Elastic Secure Marketplace For Trading Bare-metal Servers

MACS 2018

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ECE, Boston University

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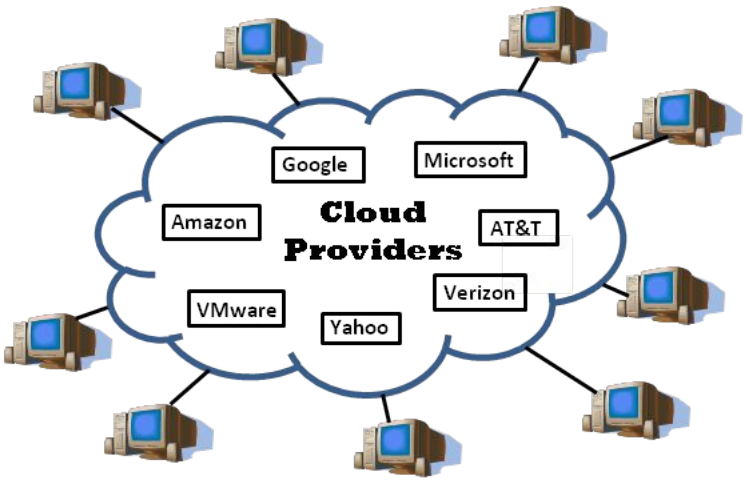
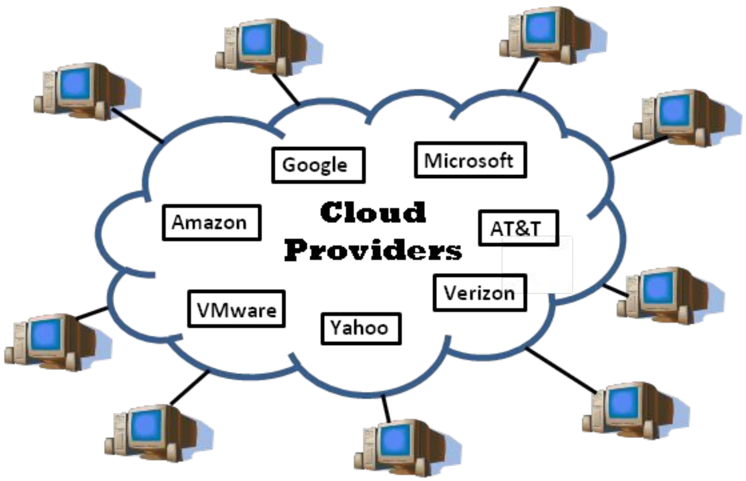
(PhD Student)
ECE, Boston University

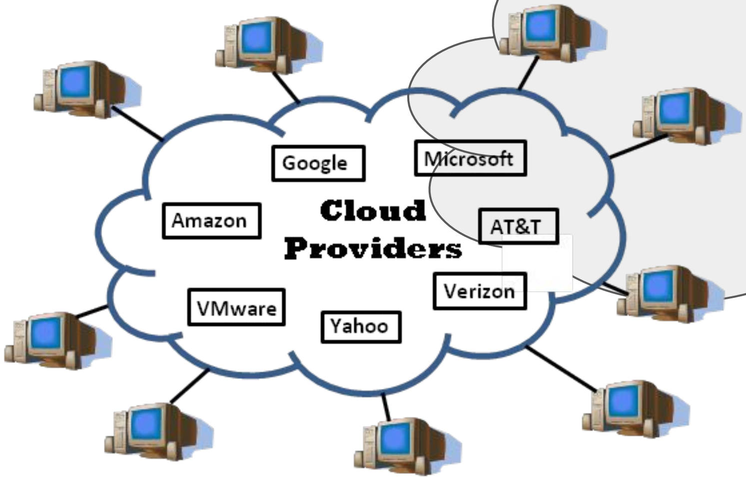


Public Cloud



Public Cloud

Private cloud

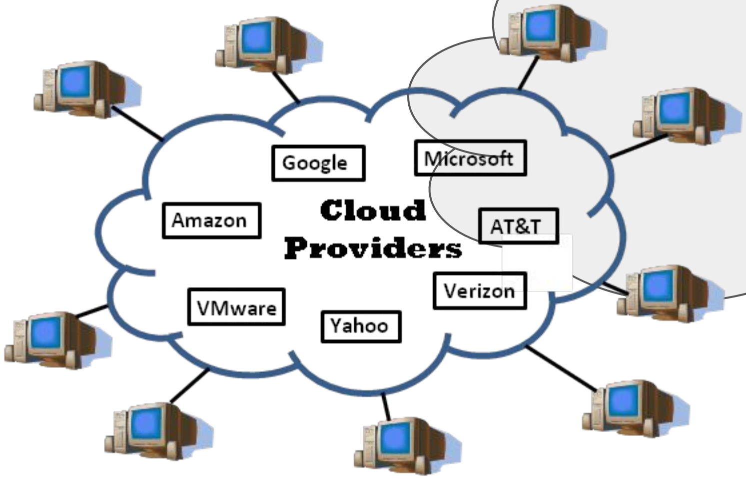


Hybrid Cloud

Public Cloud

Private cloud

Hybrid Cloud

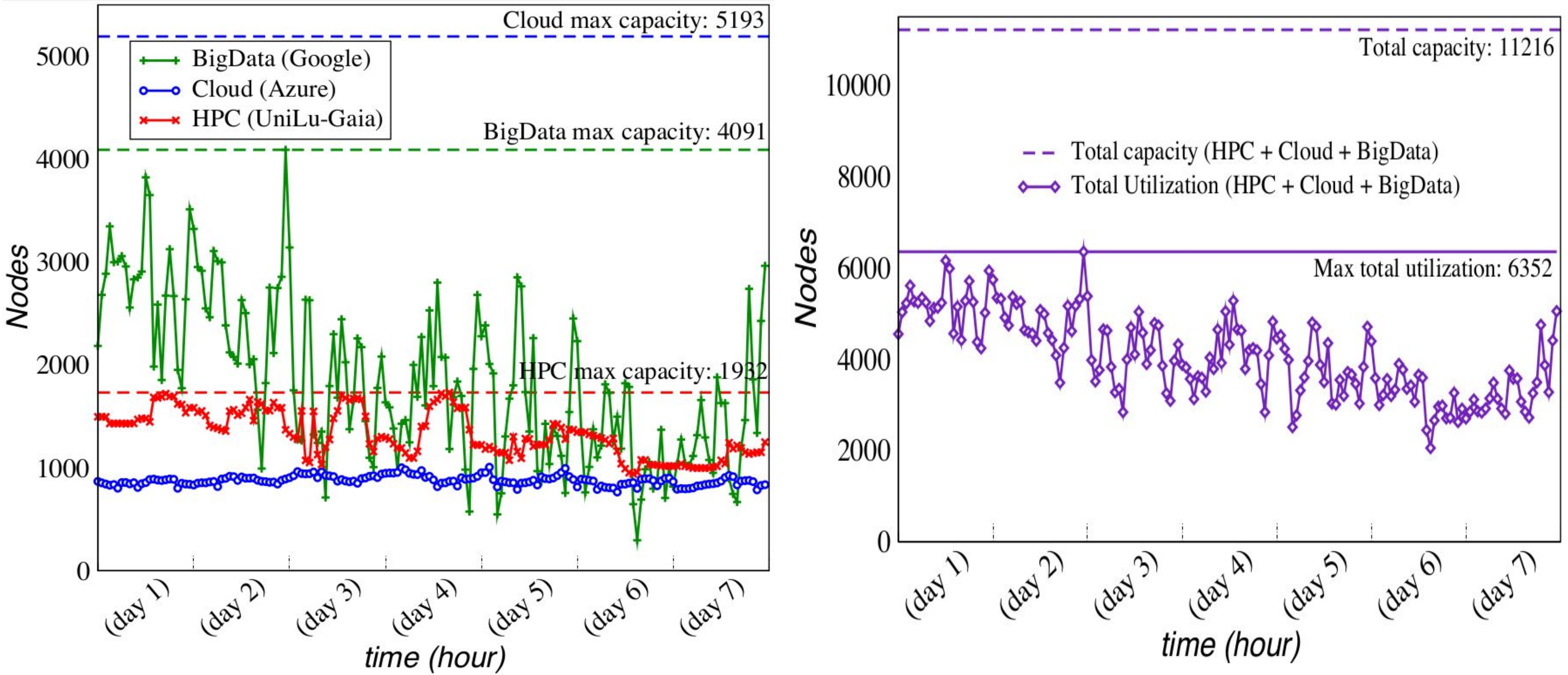


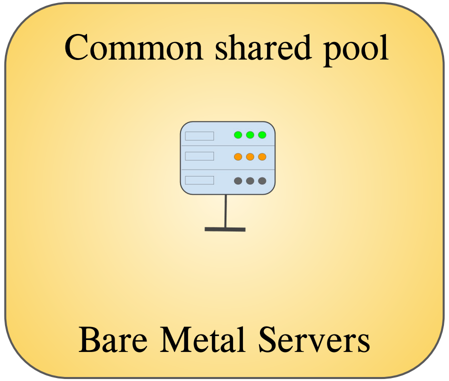
Public Cloud

CAN WE DO BETTER THAN THIS ?

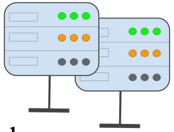
Private cloud

Share excess capacity with others




Common shared pool
Bare Metal Servers

HPC/HTC Cluster



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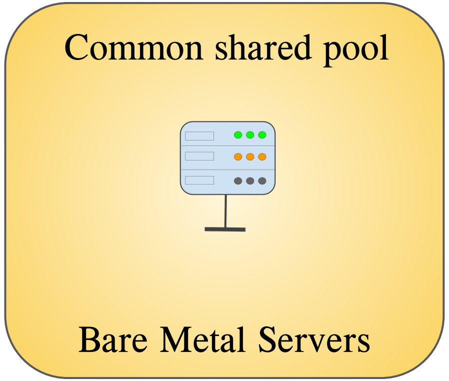

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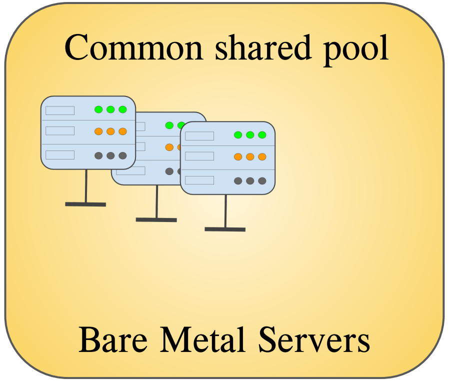

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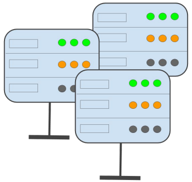
OpenStack Cluster



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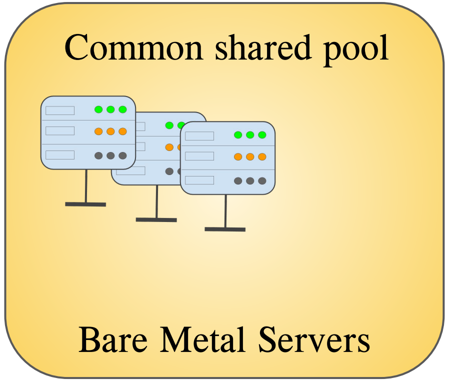

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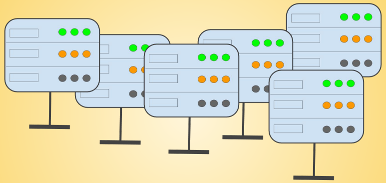

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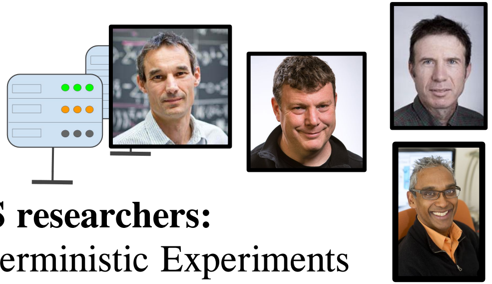

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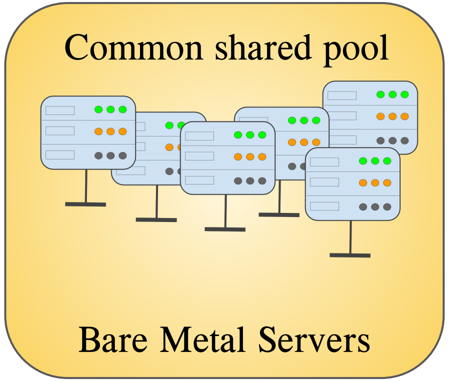

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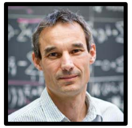


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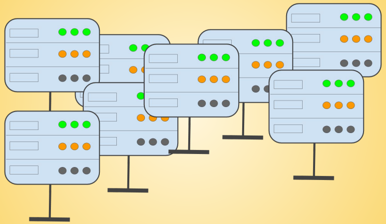

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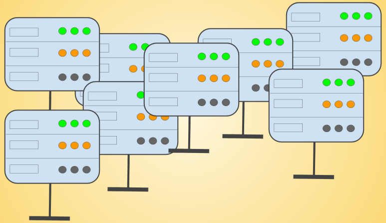

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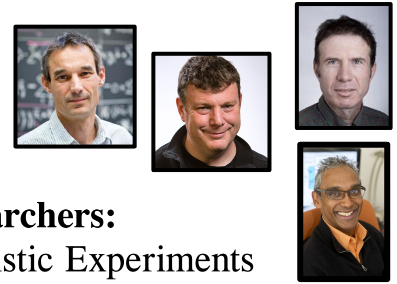

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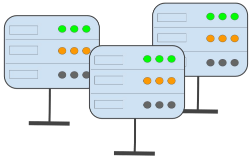
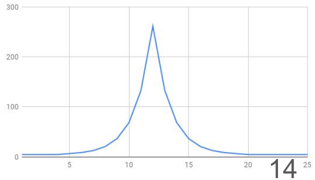
- Predictable cyclical demands.





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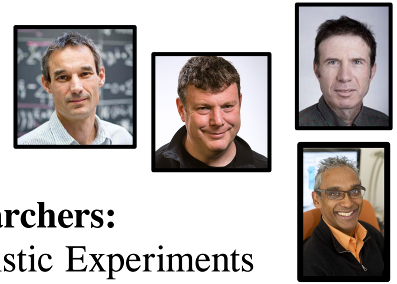

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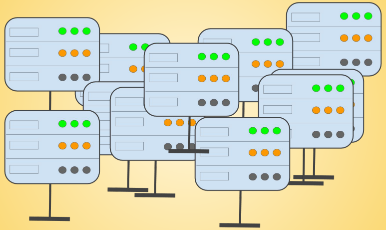

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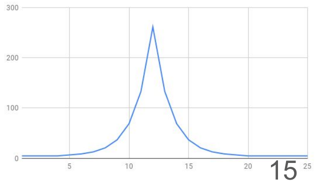

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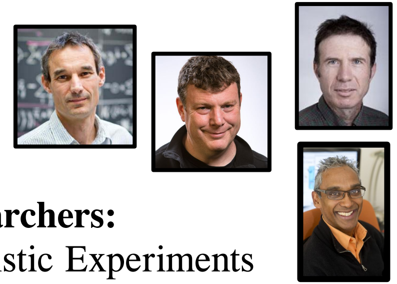

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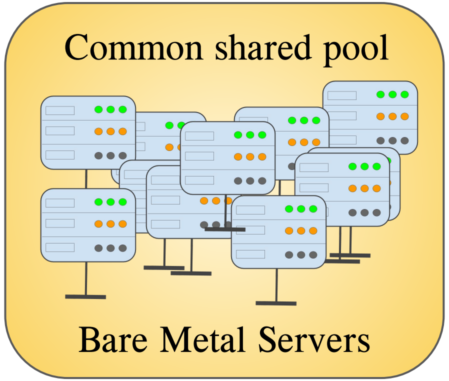

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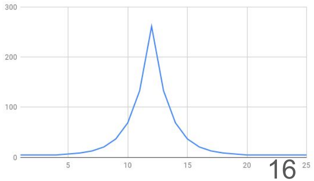

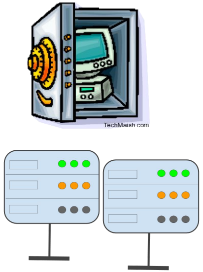

HIPAA Complaint Clusters

- Tedious and time consuming to built
- Utilization < 1%
- Willing to share if compliant hardware available when required.

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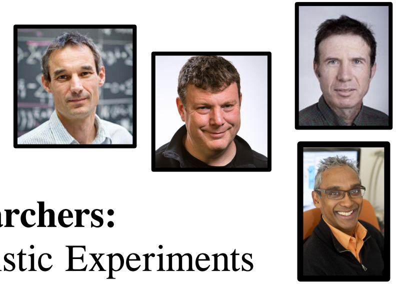

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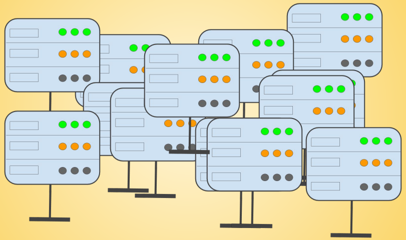

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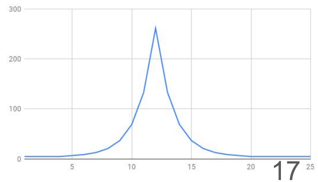

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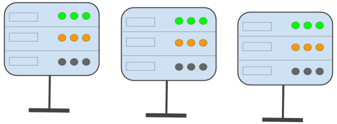

U.S. AIR FORCE

- Dedicated data-centers for National emergencies utilized mostly around 2%
- Willing to share if they can use the shared pool to ramp up their systems in during emergencies.

OpenStack Cluster

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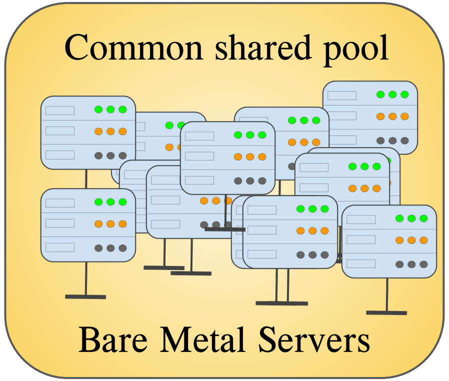

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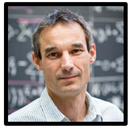

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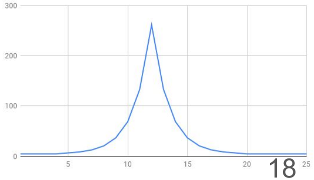

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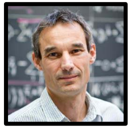


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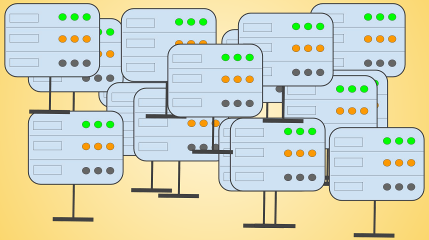

Bare Metal Servers

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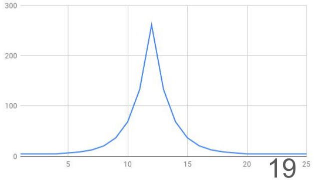

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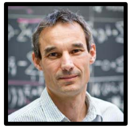


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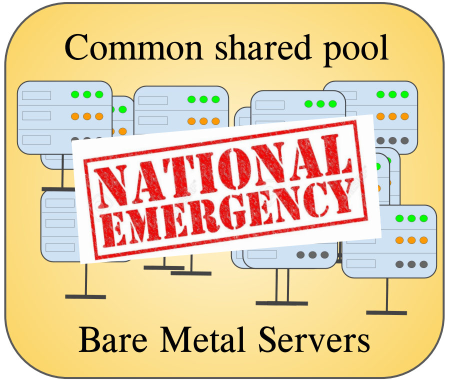

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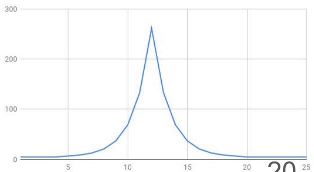

How do we achieve this ?

