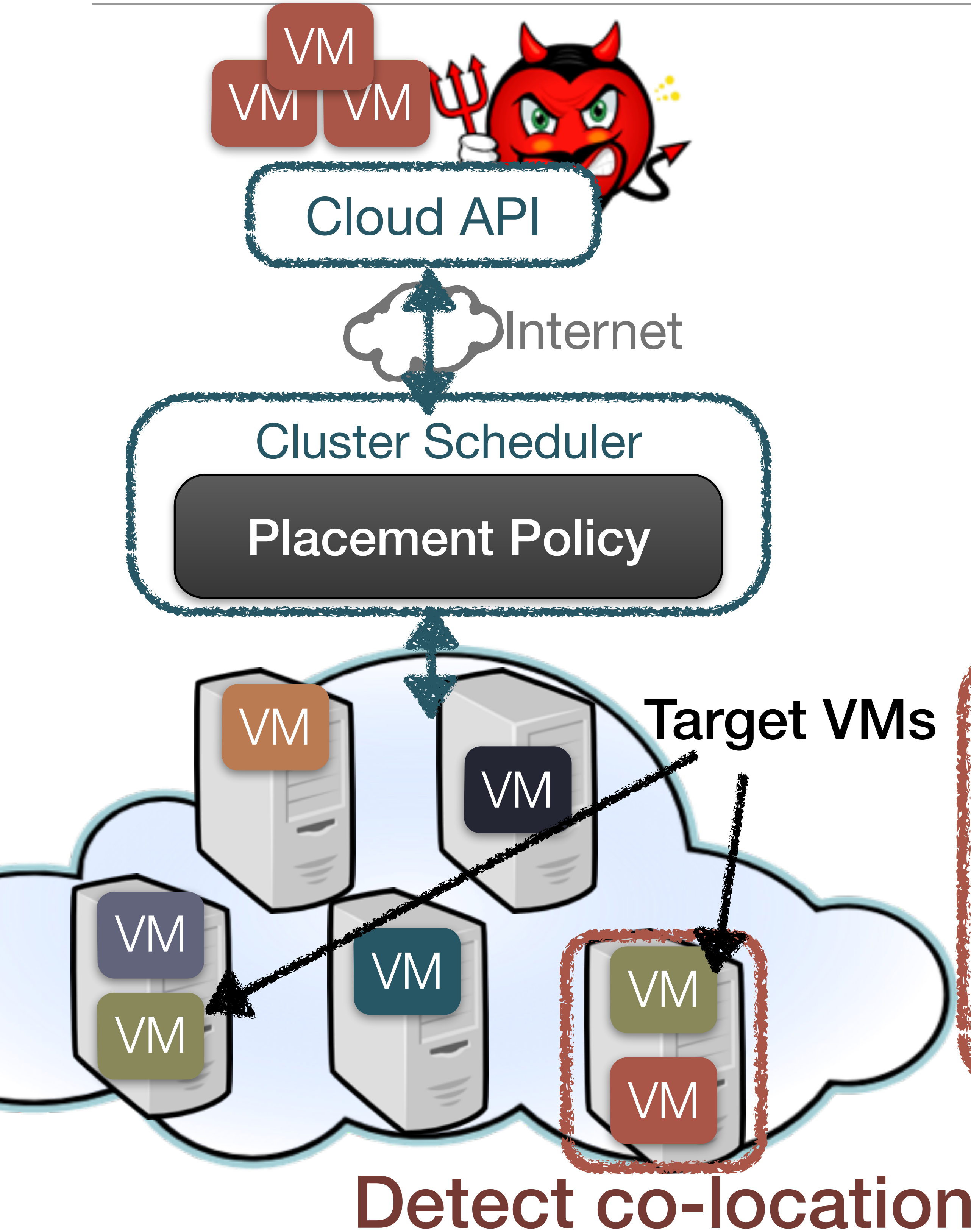
Our Work:
Exploring Co-location Attacks in Modern Clouds



Steps in achieving co-location:

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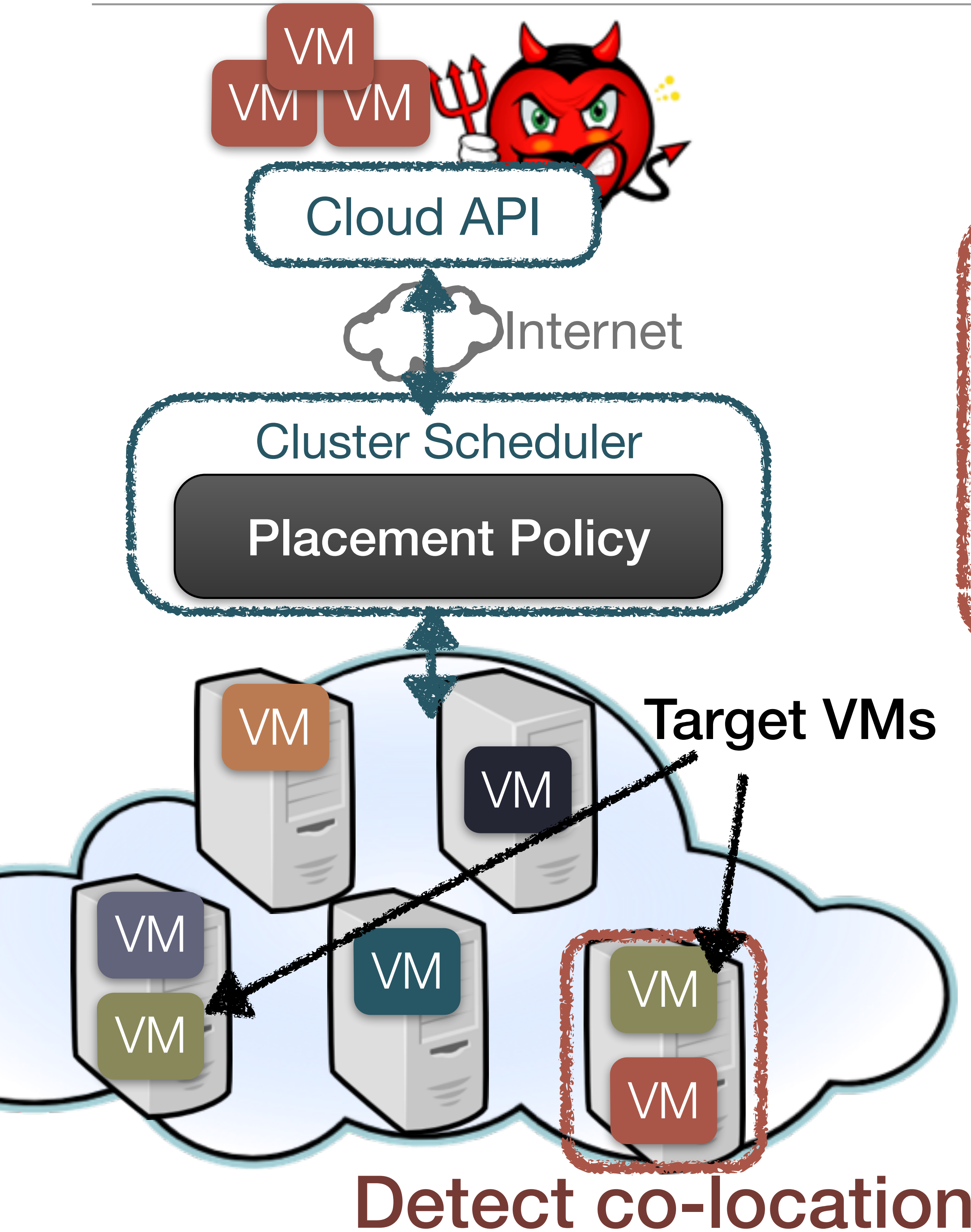

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Big Picture: Placement Vulnerability Study

Placement Policy

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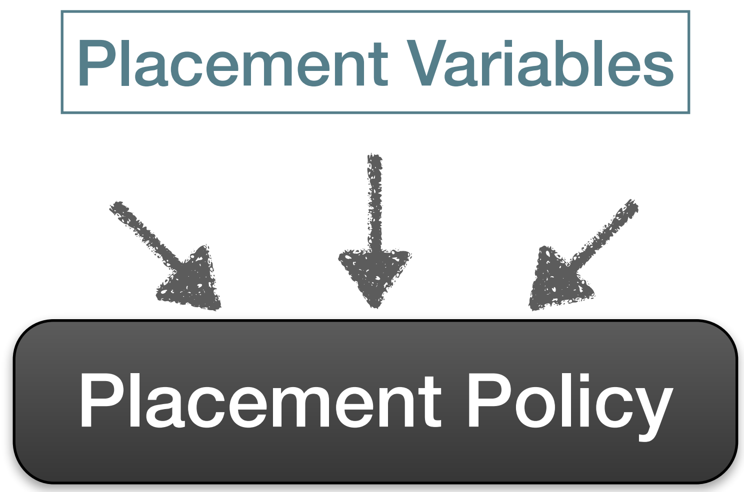
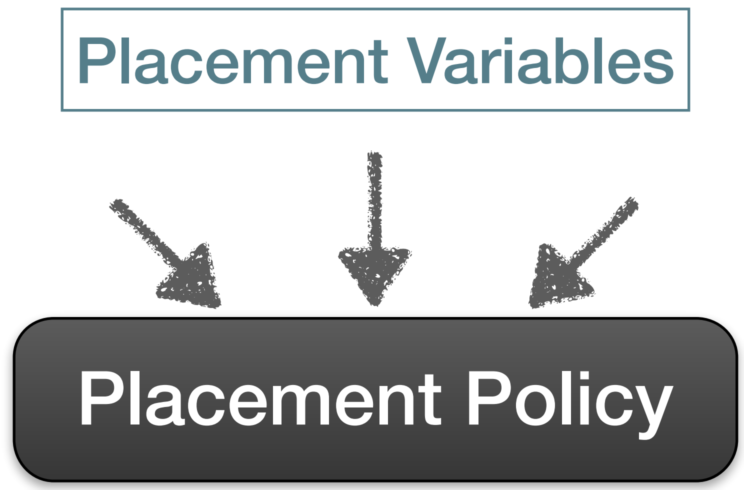


Big Picture: Placement Vulnerability Study

e.g., # VMs, when you launch, datacenter, VM type, etc.



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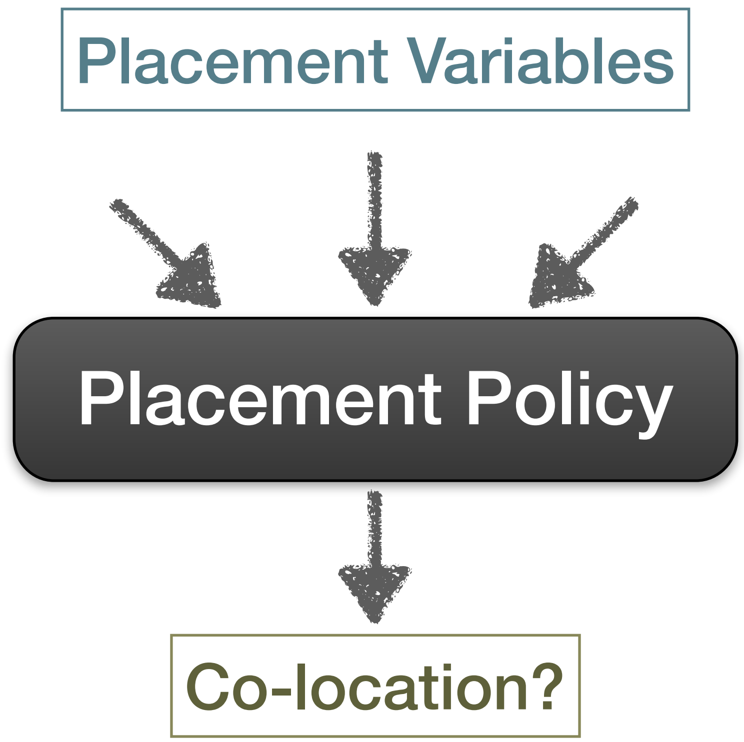

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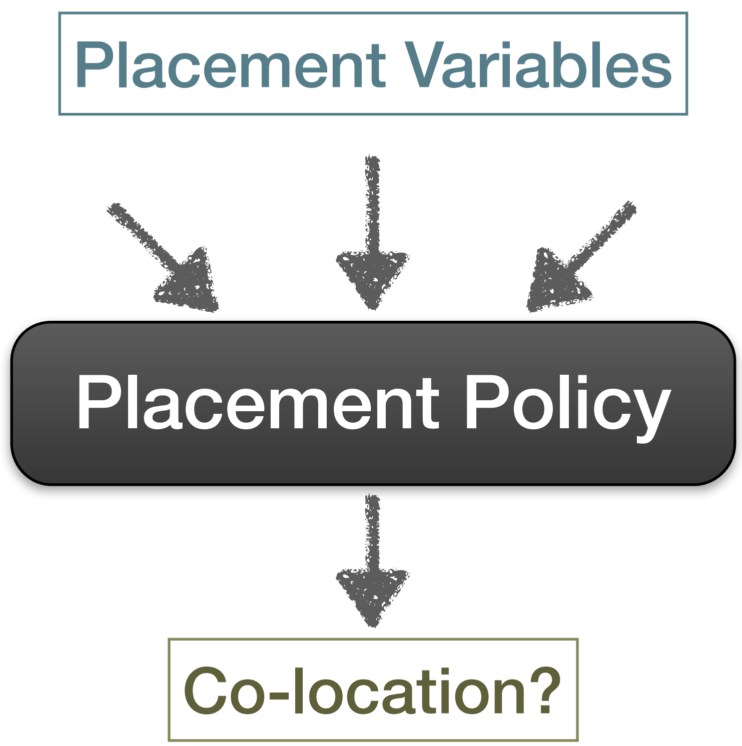

