REPTTACK: EXPLOITING CLOUD SCHEDULERS TO GUIDE CO-LOCATION ATTACKS

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Introduction

Micro-architectural Attacks

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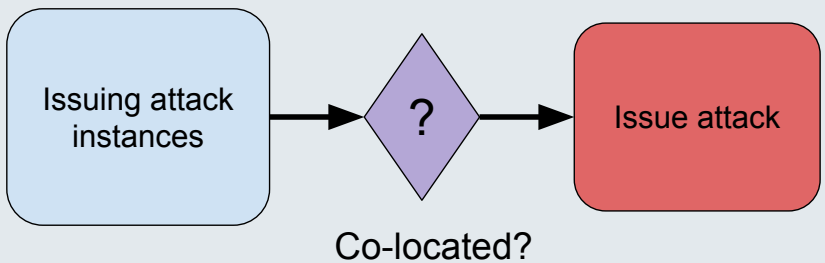
Micro-architectural attacks have become a threat to cloud users!

1. Side-channel attack.
2. Transient execution attack.
3. Rowhammer attack.
4. Faults attack.
5. ...

Prerequisite of Micro-architectural Attacks

Workflow of Attack (Ristenpart et al., 2009)

1. Submit attack program to the cloud.
2. Determine if victim is co-located.
3. Start stealing information / interfere with victim program.



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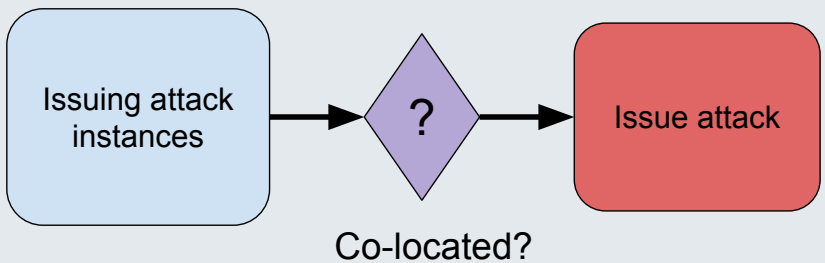

Before attack, achieving co-location is required.

Motivation

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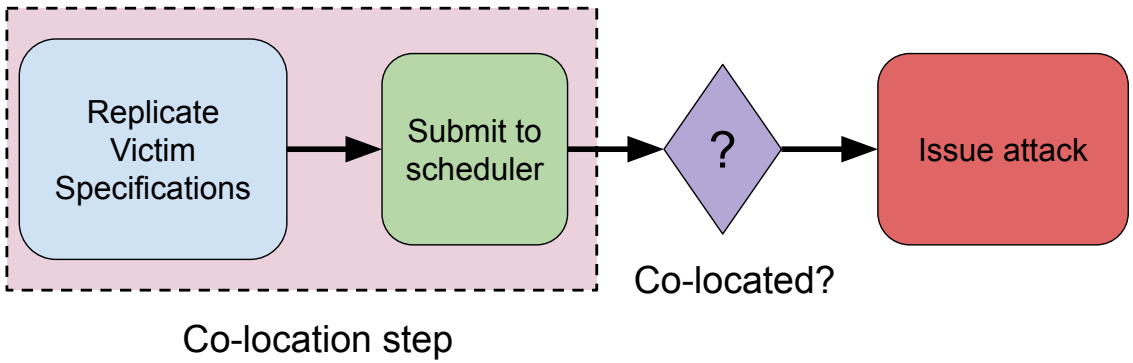
Important to study how to achieve co-location

Brute-force issuing can be easy to defend.

- For attackers: without co-location strategies, subsequent attacks are impossible
- For defenders: more efficient to defend and patch at scheduler level

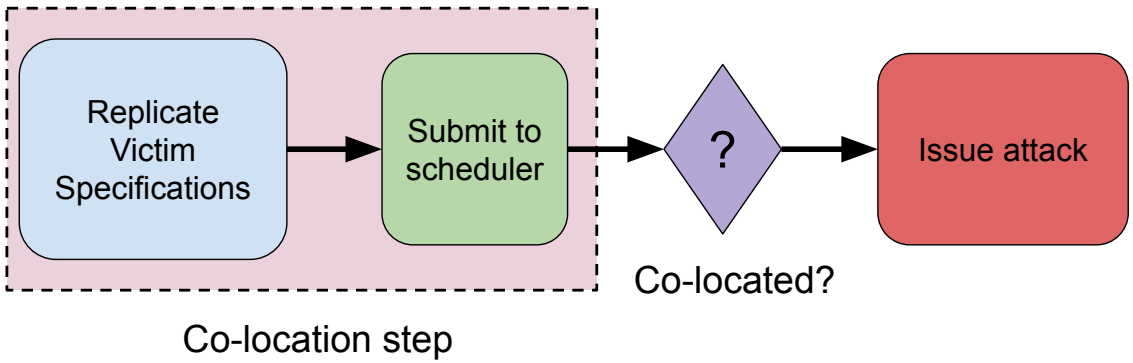
Vulnerabilities in the scheduler should be studied.

Focus of this work



- We focus on co-location step.

Focus of this work



- We focus on co-location step.
- We don't consider how the attacker obtains location status.
- We don't consider how a specific type of attack works.

Threat Model

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Cloud providers

- Trusted, do not assist attackers
- Treat all users (malicious and non-malicious) equally

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Users

- All users have the same privilege and can only access their own allocated resources.
- Attackers knows about victim applications.
- Non-malicious users always try to optimize the scheduling outcome.