- **Goal 1: Elastic sharing of hardware between different deployment system**
  - Mechanism that supports movement of bare-metal nodes between different clusters.
  - Allows clusters to choose their own method of deploying operating system and application software.
- **Goal 2: Minimize the cost of moving nodes between clusters.**
  - Minimize the time to setup a cluster.
  - Reduce dependency of state of clusters on the underlying hardware.
- **Goal 3: Security for sharing bare-metal servers between non-trusting entities.**
  - Protecting incumbent users of bare-metal nodes from malicious previous tenants.
  - Protecting incumbent users of bare-metal nodes from future malicious tenants.
- **Goal 4: A system to incentivize sharing of bare-metal servers.**
  - Encourage users to give up their nodes when they do not need them.
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Goal 1: Elastic sharing of hardware between different deployment system

HPC

BIG Data

Cloud

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HPC

BIG Data

Cloud

slurm
workload manager

hadoop

openstack™

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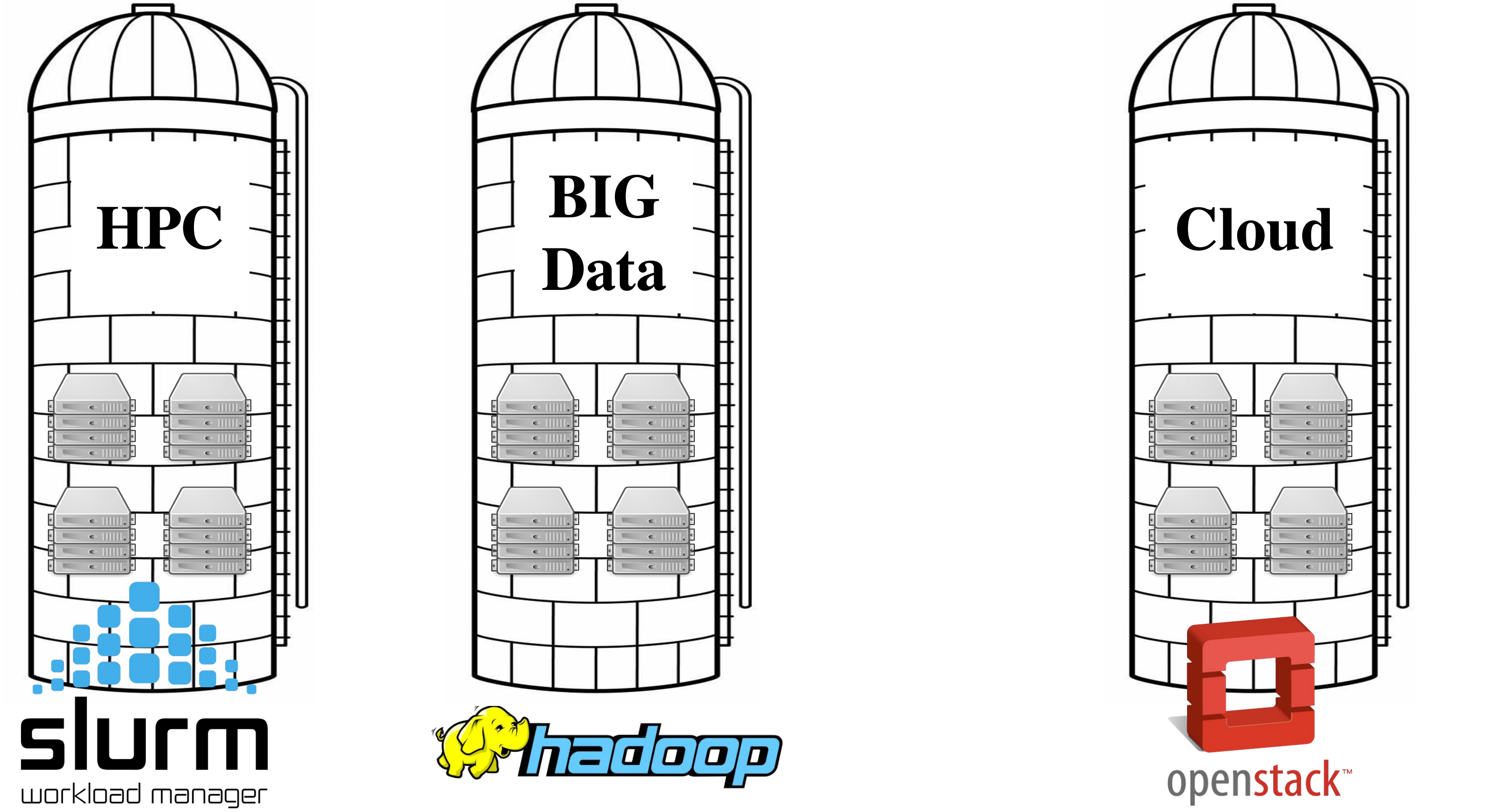

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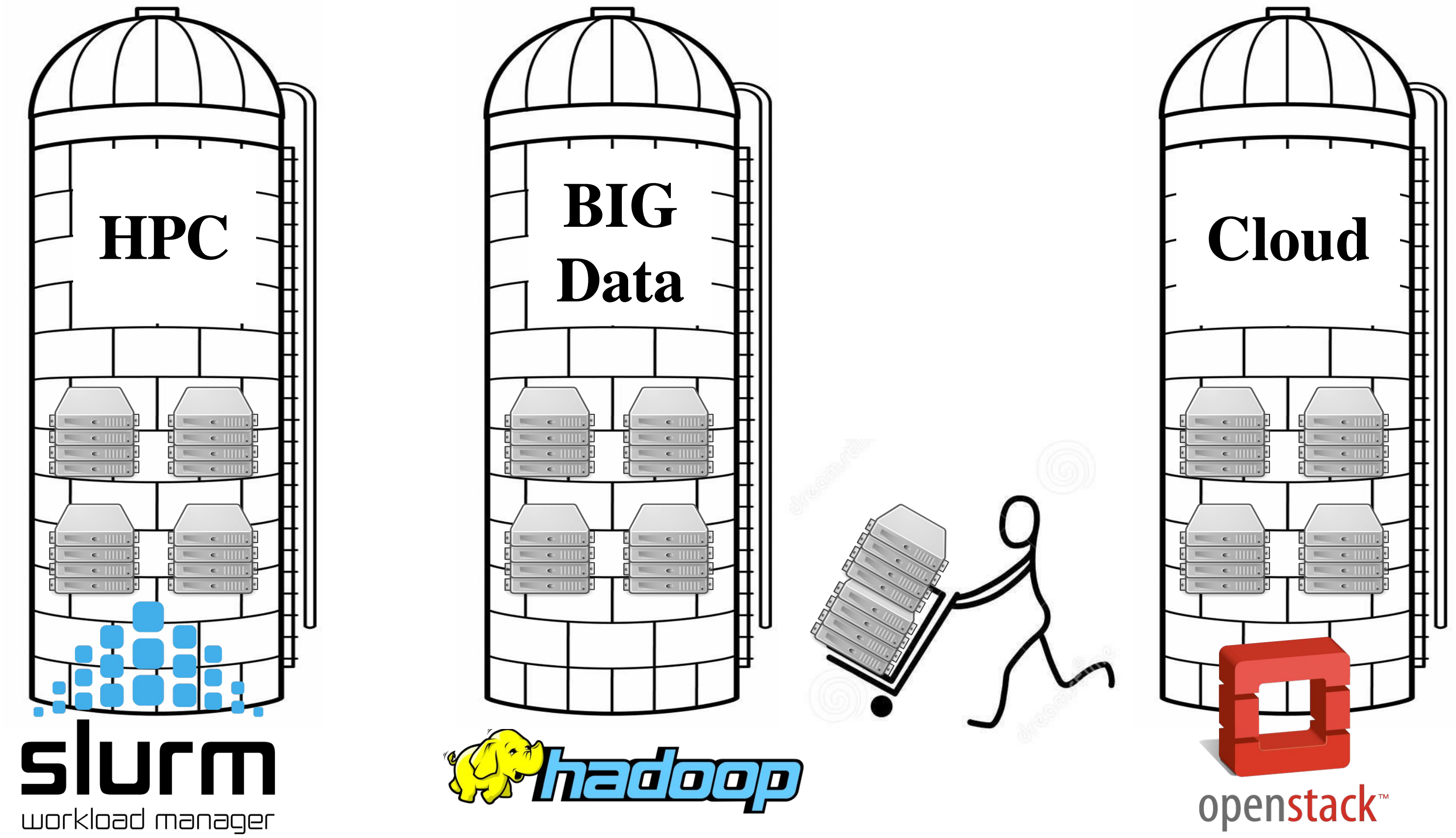

Hardware Isolation Layer (HIL)

A fundamental new layer in the data center

that decouples server allocation

from how they are provisioned.

J. Hennessey, et al., "HIL: Designing an Exokernel for the Data Center", SoCC '16

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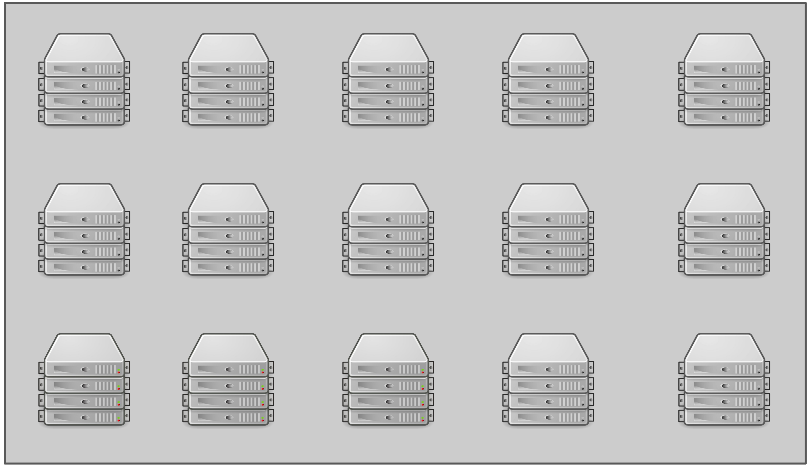
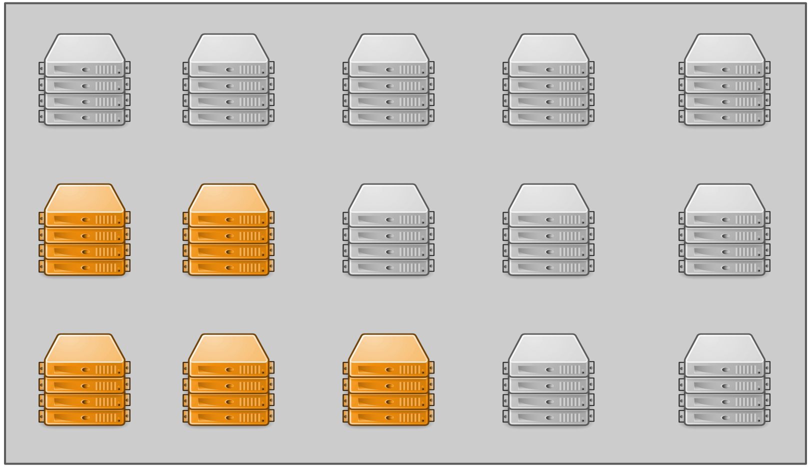


Colocated pool of Bare Metal Server

Hardware Isolation Layer (HIL)



Allocate
Bare Metal Servers

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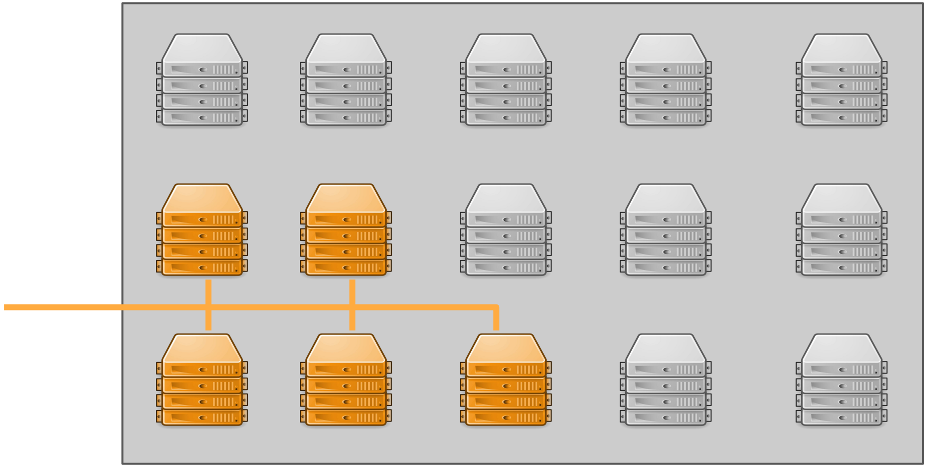
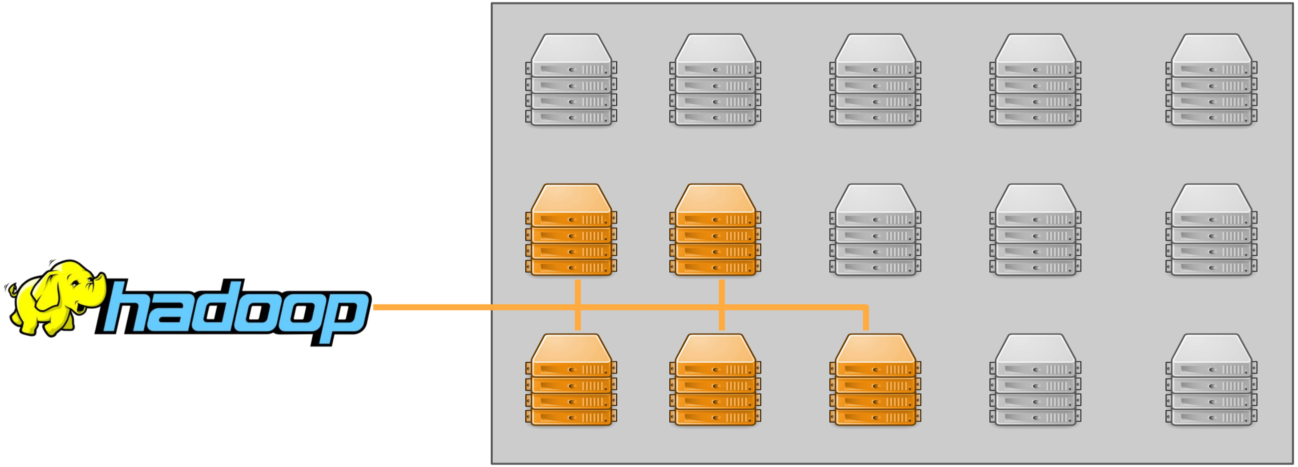


Connect Network

Hardware Isolation Layer (HIL)



Install using your favourite Provisioning System

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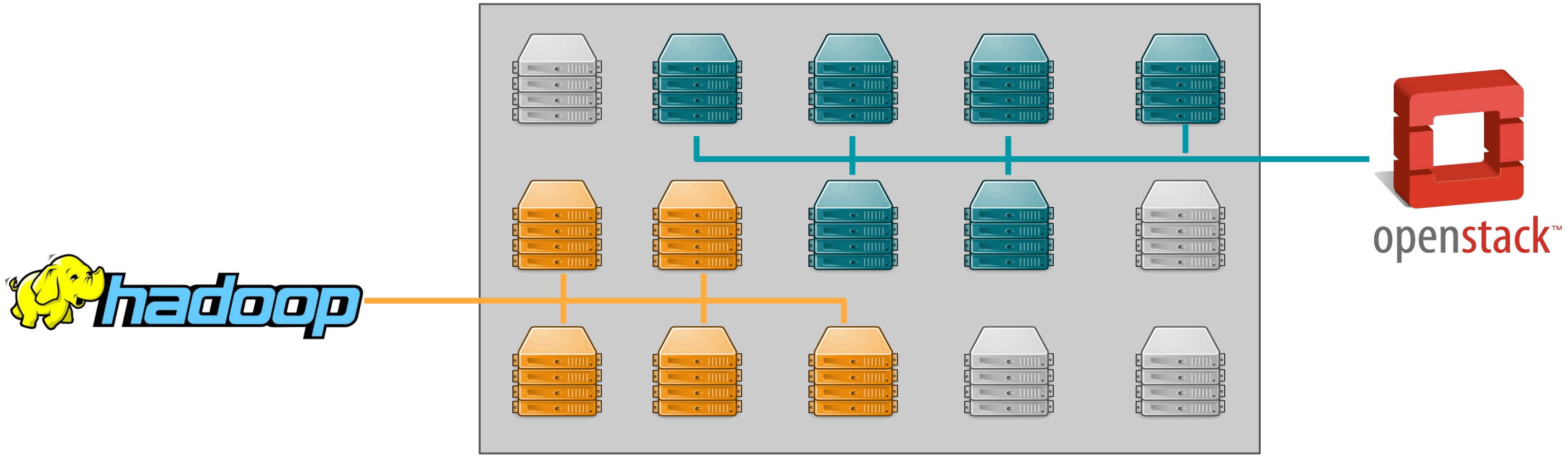

Just 2 api calls: Move nodes between clusters

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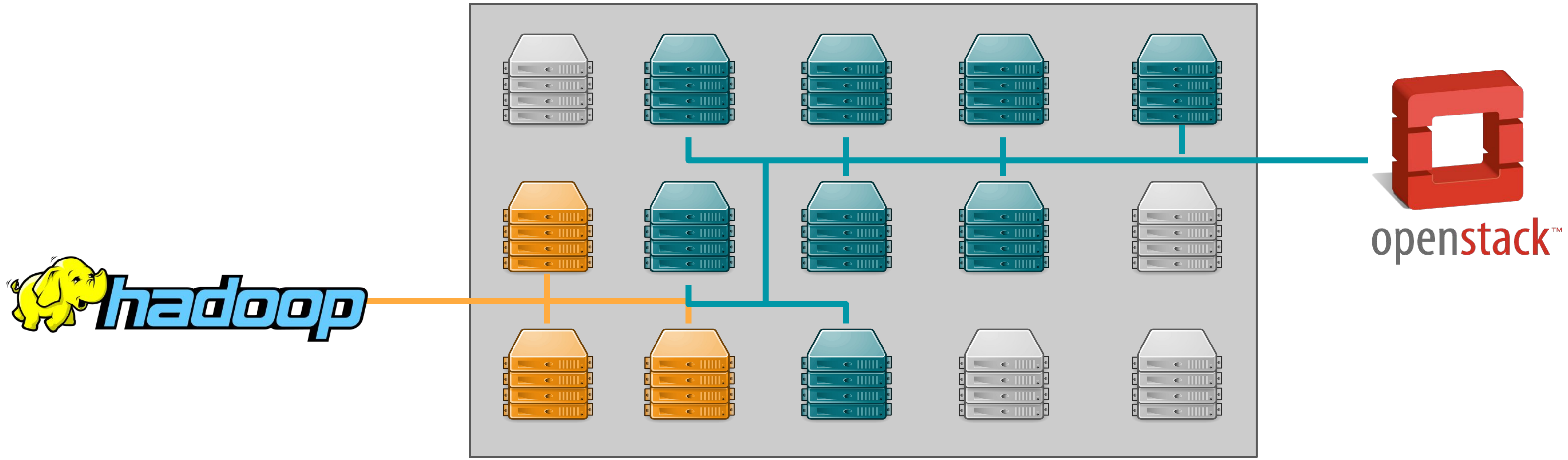