Fix Placement Variables

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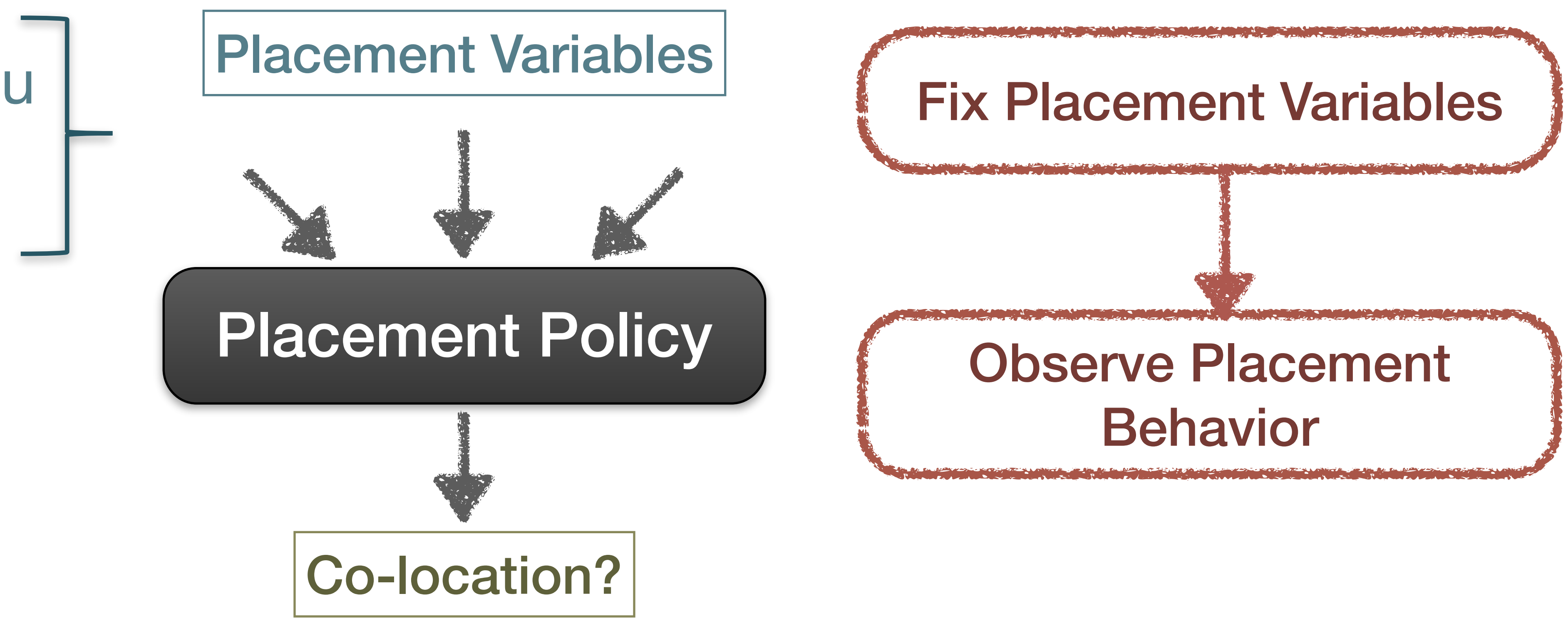

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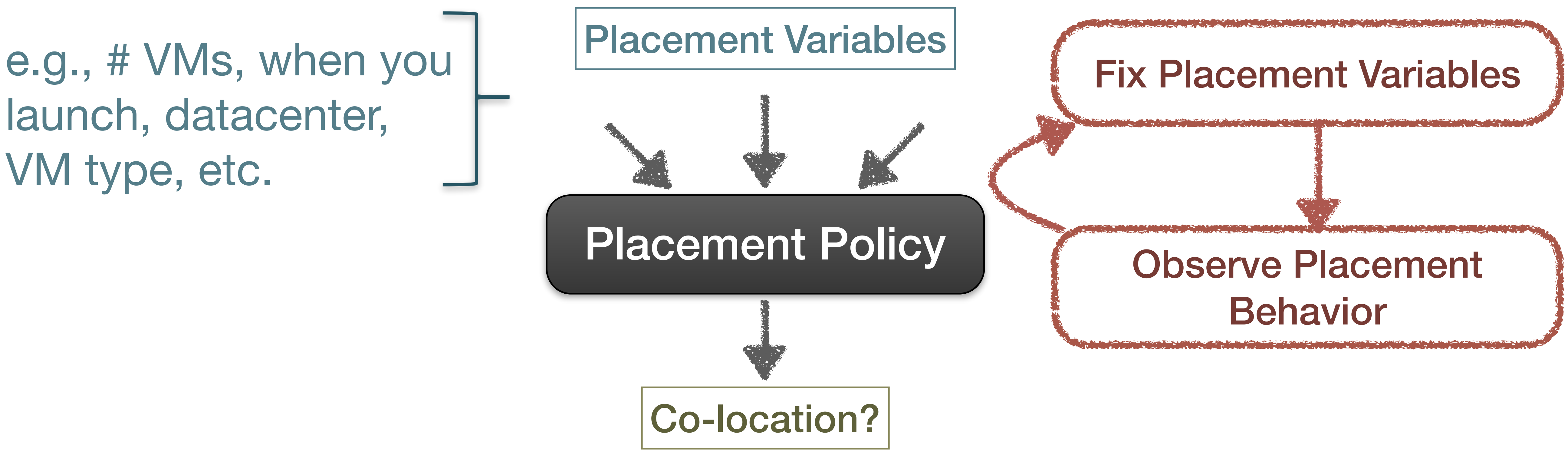

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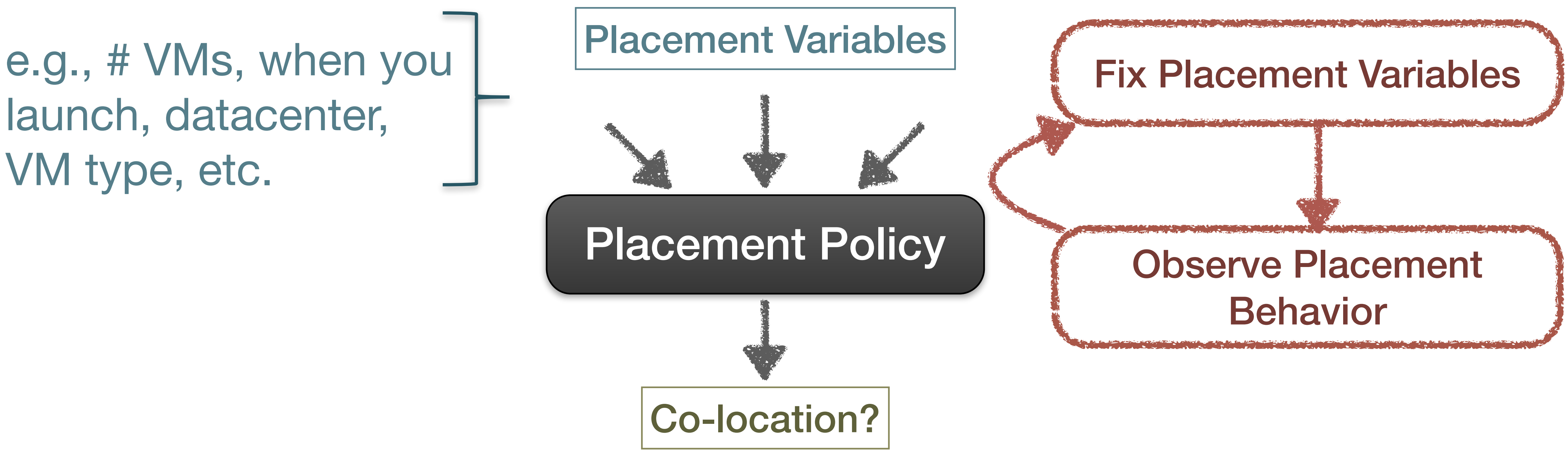

Study spanning 3 months, exploring 6 placement variables, spending more than $200 per cloud

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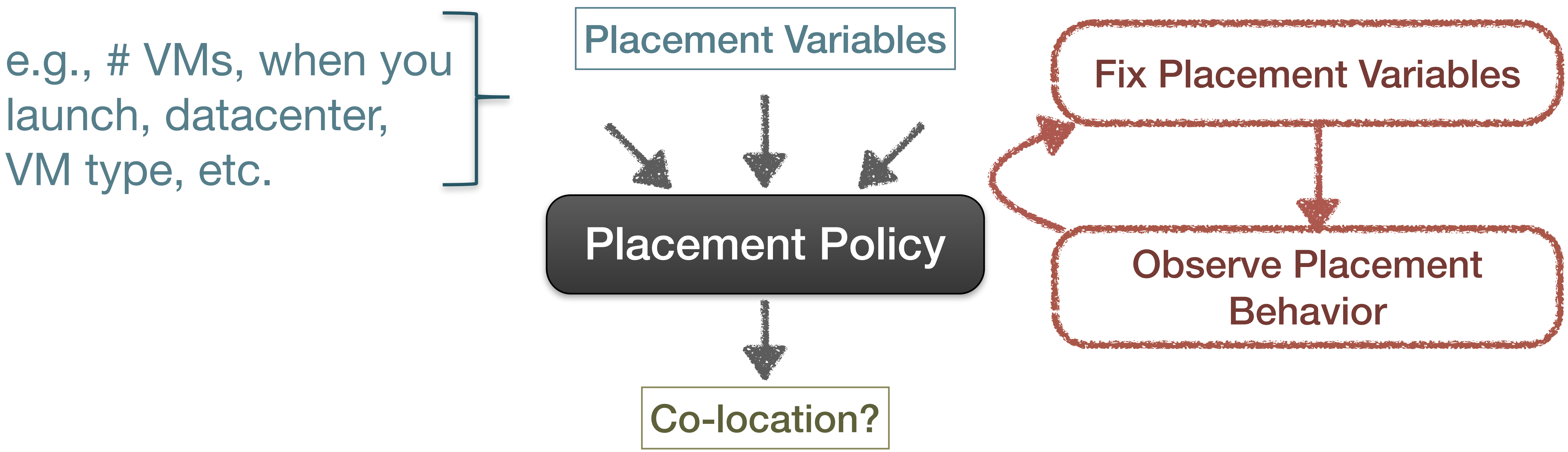

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amazon web services™ EC2

Microsoft Azure

Study Setup

- Two distinct accounts: proxy for victim and attacker

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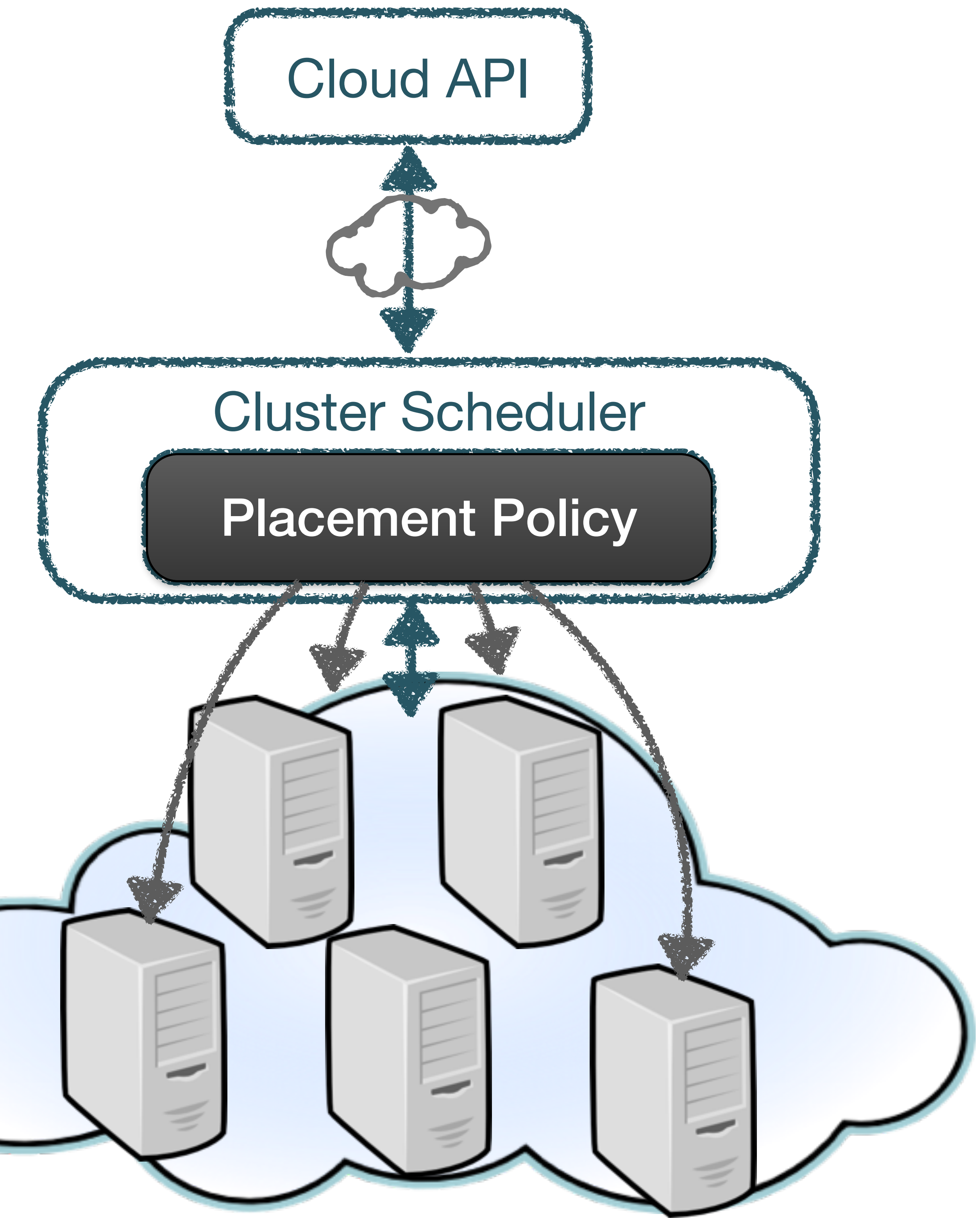
- 9 samples per strategy with 3 runs per time of day & 2 days of week (weekday/weekend)

How hard should it be to achieve co-location?