Method

Targeted Scheduler

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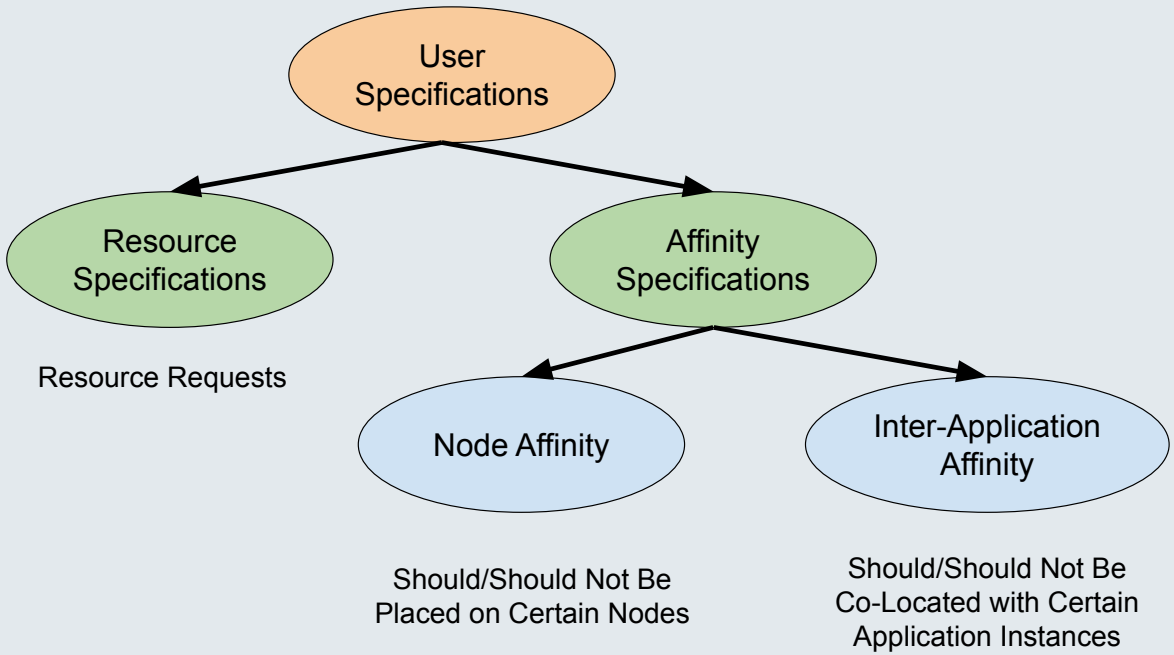
User submitted requirements



Targeted Scheduler

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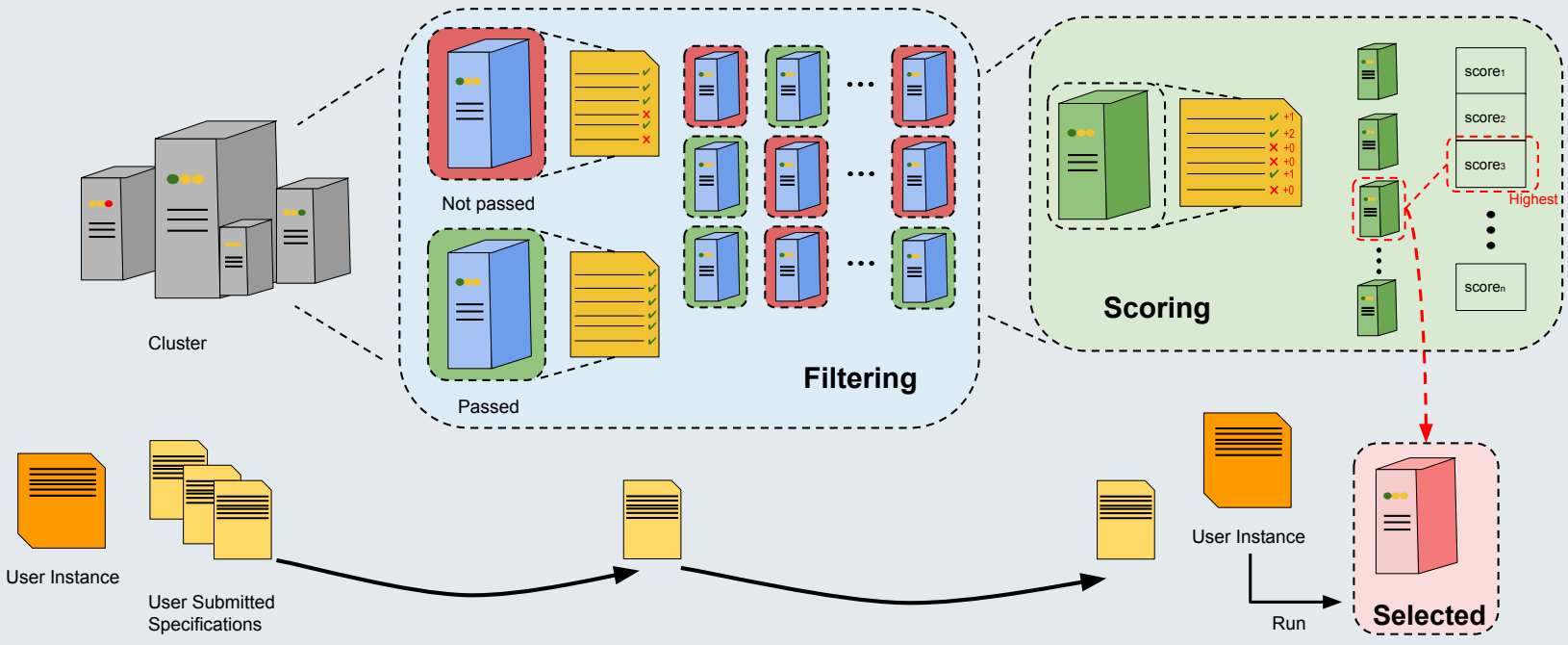
Filter-score scheduler



Targeted Scheduler

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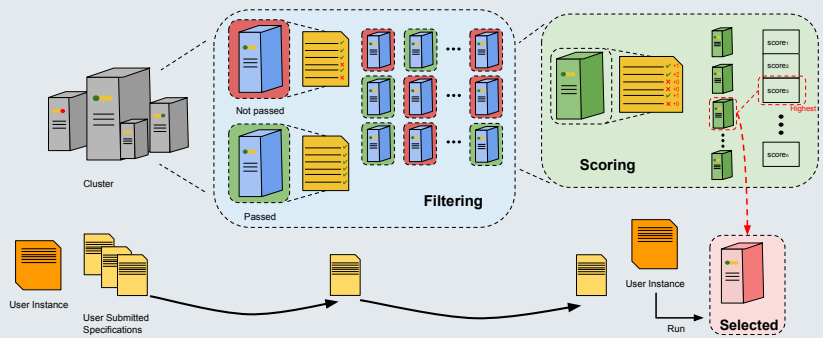
Widely used type of scheduling pattern ("Kubernetes," 2021; "OpenStack," 2021).