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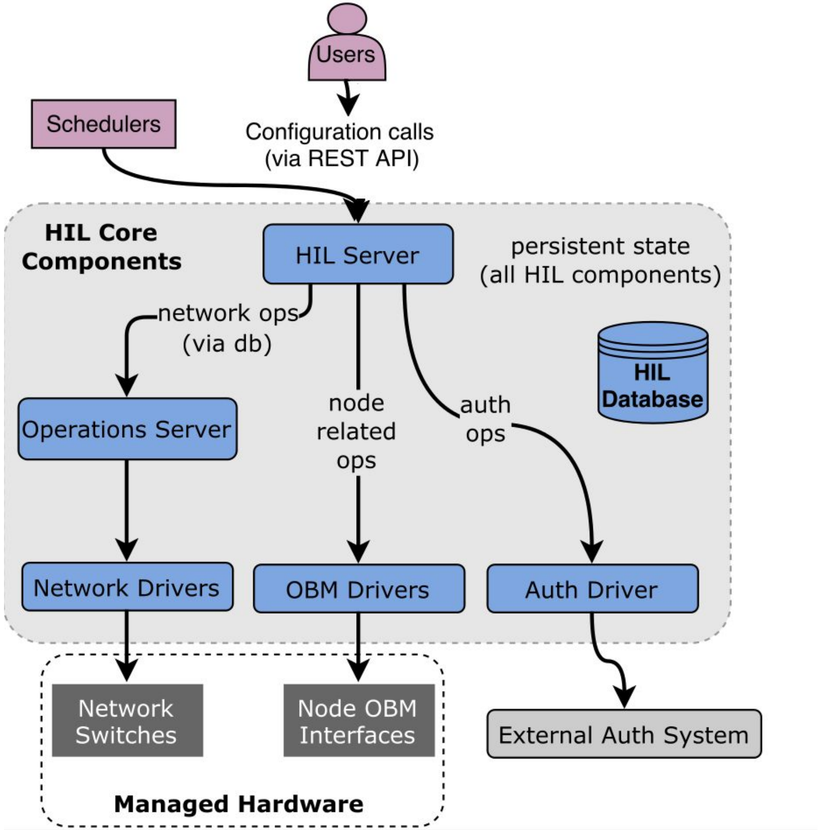

- **Minimal Attack Surface:** Core code ~3000 LoC
- **Standard proxy interface:**
  - Out of band management of servers
  - Network calls of switches.
- **Extensible:**
  - Cisco, Brocade, Dell, Openvswitch
  - Authentication: Database, Keystone
- **Compatible with any provisioning system:**
  - IRONIC, MaaS, emulab,
  - Forman, Geni, xCAT, M2, etc
- Used in production for over two years at MOC

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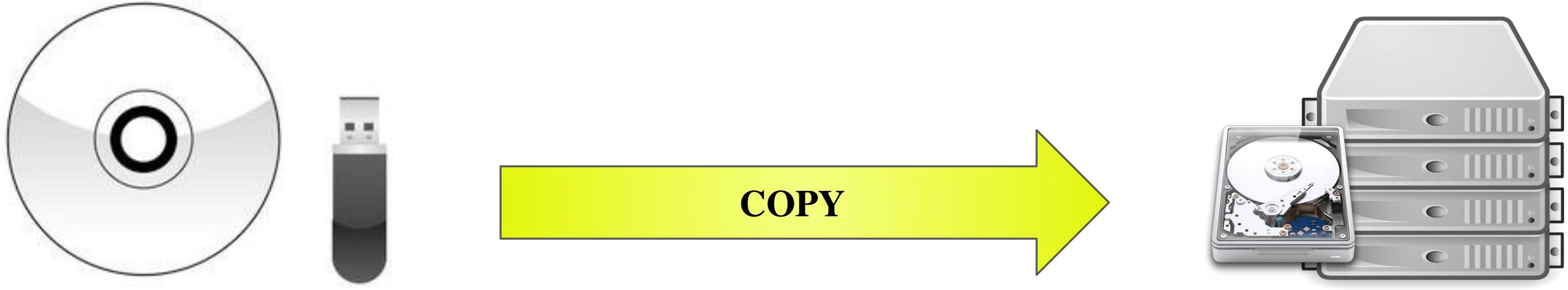
Existing Bare Metal Offerings Provision to Local Disk - Stateful

Over the network from an ISO or a Pre-installed image

aws emulab MAAS openstack rackspace SOFTLAYER an IBM Company



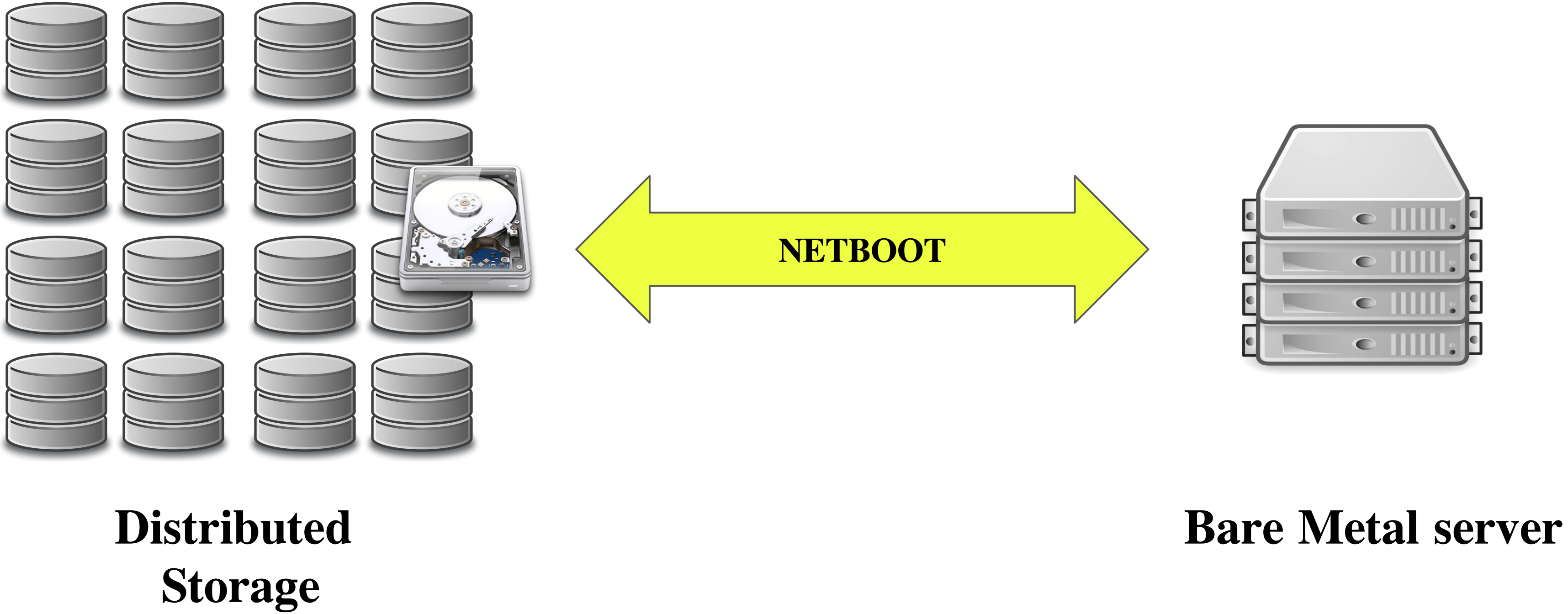
Heroic approaches have been proposed:

Y. Omote, T. Shinagawa, and K. Kato, “Improving Agility and Elasticity in Bare-metal Clouds,” ASPLOS’15

Problems with Stateful provisioning

- **Slow Provisioning**
  Upto tens of minutes to provision
- **Boot Storms**
  Heavy network traffic
- **Single point of failure.**
  Loss of both OS and application
- **Bad for moving between services.**
  Have to provision from scratch, everytime.

Could we provision Bare Metal like Virtual Machines



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- ~~**Bad for moving between services.**~~

  ~~Have to provision from scratch, everytime.~~

★ **Only copy what you need.**

★ **Multiple NICs and Distributed File System**

★ **Reboot from a saved Image**

M2: Malleable Metal as a Service

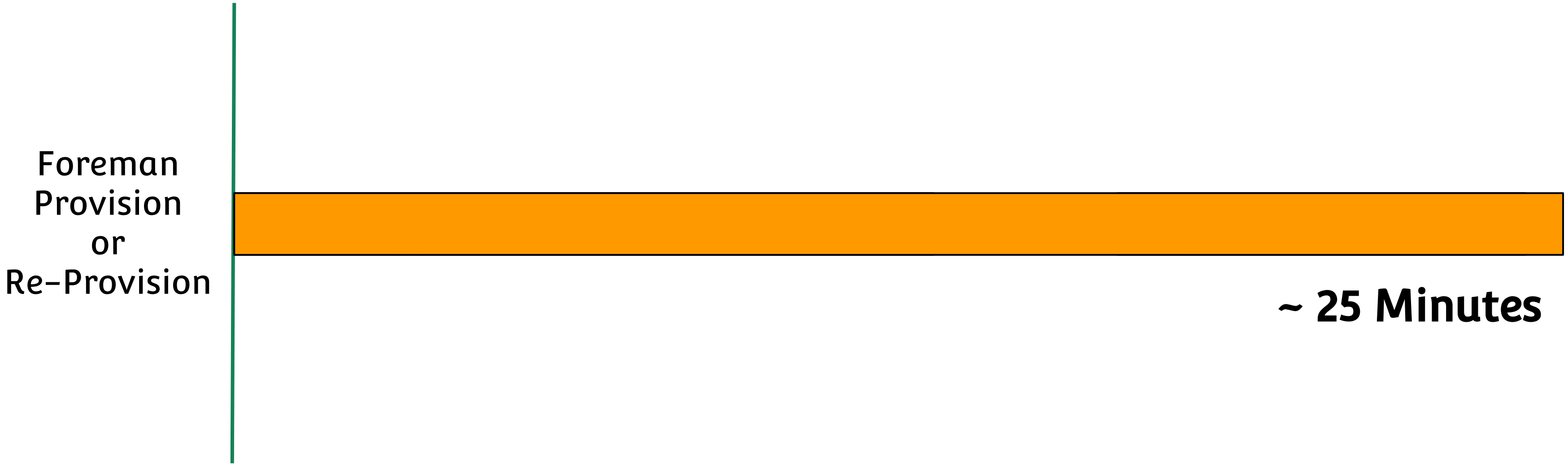
Simple Microservice

for

Rapid Provisioning and Image Management

"An Experiment on Bare-Metal BigData Provisioning", HotCloud 16
"M2: Malleable Metal as a Service." IC2E 2018

Provisioning/Re-Provisioning Times Comparison For Single OpenStack Node



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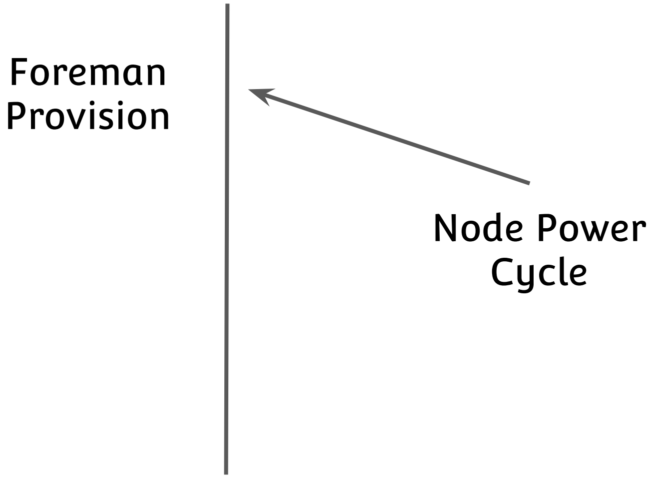

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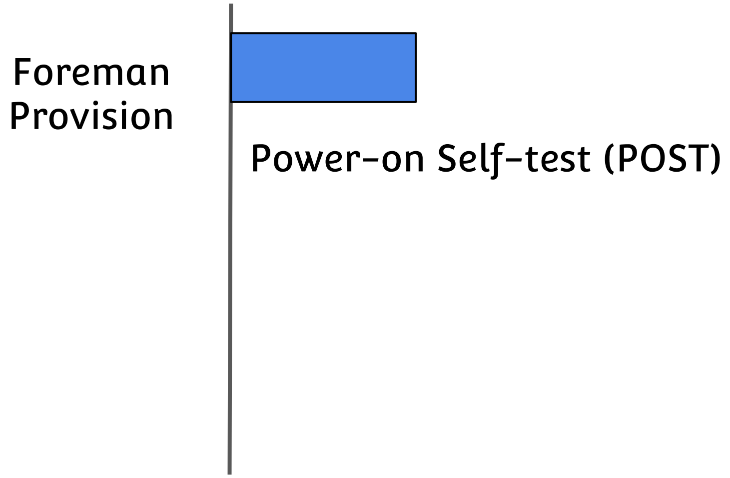

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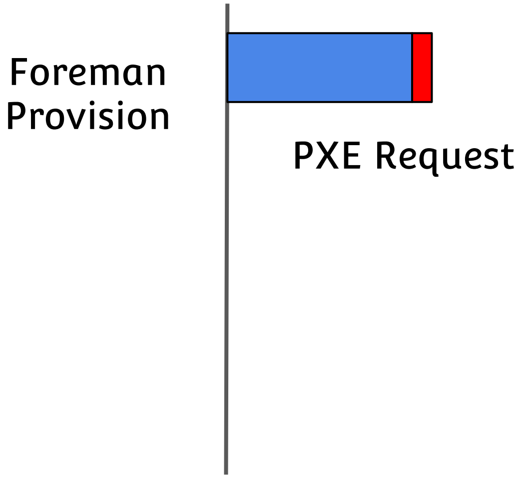

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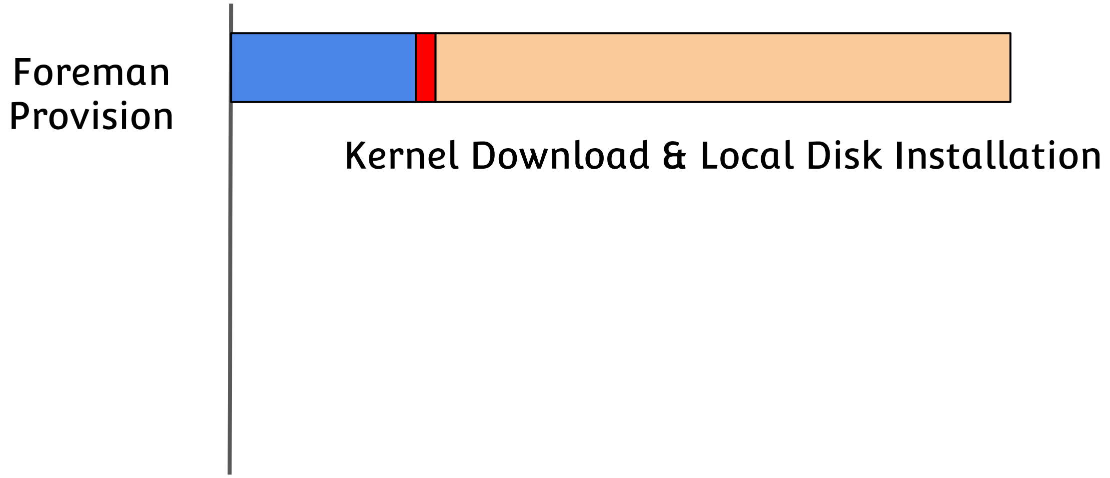

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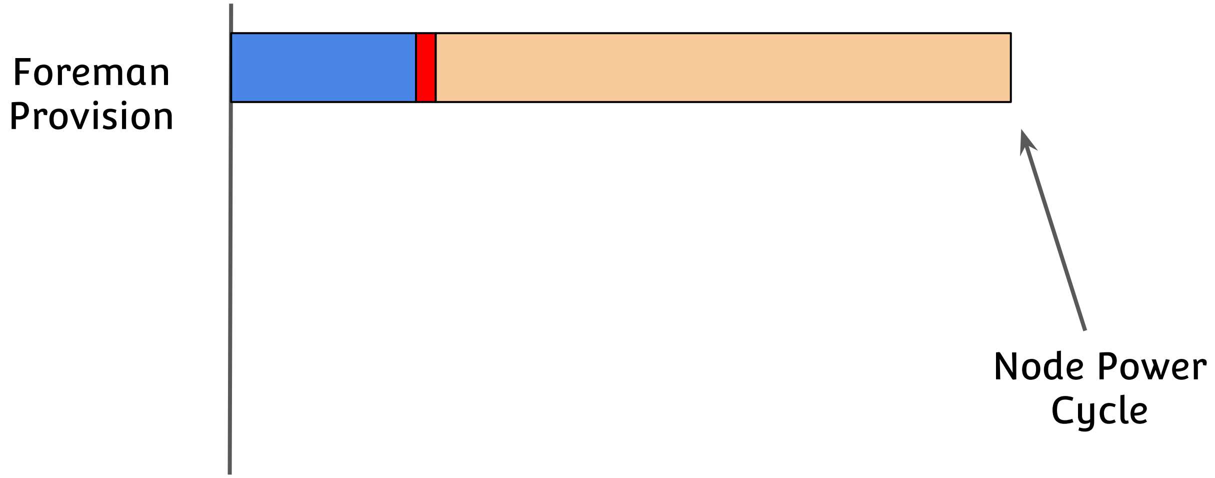

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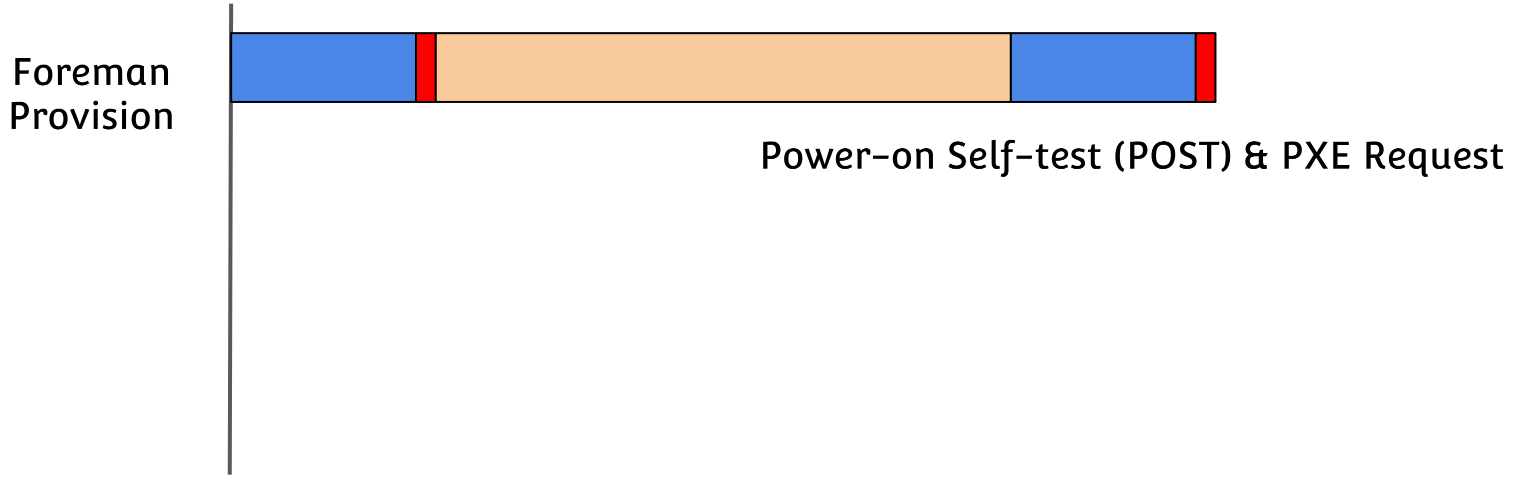