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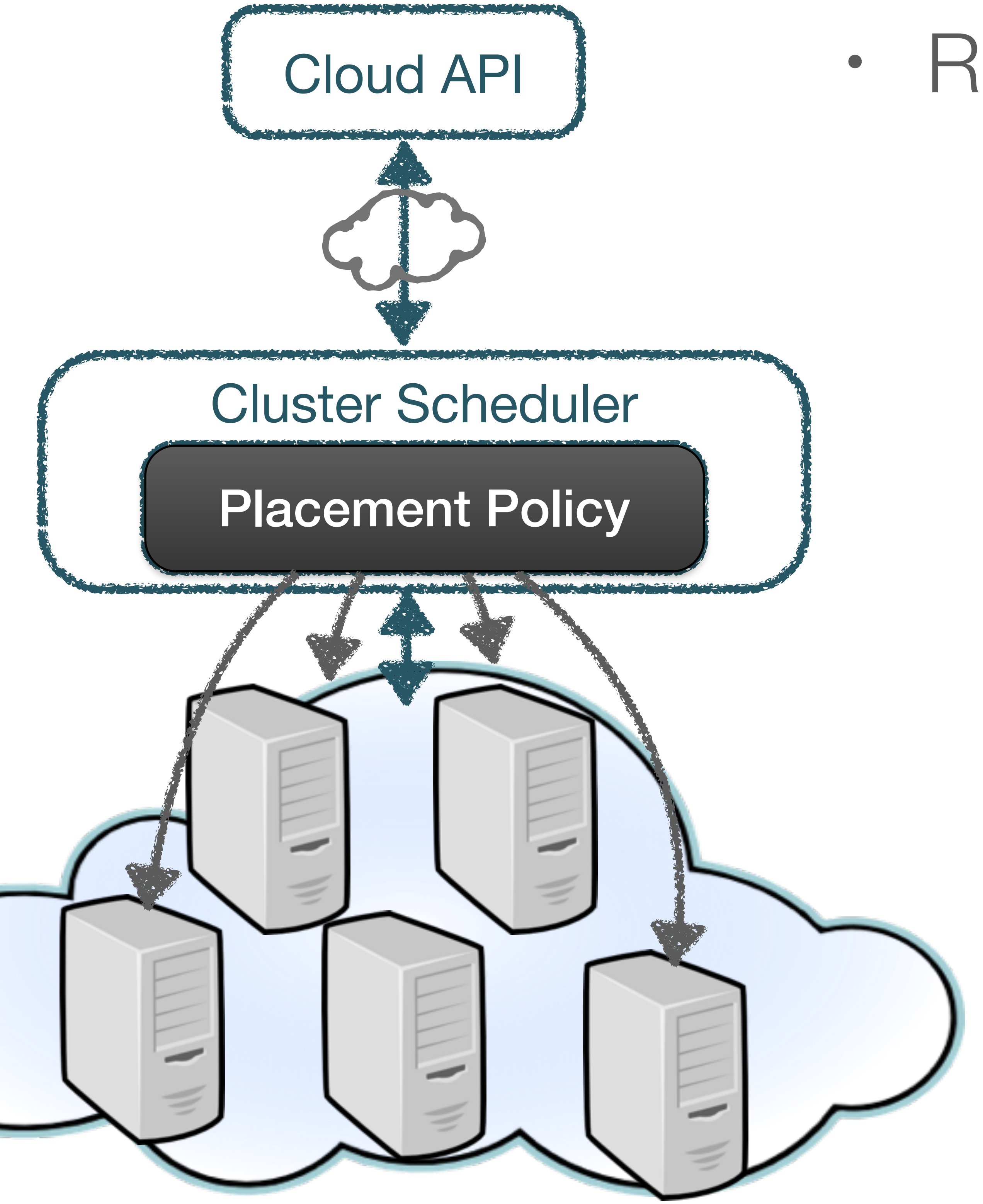

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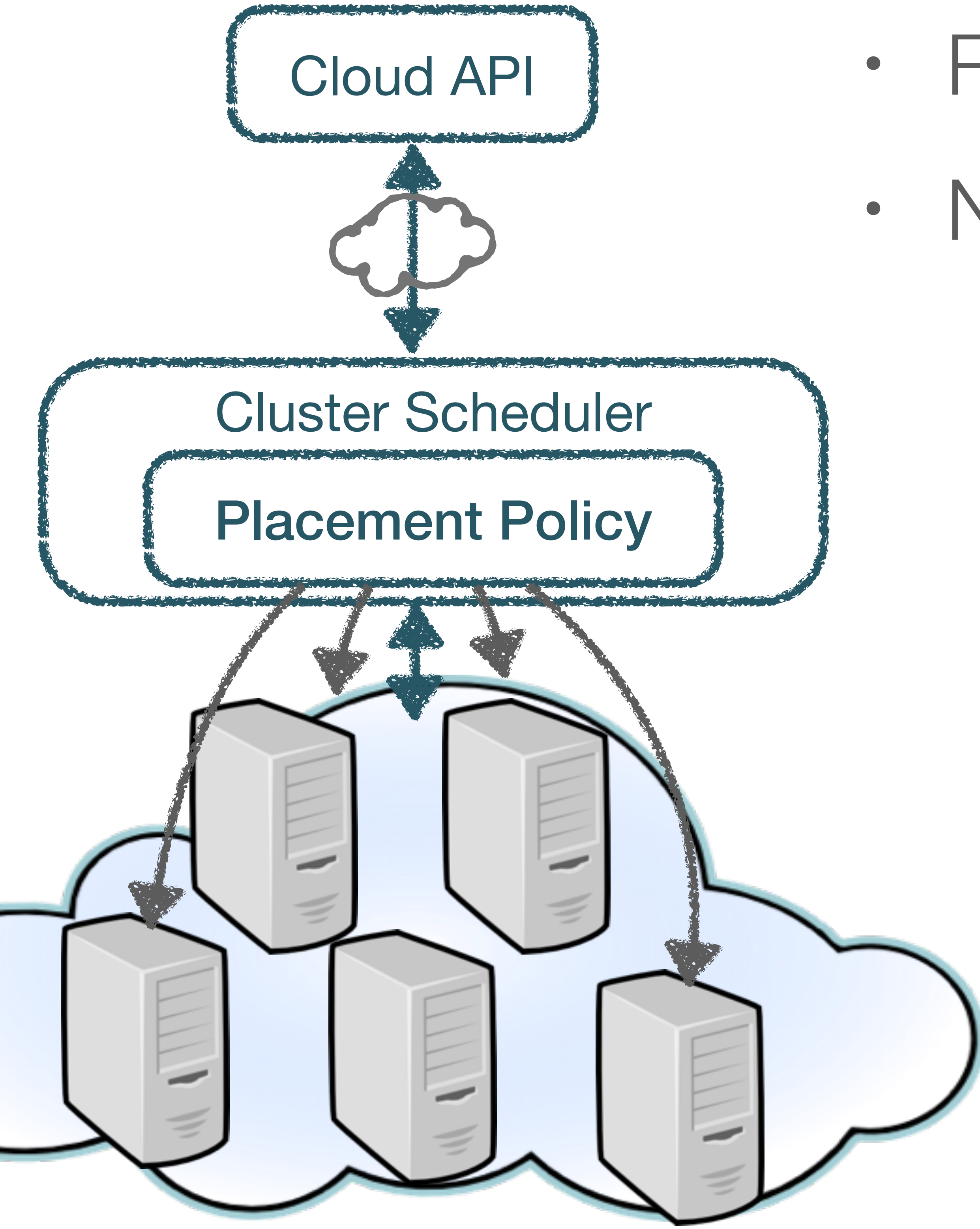

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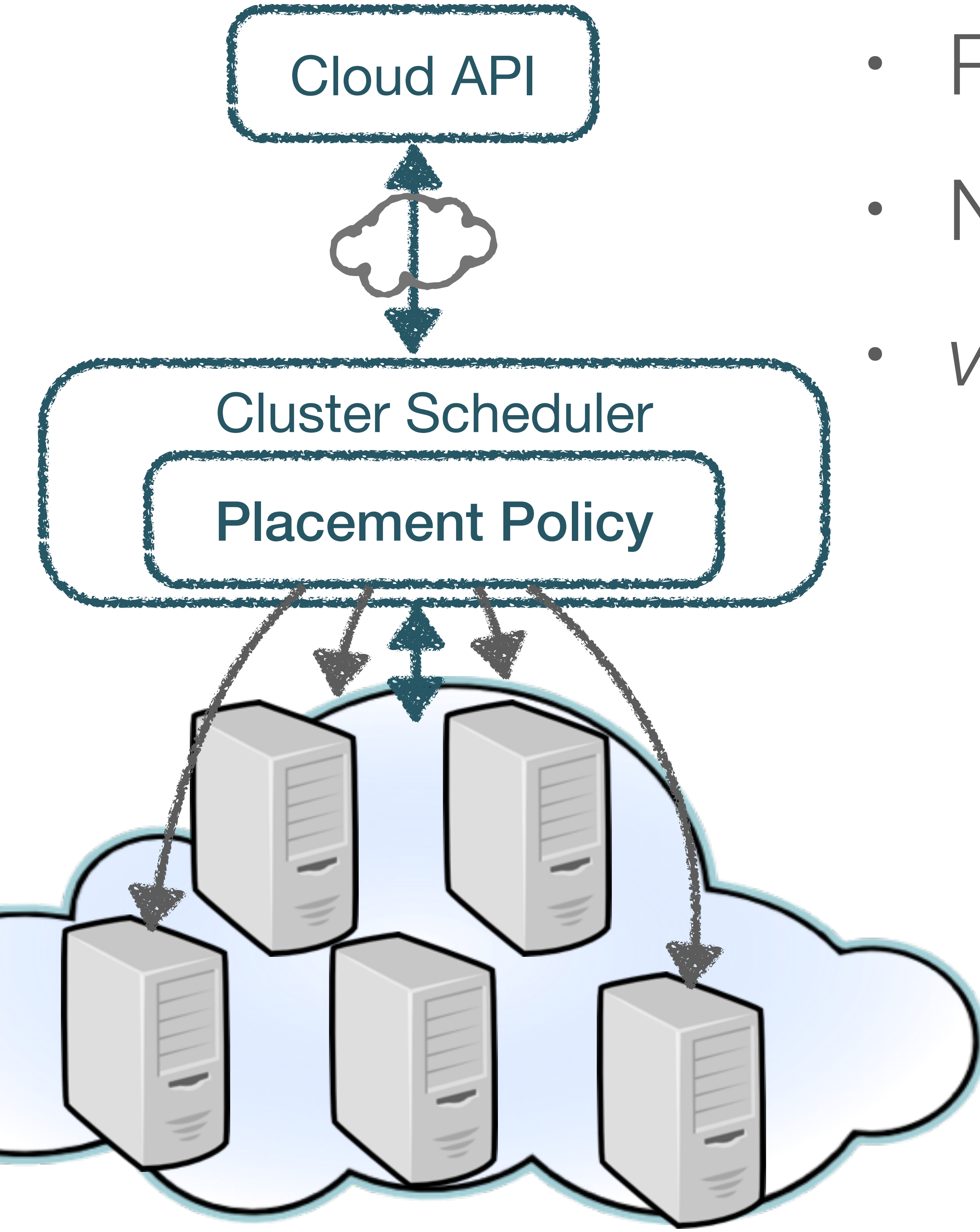