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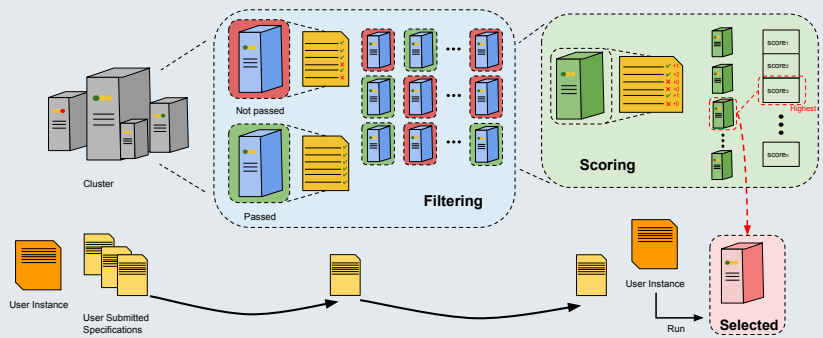
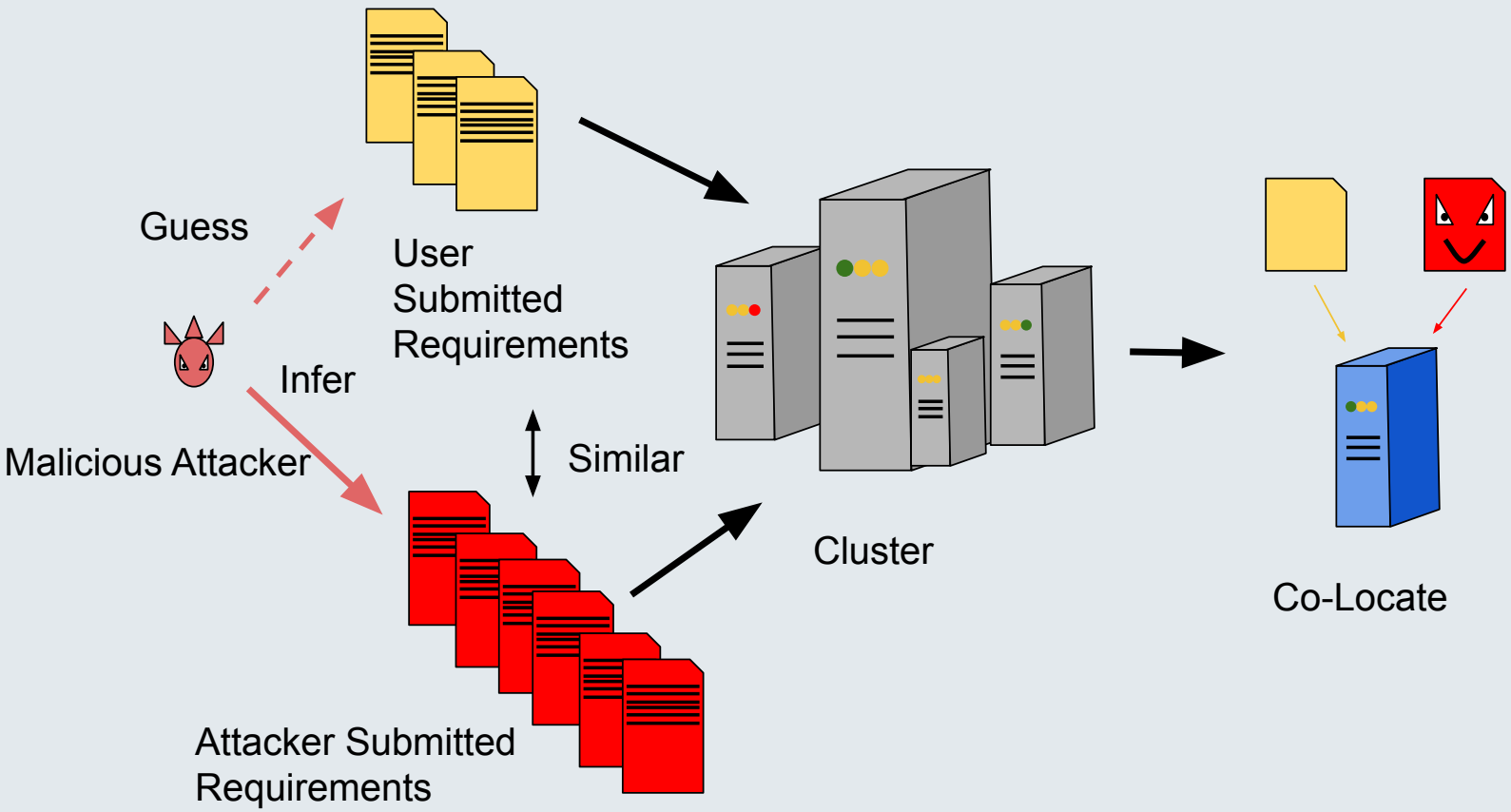


- Filtering and scoring based on user specifications
- Filtering: Find a list of candidates that satisfy user needs
- Scoring: Rate every candidate and select the one with highest score

