

# Beyond the Clouds, the DISCOVERY Initiative



Credits: NASA

Localization is a key element to deliver  
**efficient** as well as sustainable Utility Computing Solutions



Adrien Lèbre / Ascola Project Team  
Orange Labs - High Performance Cloud & Big Data - May 23, 2013

# xxx Computing

- Meta / Cluster / Grid / Desktop / “Hive” / Cloud / Sky ...
- A common objective: provide computing resources (both hardware and software) in a flexible, transparent, secure, reliable, ... way

⇒ xxx as Utility Computing

- Challenges

Software/Hardware heterogeneity

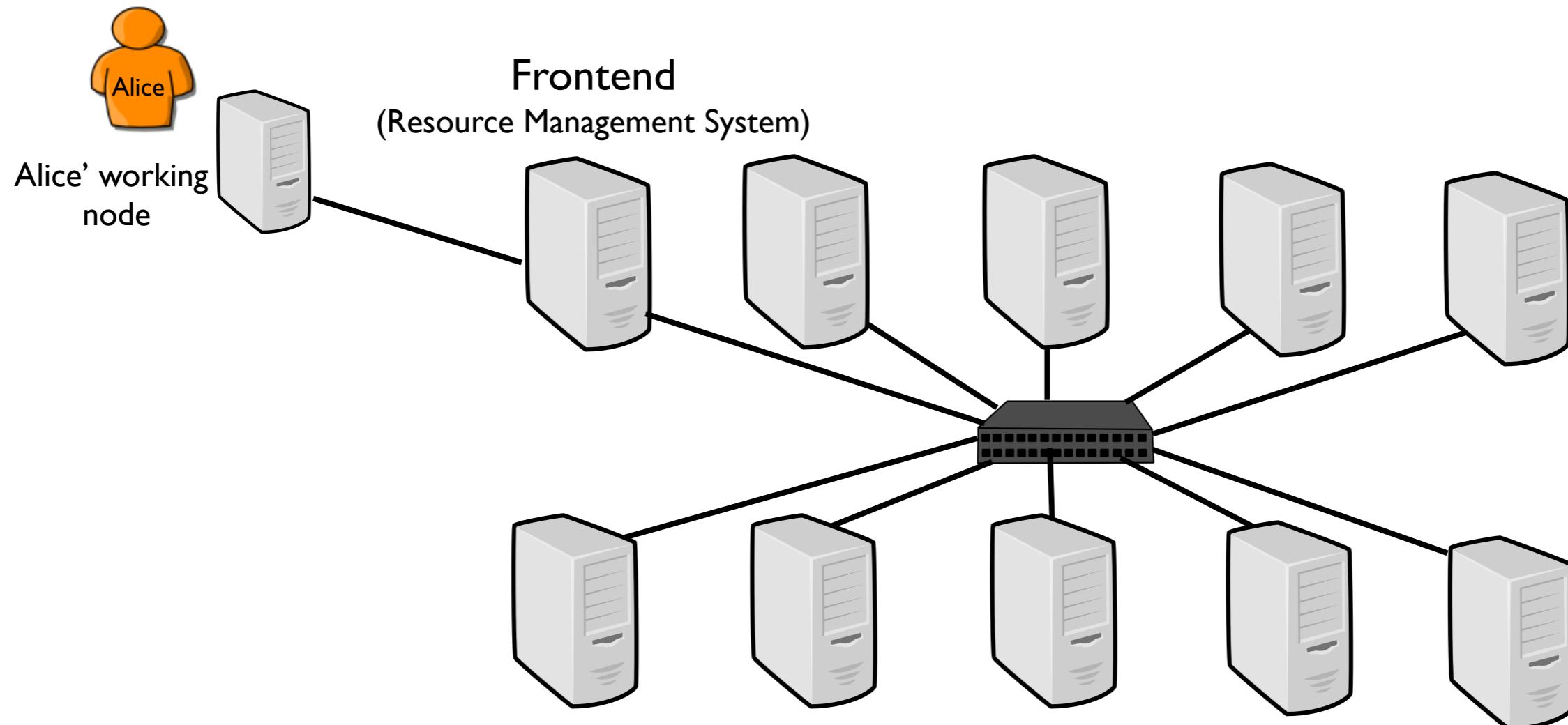
Security (Isolation between applications, ...)

