Keeping a Hypervisor Fleet Up to Date with Minimal Customer Disruption

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#SRECON26
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$whoami

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Akamai

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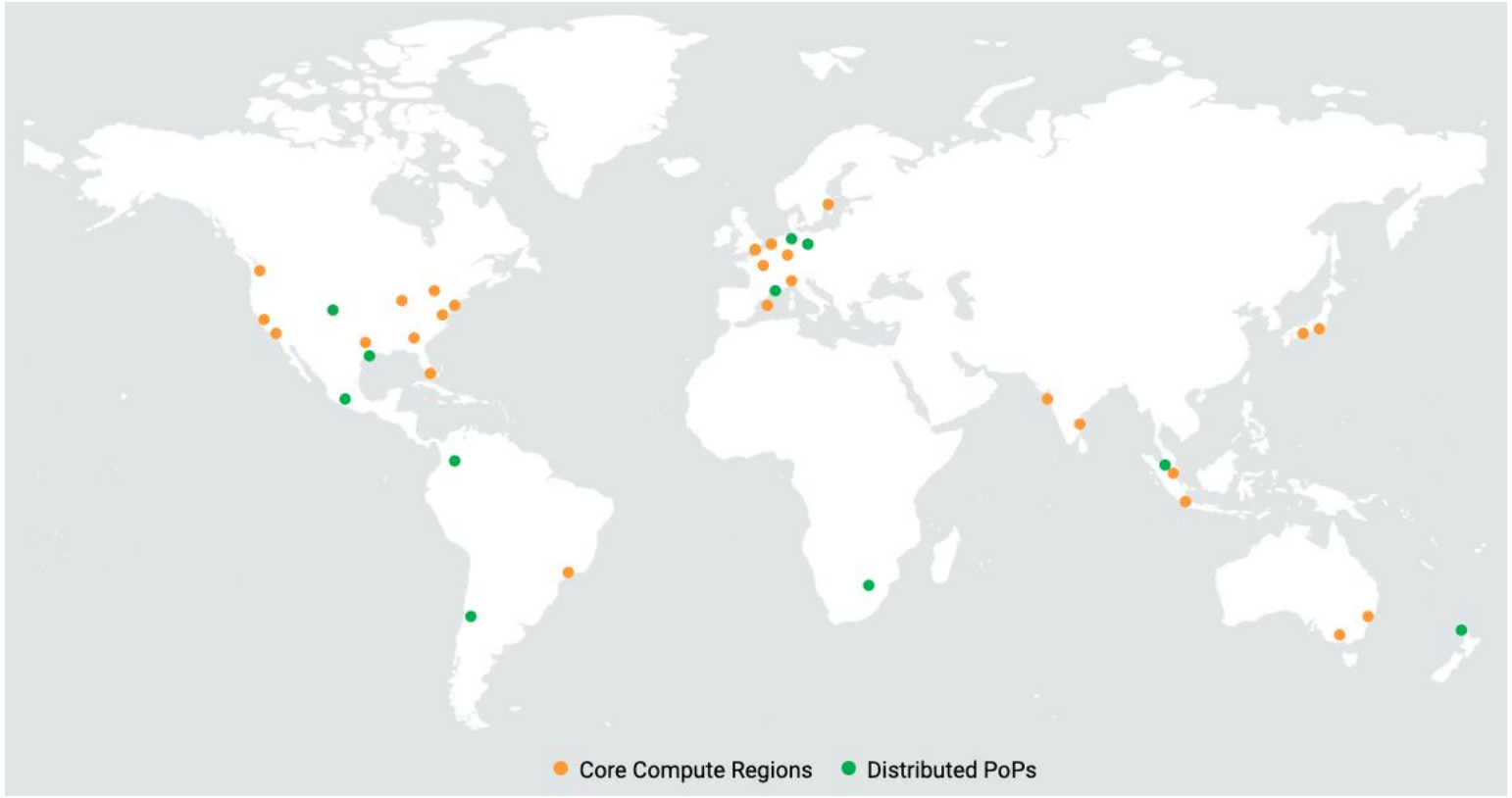
Network Optimization team

I've worked on:

- CDN capacity planning / content allocation
- Virtual machine allocation
- Large scale scheduling problems

Akamai’s Cloud Infrastructure



Hypervisor Maintenance

- Kernel, OS, firmware updates
- Preventative hardware maintenance
- Most maintenance activities require reboot

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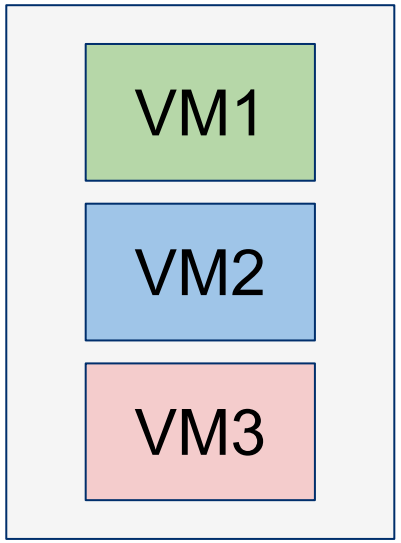
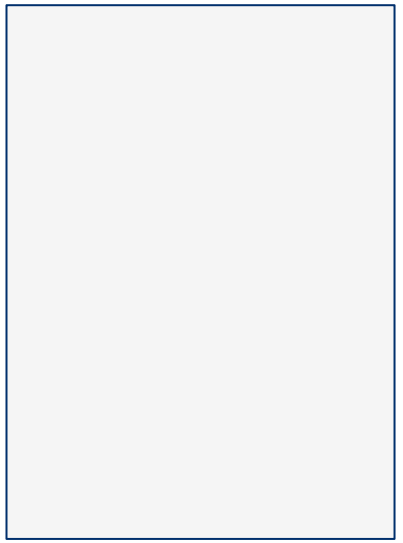
Hypervisor Maintenance

Host with
old software



Spare host
with new software



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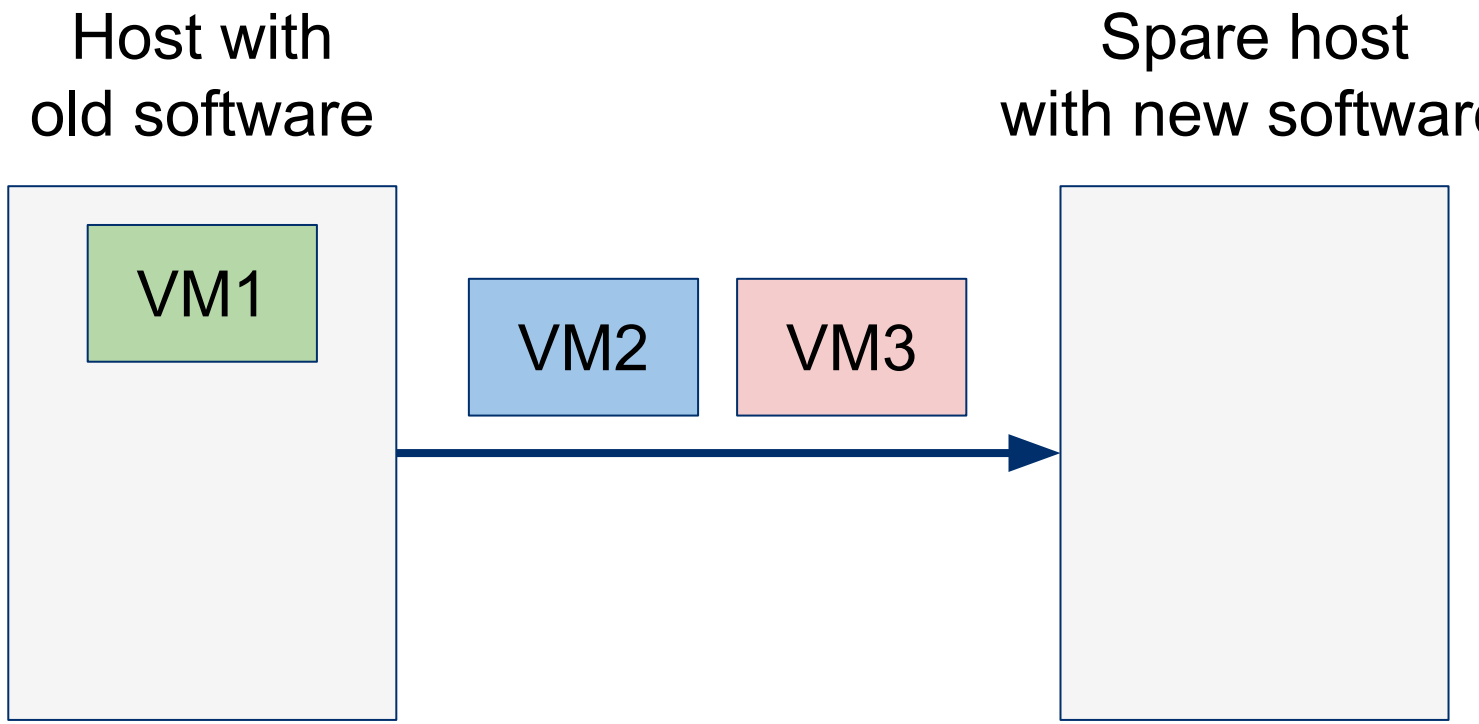
Hypervisor Maintenance