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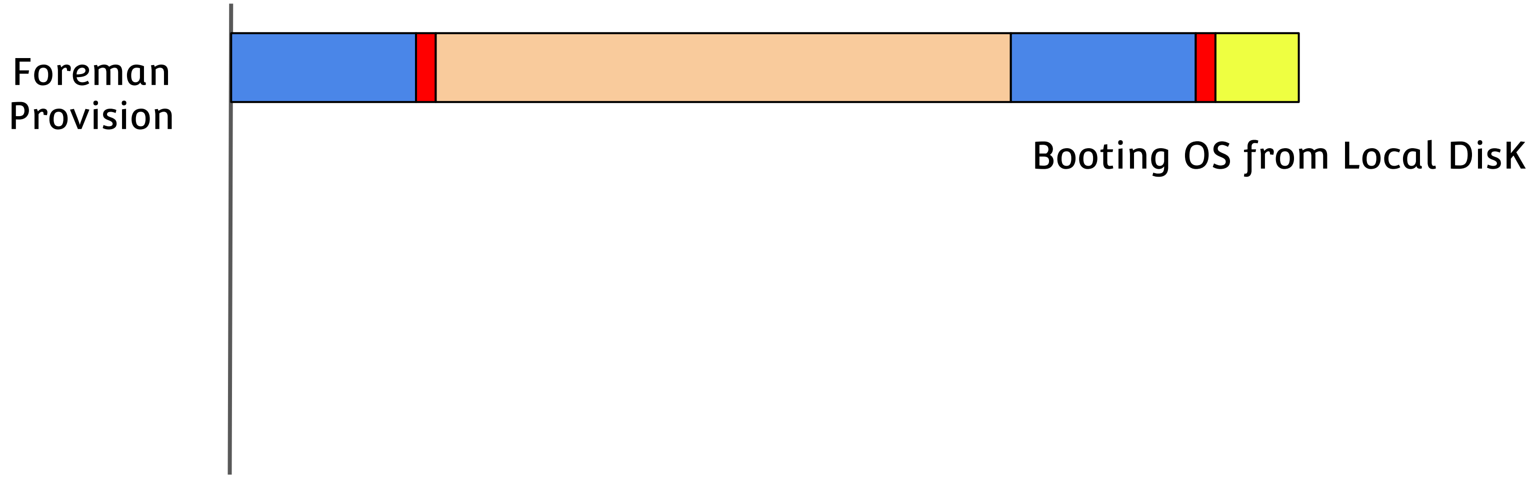

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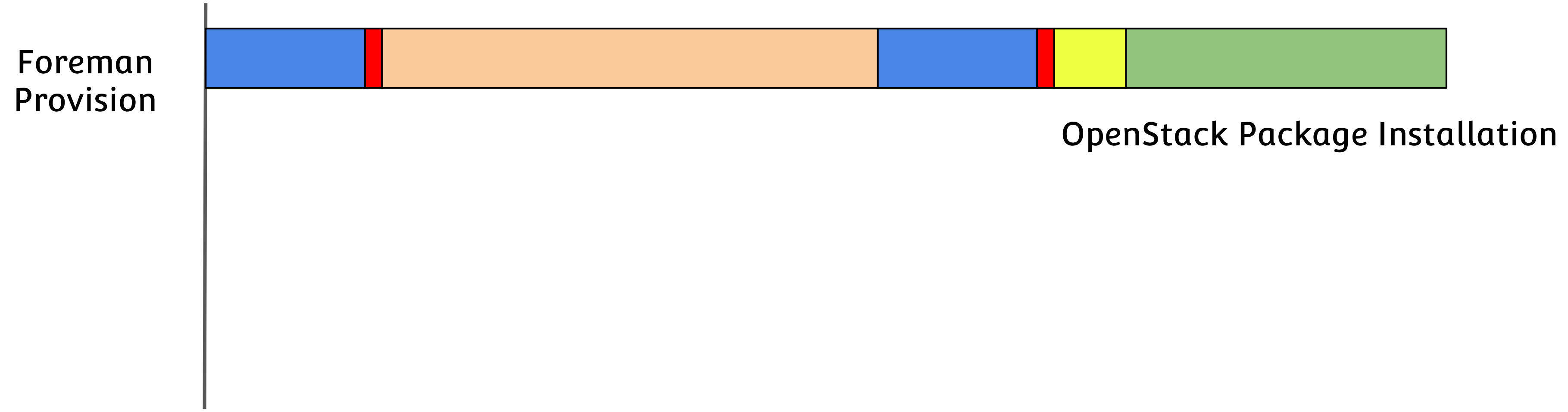

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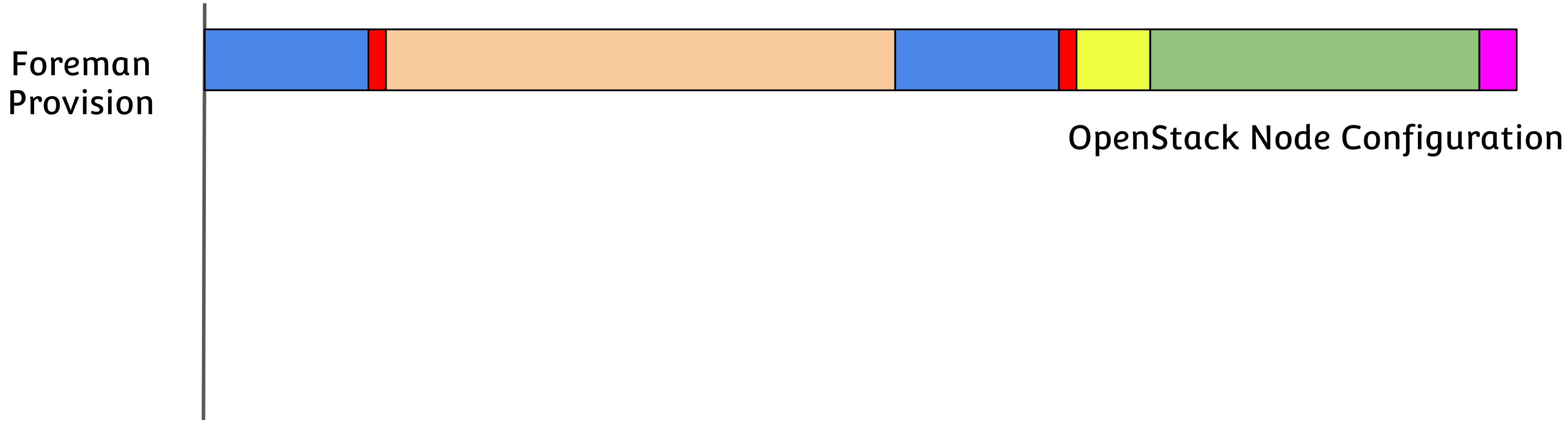

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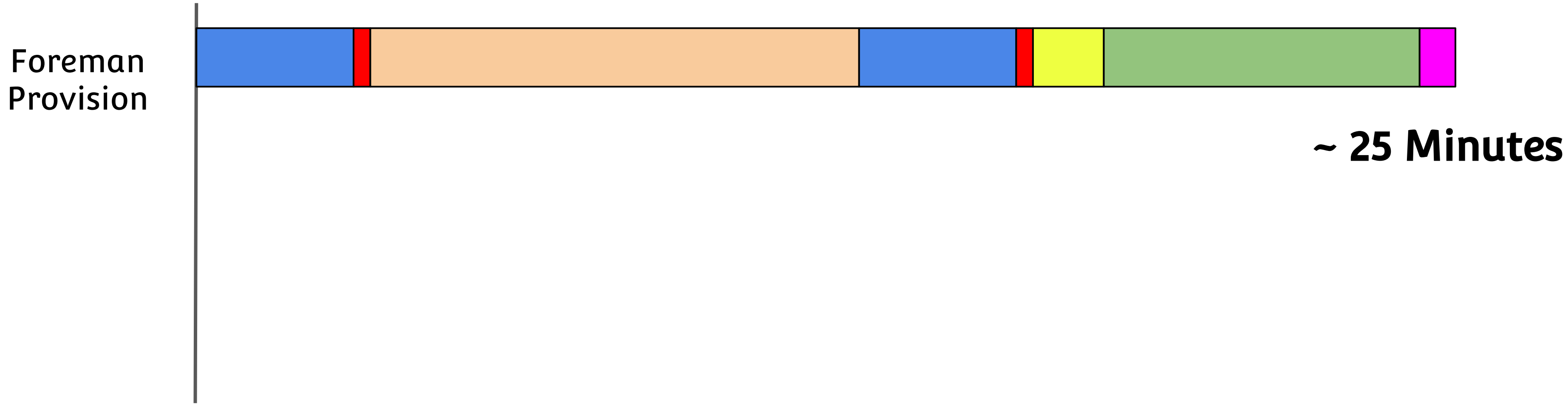

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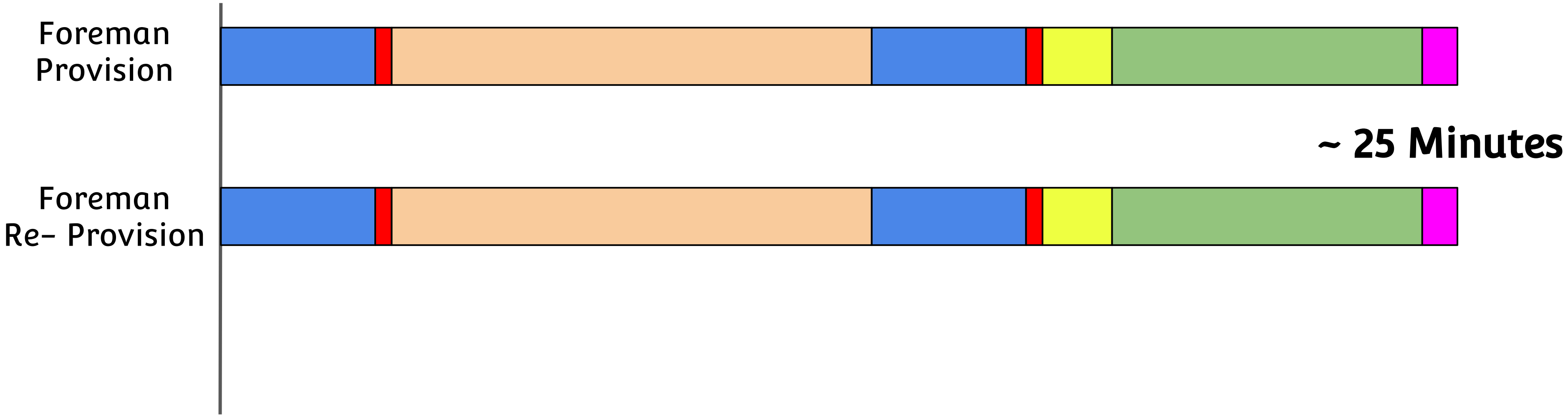

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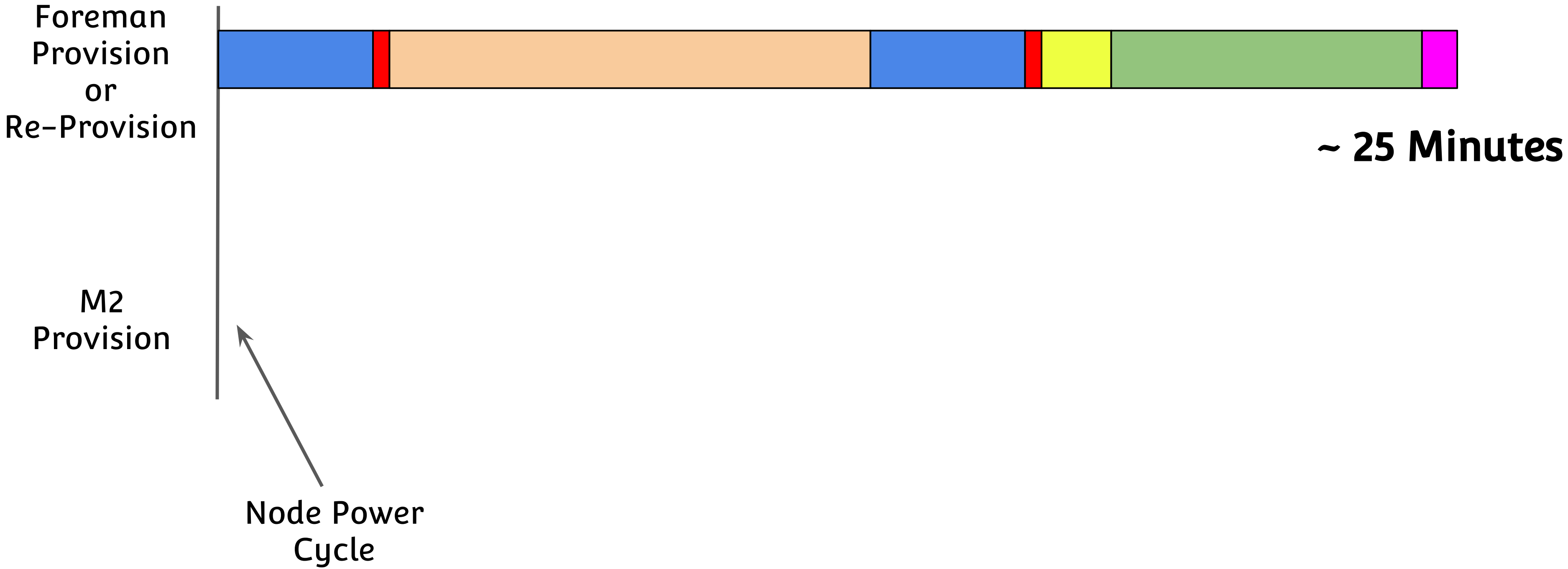

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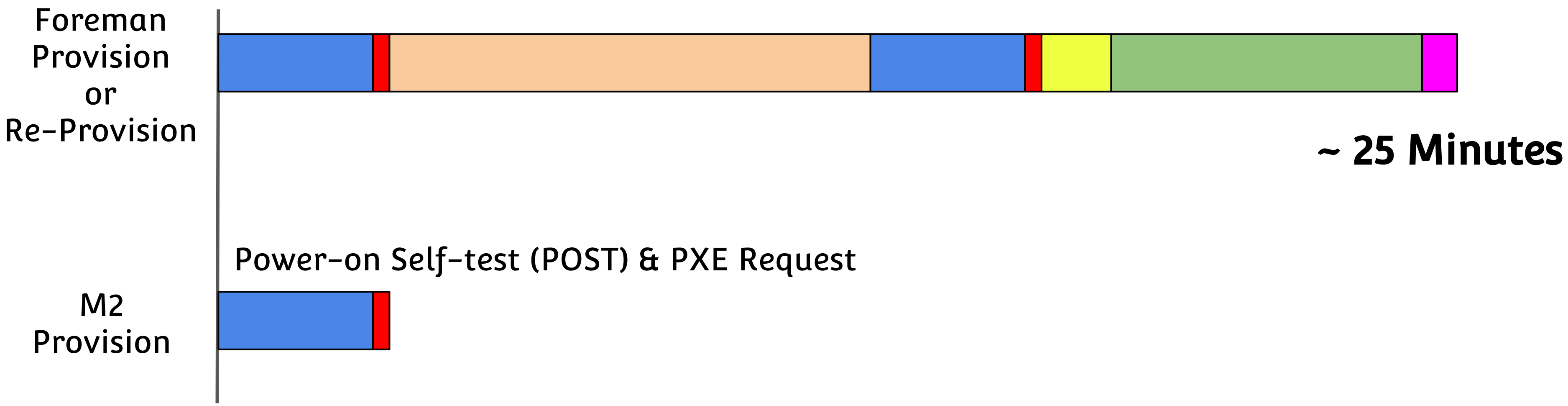

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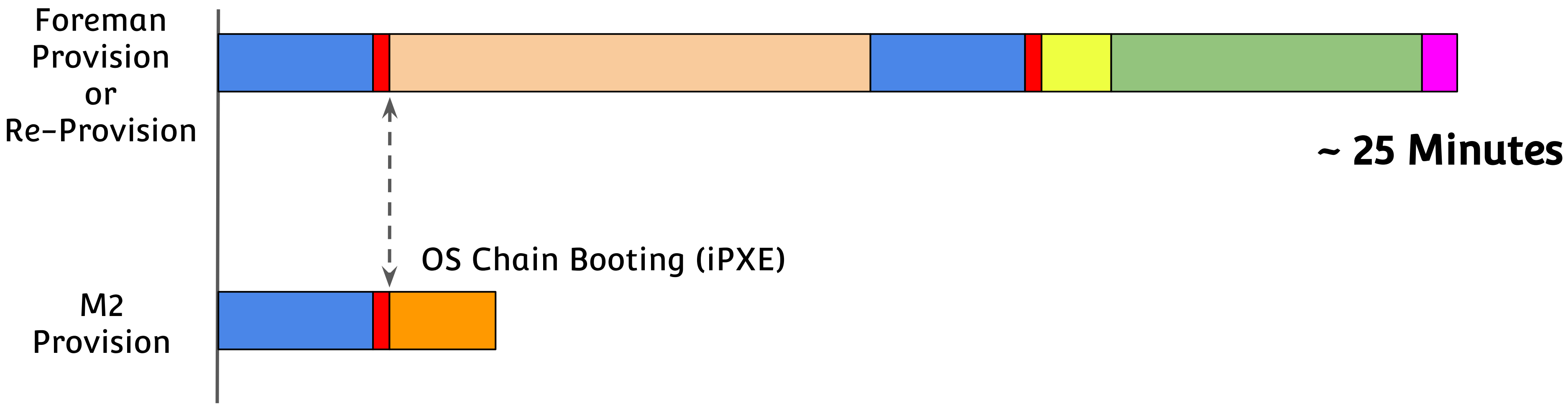

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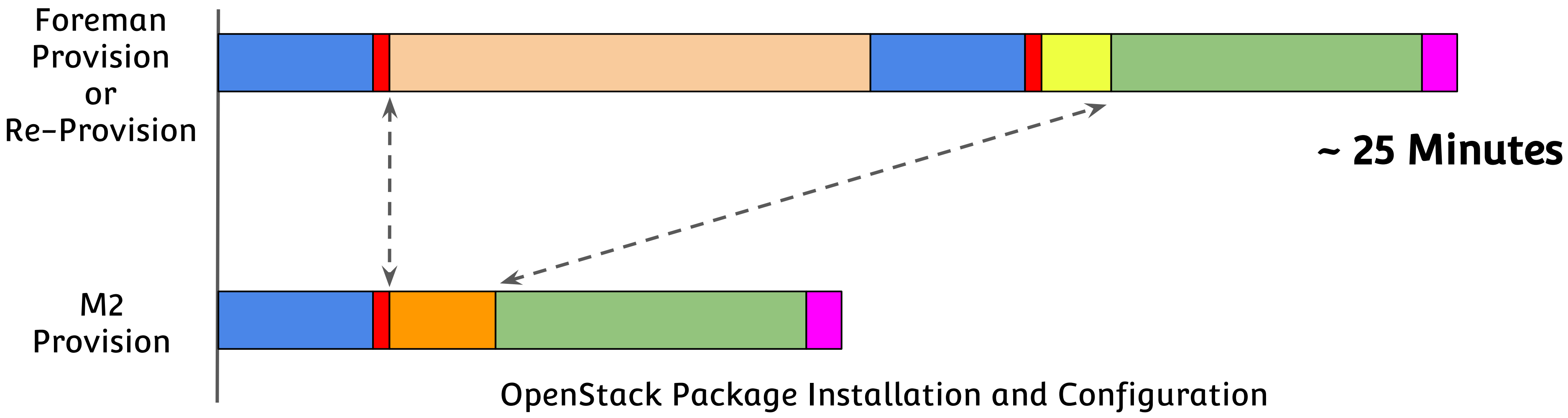