Attack Strategy

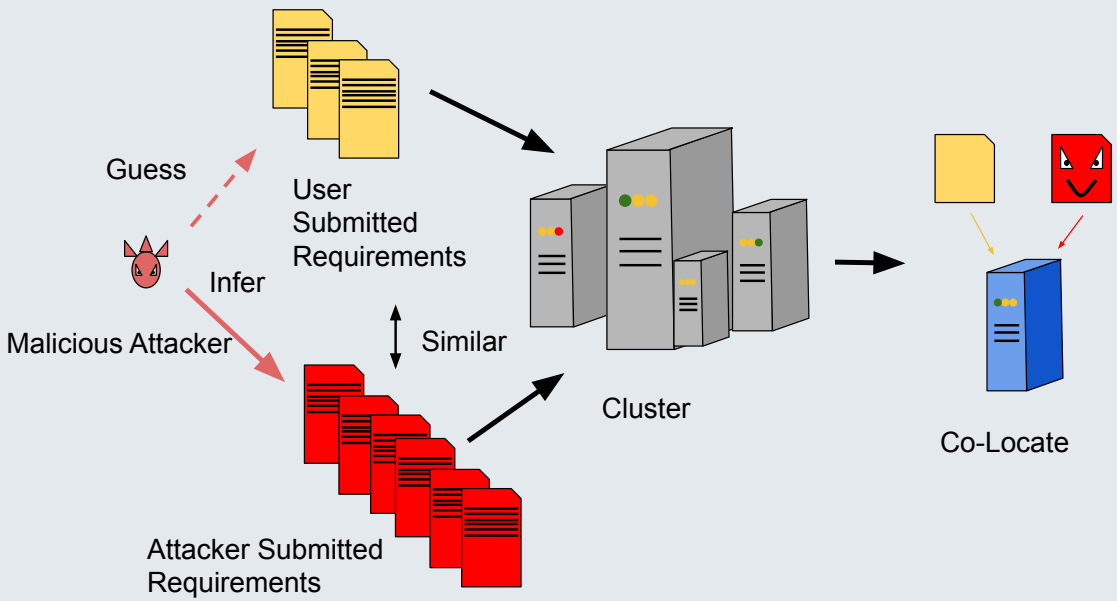
Replicating user specifications



Attack Strategy

Replicating user specifications

Exploit scheduler features.



- Infer victim submitted requirements/preferences

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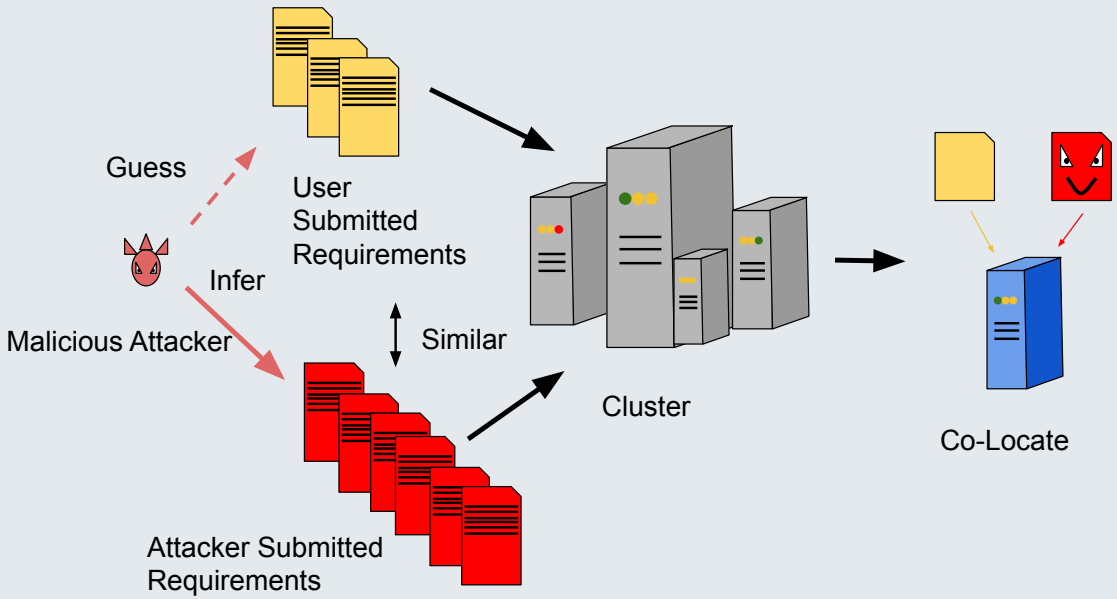

- Infer victim submitted requirements/preferences
- Replicate these specifications to the scheduler

Evaluation

Experiment Setup

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Simulation

- Python behaviorial simulator, implementation based on Kubernetes ("Kubernetes," 2021)[1].

[1] It has been re-written in C++ and will be released in the future.

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Simulation

Cluster

- Experiment conducted on Kubernetes deployed on CloudLab (Duplyakin et al., 2019).
- Server configurations: heterogeneous hardware features, generated randomly.
- Applications: randomly selected from popular docker apps, user specifications generated randomly.

Simulation Results

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Single-instance attack

- What are the factors that affect attack success rate?