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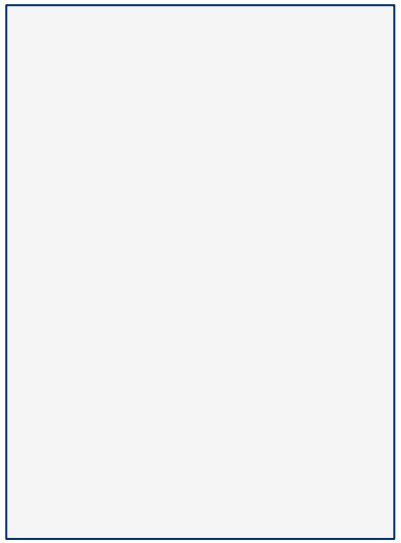
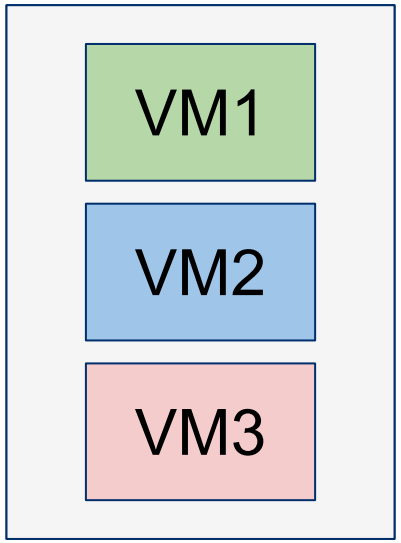
Hypervisor Maintenance

Host with
old software



Host with new
software



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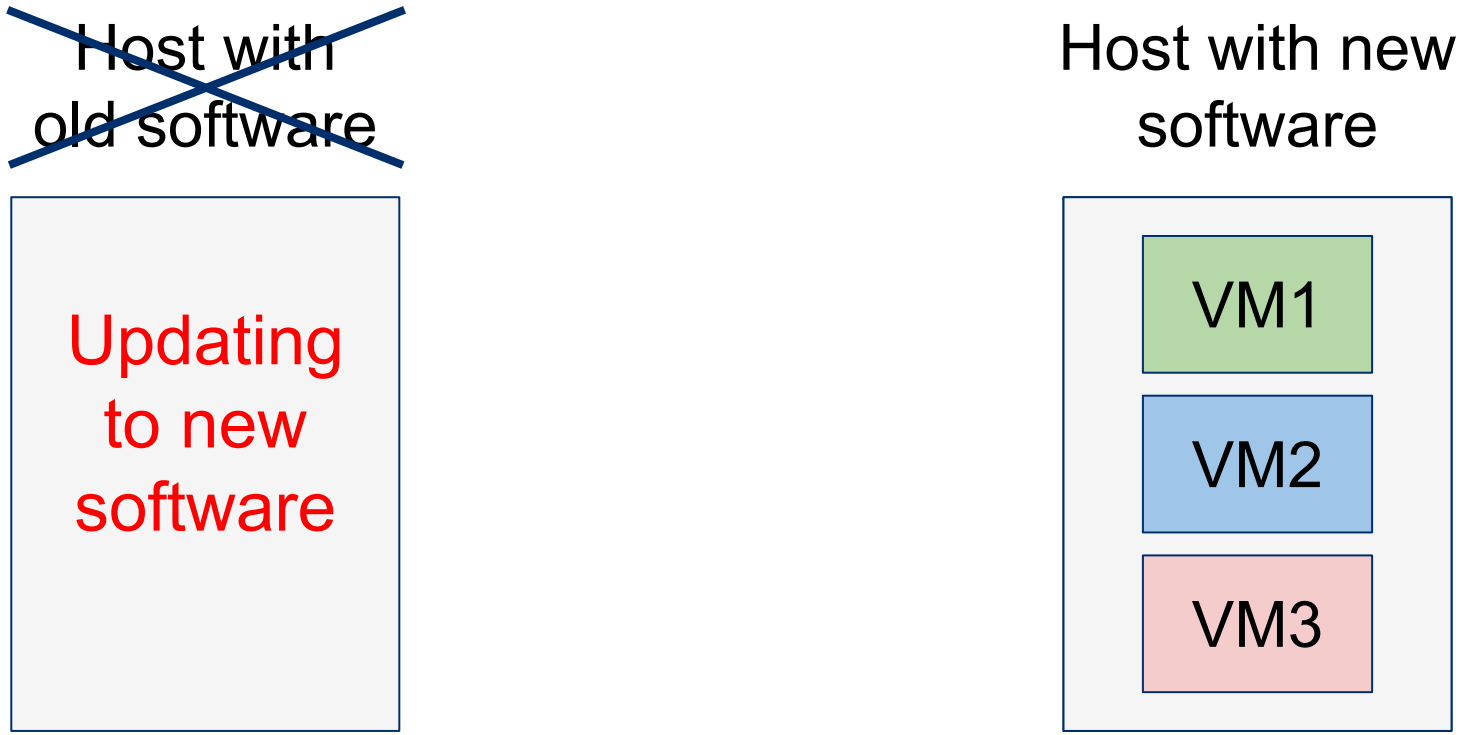
Hypervisor Maintenance



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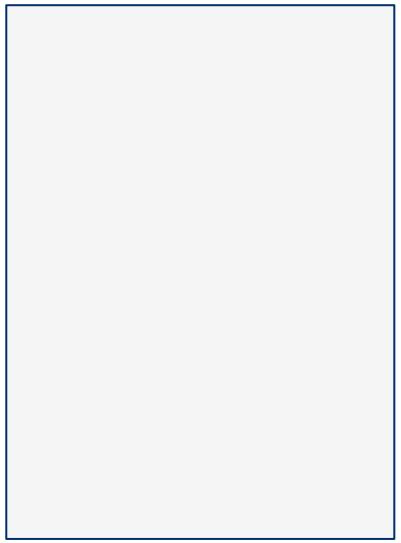
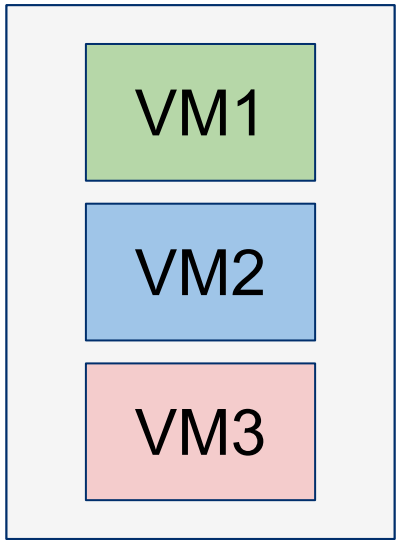
Hypervisor Maintenance