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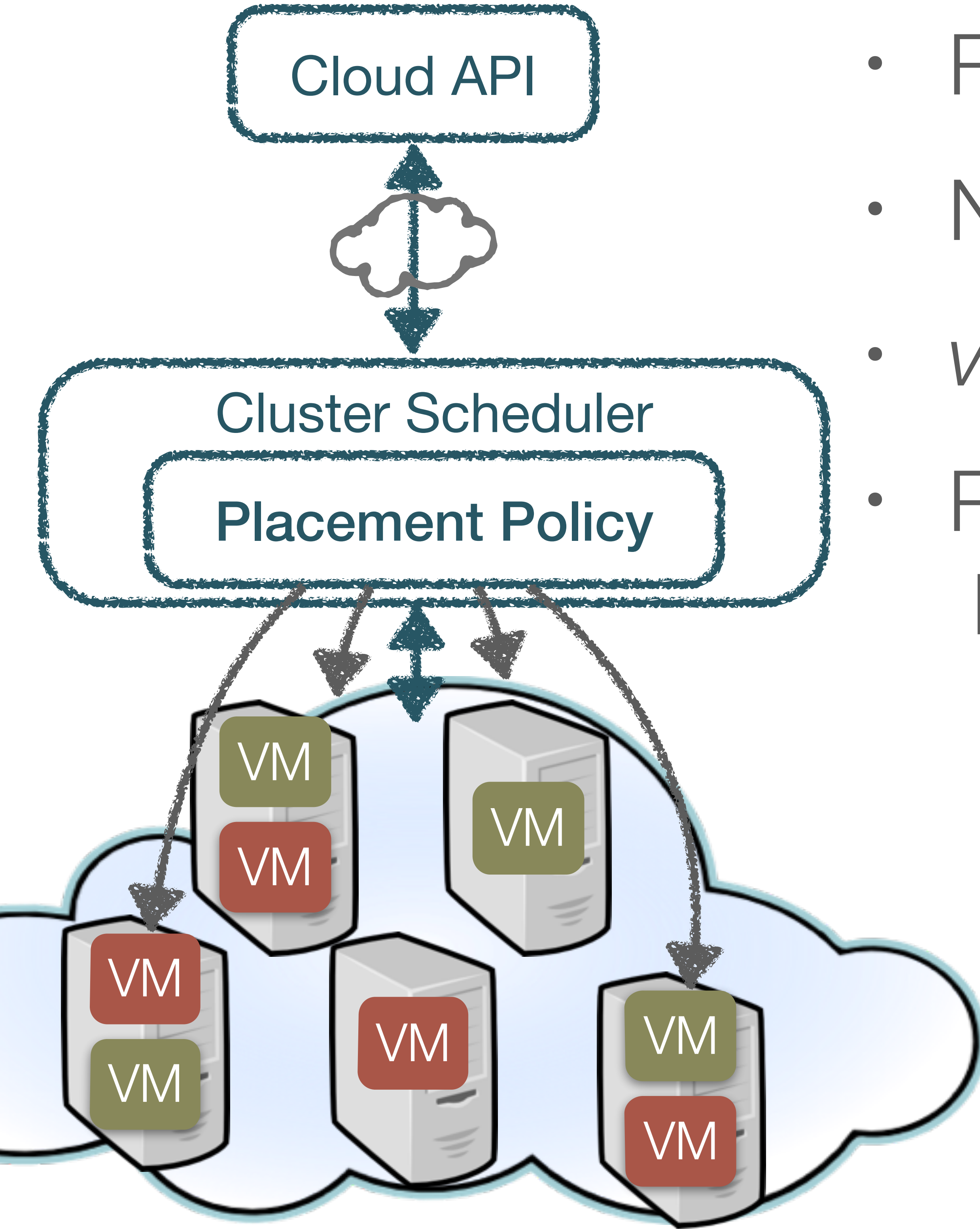

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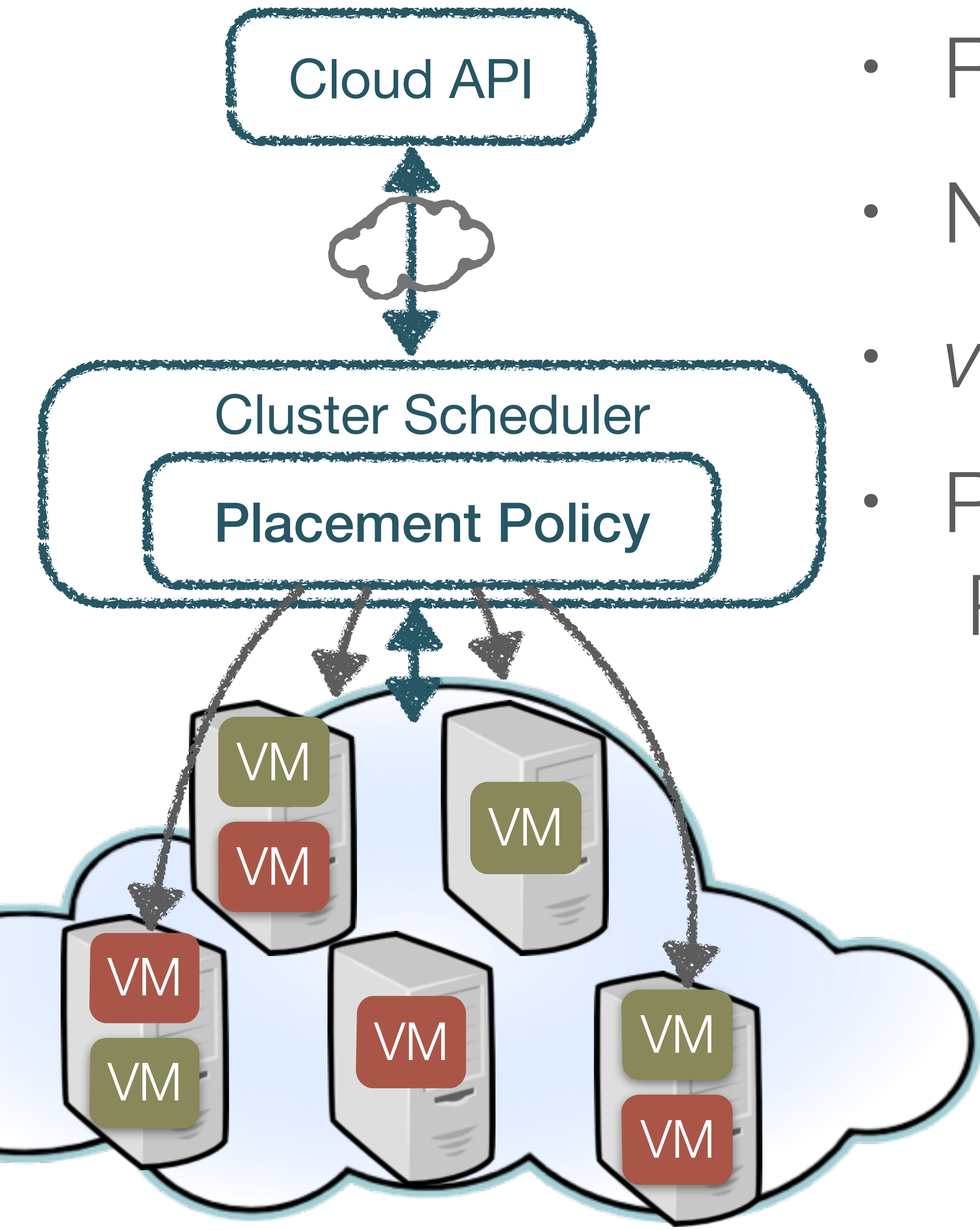

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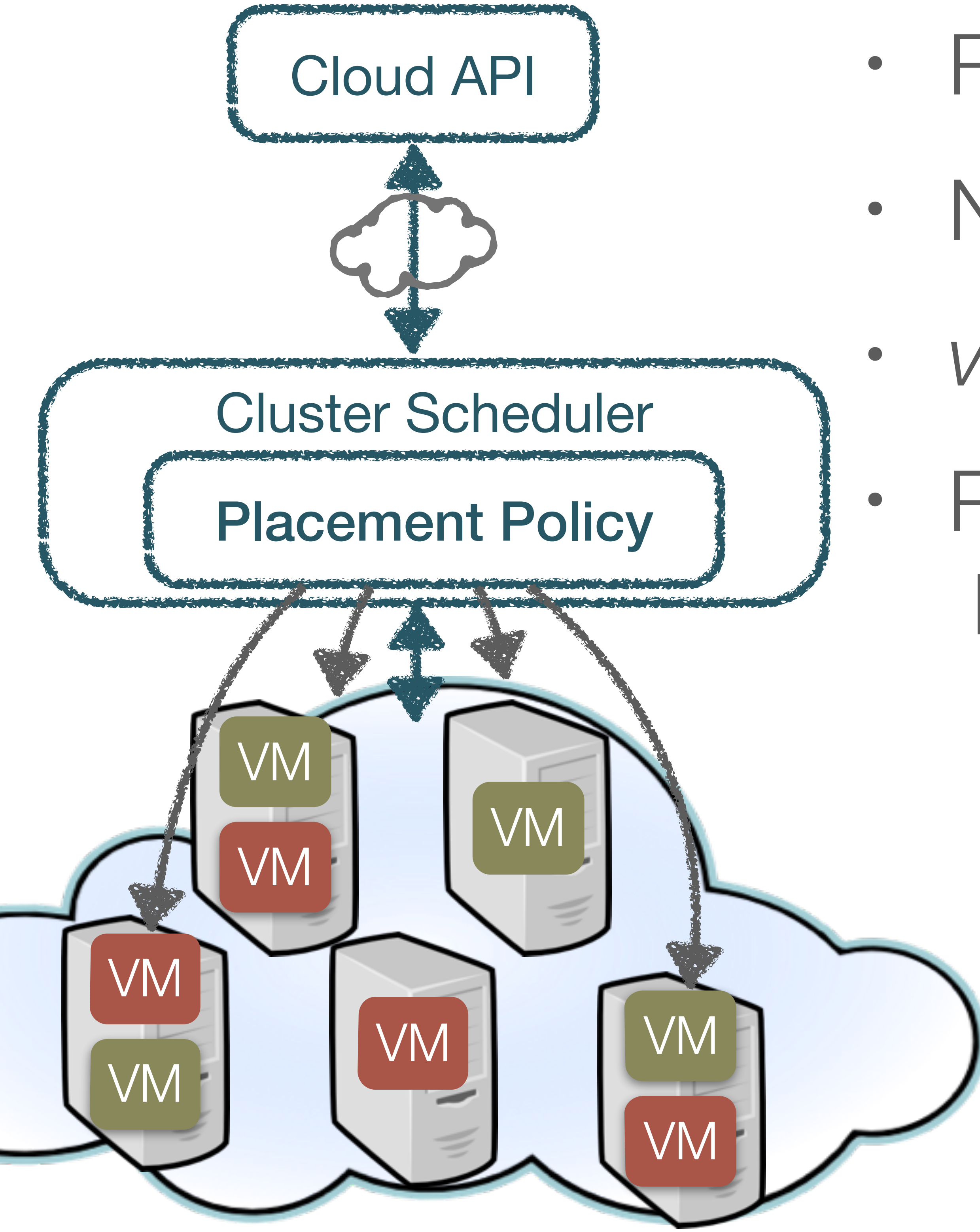

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20	**1733**
30	**1155**

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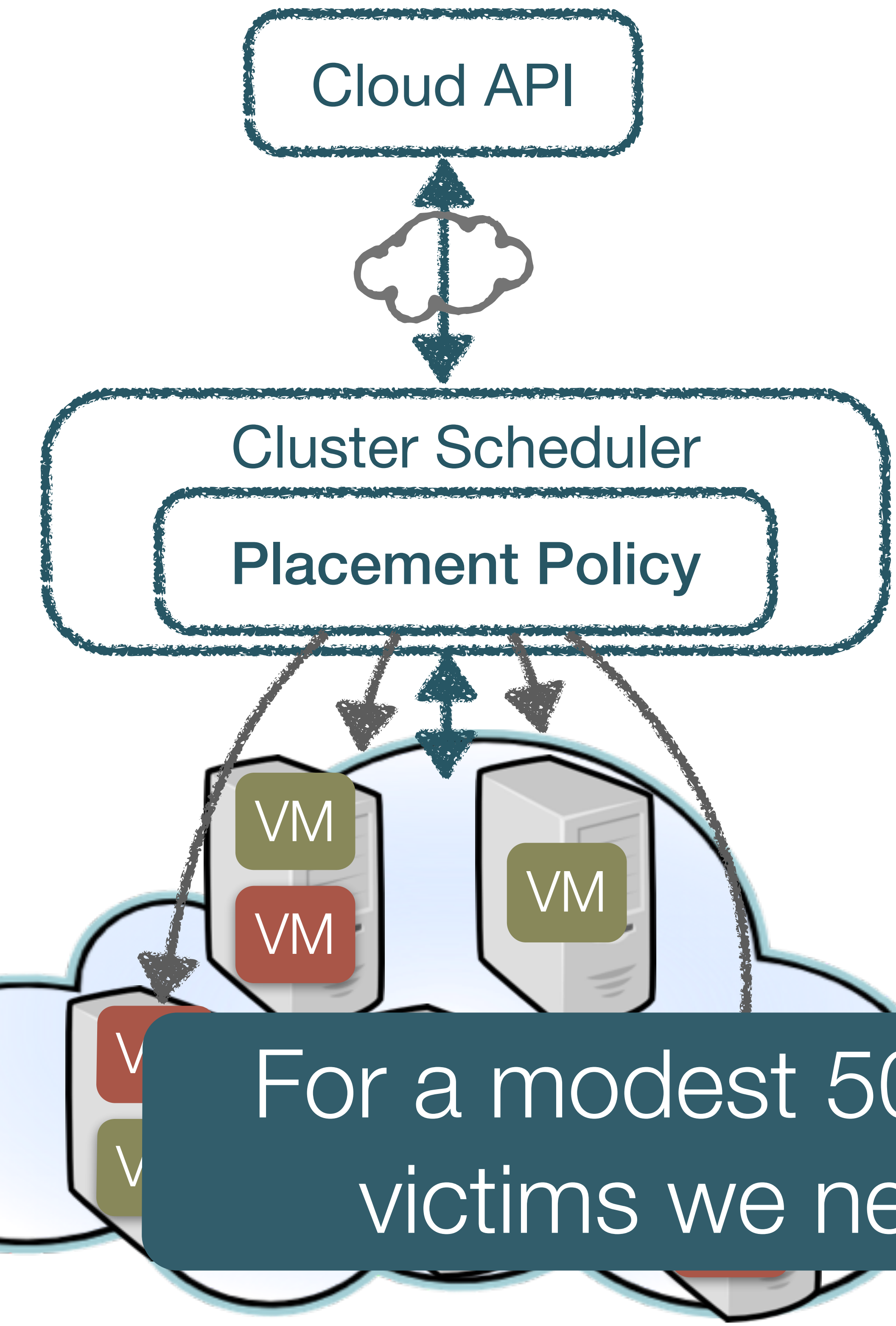