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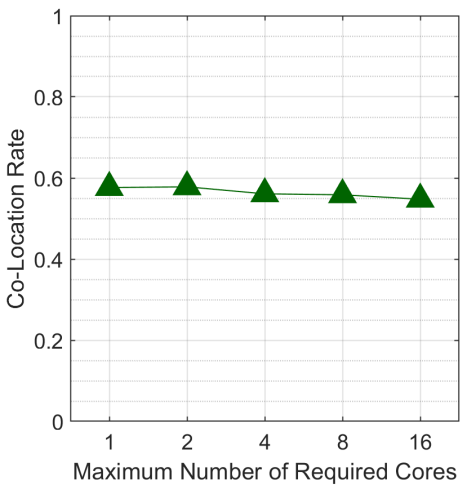
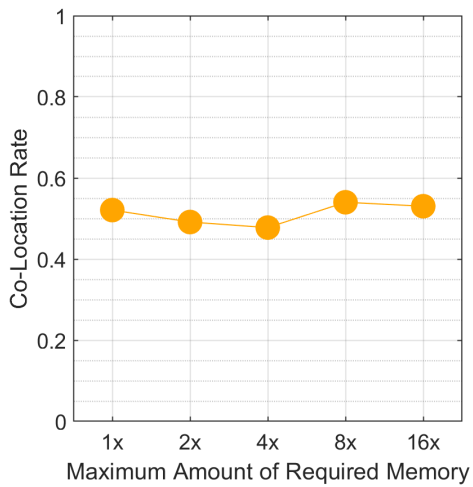
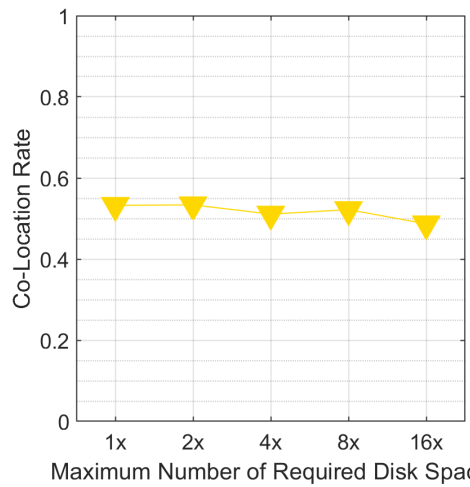
Resource requirements:







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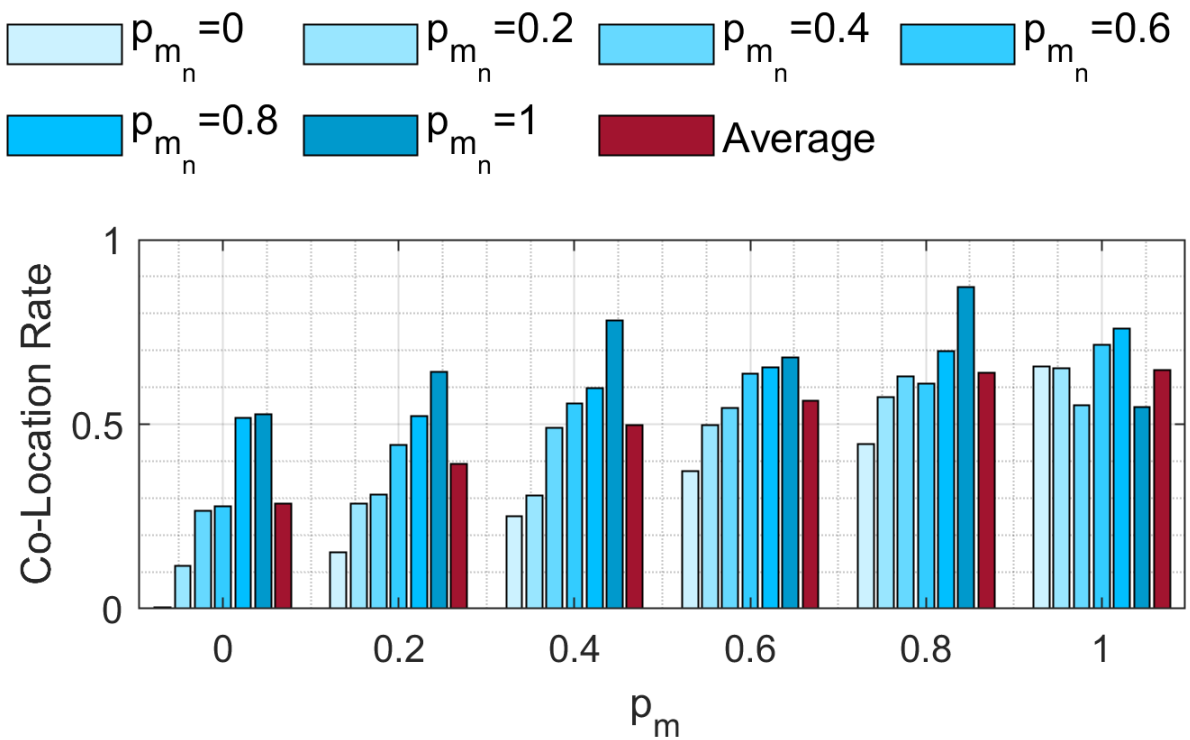
Affinity:



Simulation Results

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Multi-instance attack

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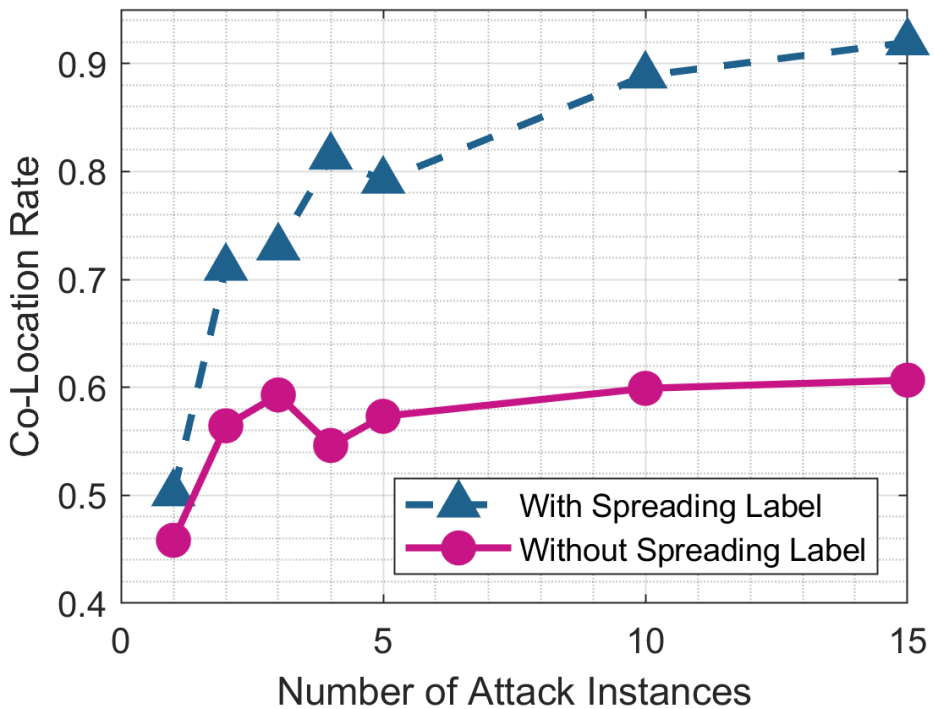