Spare host
with new software



Host with new
software



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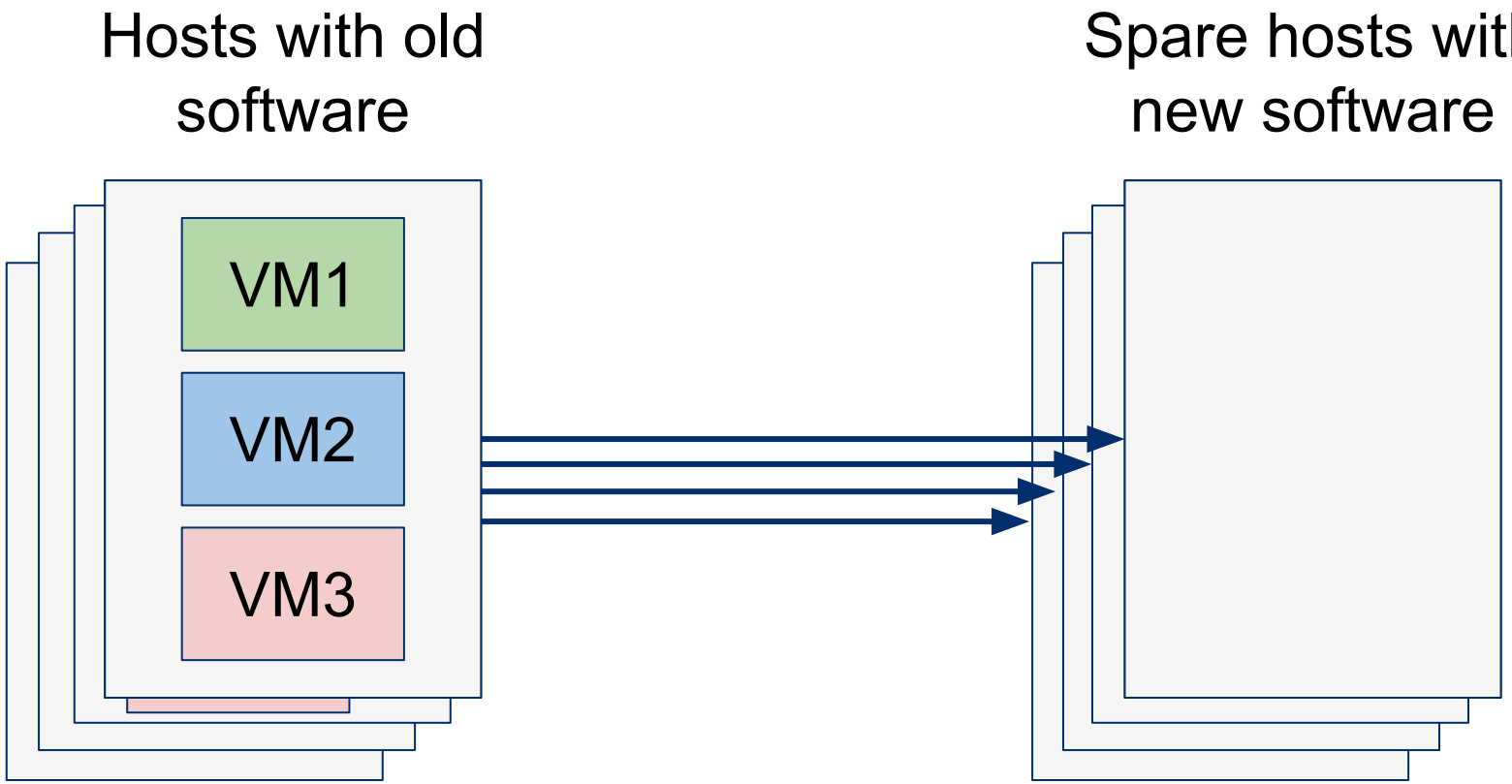
Hypervisor Maintenance at Scale



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Scenario

~100 hosts day

- You're asked to update **10,000+ hypervisor hosts**
- Hosts need reboot, VMs need to be migrated
- Customers need to be notified in advance
- You have **90 days**

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Capacity, Conflict, Concurrency
Problem #1: Capacity

- Finding **up-to-date** capacity is crucial
- Keeping availability in the datacenter stable is important

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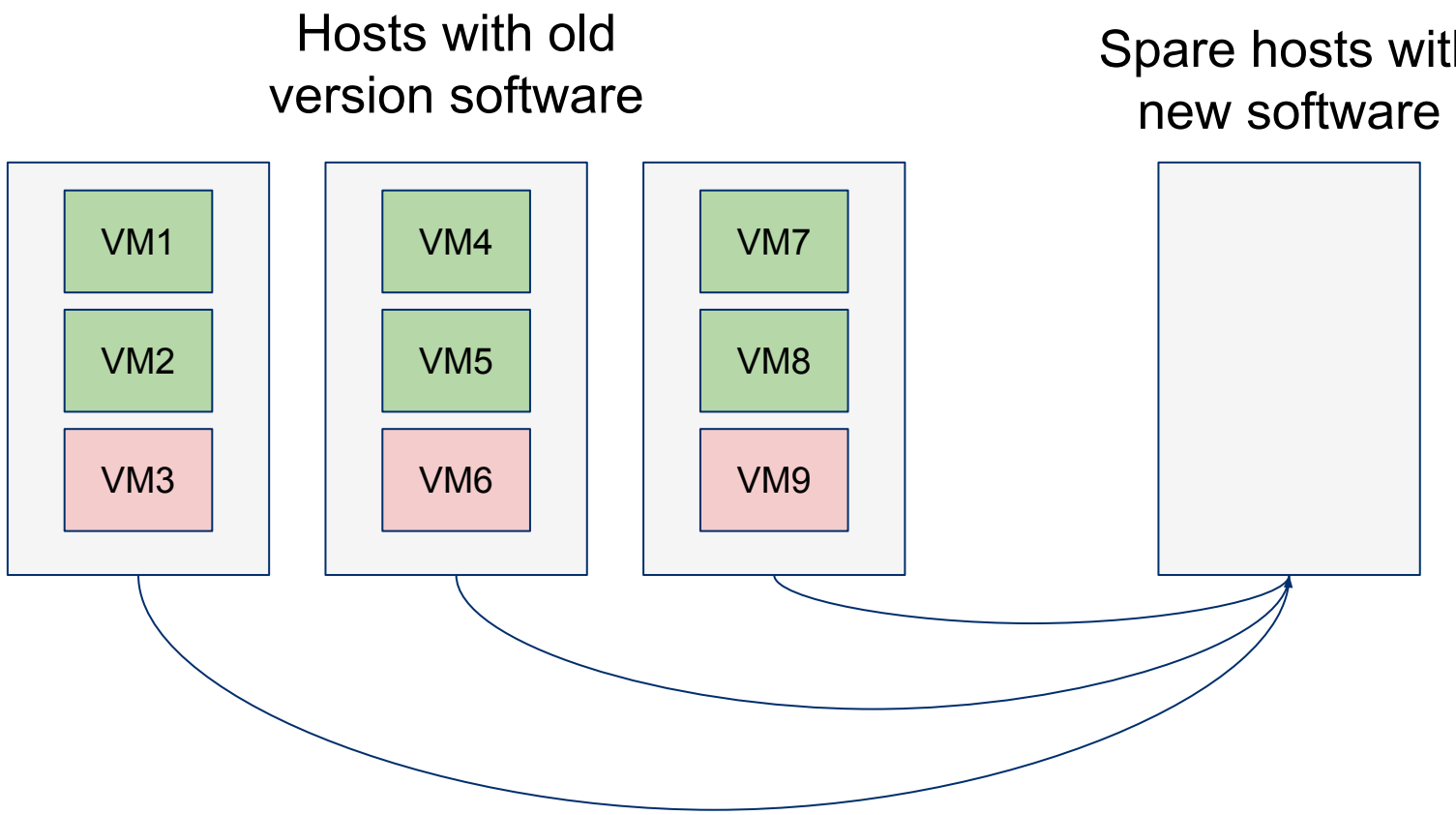
Capacity, Conflict, Concurrency
Problem #1: Capacity



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Capacity, **Conflict**, Concurrency

Problem #2: Conflict

- Customers tolerate disruption to a certain limit
- Host selection may impact customers unfairly / asymmetrically

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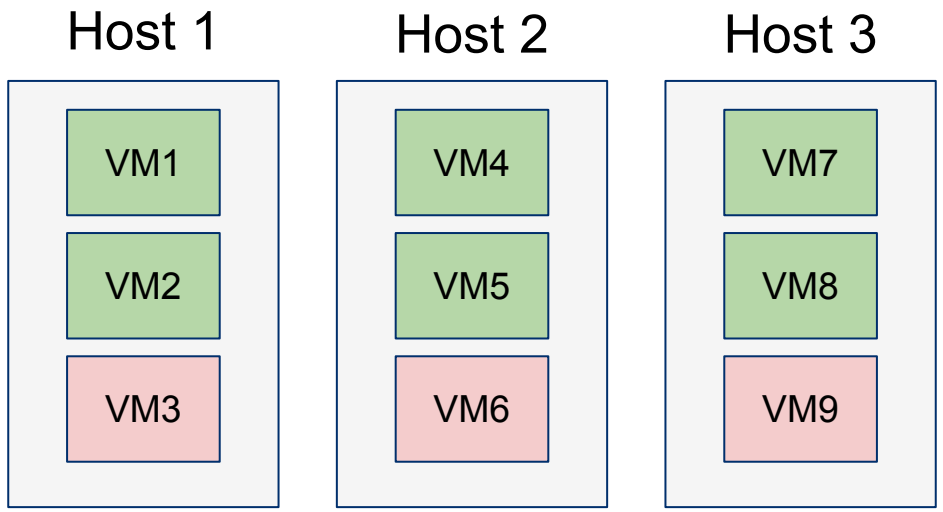
Capacity, **Conflict**, Concurrency