Reliability / Resiliency

**Data Sharing** ...

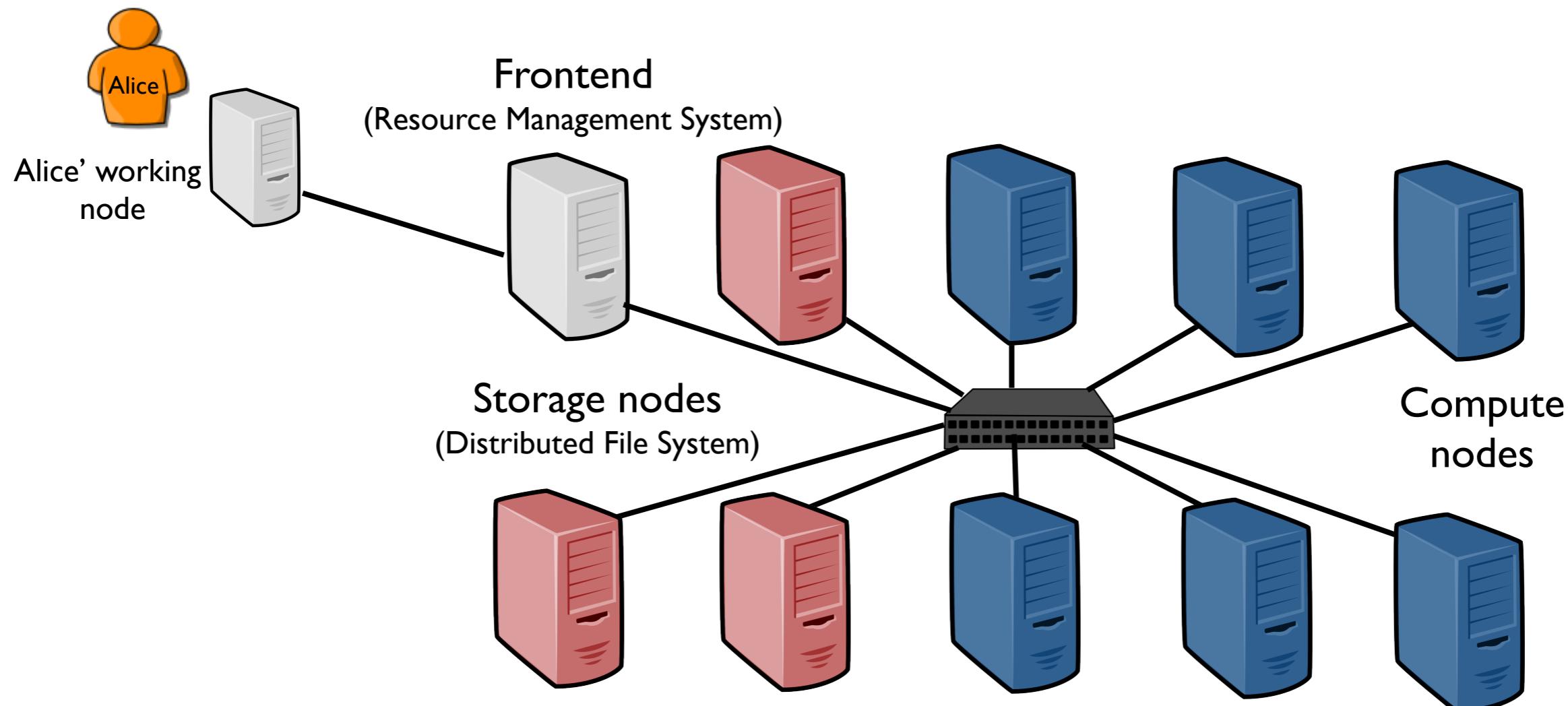
# Utility Computing and Data