Cluster Experiment Results

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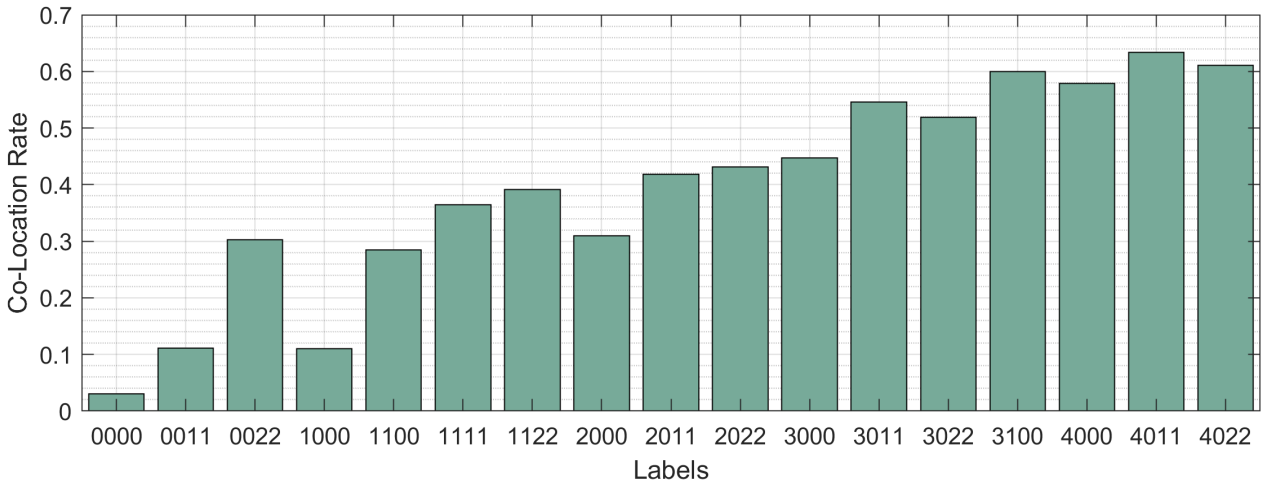

Notation: 1 2 3 4

- 1 #. of Required Node Affinity
- 2 #. of Preferred Node Affinity
- 3 #. of Required Inter-Application Affinity
- 4 #. of Preferred Inter-Application Affinity

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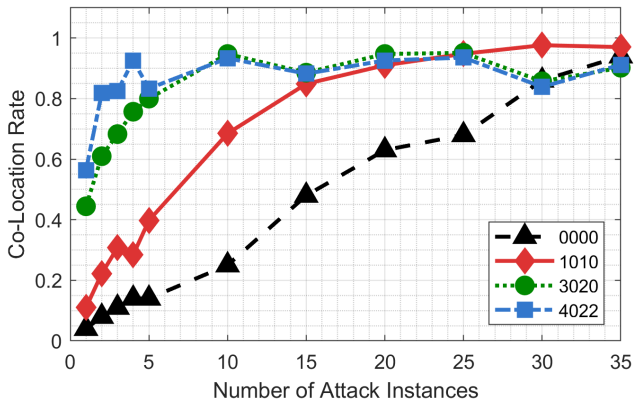
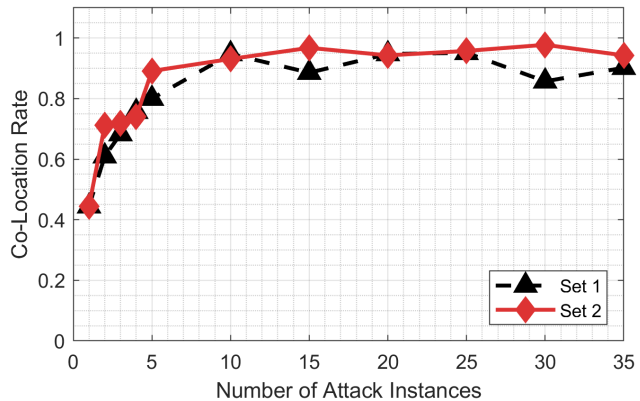
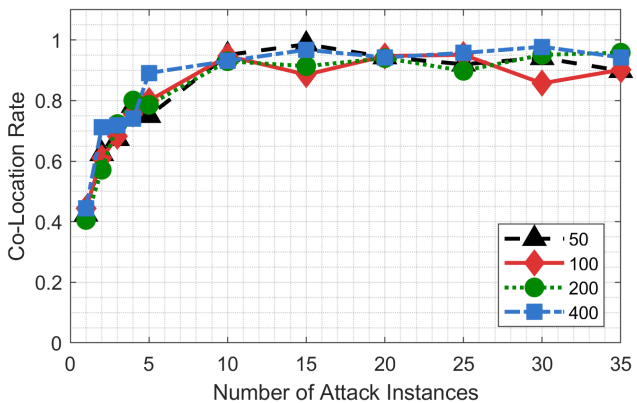
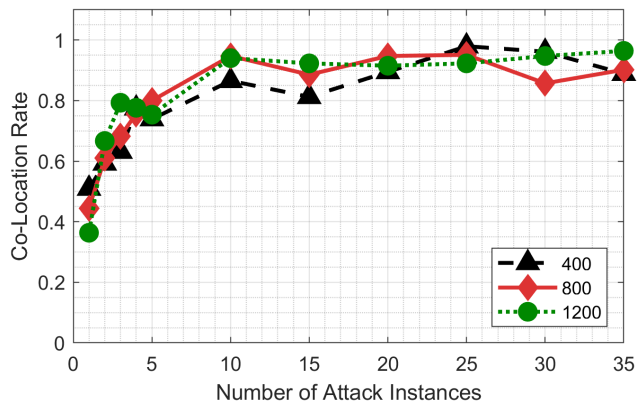