Problem #2: Conflict



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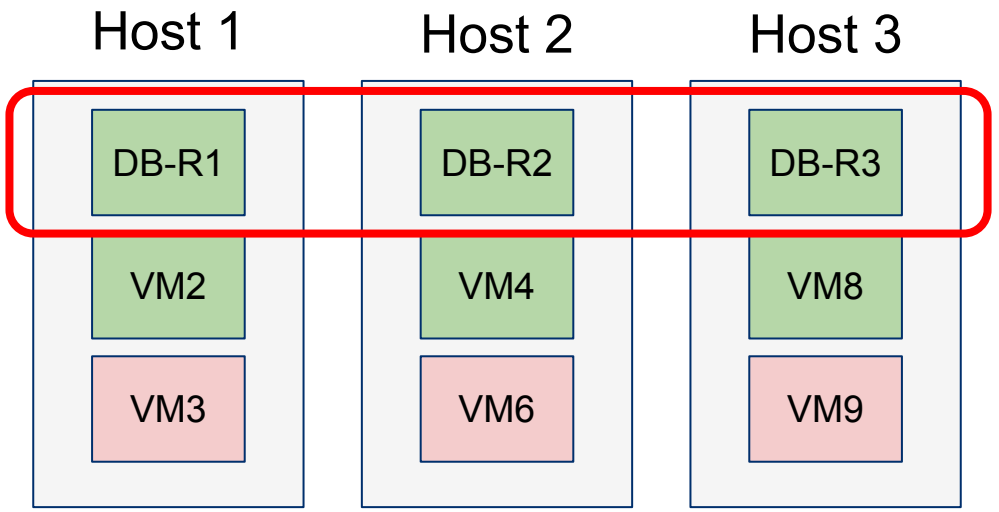
Capacity, **Conflict**, Concurrency

Problem #2: Conflict



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Capacity, Conflict, Concurrency

Problem #3: Concurrency

- Migration takes resources from the host (CPU, Disk IO, NIC)
- Top-of-rack router bandwidth is limited

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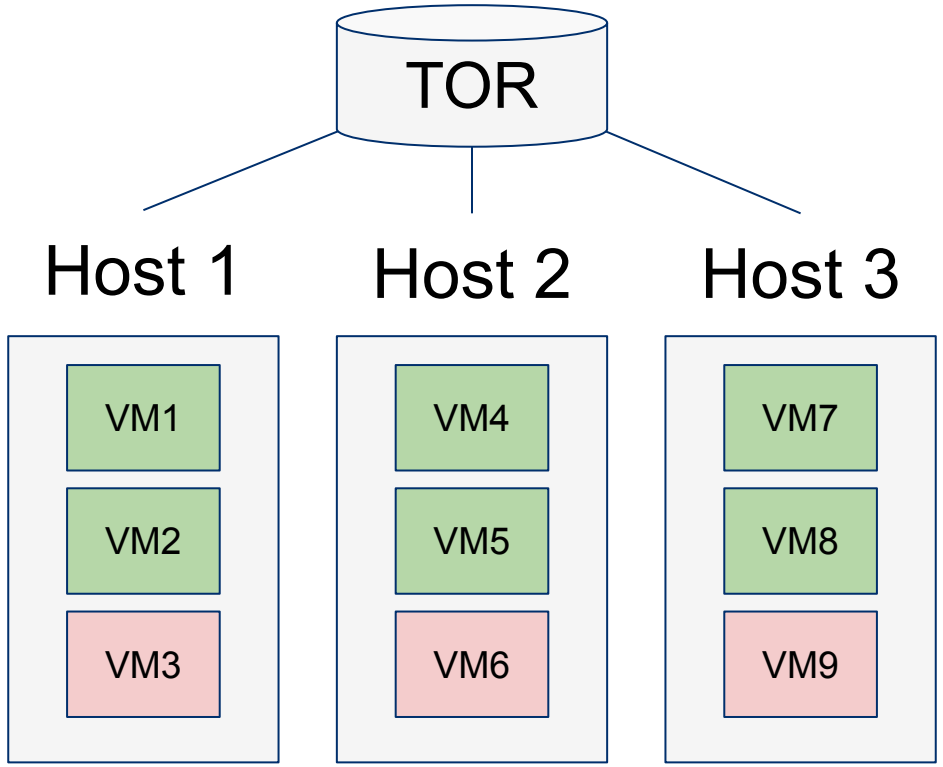
Capacity, Conflict, Concurrency

Problem #3: Concurrency



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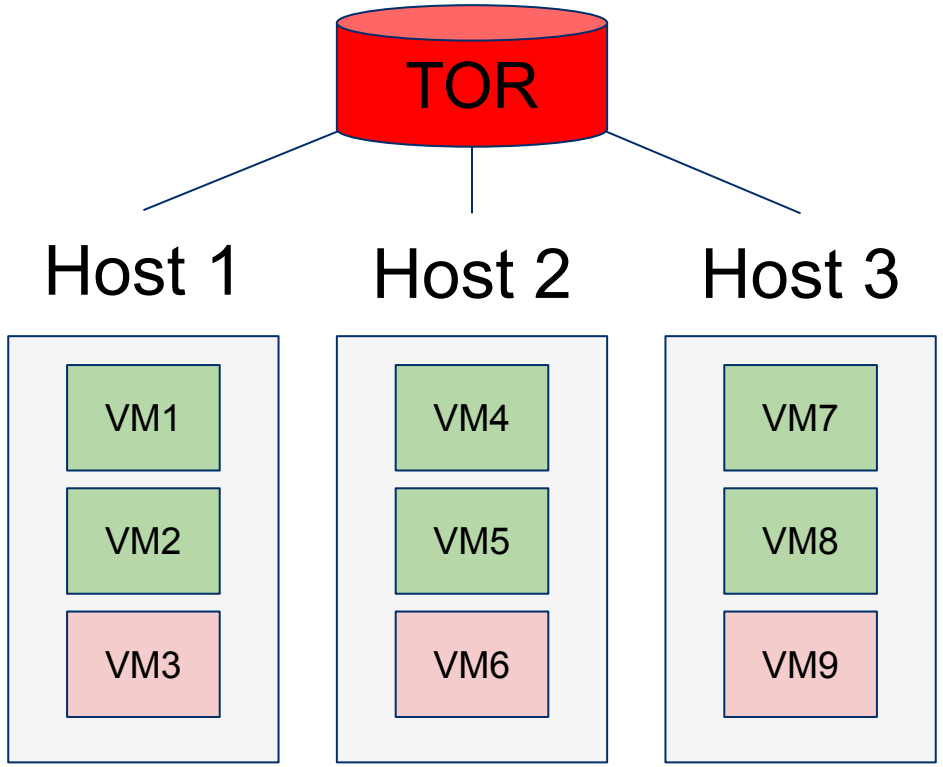
Capacity, Conflict, Concurrency

Problem #3: Concurrency



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Capacity, Conflict, Concurrency

Solution: spreadsheets?

- Takes hours of work
- Rinse and repeat in 3 months

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Solution: write an algorithm?

- Easy to say, hard to get right:
  - Hard to measure the quality of solution
  - Not flexible enough for changing constraints / business priorities

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Operations Research

- Operations research provides ways to model and solve complex problems to improve decision making
- **Mathematical optimization** is a fundamental tool in OR

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What Is
Mathematical Optimization?