Management

- Network of Workstations 1990 / 20XX



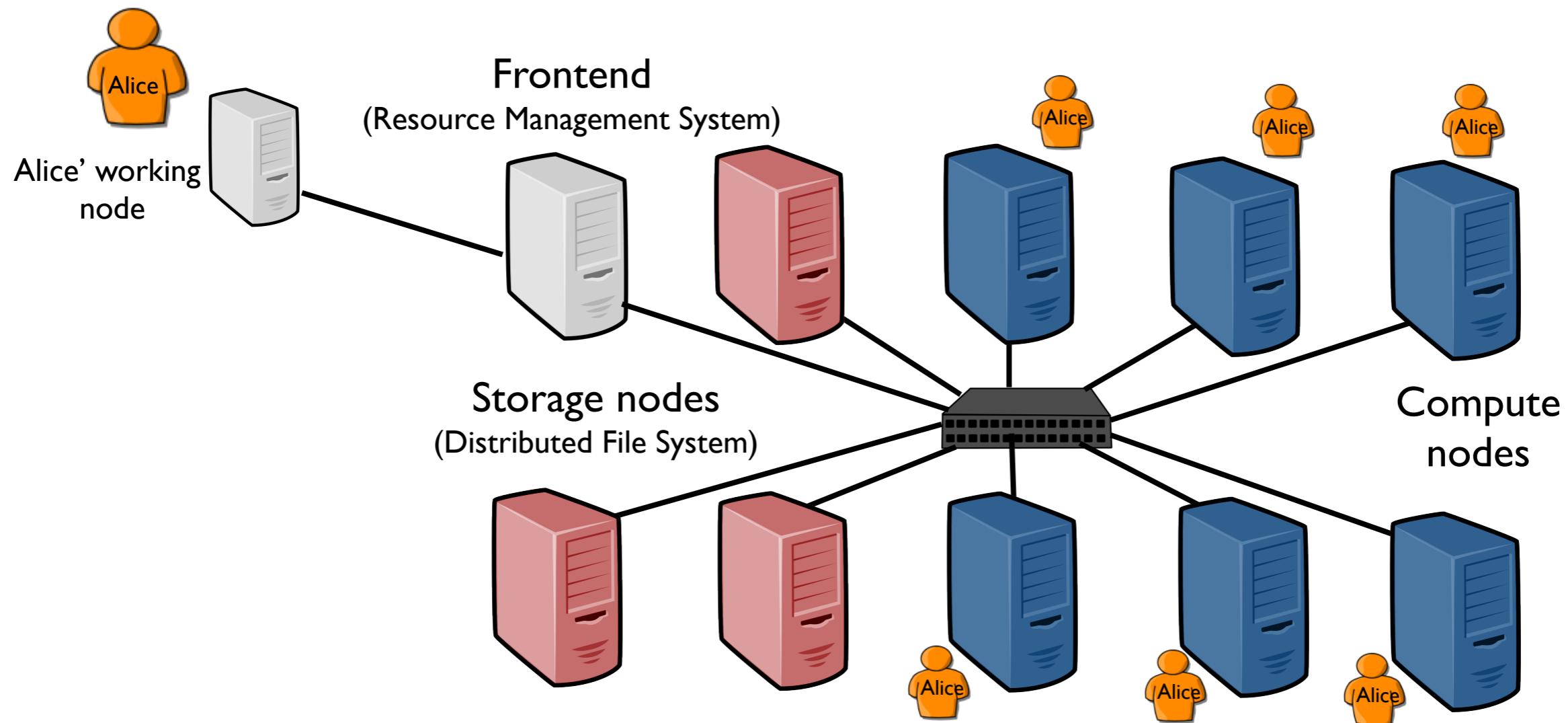