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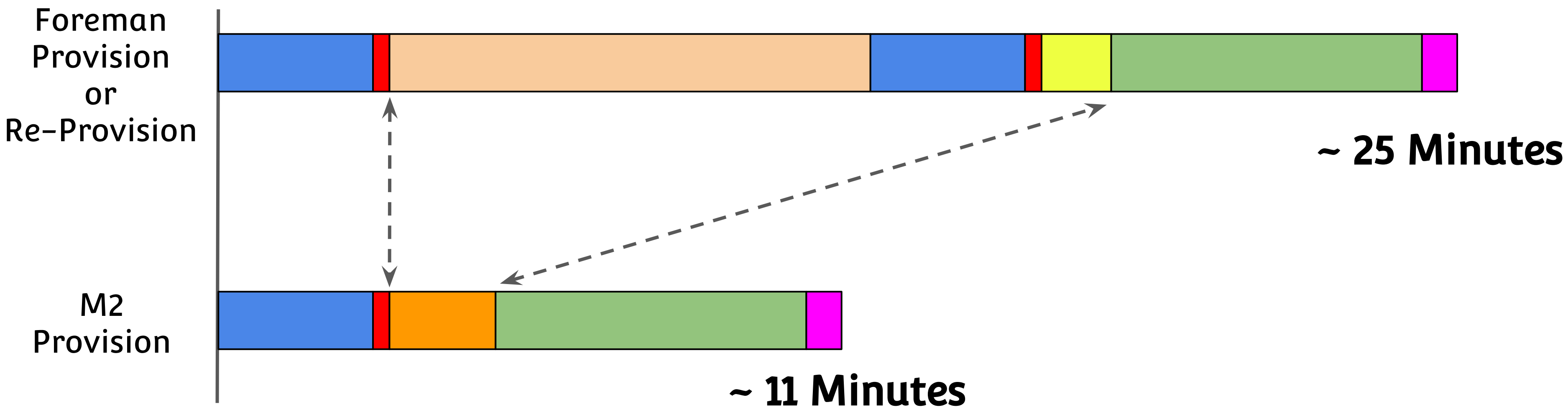

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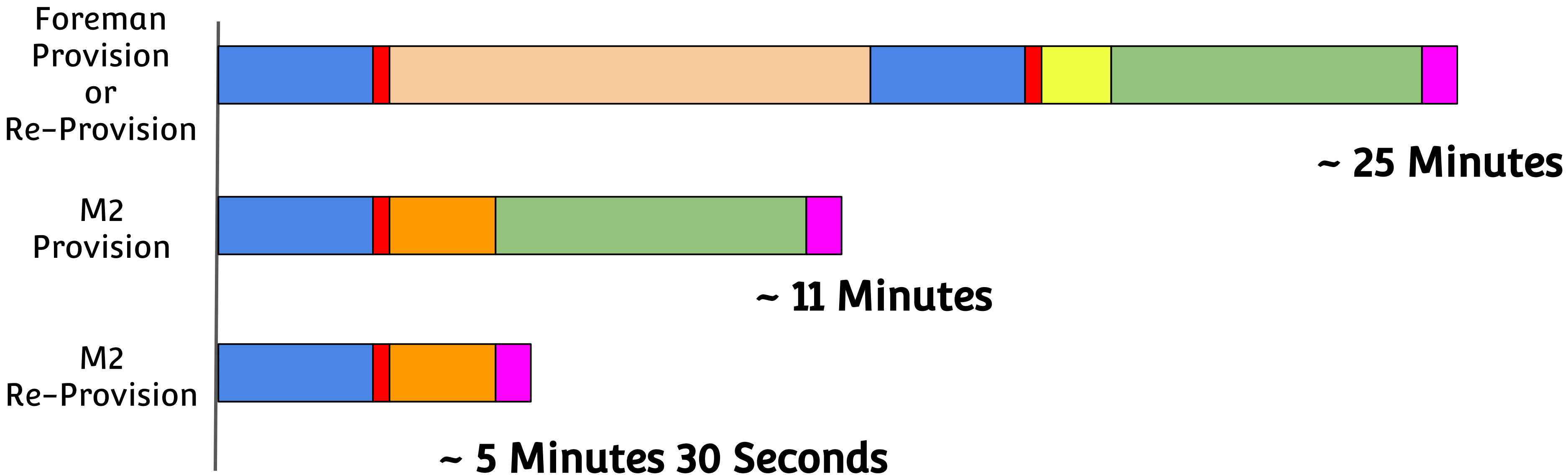

- OpenStack Package Installation overhead removed ( ).

Goal 2: Minimize the cost of moving nodes between clusters.

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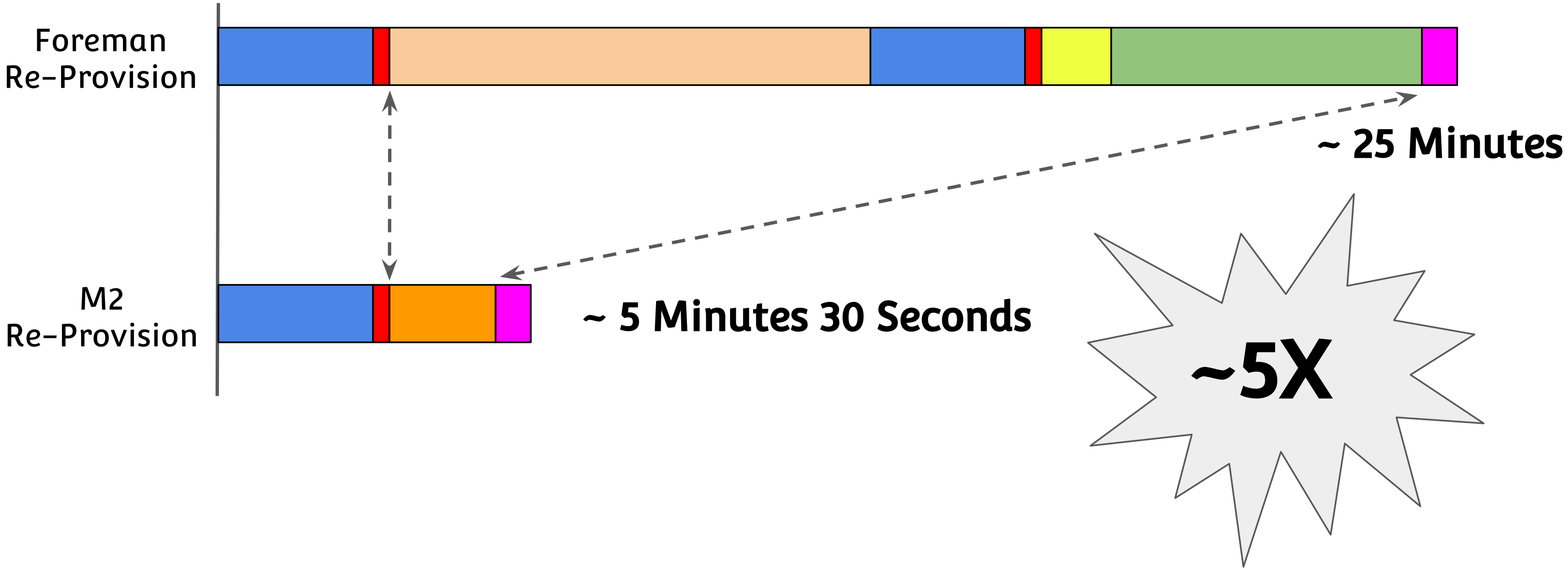

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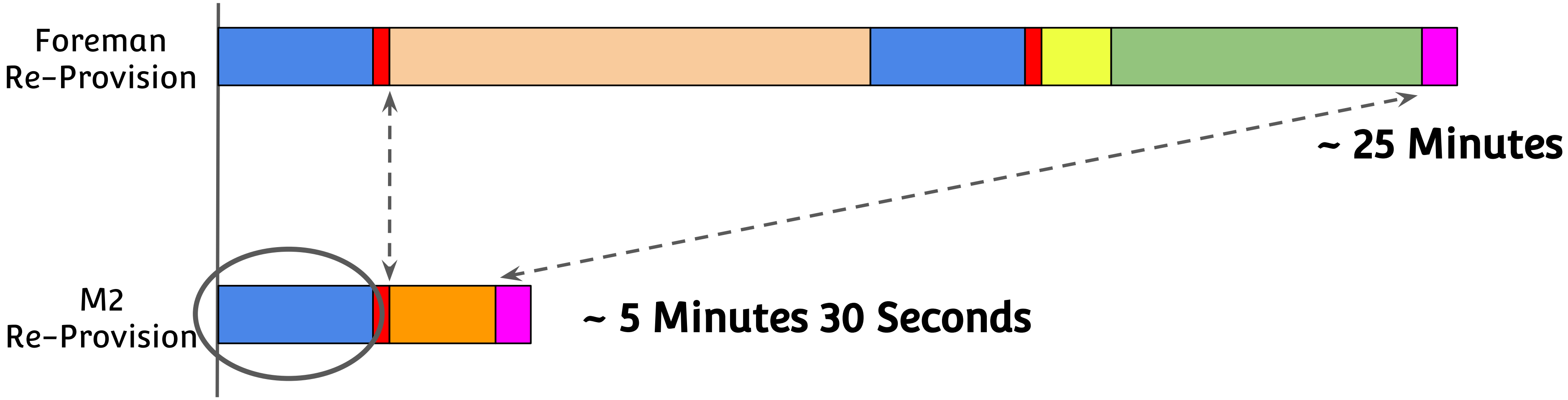


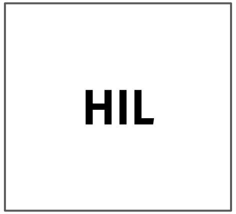
- **M2 Reduces Provisioning/Re-Provisioning Times.**
- **POST ( ) dominates M2 provisioning time.**

M2 Architecture Overview

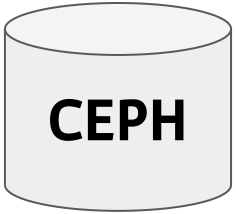
HIL

- ❑ Bare Metal Allocation
- ❑ Network Isolation (layer 2)

M2 Architecture Overview



- ❑ Data Store
- ❑ Pre-Installed Images



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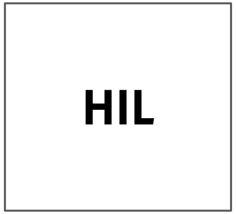
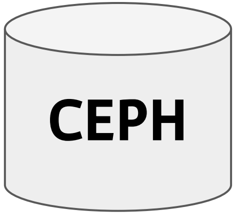
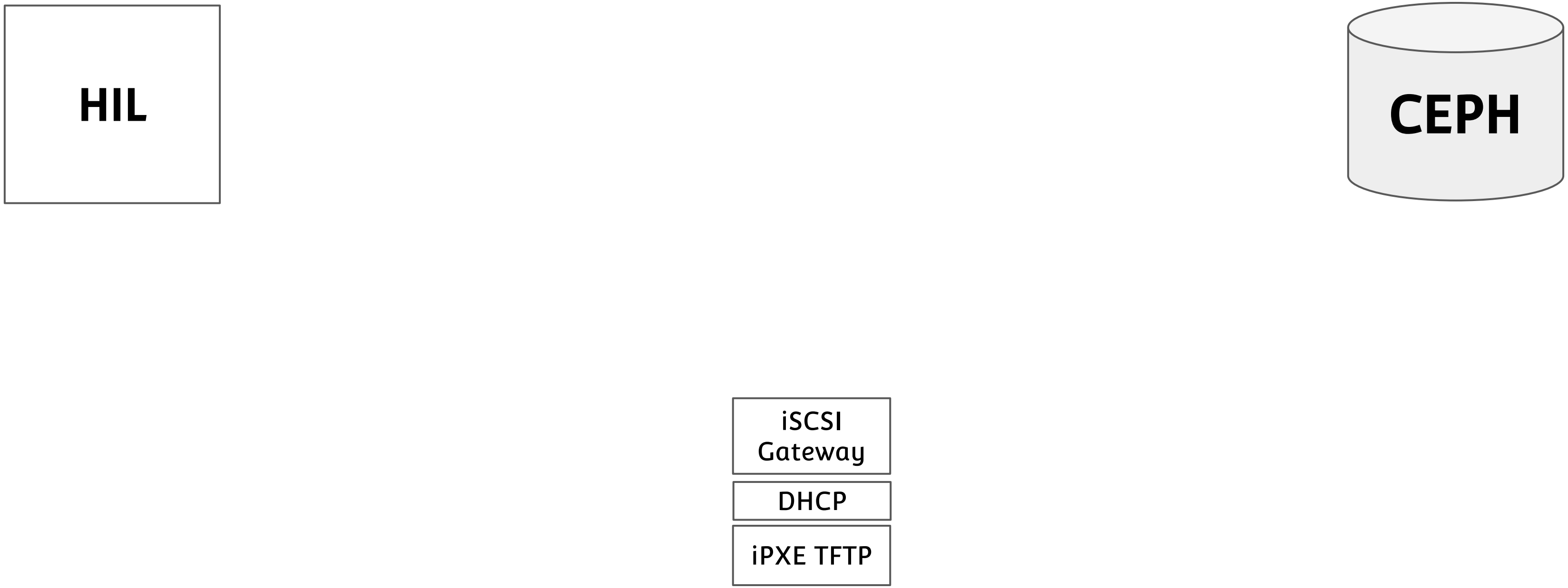




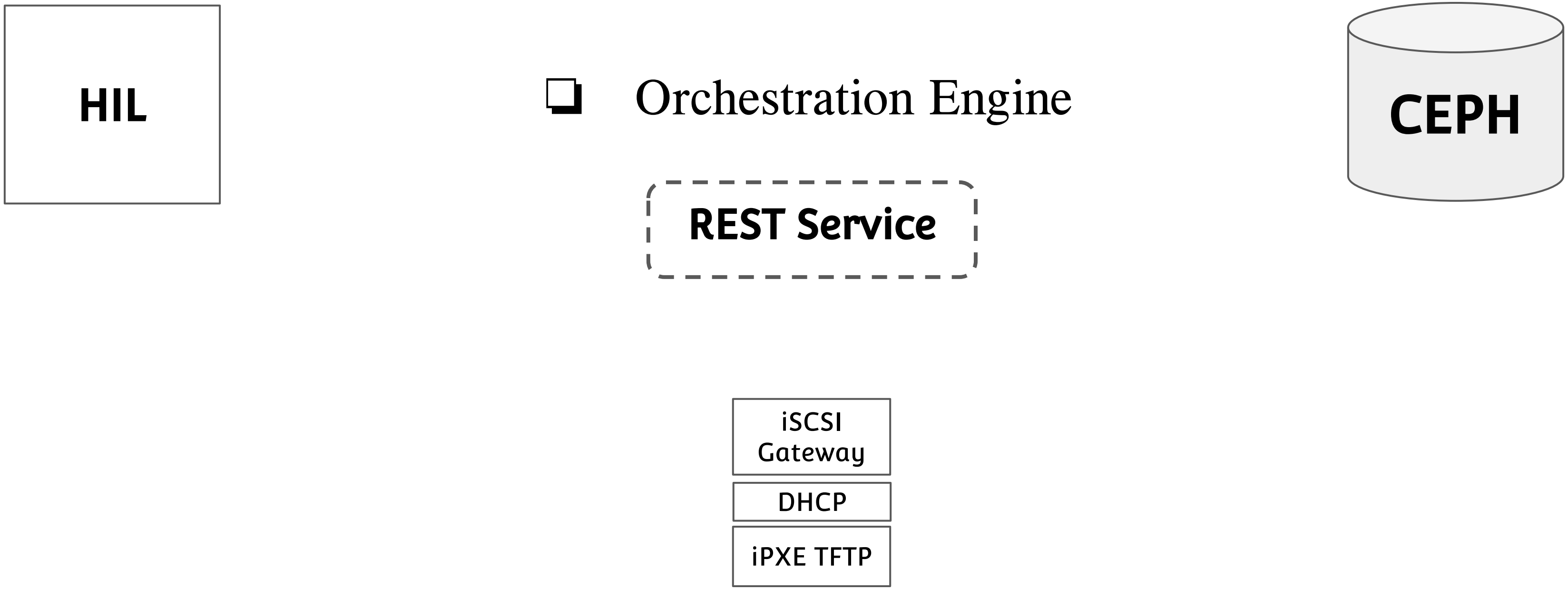
- Software iSCSI Server
- TGT Software iSCSI

M2 Architecture Overview



- ❏ Diskless Booting from iSCSI target

M2 Architecture Overview



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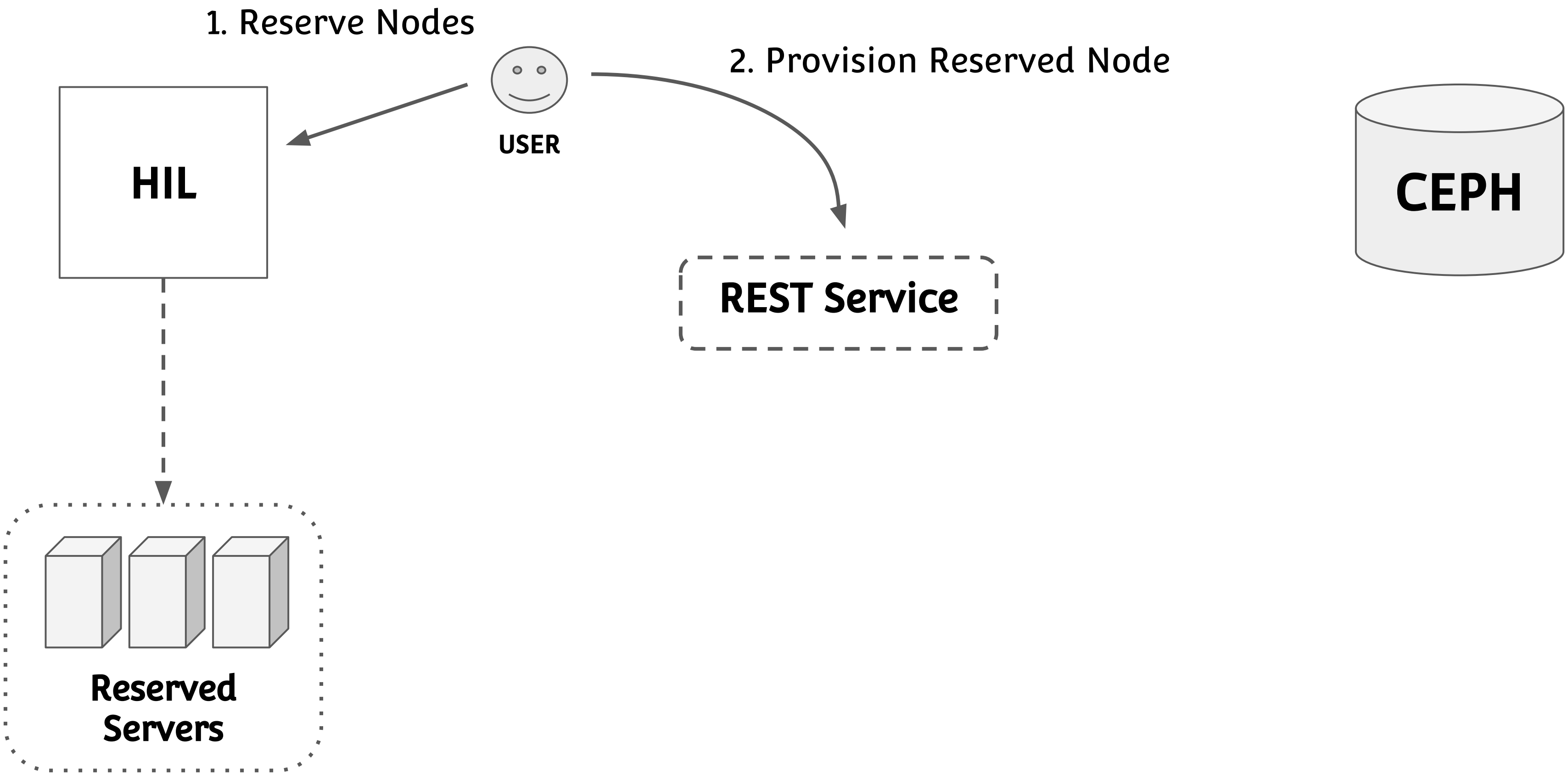