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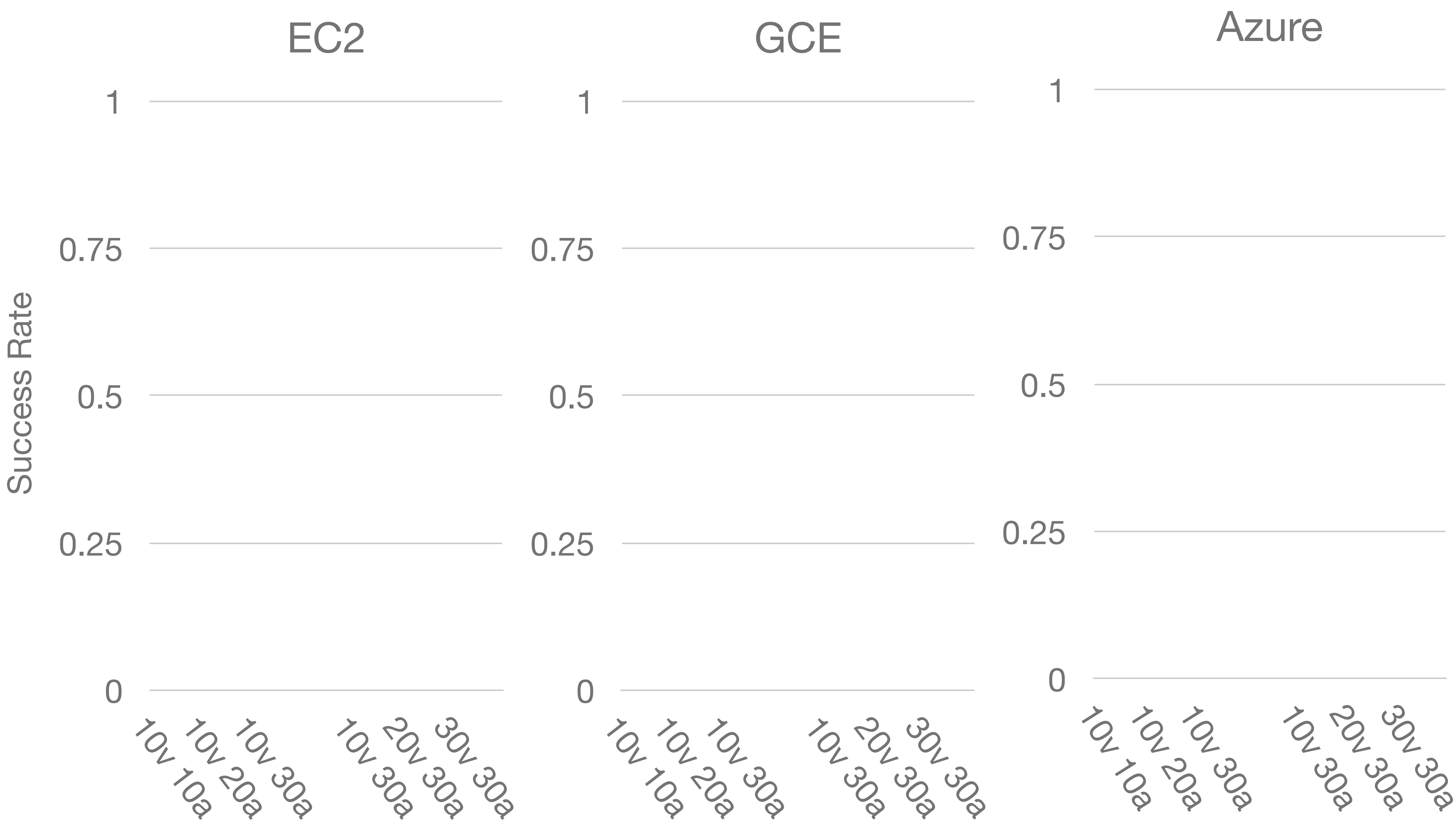
For a modest 50% success rate with 10-30 victims we need to launch ~3000 VMs

Results: Varying Number of VMs



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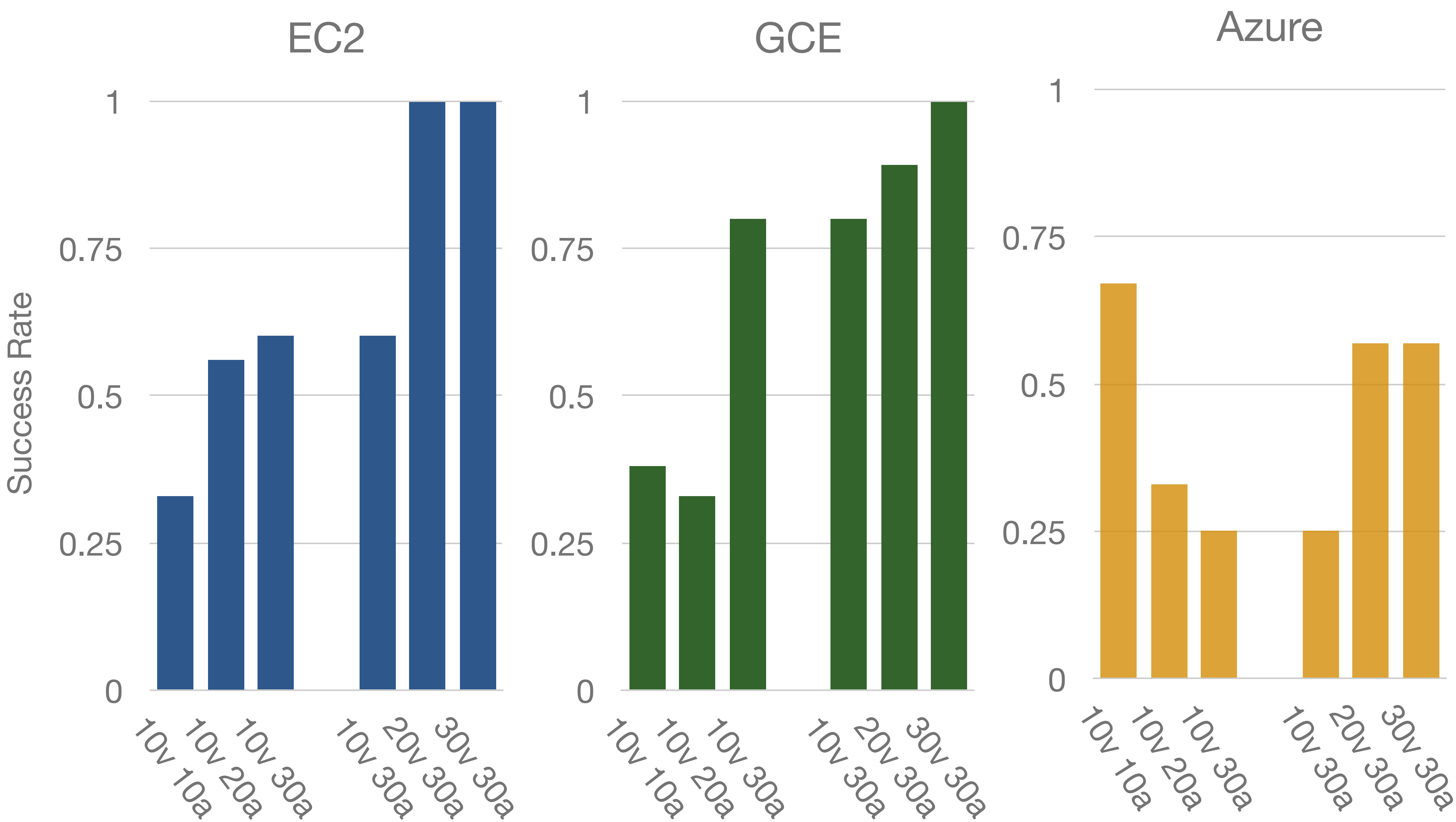

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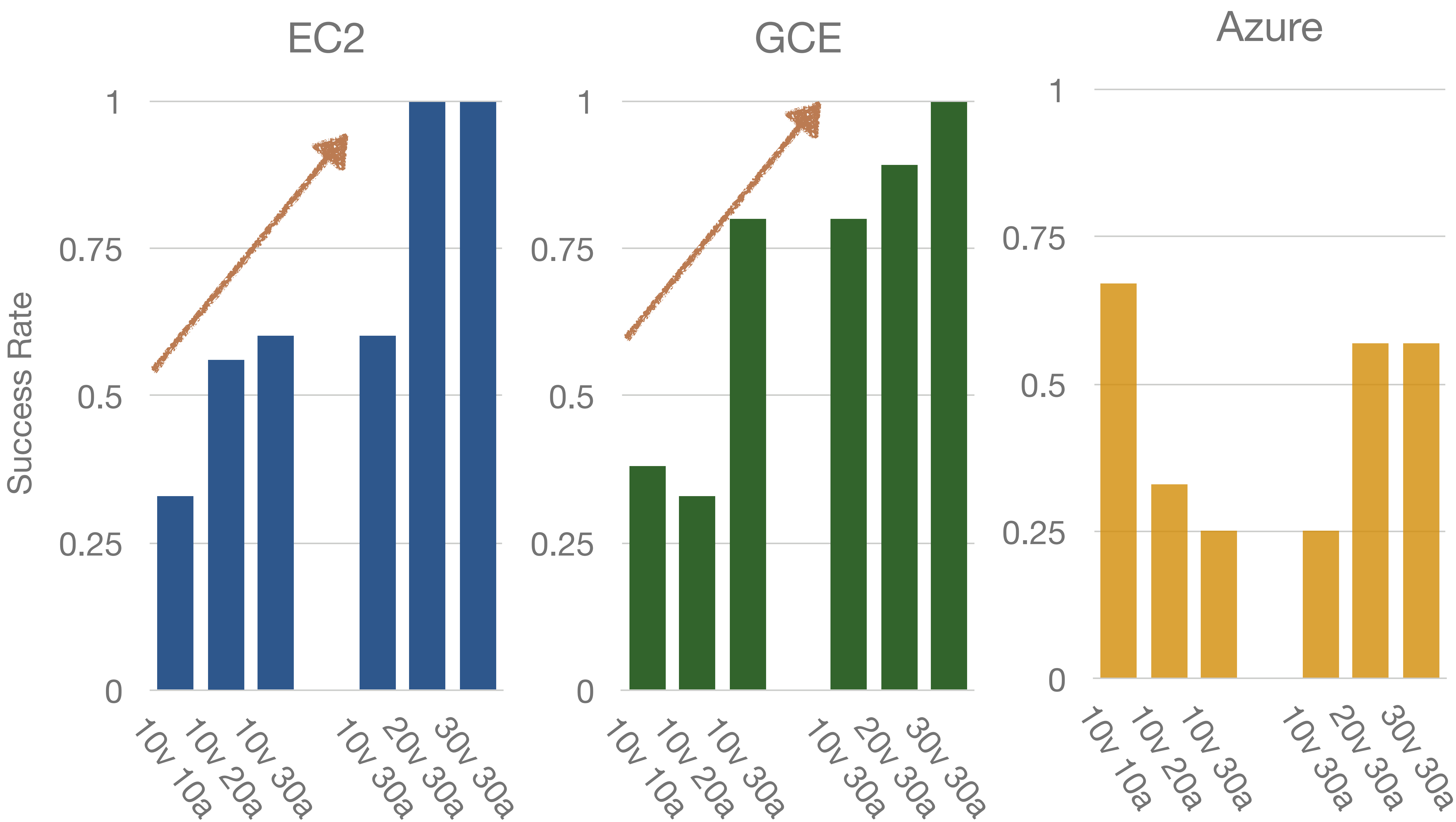