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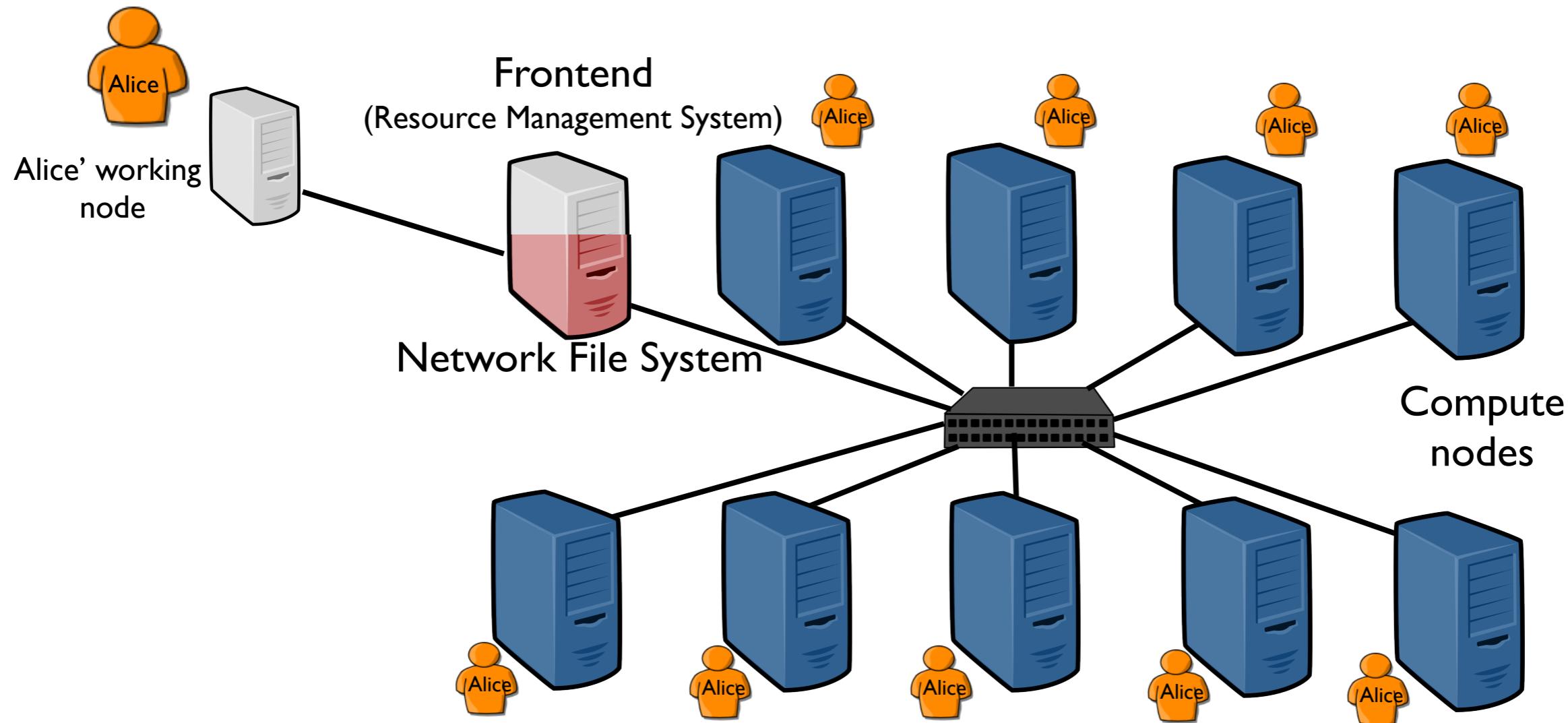
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