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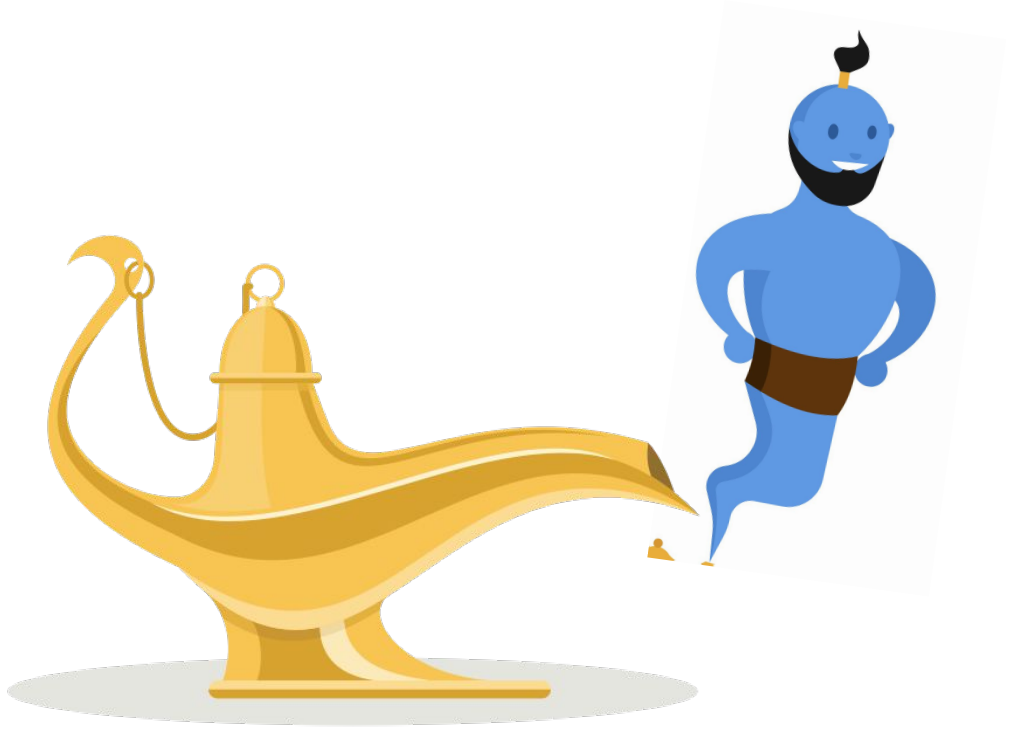
Mathematical Optimization

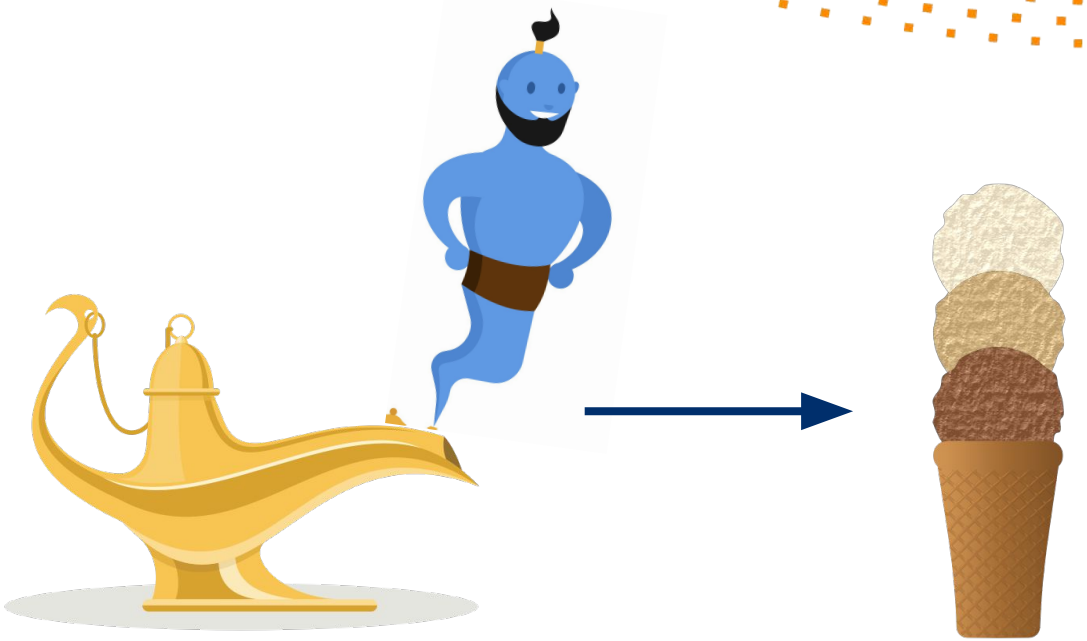


Mathematical Optimization

Give me ice cream

Chocolate or oreo
At most 3 scoops

Make me happy



“Garlic flavored ice cream” wasn’t a joke, unfortunately
https://en.wikipedia.org/wiki/Garlic_ice_cream

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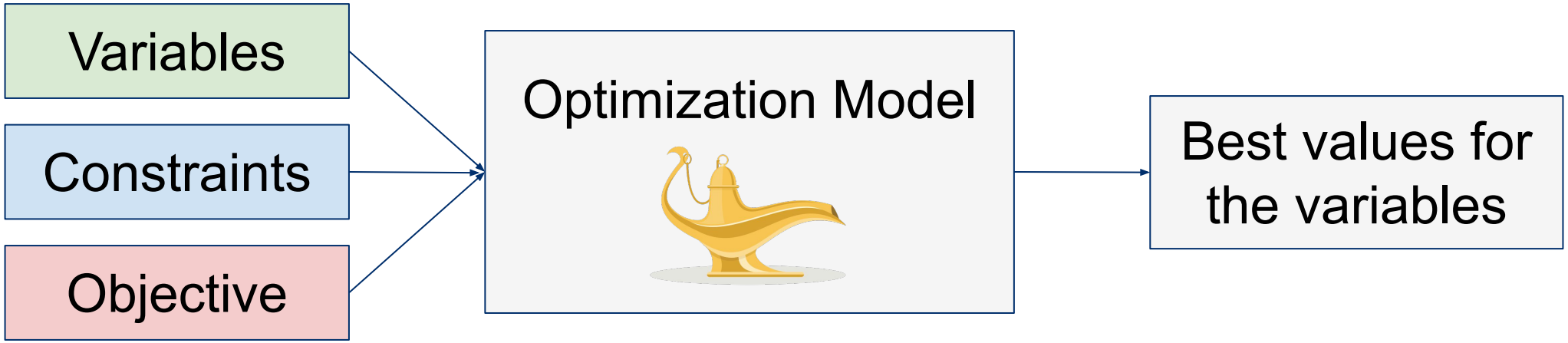
Mathematical Optimization



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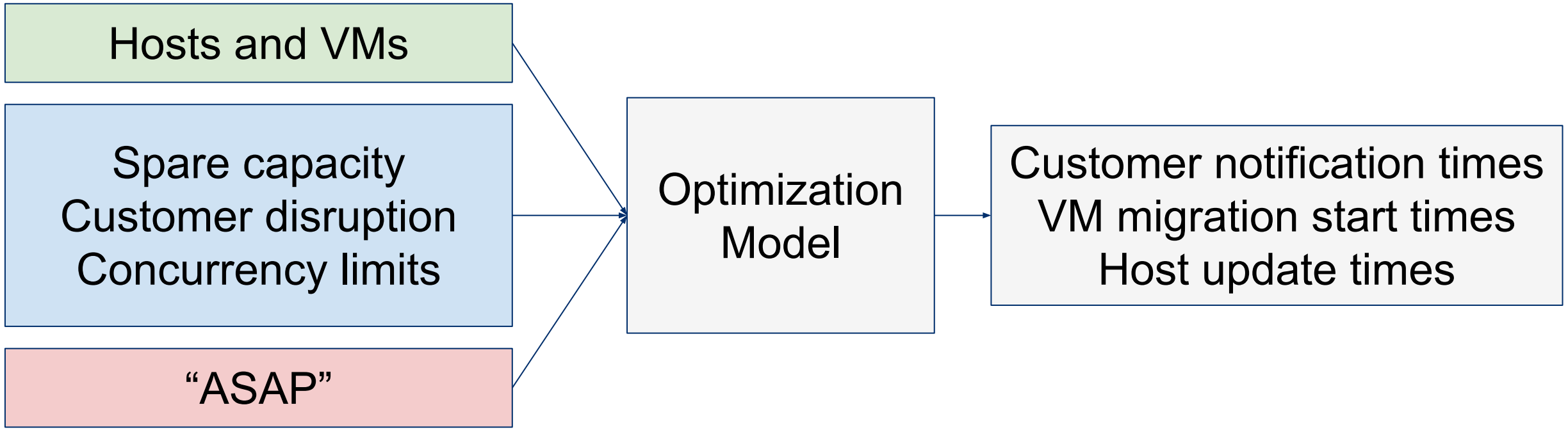
Maintenance Scheduling Mathematical Model