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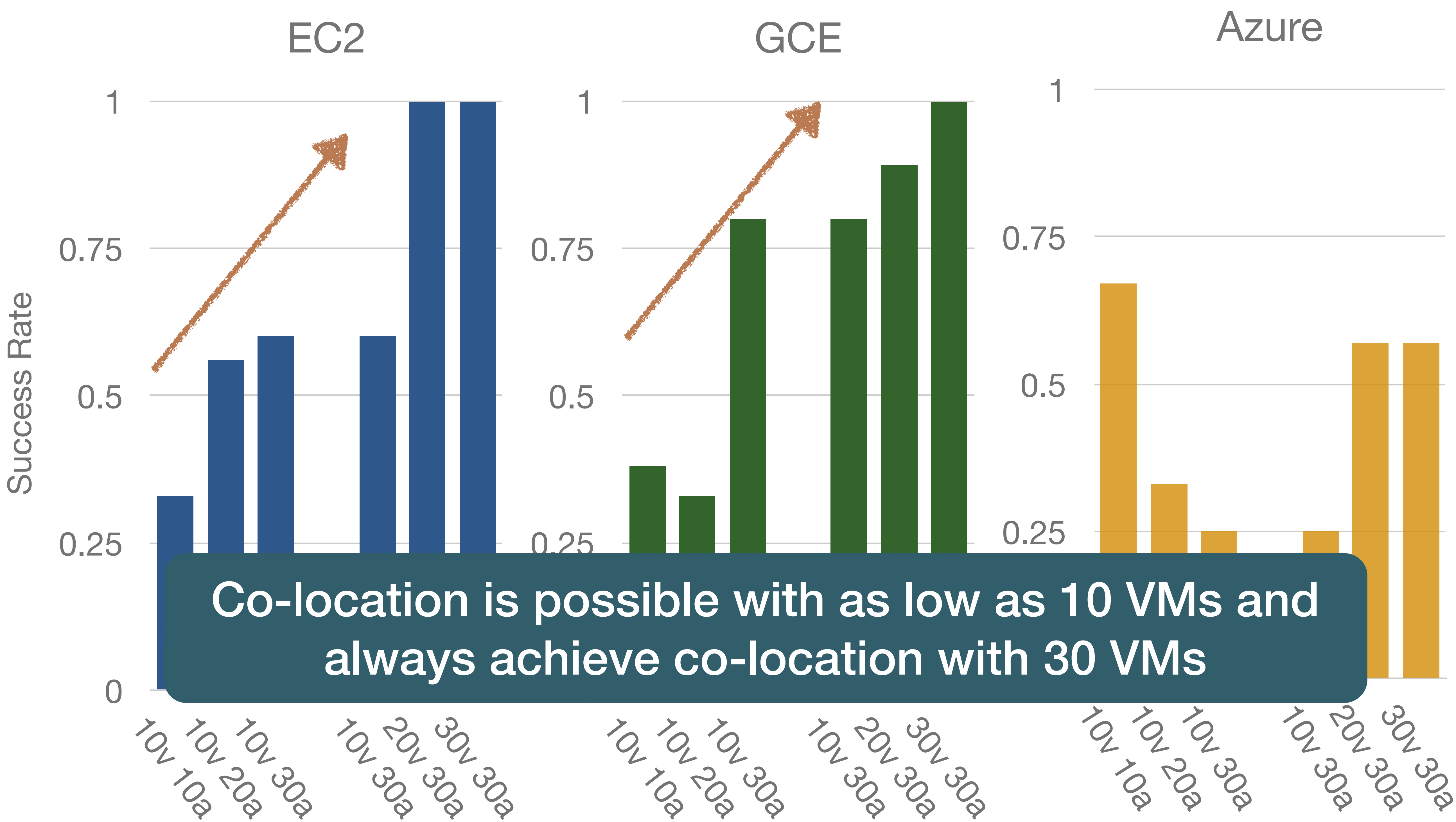
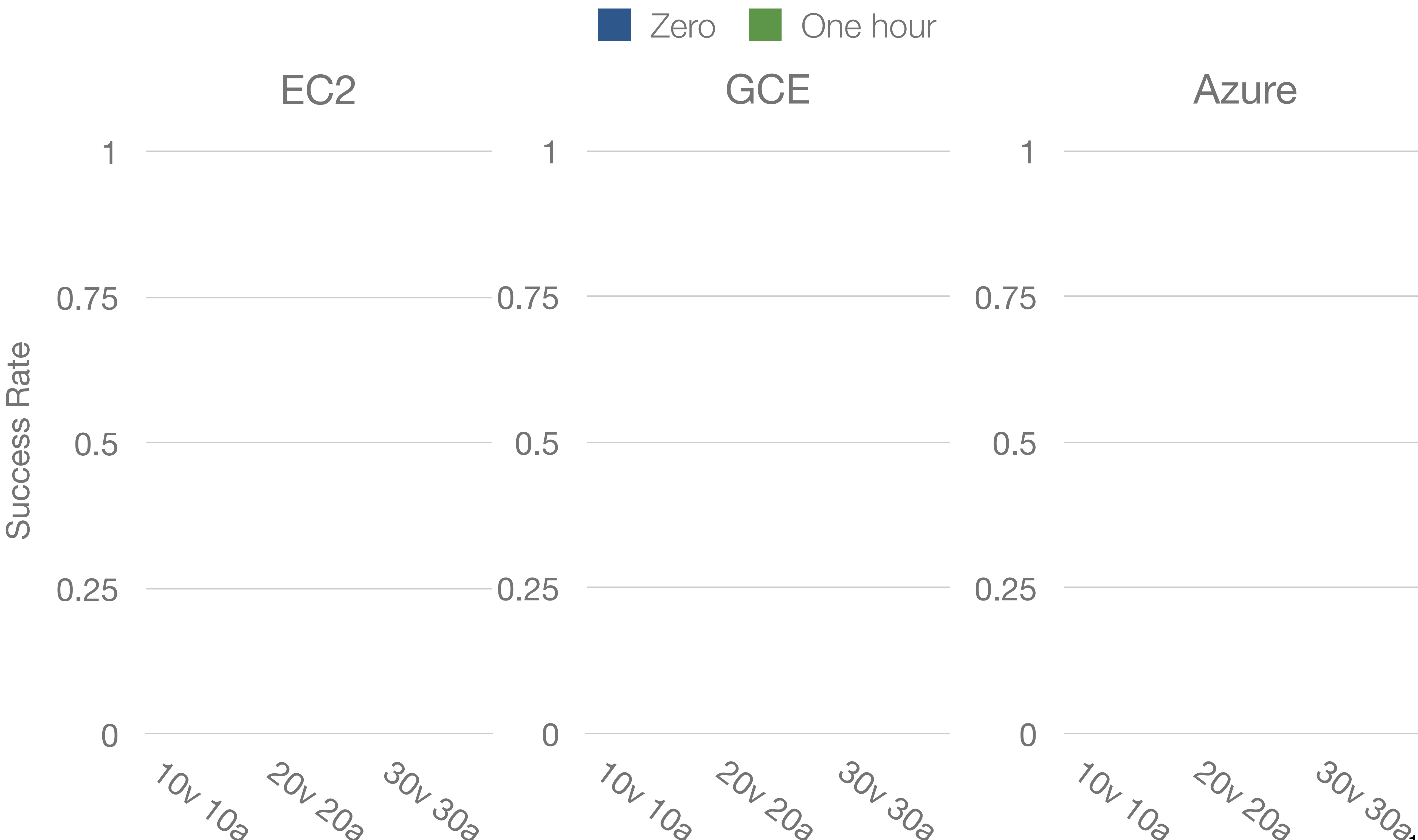


Co-location is possible with as low as 10 VMs and always achieve co-location with 30 VMs

Results: Varying Delay between Launches



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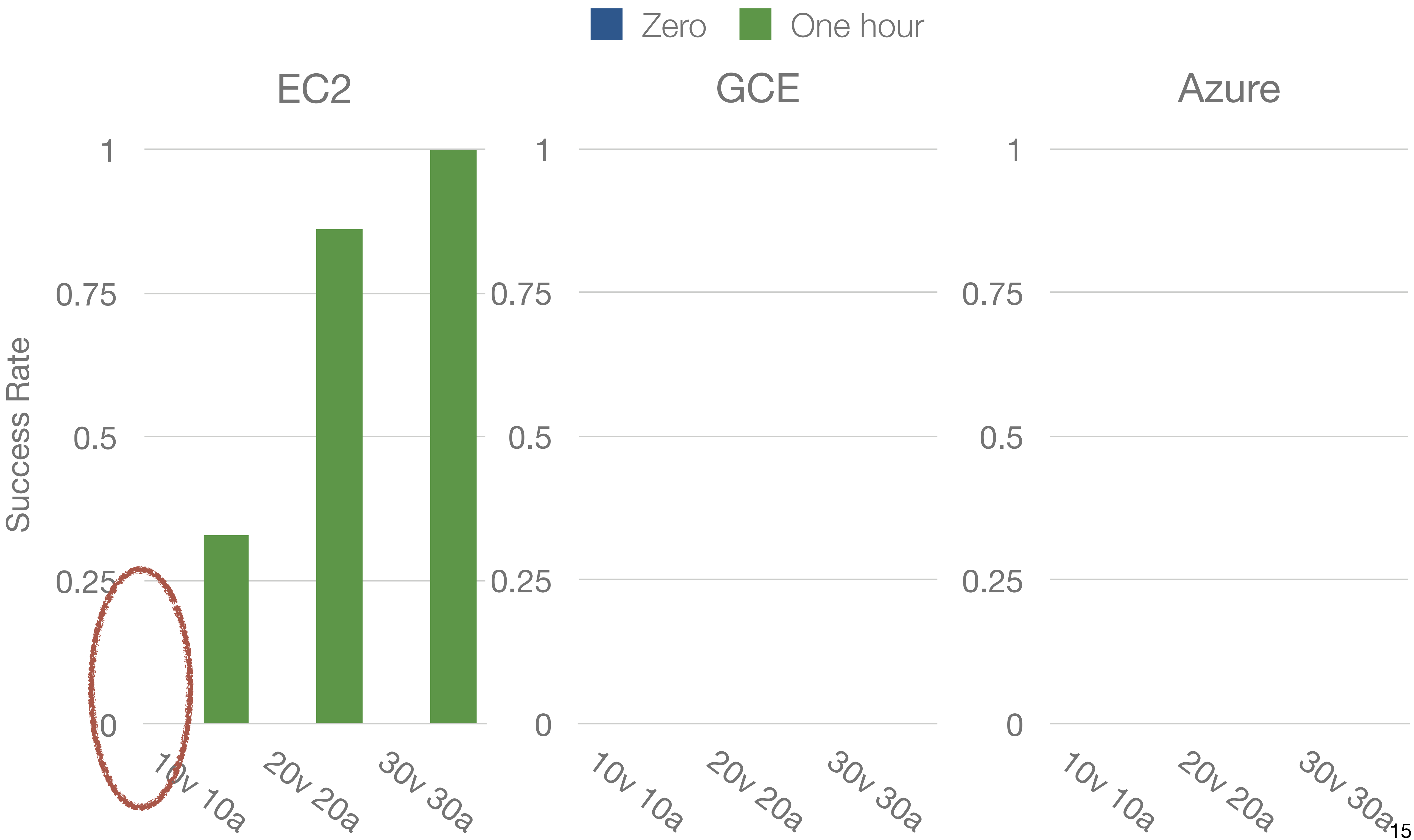

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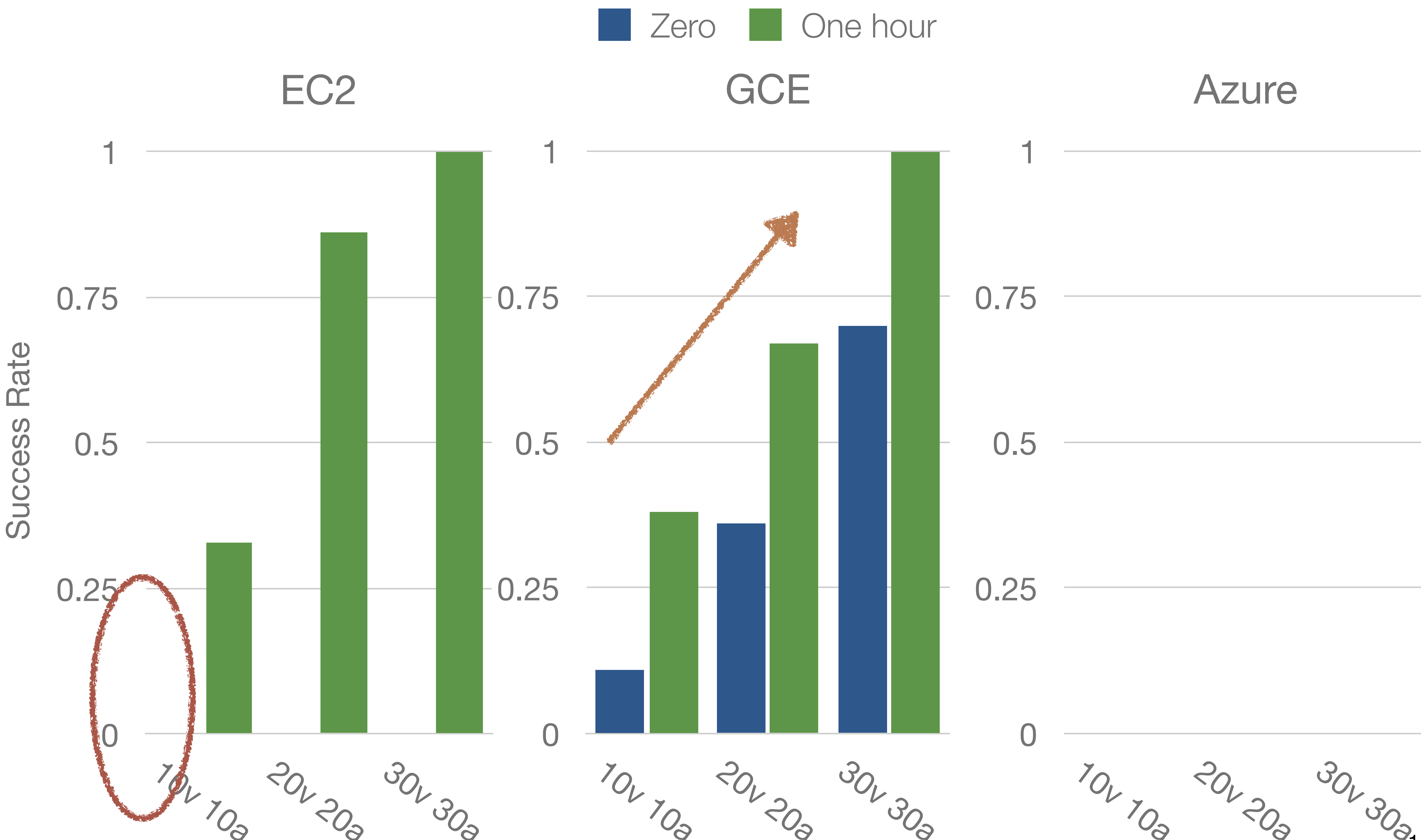