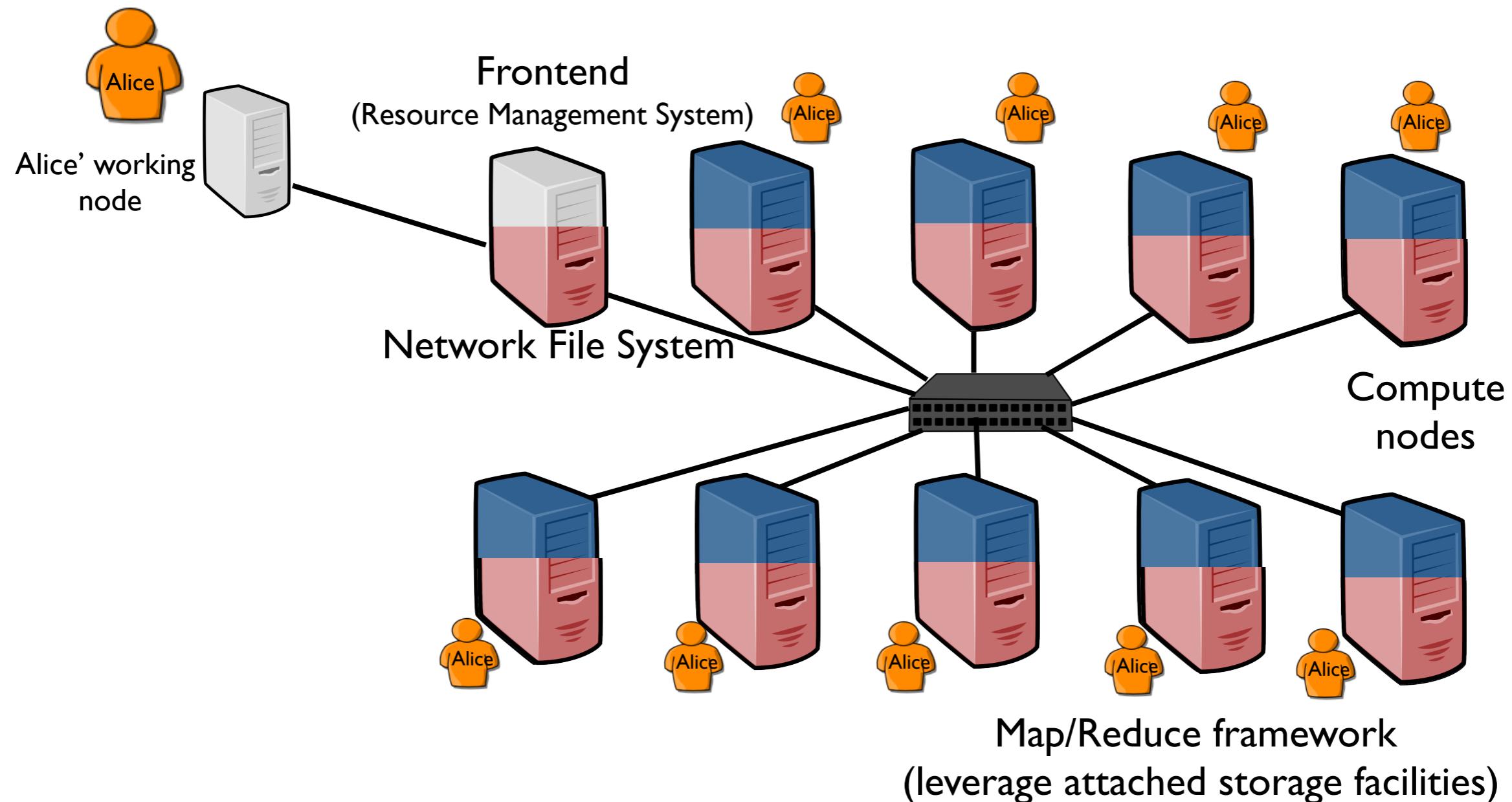
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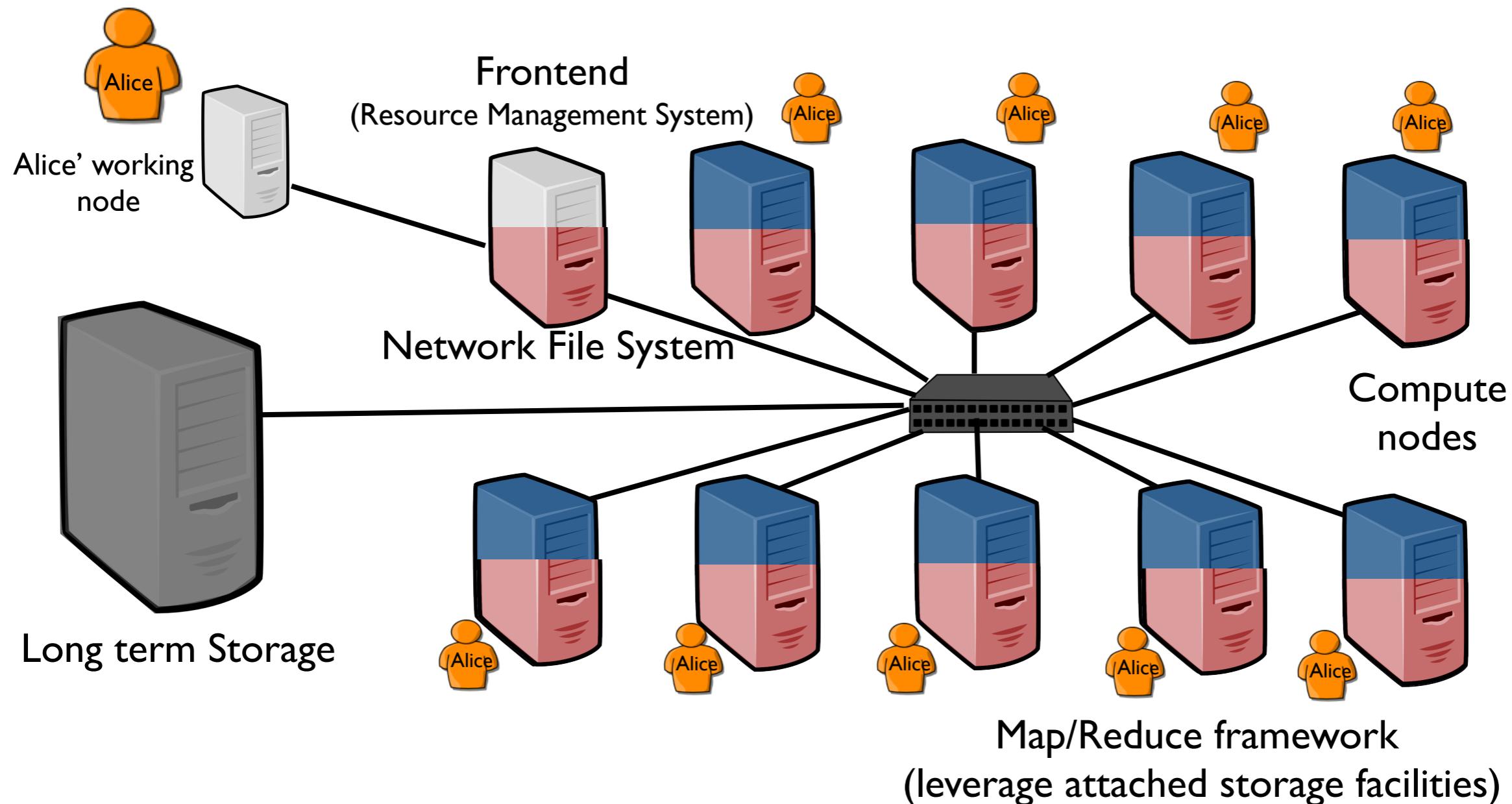