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OR-Tools CP-SAT

- Open source “portfolio solver” developed by Google (developers.google.com/optimization)

- Easy to use interface for scheduling problems:
  - Interval Variables
  - Specialized constraints:
    - AddNoOverlap
    - AddCumulative

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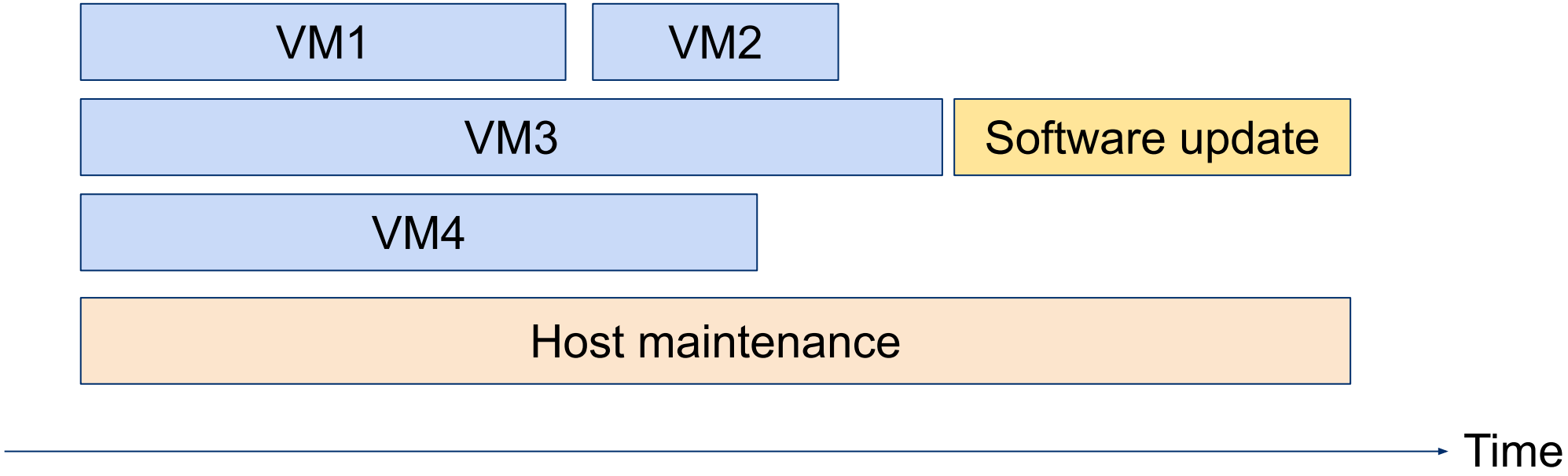
Example: AddNoOverlap



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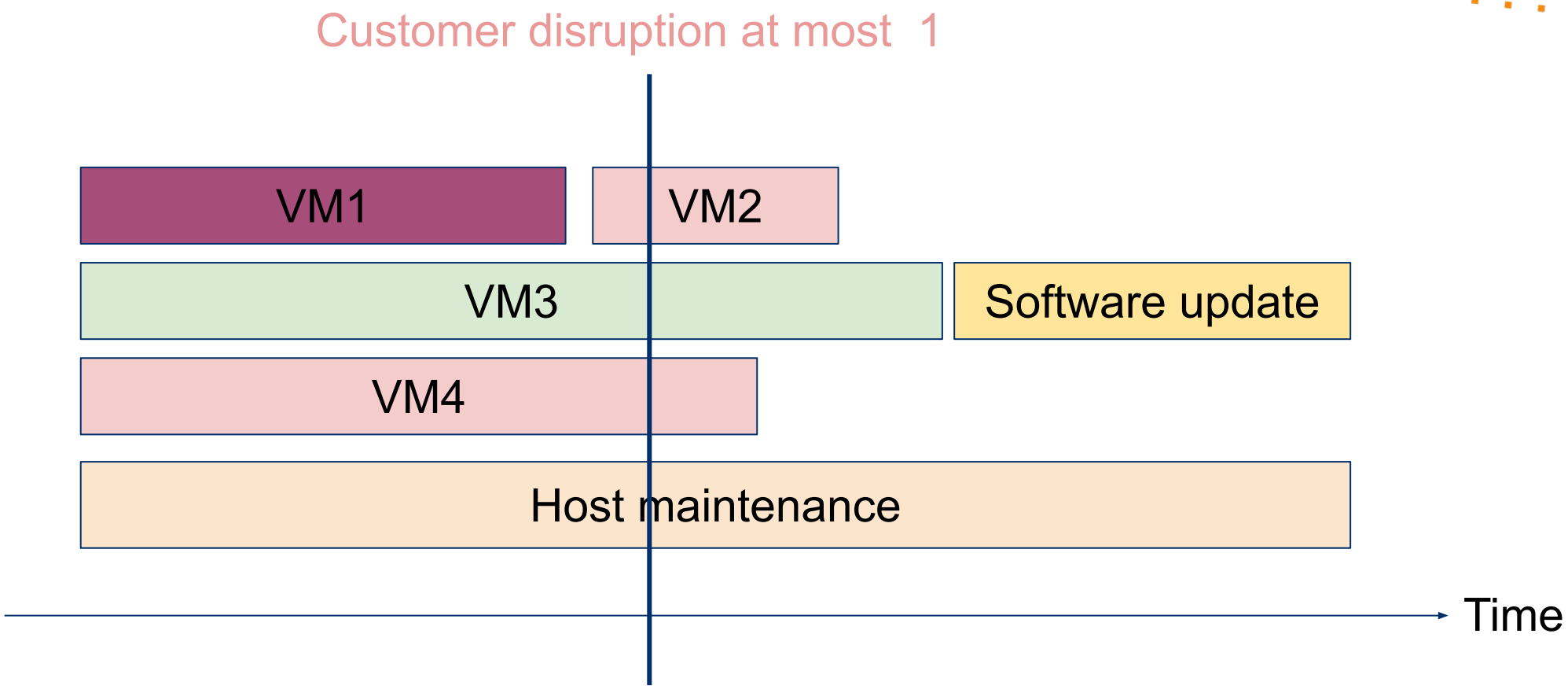
Example: AddNoOverlap



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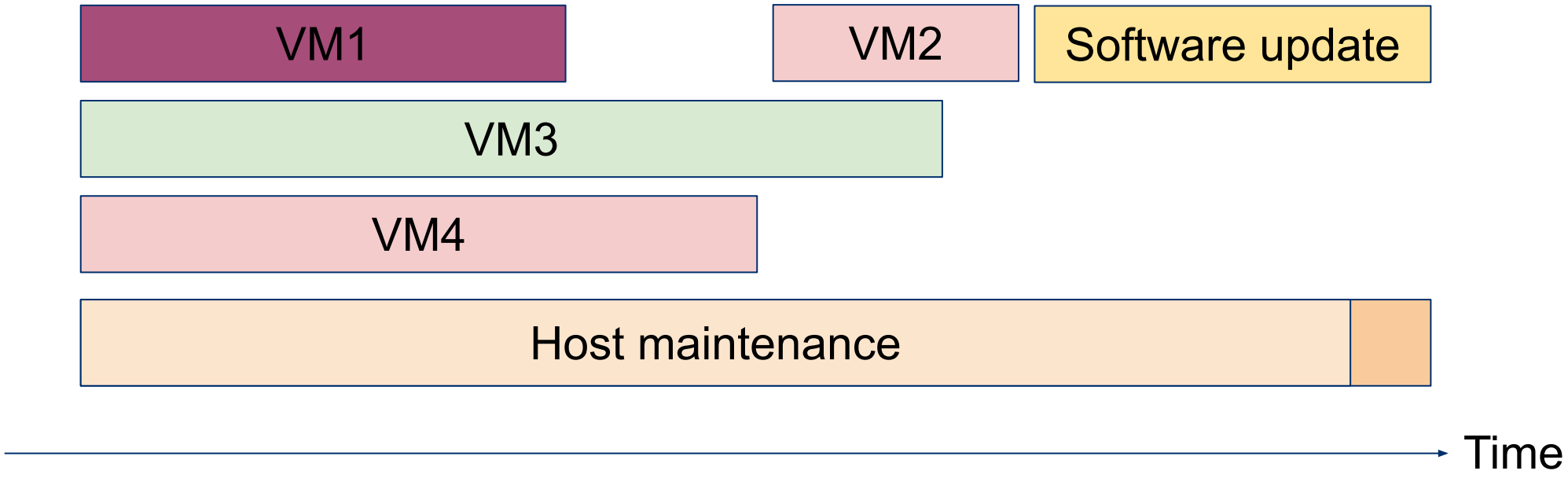
Example: AddNoOverlap