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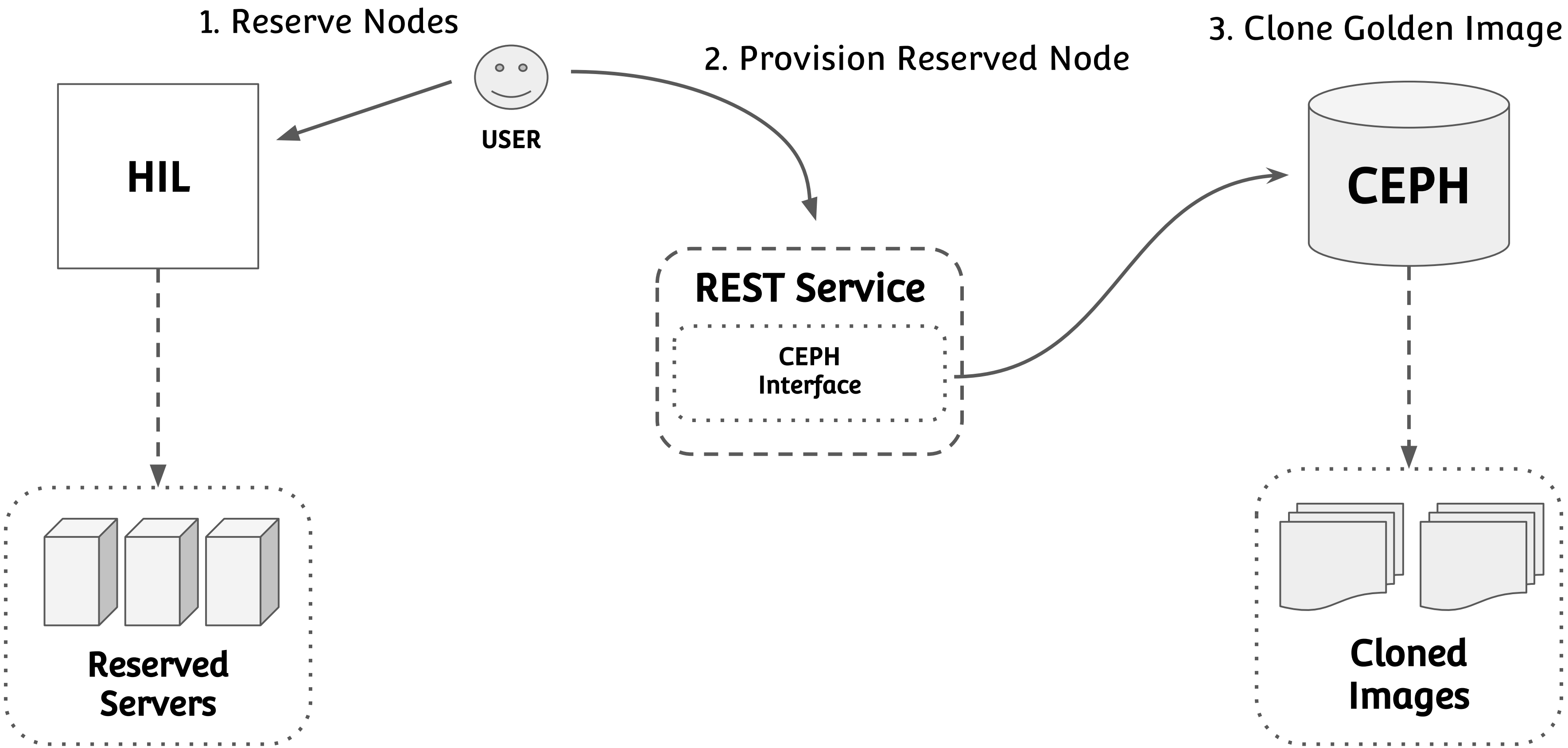

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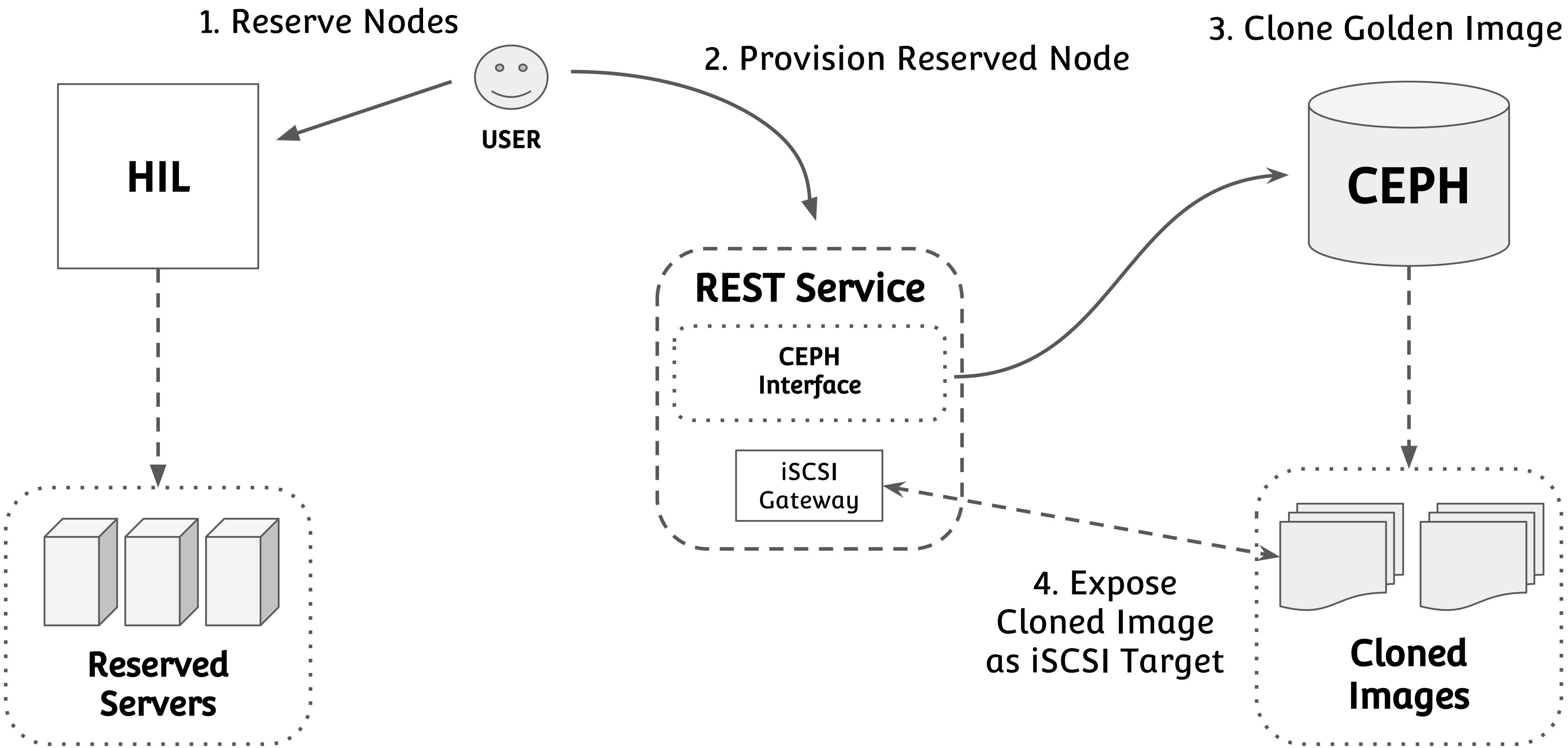

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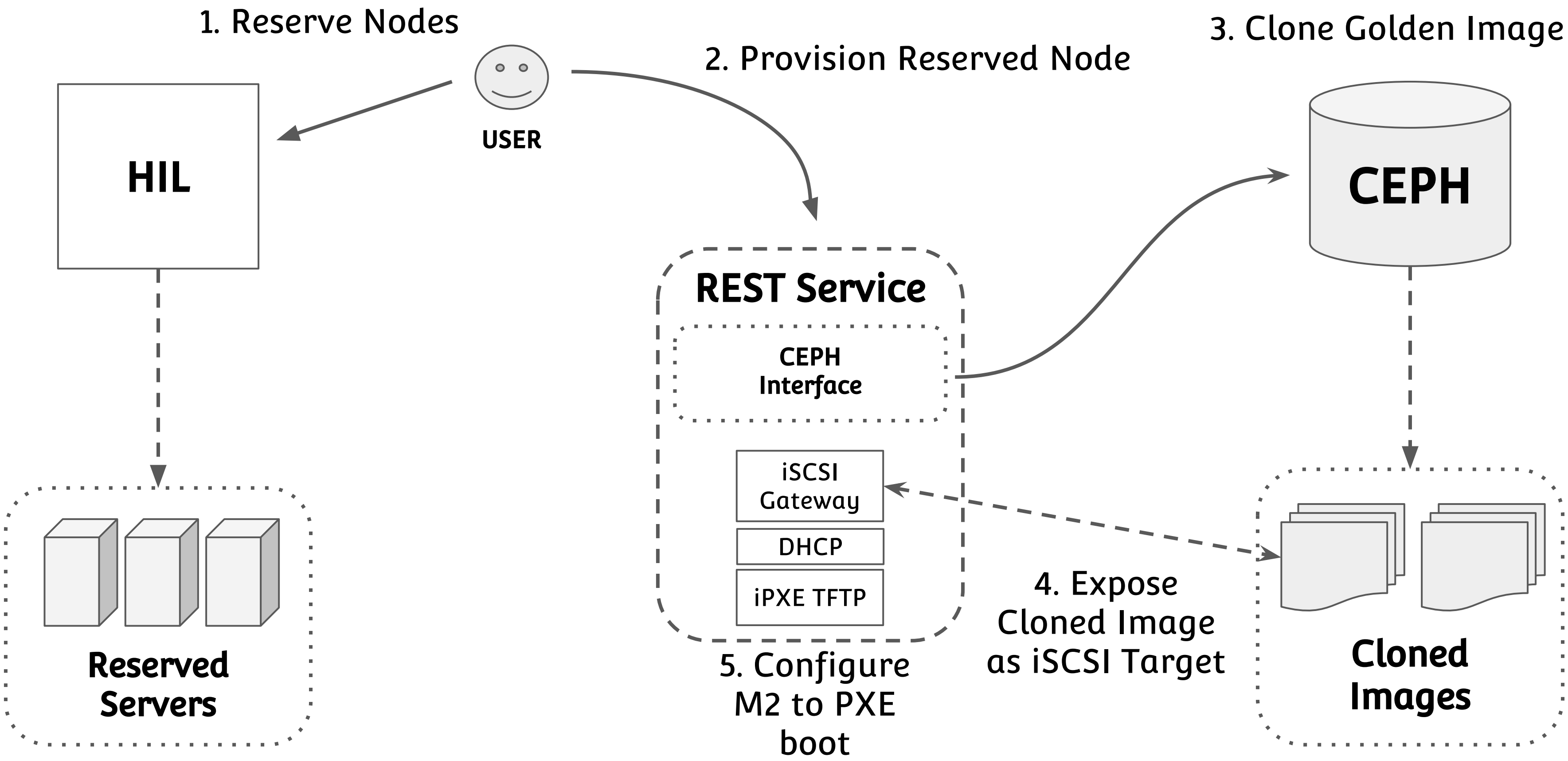

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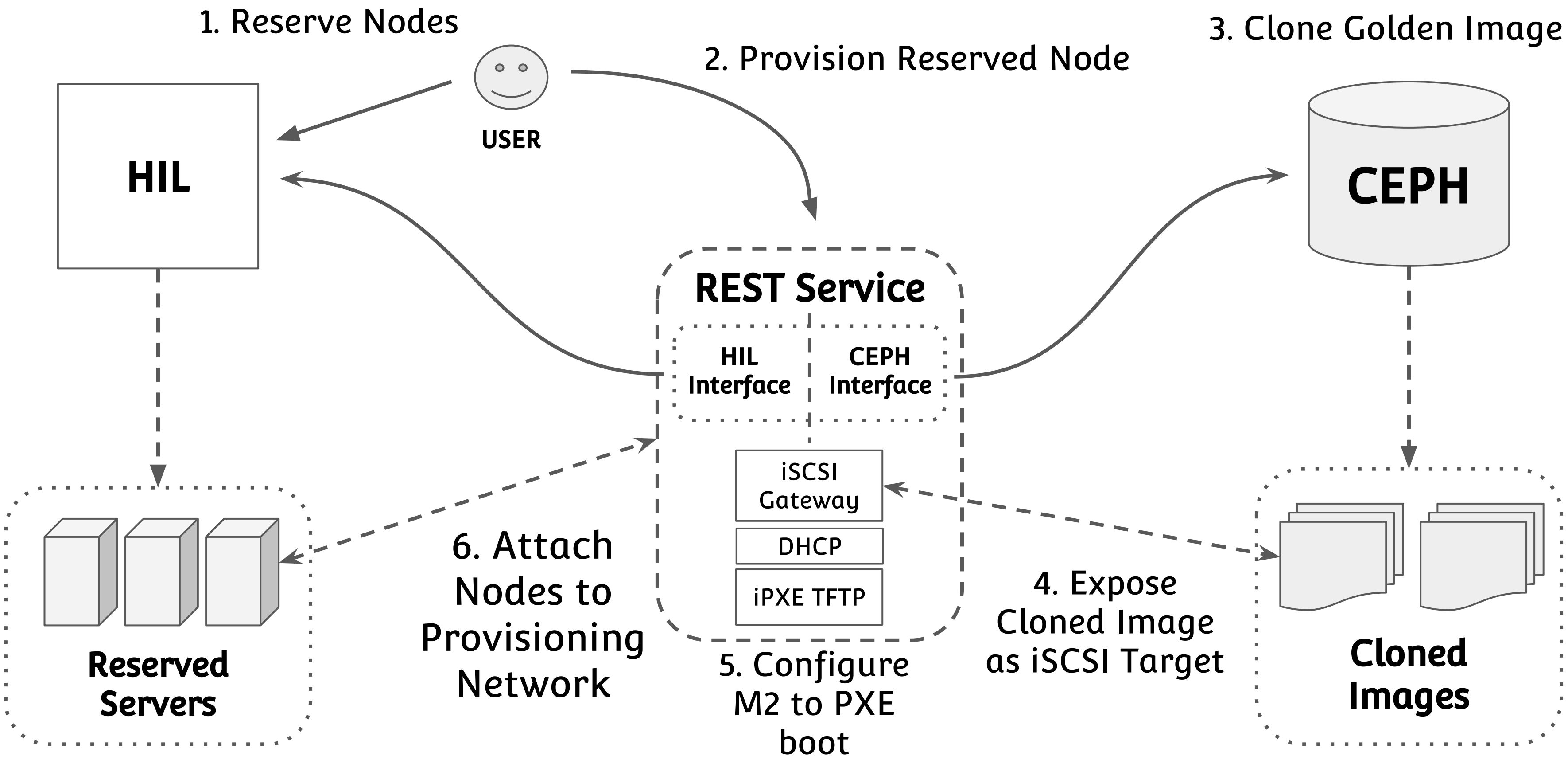

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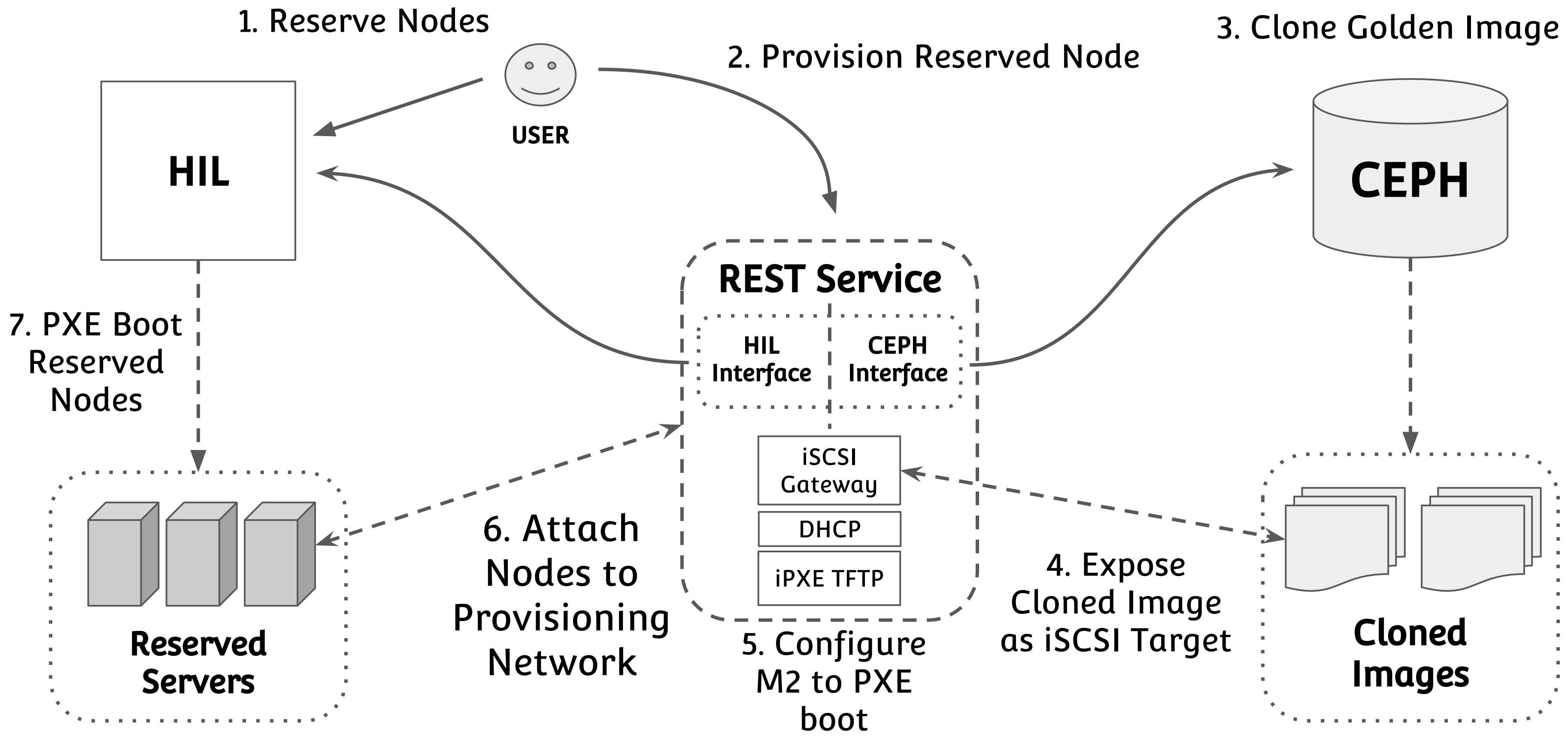

How do we achieve this ?