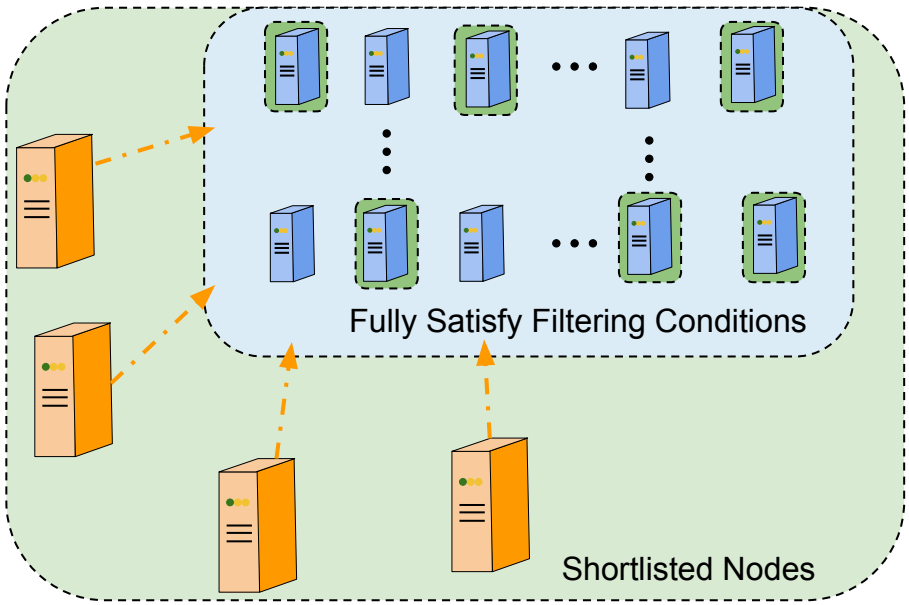






Mitigation

Mitigation Strategy



- Randomly skip affinity check during filtering.

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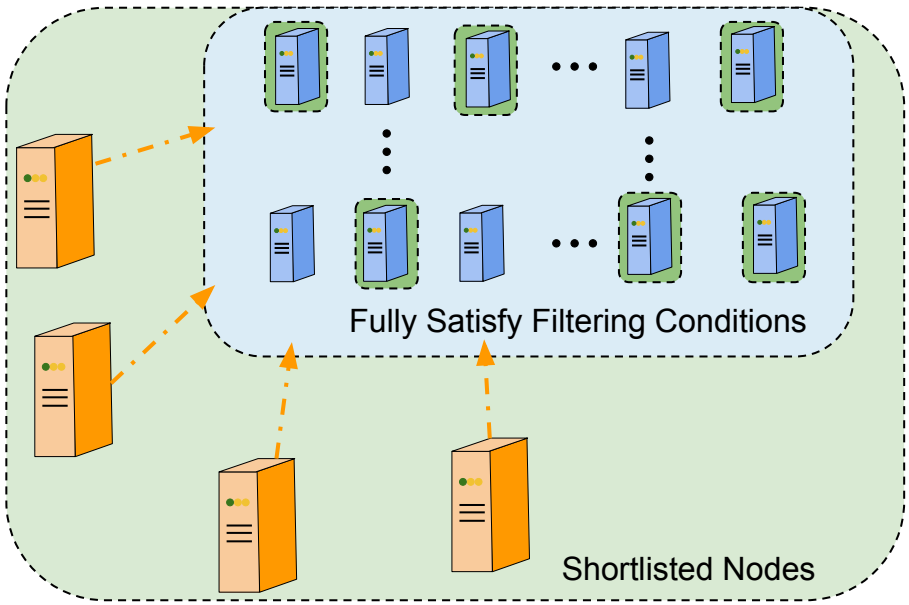
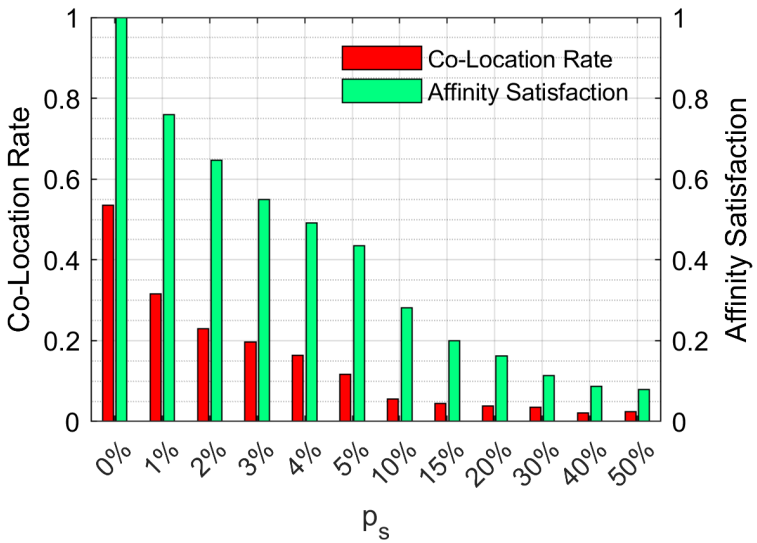
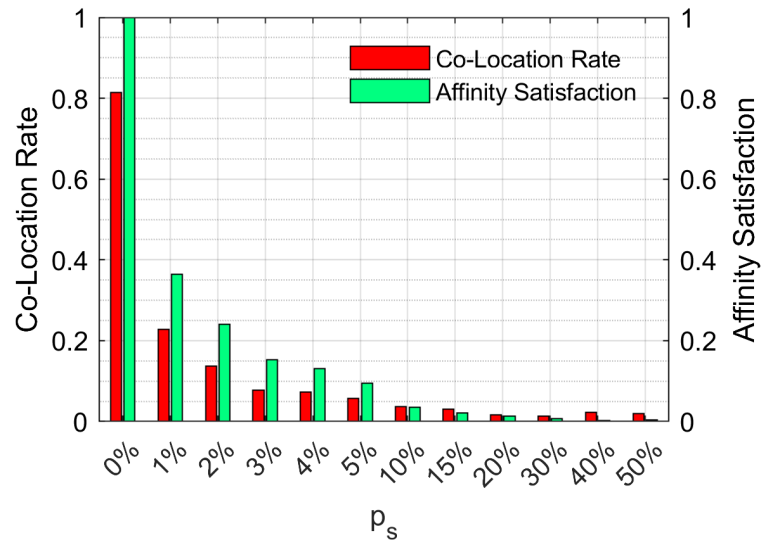