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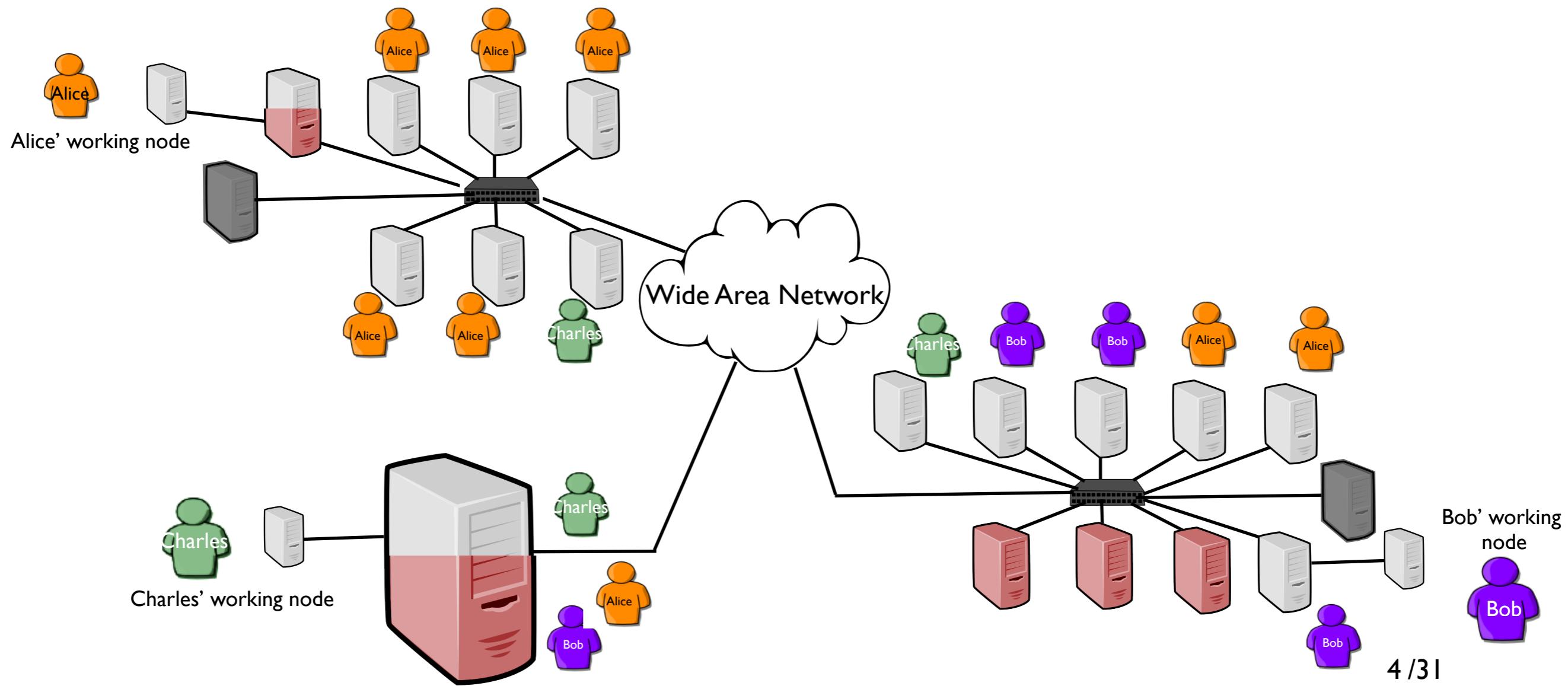