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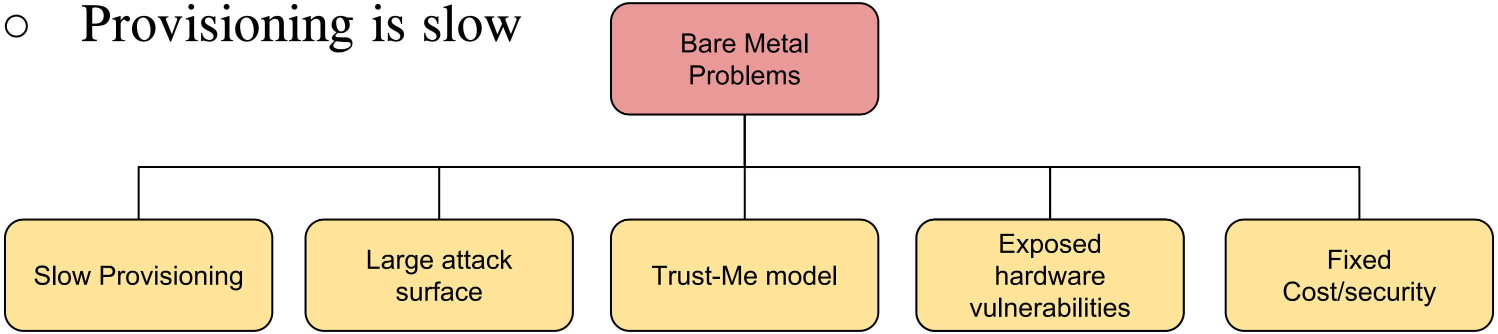
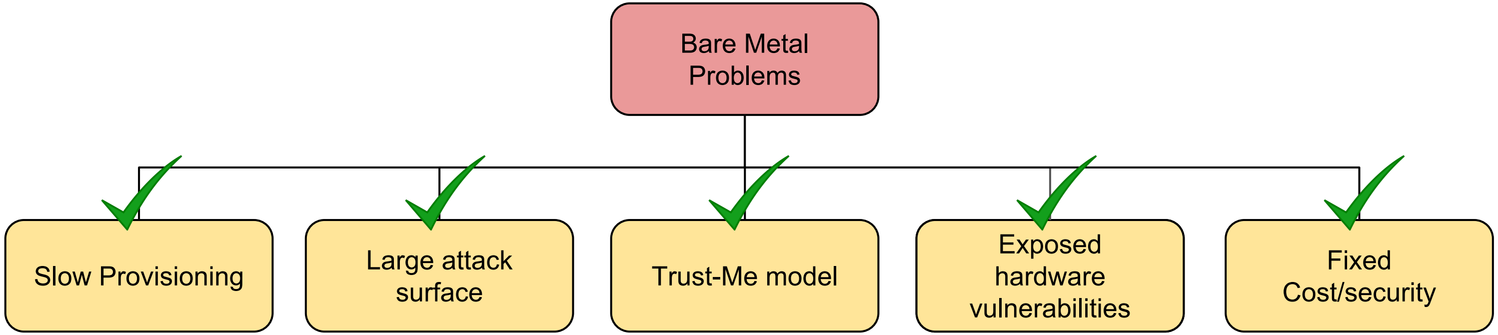
Today's Bare Metal Clouds

- Don't share machines between tenants: no co-location attacks
- However:
  - Large TCB & attack surface
  - "Trust-me" model
  - Fixed security
  - Hardware vulnerabilities is exposed to the tenants: firmware
  - Provisioning is slow



BOLTED: a new architecture for bare metal cloud

- Minimizing trust in the provider
- Supporting even the most security sensitive tenants
- Tenants can make the cost/performance/security tradeoff
- Provisioning time as fast as virtual
- Small Microservices; most can be deployed by tenants and not in TCB



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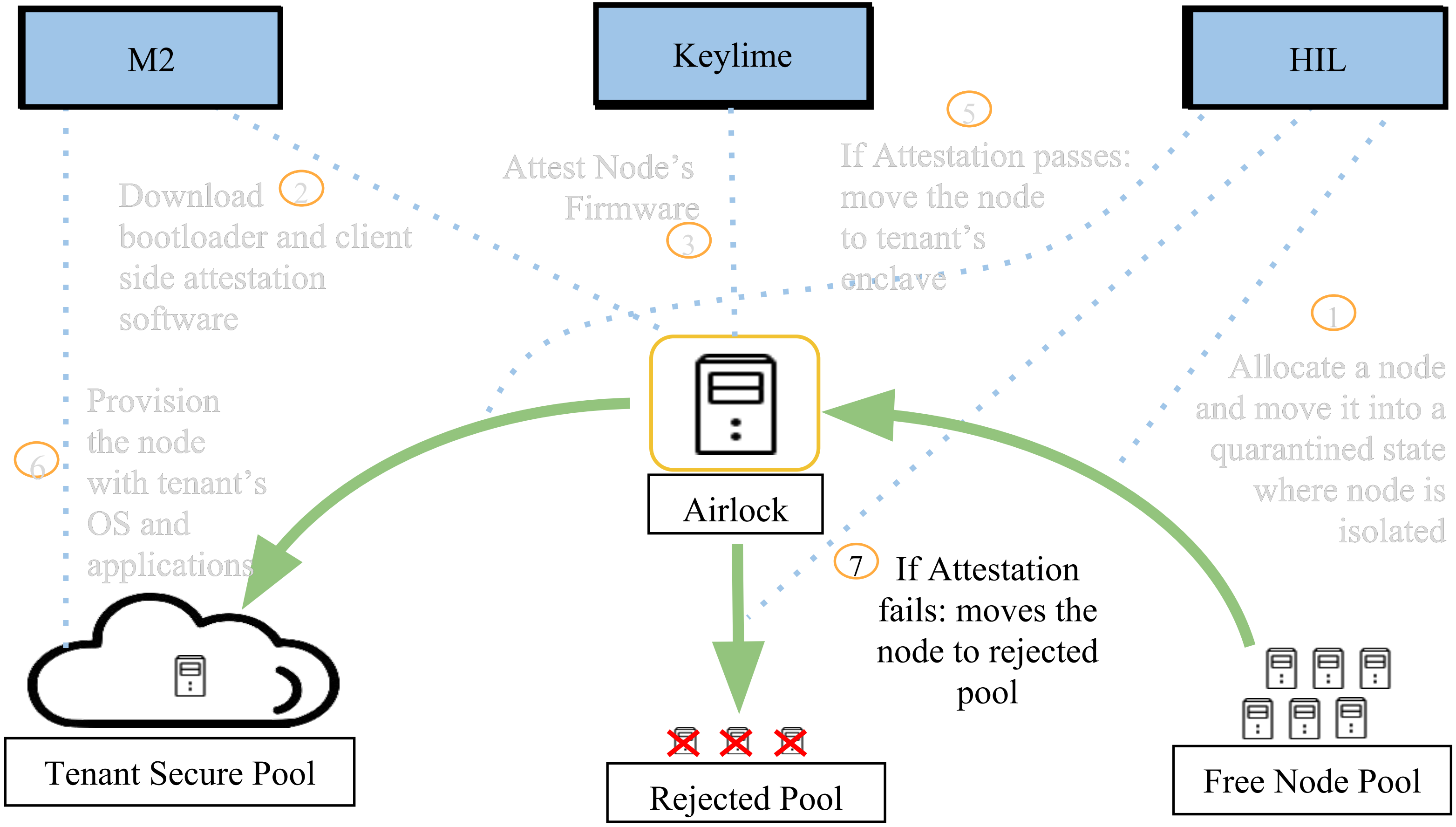
Bolted architecture



How do we attest a node?

- Software hash measurements are stored in TPM
- Attestation client side sends these measurement ro server side
- Attestation server side check them against a whitelist

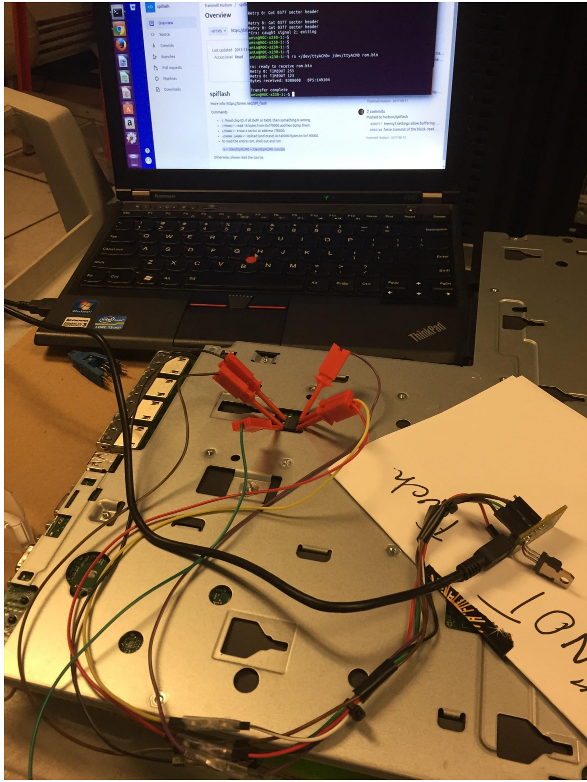
Airlock

What about the firmware?

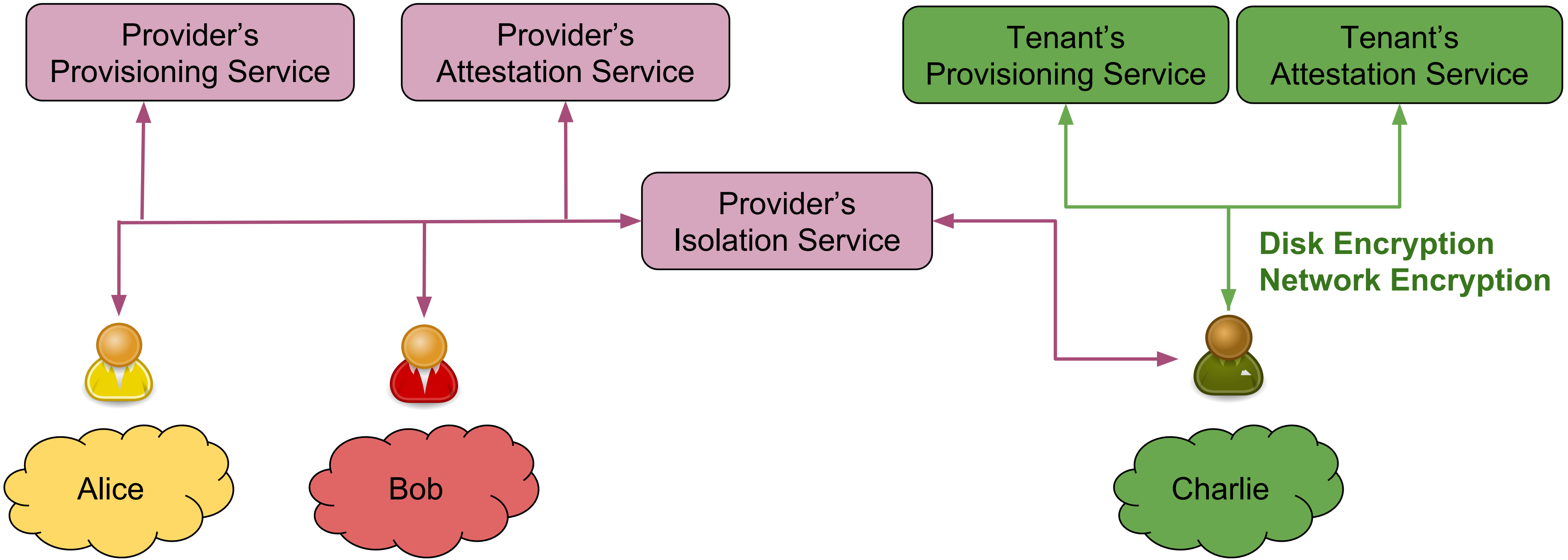
- Legacy BIOS, UEFI, … are huge
  - Vulnerable to attacks;
    potentially enabling tenants to modify FW
  - No way for tenant to inspect FW

- LinuxBoot: A stripped down linux firmware
  - Small, Open source
  - Deterministically built

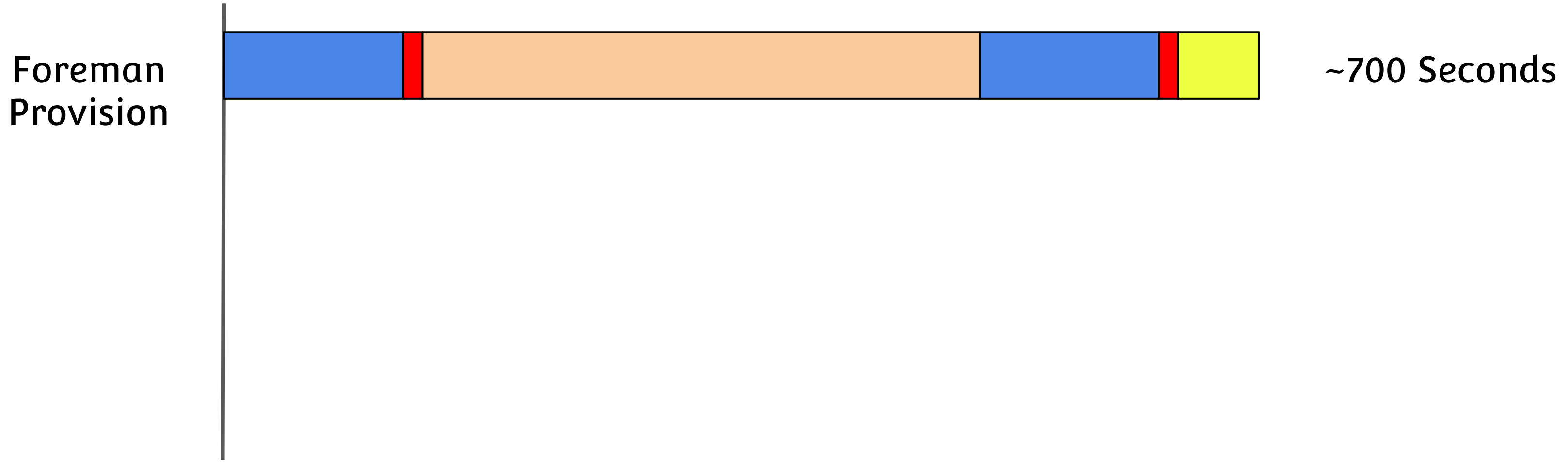
- Bolted works with either UEFI or LinuxBoot



Answering different needs of different tenants



Bolted - Performance/Security tradeoff



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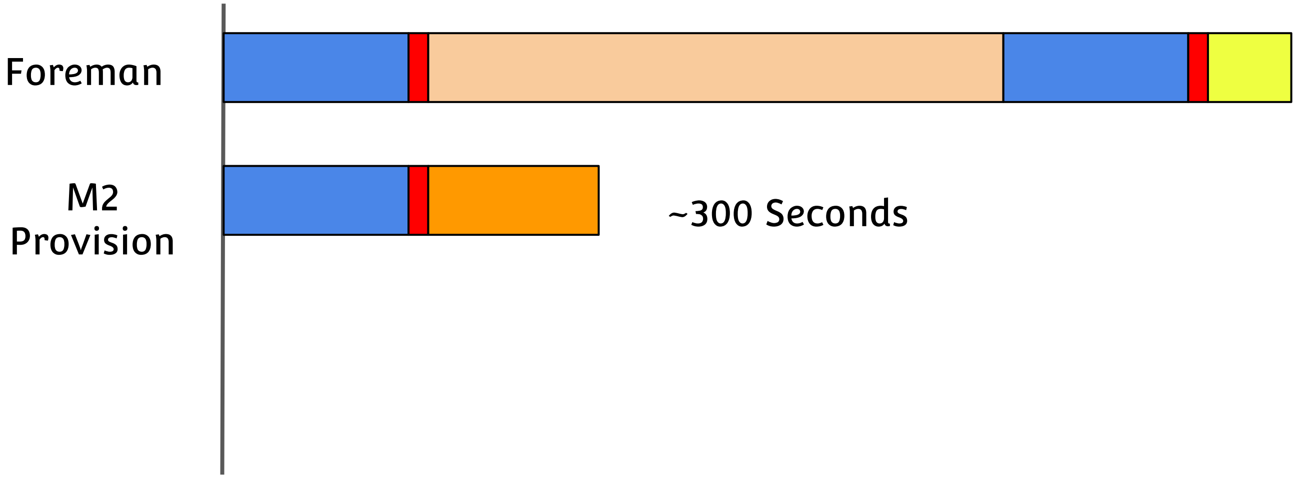

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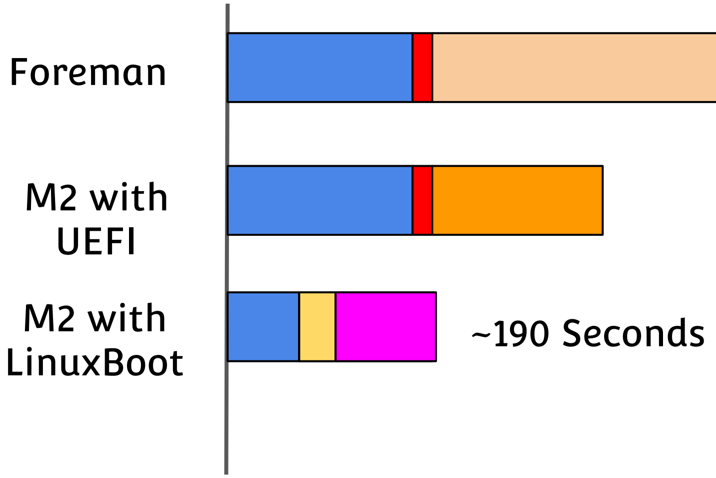

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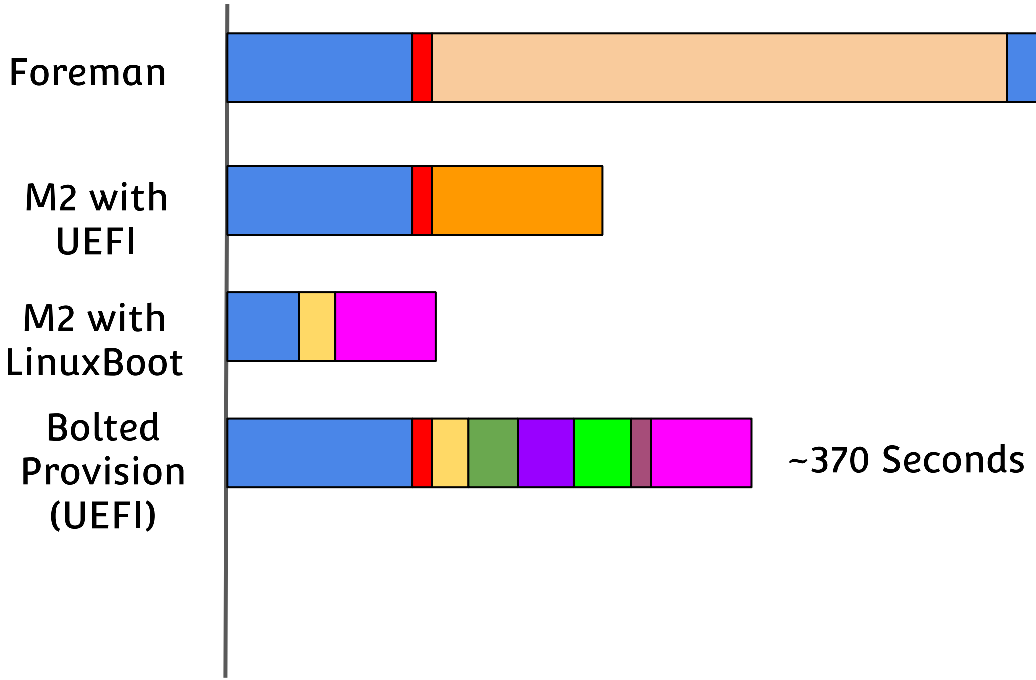