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Fleet Maintenance Planner

- Centralizes decisions of “who” and ”when”
- Produces all the data needed to schedule maintenance
- Enables optimal maintenance scheduling at scale

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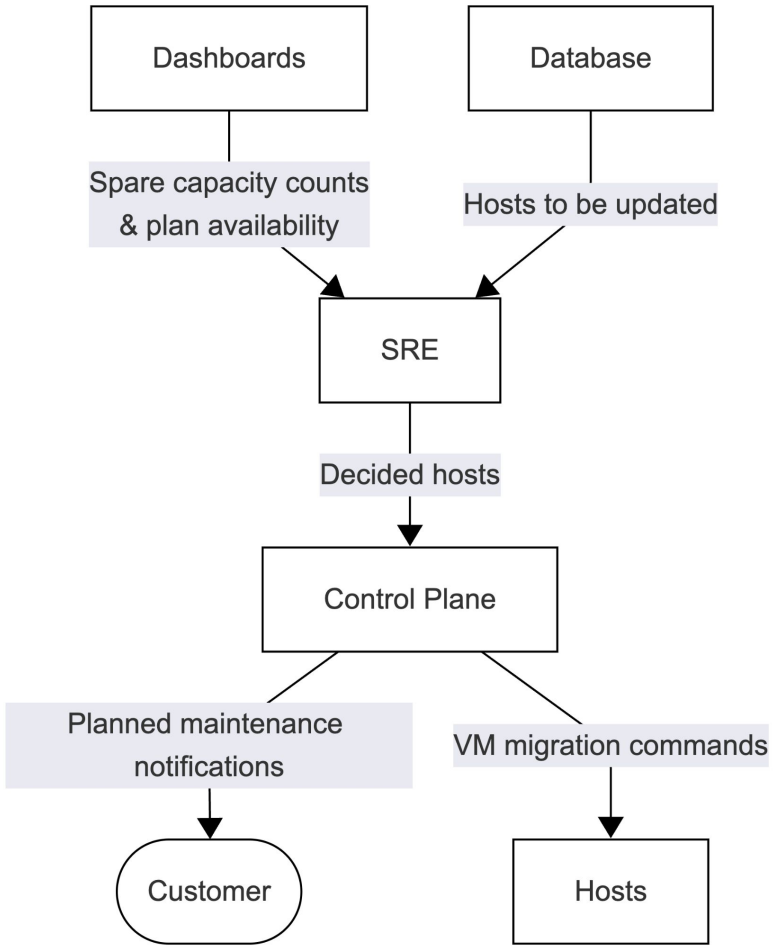
Maintenance Scheduling (before)



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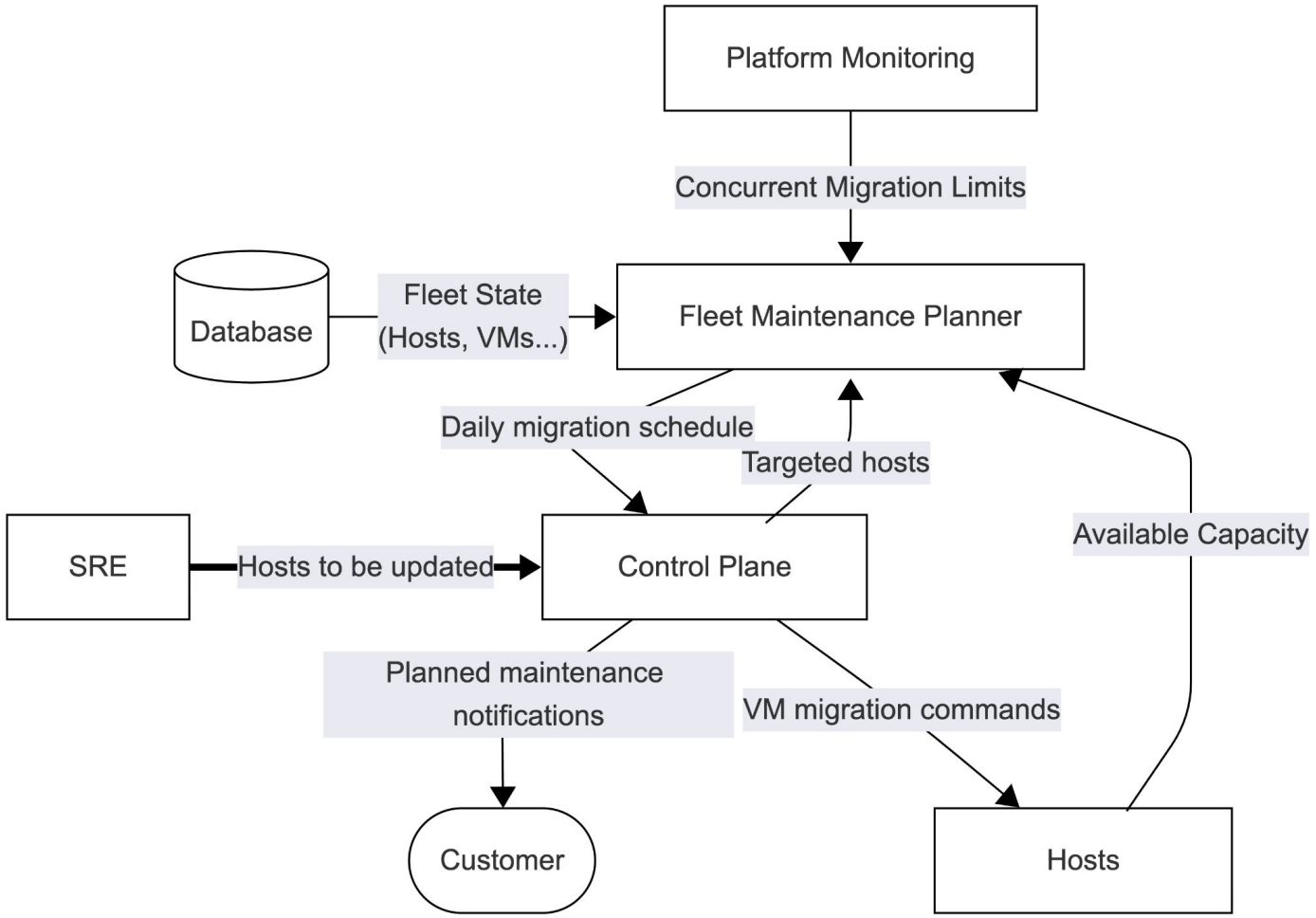
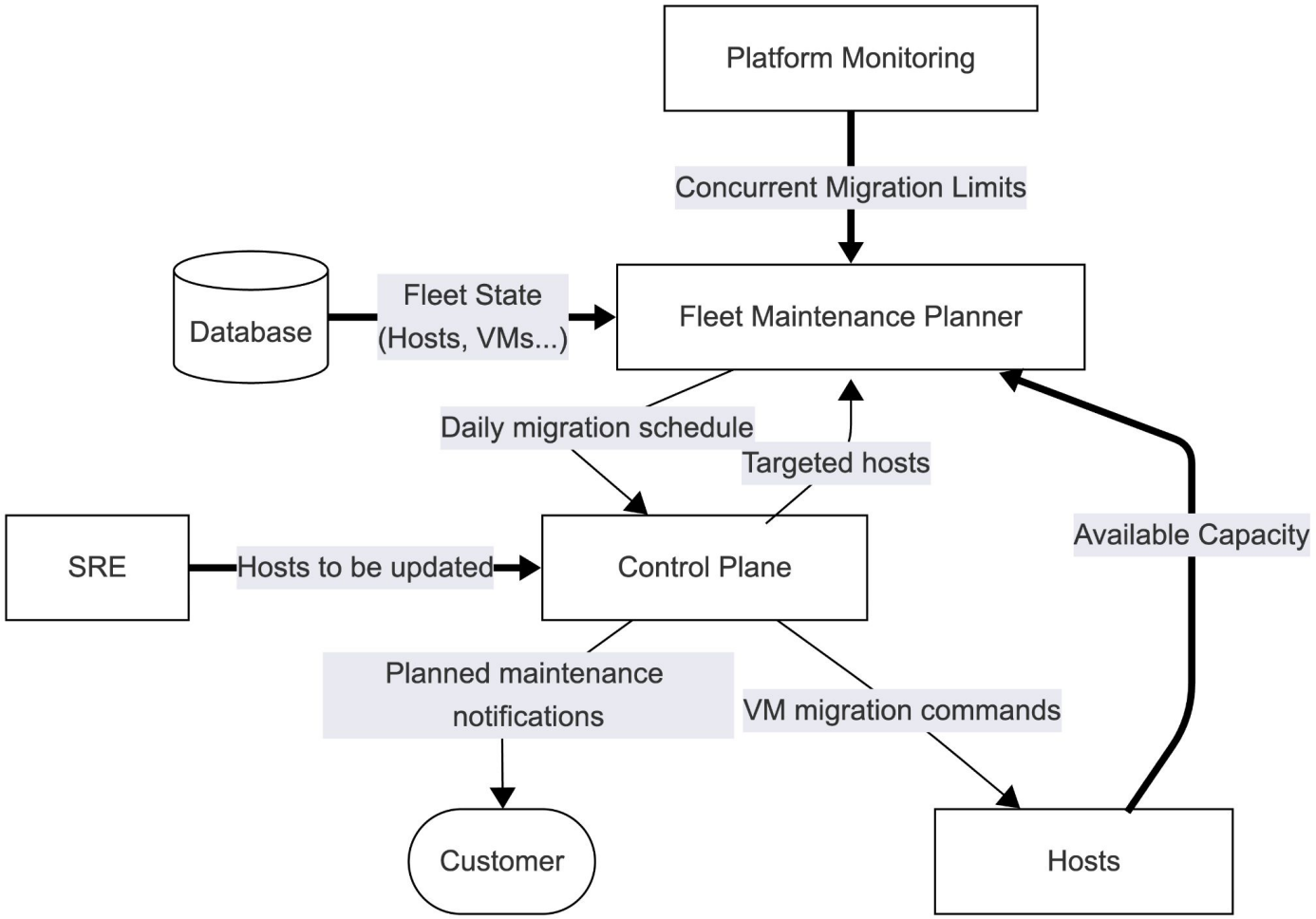
Maintenance Scheduling (after)