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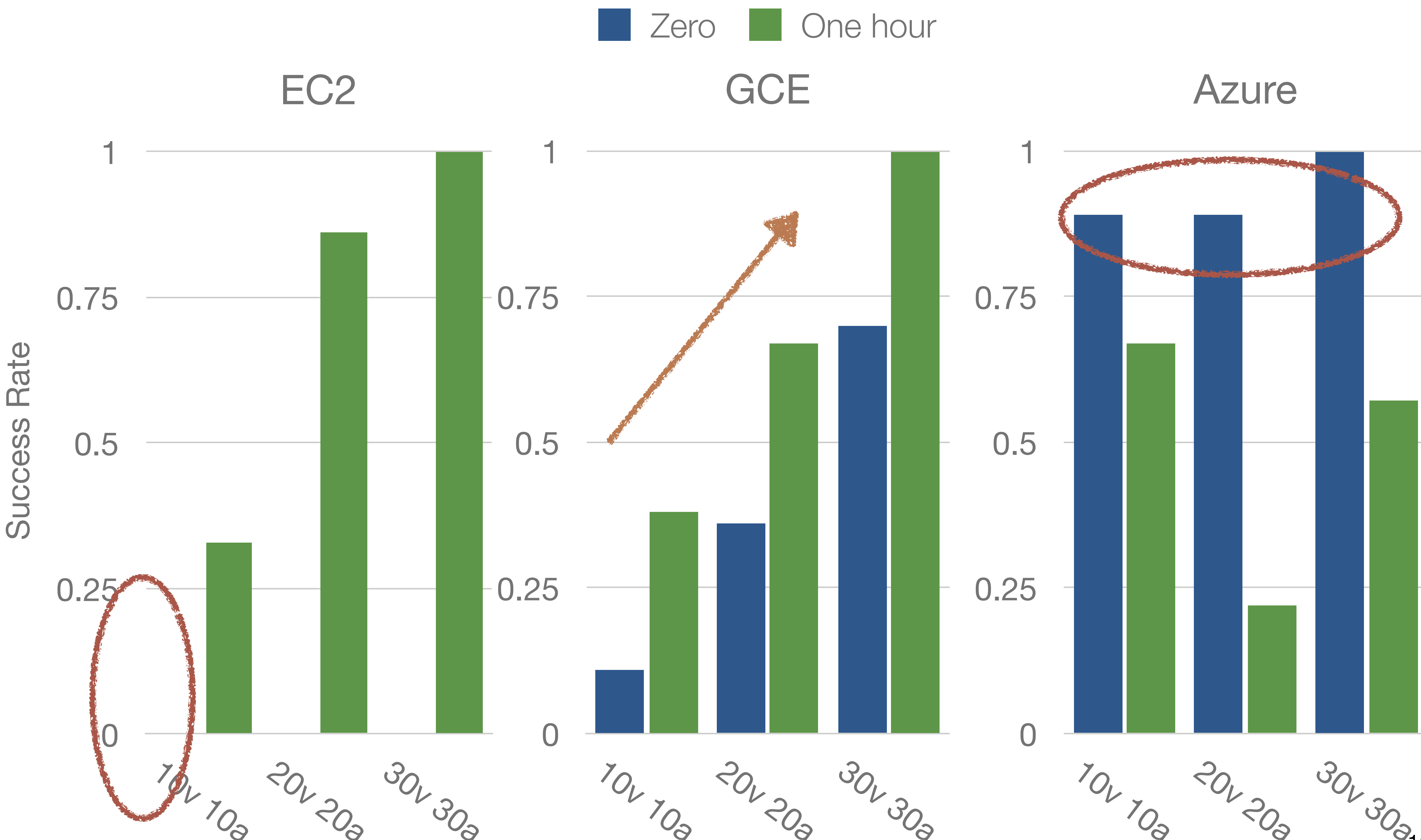

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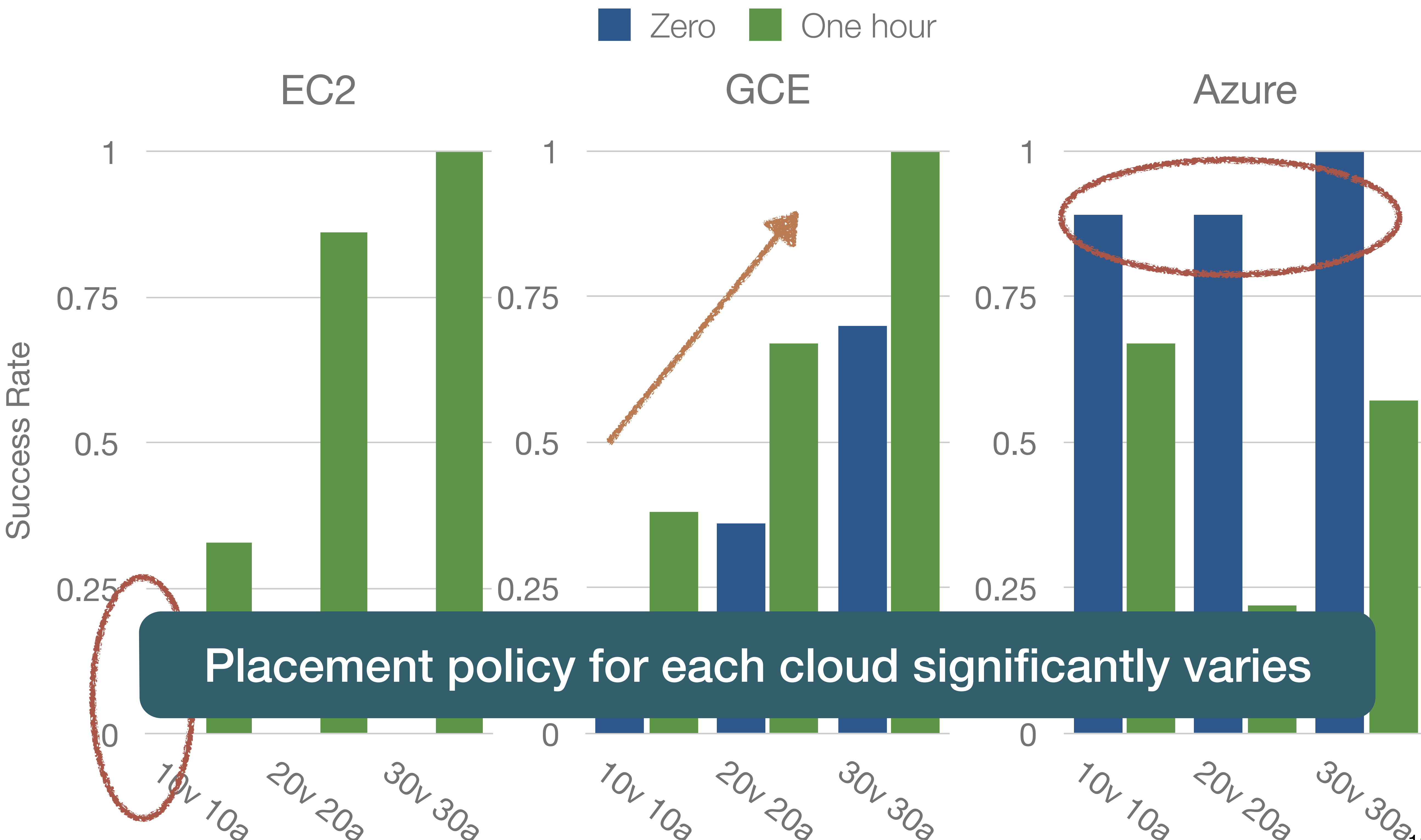
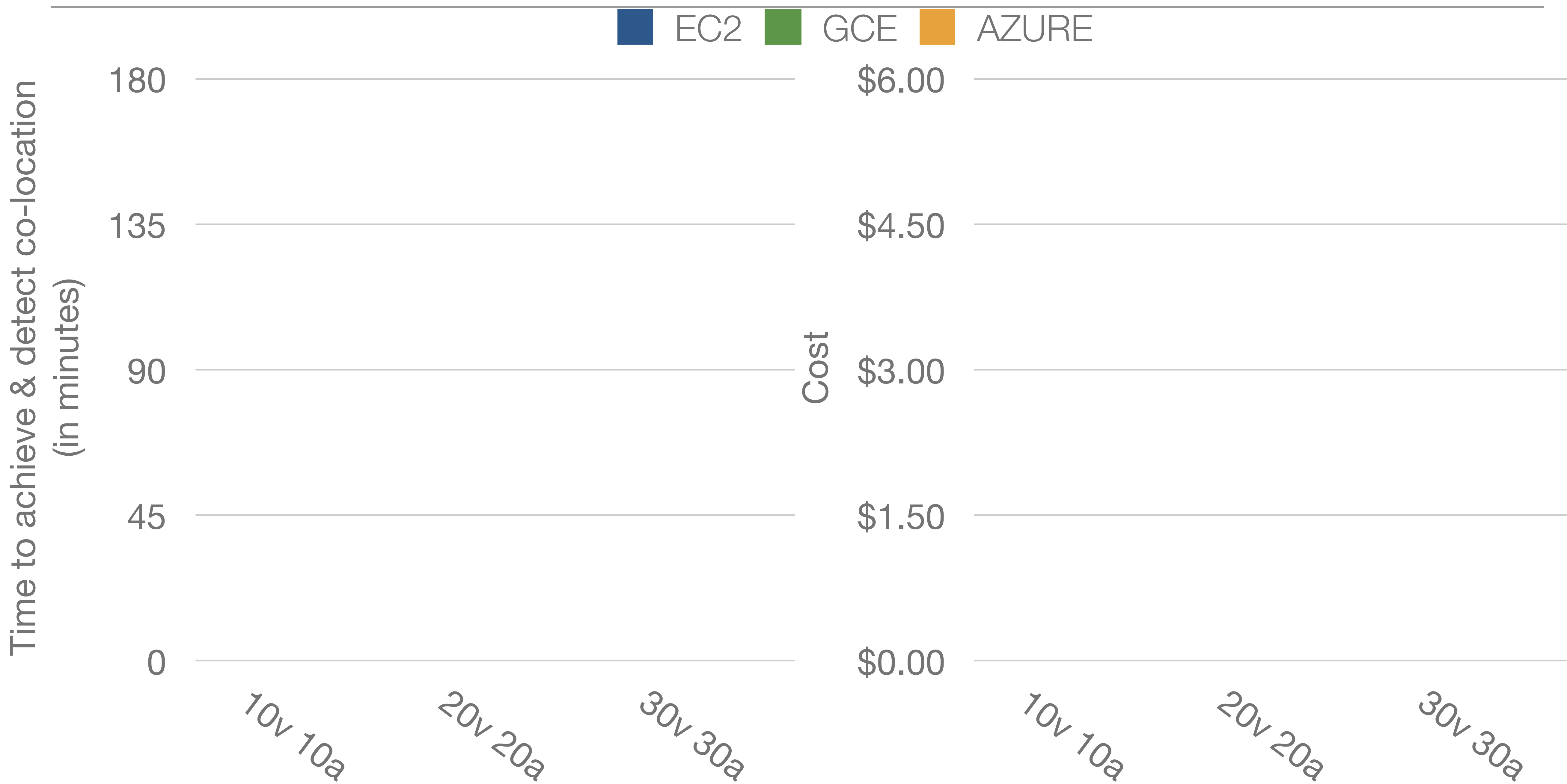


Placement policy for each cloud significantly varies

Cost of a Launch Strategy



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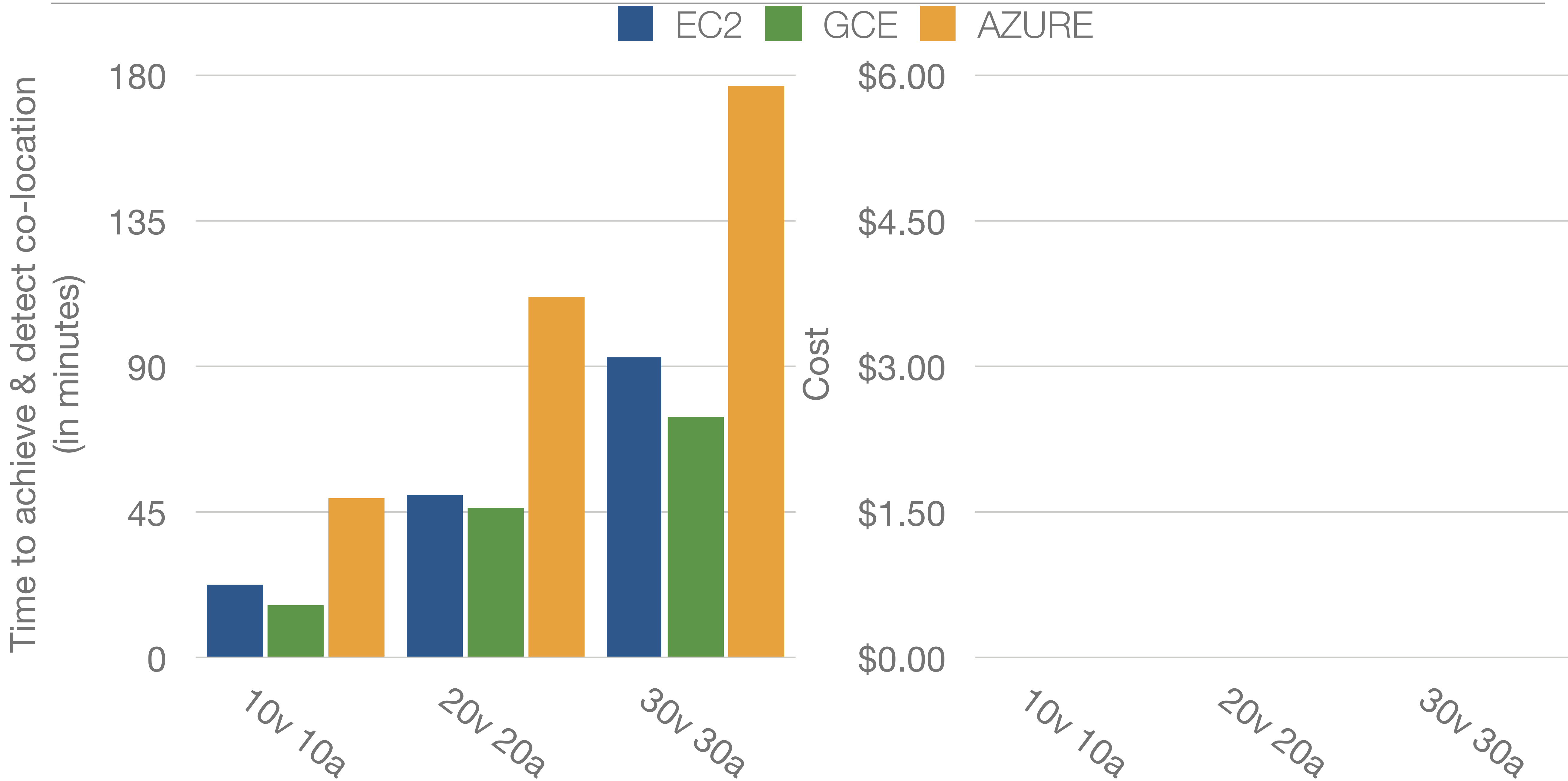