- Randomly skip affinity check during filtering.
- **Adding randomness!**

Mitigation





Cost: measured by average number of violated specifications

p_{m_n}, p_{m_a}	$p_s = 0\%$	$p_s = 1\%$	$p_s = 2\%$	$p_s = 3\%$	$p_s = 4\%$	$p_s = 5\%$	$p_s = 10\%$	$p_s = 15\%$	$p_s = 20\%$
0.5	0.00	0.45	0.68	0.88	1.07	1.19	1.68	2.00	2.17
0.9	0.00	1.65	2.29	2.78	3.02	3.33	4.04	4.40	4.57

Discussion

Trade-off

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Trade-off between security and performance

Let users have control over scheduling outcomes

- Better performance: can run on more suitable machines
- Worse security: location in the cloud can be relatively accurately determined

Roofline Model

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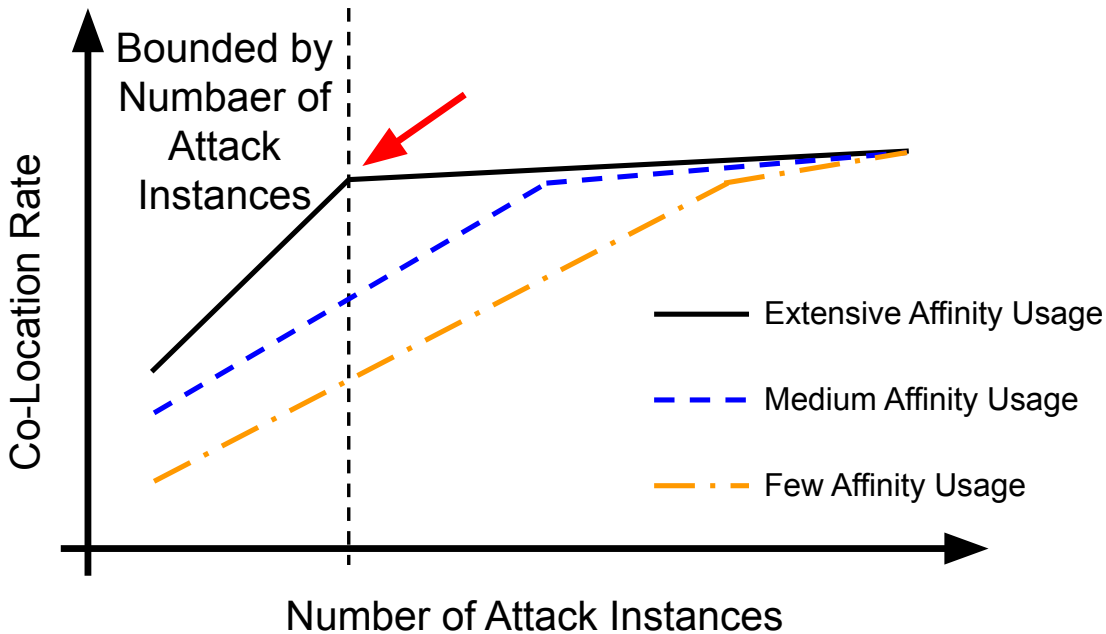
Optimum trade-off point exists



Suggestions

For cloud managers

- Expose heterogeneity as little as possible
- Bring randomness to scheduling process

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- Expose heterogeneity as little as possible
- Bring randomness to scheduling process

For users

- Utilize heterogeneity as little as possible
- Keep scheduling specifications confidential

Suggestions

For attackers

- Study target applications
- Use multiple attack instances with different possible specifications to increase coverage
- Be aware of the trade-off point of attack instance: optimize for cost of attack

Conclusion

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Our contributions

- Affinity feature in filter-score schedulers are prone to be exploited
- Repttack: an attack method to increase the chance of achieving co-location in a heterogeneous cluster
- Mitigation technology
- Guidelines for cloud managers and users

References

Duplyakin, D., Ricci, R., Maricq, A., Wong, G., Duerig, J., Eide, E., Stoller, L., Hibler, M., Johnson, D., Webb, K., Akella, A., Wang, K., Ricart, G., Landweber, L., Elliott, C., Zink, M., Cecchet, E., Kar, S., & Mishra, P. (2019). The design and operation of CloudLab. *Proceedings of the USENIX Annual Technical Conference (ATC)*, 1–14. https://www.flux.utah.edu/paper/duplyakin-atc19

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