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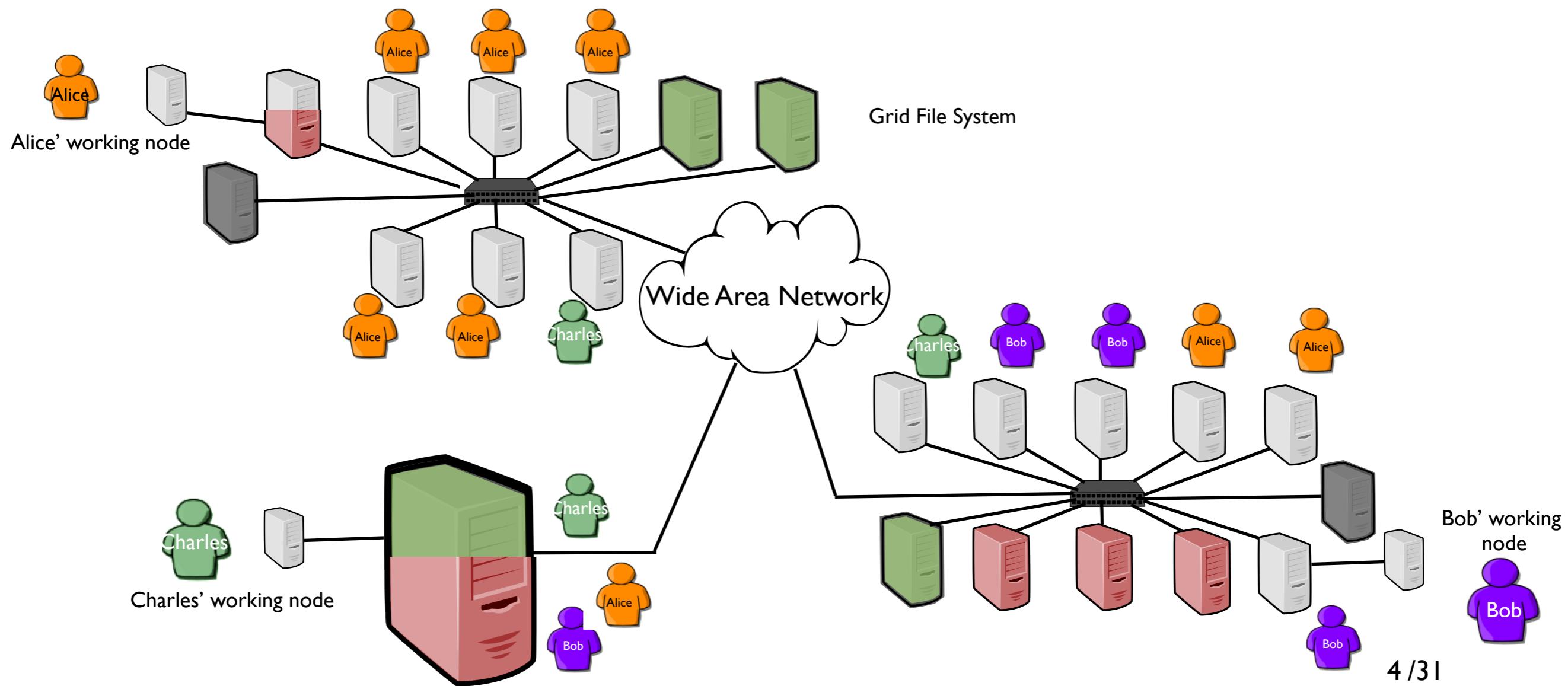
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