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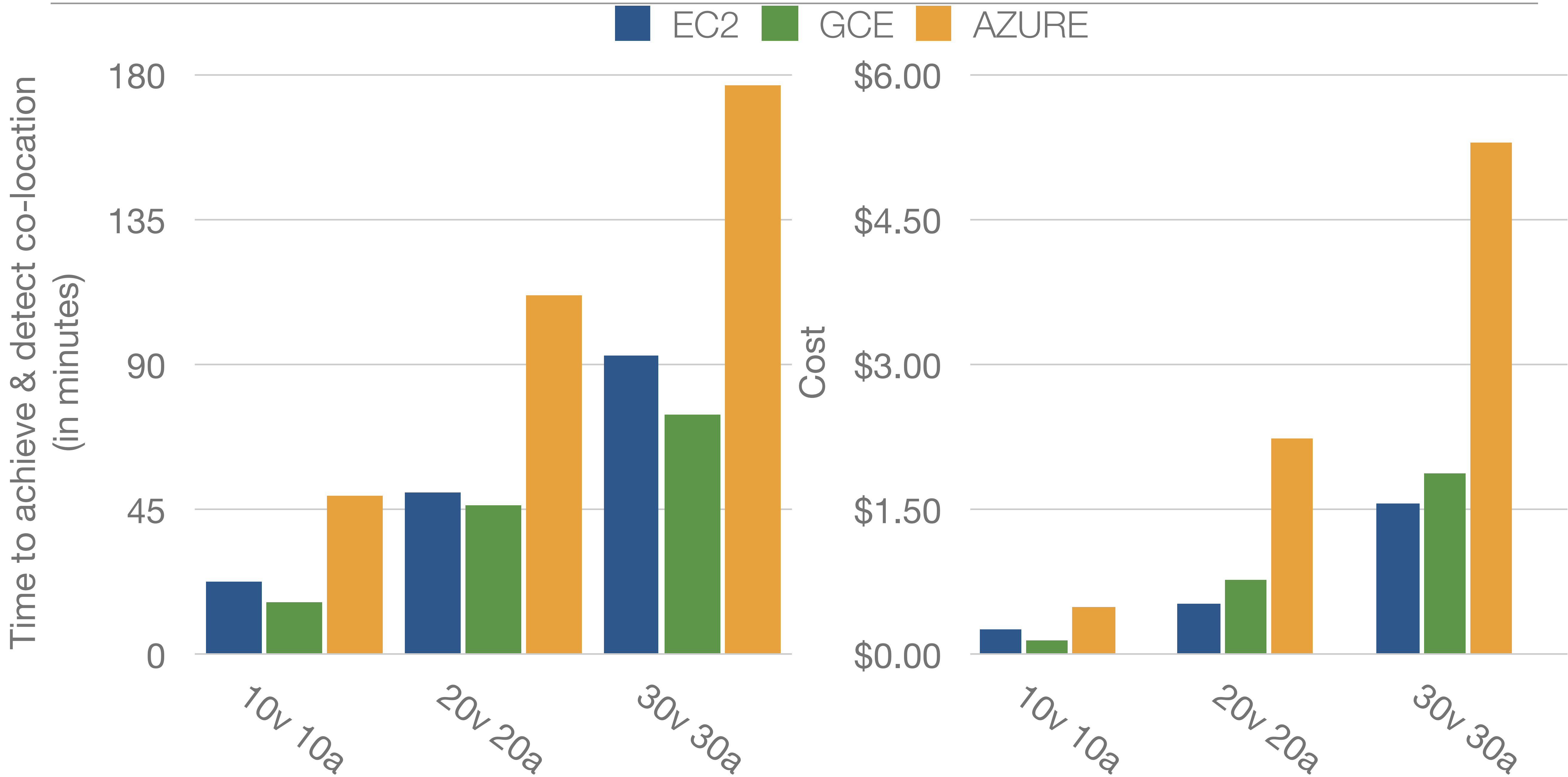

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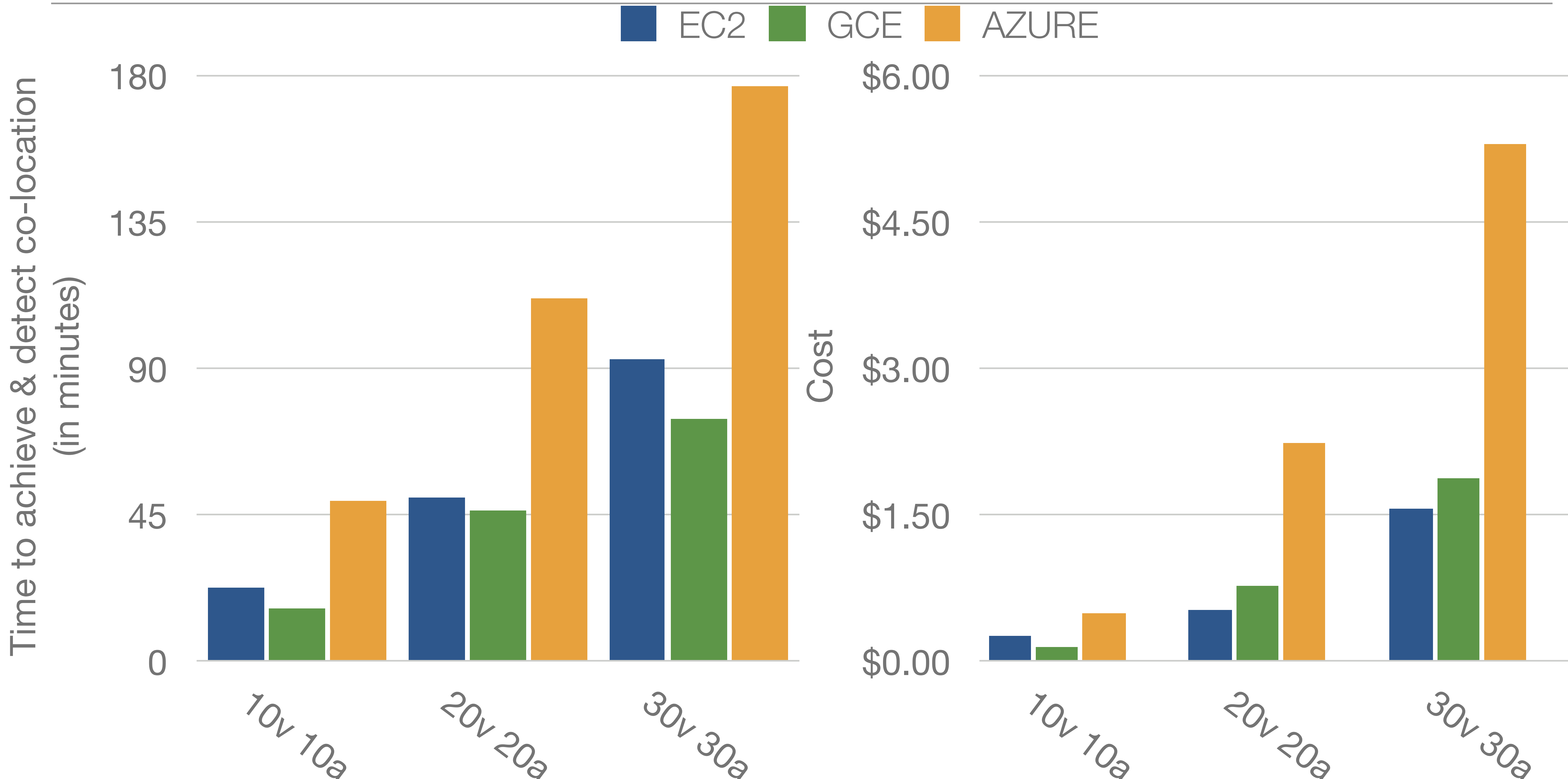

The cheapest launch strategy costs as low as 14 cents

Other Interesting Results

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  - GCE: europe-west1-b and EC2: us-west-1 (CA)

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- … and many more in the paper

Some Strategies Work Better than Others

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Example strategies on EC2

Launch Strategy	v x a
Launch 10 VMs in less popular datacenter	10x10
Launch 30 VMs 1 hour after victim VM launches	30x30
Launch more than 20 VMs 4 hours after victim VM launches	20x20

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Example strategies on EC2

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Launch Strategy	v x a	Cost in Cloud	Cost under Random Placement*
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Launch more than 20 VMs 4 hours after victim VM launches	20x20	$0.52	$53.76

*Random Placement of VMs on N hosts,
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Example strategies on EC2

Launch Strategy	v x a	Cost in Cloud	Cost under Random Placement*	Success rate norm. w/ random*
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Launch 30 VMs 1 hour after victim VM launches	30x30	$1.56	$32.75	1/0.6 (=1.67)
Launch more than 20 VMs 4 hours after victim VM launches	20x20	$0.52	$53.76	1/0.33 (=3.03)

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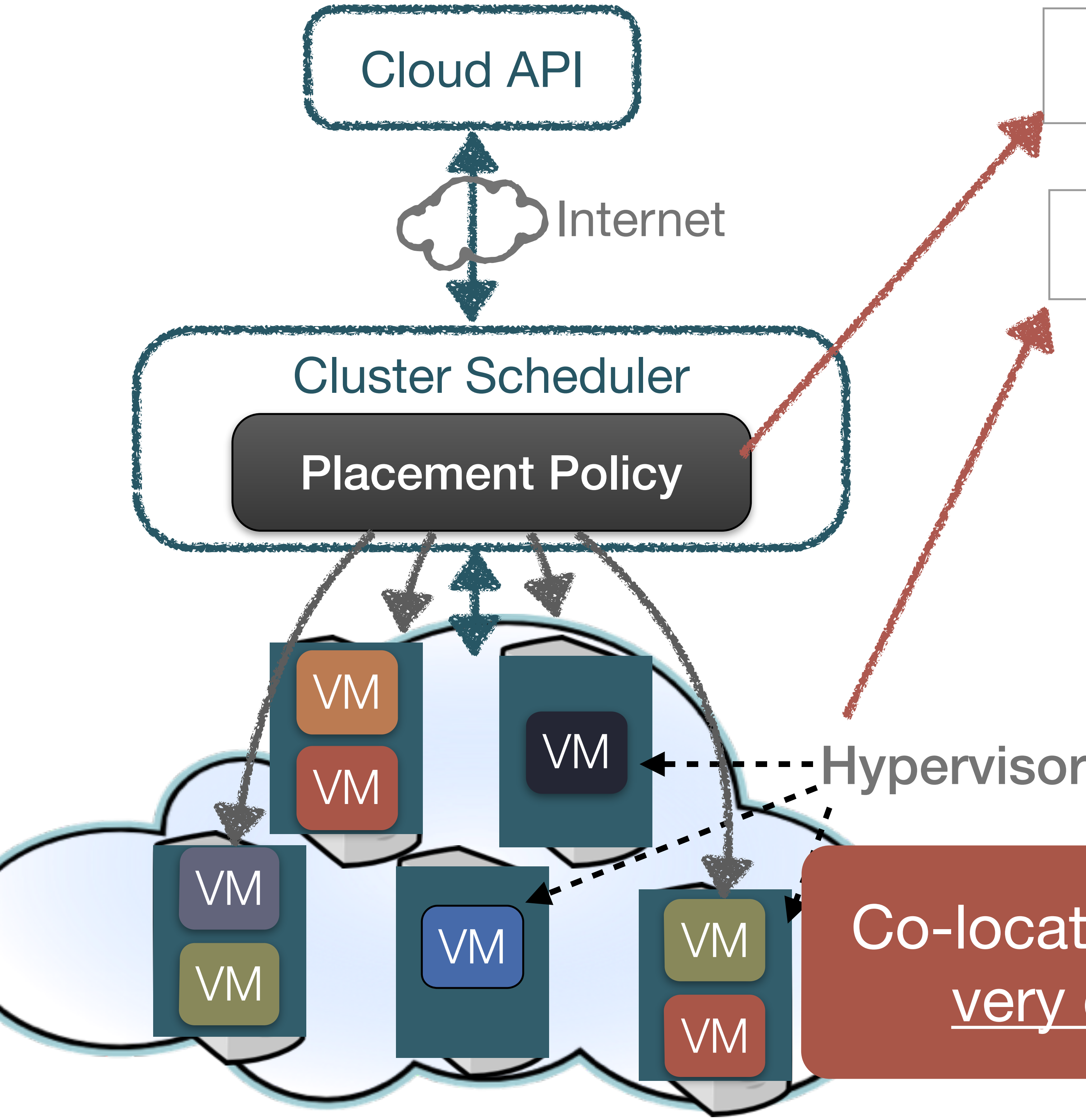
Summary: Co-location Attacks in Modern Clouds



(1) Controls co-location

(2) Provides isolation

- **Cross-VM Side- and covert-channels** [Ristenpart'09, Xu'11, Wu'12, Zhang'12, Yarom'14, Liu'14, Gruss'15]
- **Resource-stealing, DoS** [Zhou'11, Varadarajan'12]

Co-location attacks are <u>practical</u> and <u>very cheap</u> in modern clouds!