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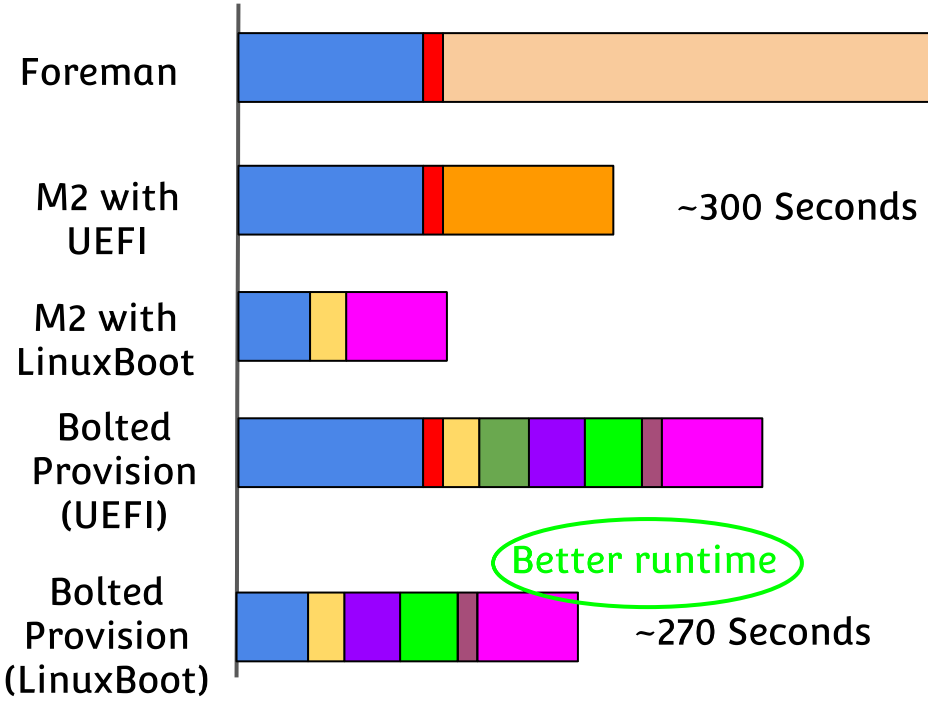

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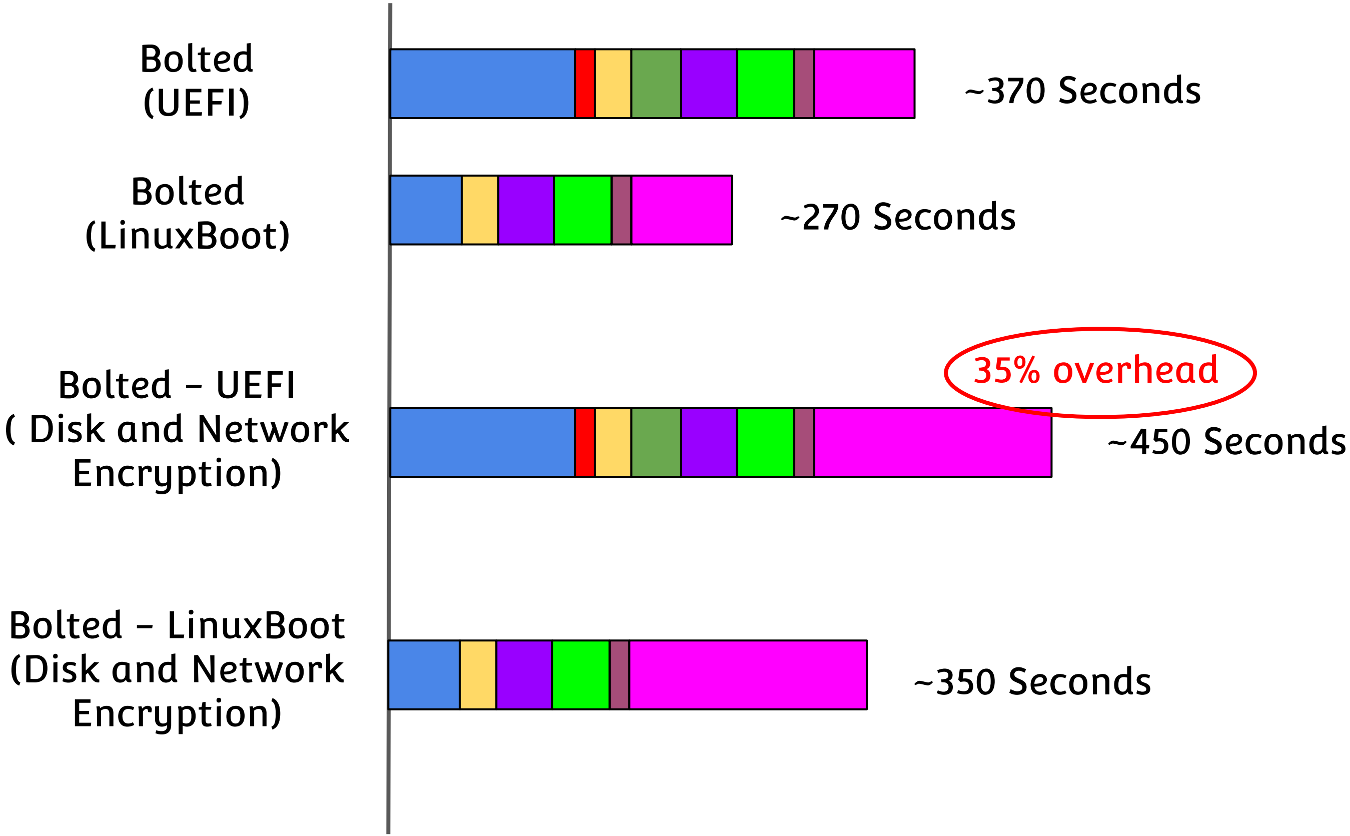
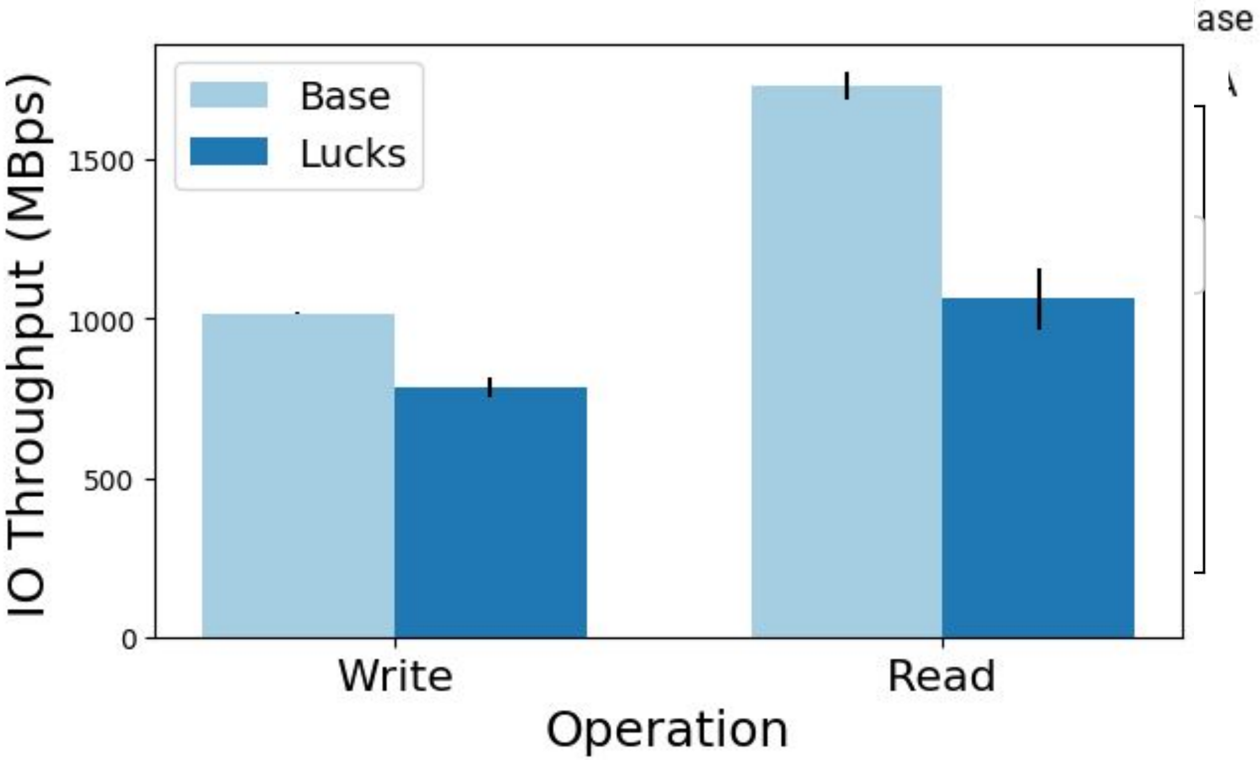
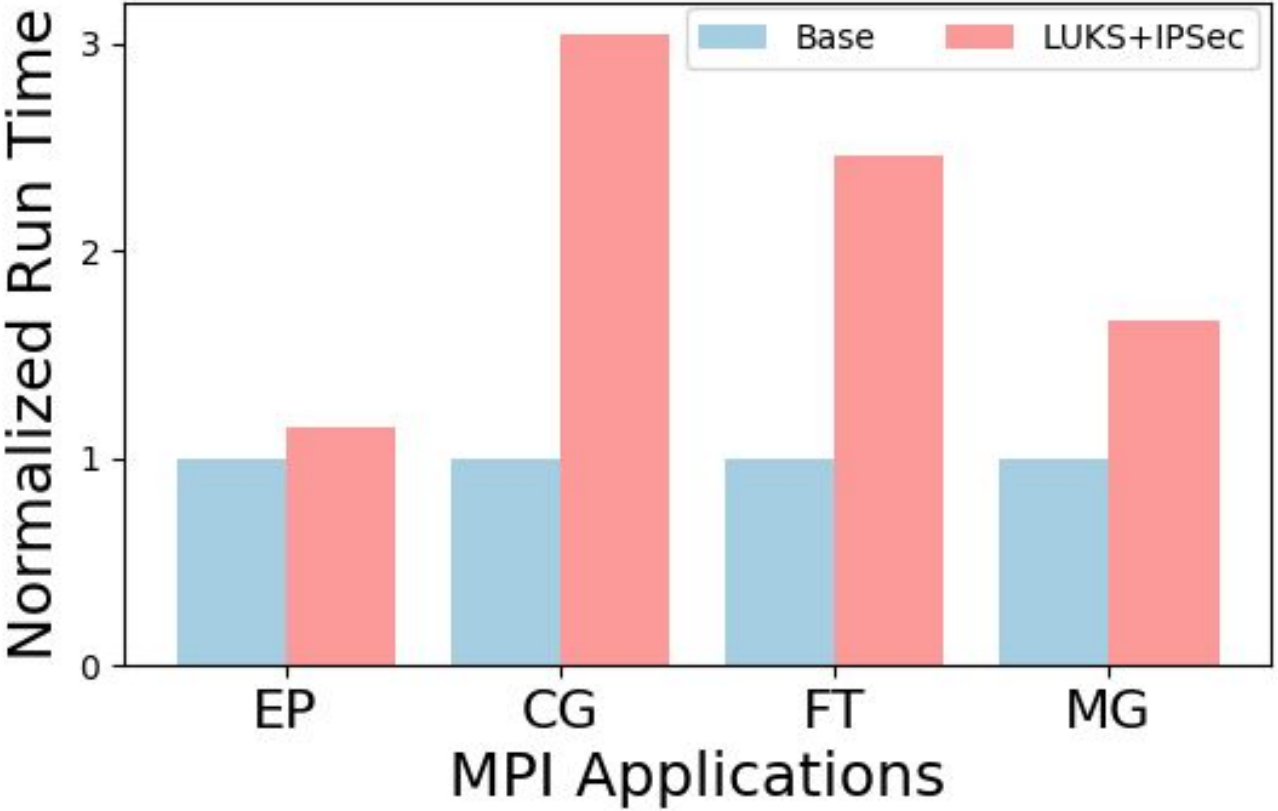


Runtime Overhead: Microbenchmarks



Runtime Overhead: Real World Applications

16 Dell M620 nodes, 64 GB memory, 2 Xeon E5-2650 v2 2.60GHz processors 8 cores



Bolted: A Secure Cloud with Minimal Provider Trust

Putting tenants, rather than the provider, in charge
to choose the tradeoffs between security, price, and performance

“A Secure Cloud with Minimal Provider Trust”, HotCloud’18
“Tenant Controlled Security for Bare Metal Clouds”, submitted to EuroSys’19

How do we achieve this ?

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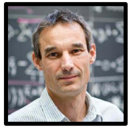
HPC/HTC Cluster

- Unlimited CPU demand.
- Aggregated CPU usage per month
- Happy to share if monthly CPU usage > HPC owned CPUtime

OpenStack Cluster

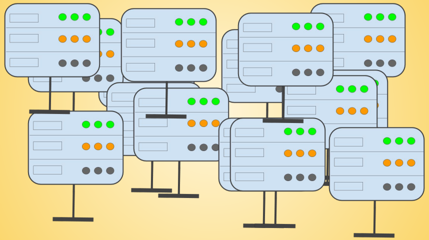
- Interactive demand: Short term peaks.
- Let other use than running idle




OS researchers:
Deterministic Experiments

- Need **"Exact-same-hardware"**
- Willing to share if guaranteed availability "exact-same-hardware" is guaranteed to be available on demand.
- Peak demand : paper deadlines

Common shared pool



Bare Metal Servers

U.S. AIR FORCE

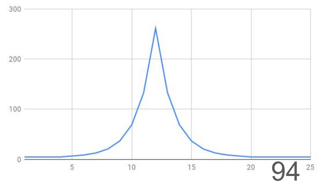
- Dedicated data-centers for National emergencies utilized mostly around 2%
- Willing to share if they can use the shared pool to ramp up their systems in during emergencies.

HIPAA Complaint Clusters

- Tedious and time consuming to built
- Utilization < 1%
- Willing to share if compliant hardware available when required.

Scalability Lab @ Red Hat

- High volume demand: 1000s of servers
- Predictable cyclical demands.



Requirements

How do we satisfy all these divergent needs ?

- Access to hardware you own whenever you want.
- Ability to reserve nodes for future use.
- Ability to request and offer specific hardware.
- Strong incentive to give up nodes when
  - You do not need them
  - Or someone else needs them more than you do.

Solution: Marketplace with an underlying economic model

Towards a Simple Marketplace: First-Steps

Assumptions:

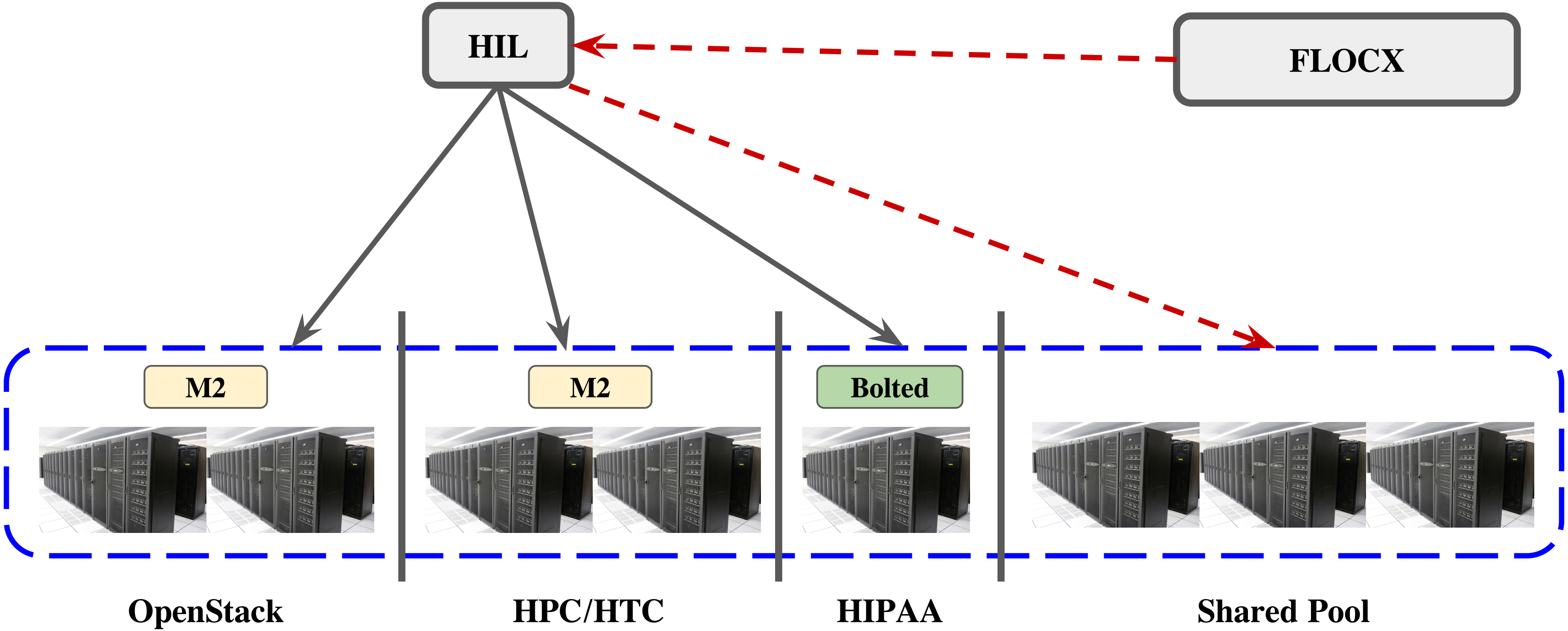
- Homogeneous pools of Bare-Metal Servers
- Marketplace Tracks of Tenant Credits and Server Ownership

Incentivization:

- Tenants Accrue Credits when Other Tenants Lease their Servers
- Expend Credits to Lease Servers
- Price High $\Rightarrow$ Release Servers

Goal 4: A system to incentivize sharing of bare-metal servers.

FLOCX: Marketplace for Bare-Metal Servers



Future Features

- **Bids:** Requesting hardware at desired asking price-range
- **Offers:** Complex time intervals for sharing idle nodes
- **Advanced Reservation System:** Ability to make reservations in future
- **Dynamic Pricing:** Prices reflecting demand and supply fluctuations

Agent-Based Trading

- Initially human bid/offer resources in the FLOCX
- Consequently, develop agents for automated trading
  - Exemplary agents for HPC and OpenStack
  - HPC Agent: maximize CPUtime
  - OpenStack Agent: maximize revenue

Future Directions

- Integrate these services in all the clusters at MGHPCC.
- Scaling and Productizing:
  - Increase open source community support.
  - Improve robustness for each service.
- Formalizing the security guarantees from hardware isolation using the Universally Composable (UC) security framework.
- Expanding the attestation workflow to include all firmwares.
- Integration of extra layers of encryptions for additional compliance regimes.
- Enable Organization to Deploy and Manage agents for automatic trading of resources.

Questions / Feedback

Elastic Secure Marketplace for Trading Bare-metal Servers

where sharing (servers) is always good !!

Thank You