Maintenance Scheduling (after)



Feedback Loops

Fleet state is dynamic:

- Spare capacity depends on successful updates
- Migration limits change with infrastructure health
- VMs are short-lived

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Optimization Model Observability

Tracking “optimality”

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Side Benefit: Scenario Analysis

- “What if we need to update the whole fleet tomorrow?”
- “What if we scale the data center 2x in a year?”
- “What if customer X scales 10x?”

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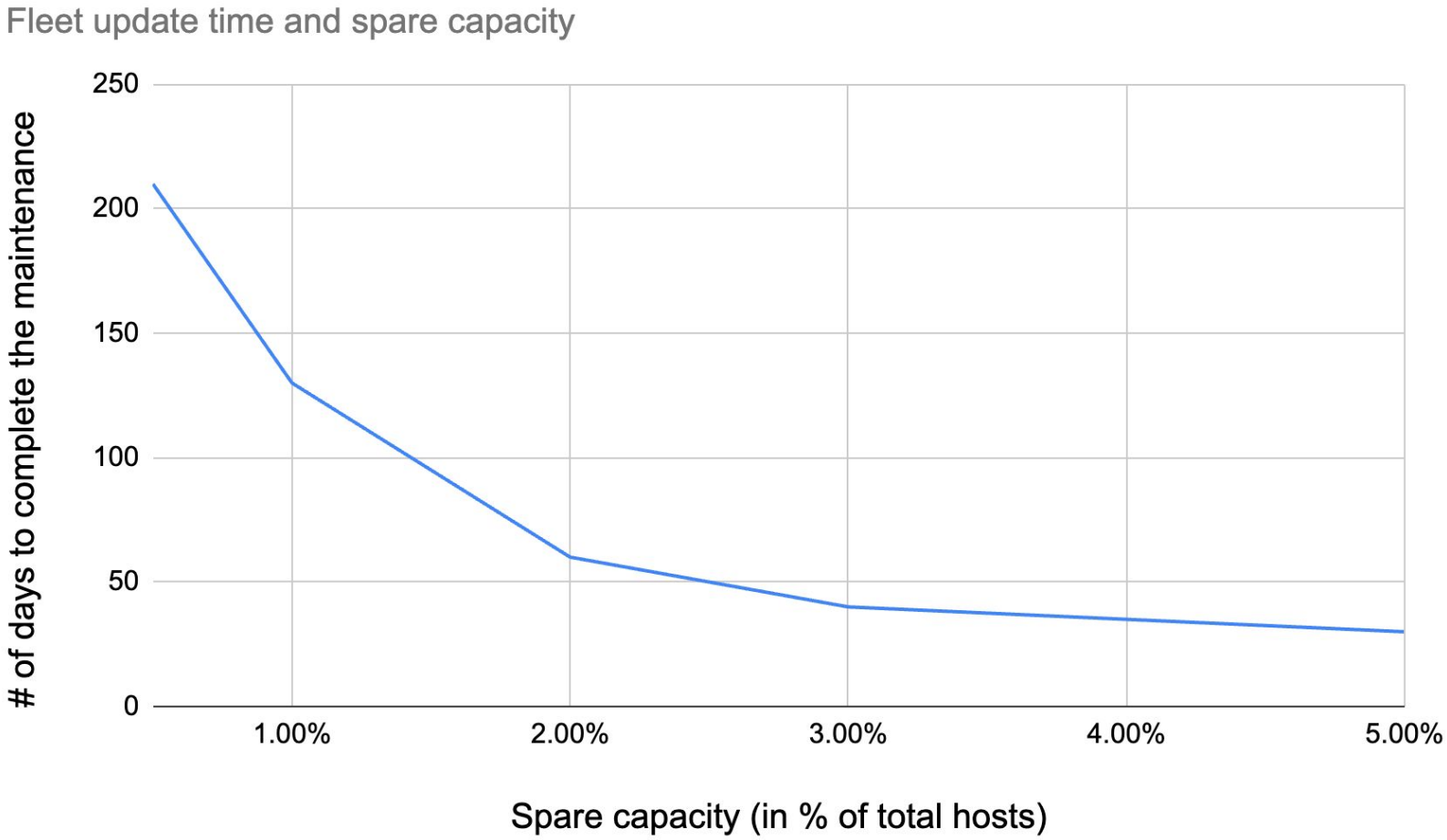
Fleet update time and spare capacity
# of days to complete the maintenance
250
200
150
100
50
0
1.00%
2.00%
3.00%
4.00%
5.00%
Spare capacity (in % of total hosts)

Summary

Mathematical optimization:

- Solve problems at scale
- Flexible & allows for incremental development
- Gives you tools to answer business questions

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Thank you!
Questions?

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/in/atalay-kutlay

Extra Slides

Why not MILP?

- Performance: even commercial MILP solvers are not competitive for RCPSP problem (very similar to cloud maintenance scheduling)
- Ease of development: OR-tools has specialized variables for scheduling
- MILP models are hard to get right for scheduling problems:
  - Time-index based models are too expensive, doesn't scale well
  - Compact models are more complex

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CP-SAT Interval & AddNoOverlap Example

```
planning_horizon = 24 * 120 # 120 days

start_var = model.new_int_var(0, planning_horizon, f"{vm}_start")
end_var = model.new_int_var(0, planning_horizon, f"{vm}_end")
migration_duration = 10

vm_interval_var = model.new_interval_var(
    start=start_var, size=migration_duration, end=end_var, name=f"
{vm}_interval"
```

```
vm_intervals = list()

model.AddNoOverlap(vm_intervals)
```

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Complete Problem Statement for Hypervisor Maintenance in Cloud

We need to schedule host evacuations so that:

- Customer impact is below the “disruption budget”
- Only the capacity carved out for the maintenance is used
- Migrations do not cause performance issues / network bottlenecks

Our goal is to:

- Minimize the total duration of software updates

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Maintenance Scheduling Problem

Variables:

- Each VM's notification / migration start time
- Each host's status change time
- Each host's software update time

Objective:

Finishing the updates as fast as possible.

Constraints:

- Number of hosts "under maintenance" can not exceed spare capacity
- No "maintenance group" has more VMs migrating than disruption budget
- Each VM gets the notification period according to its maintenance policy
- Concurrent VM migrations are limited in host, rack, and datacenter levels

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