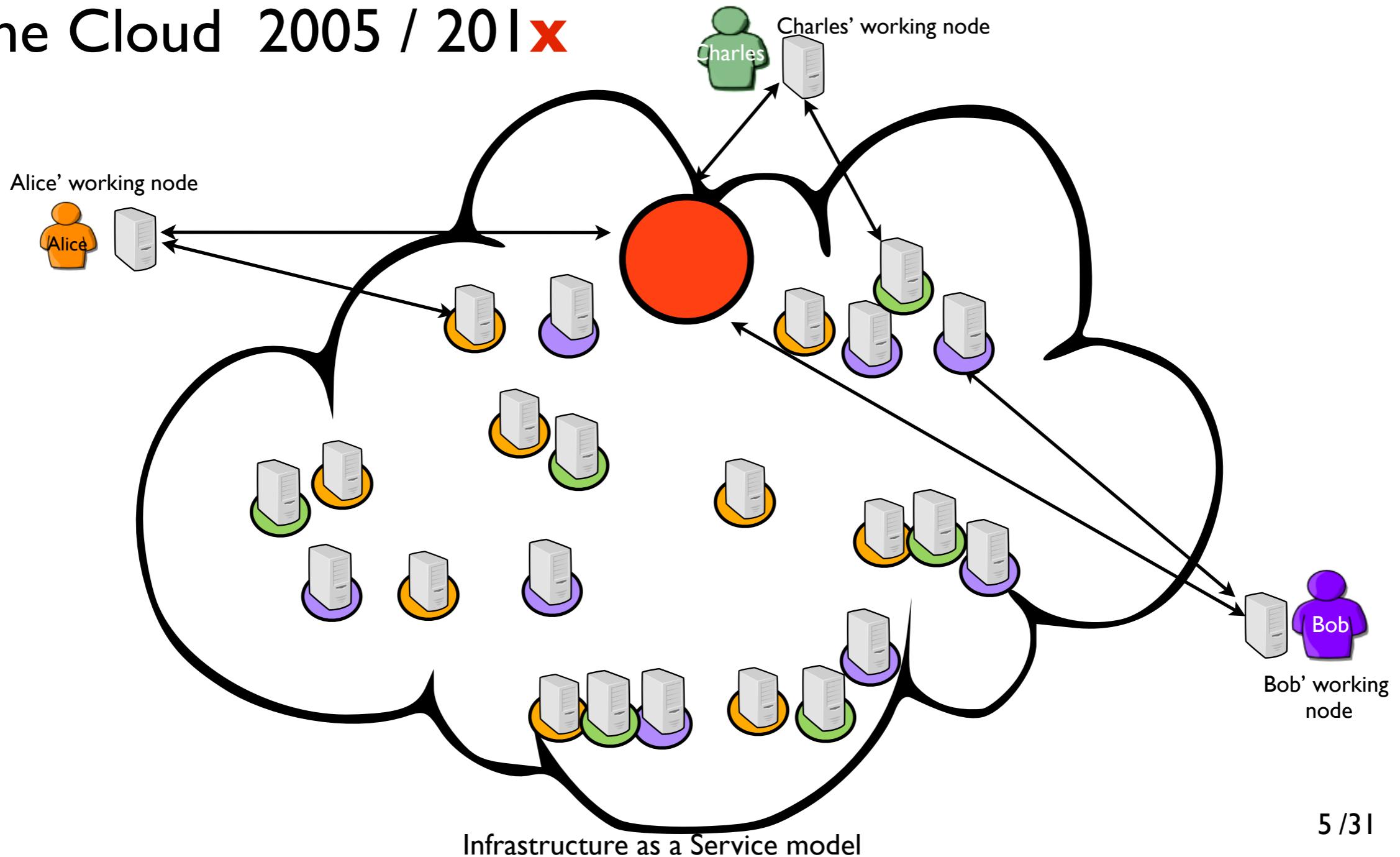
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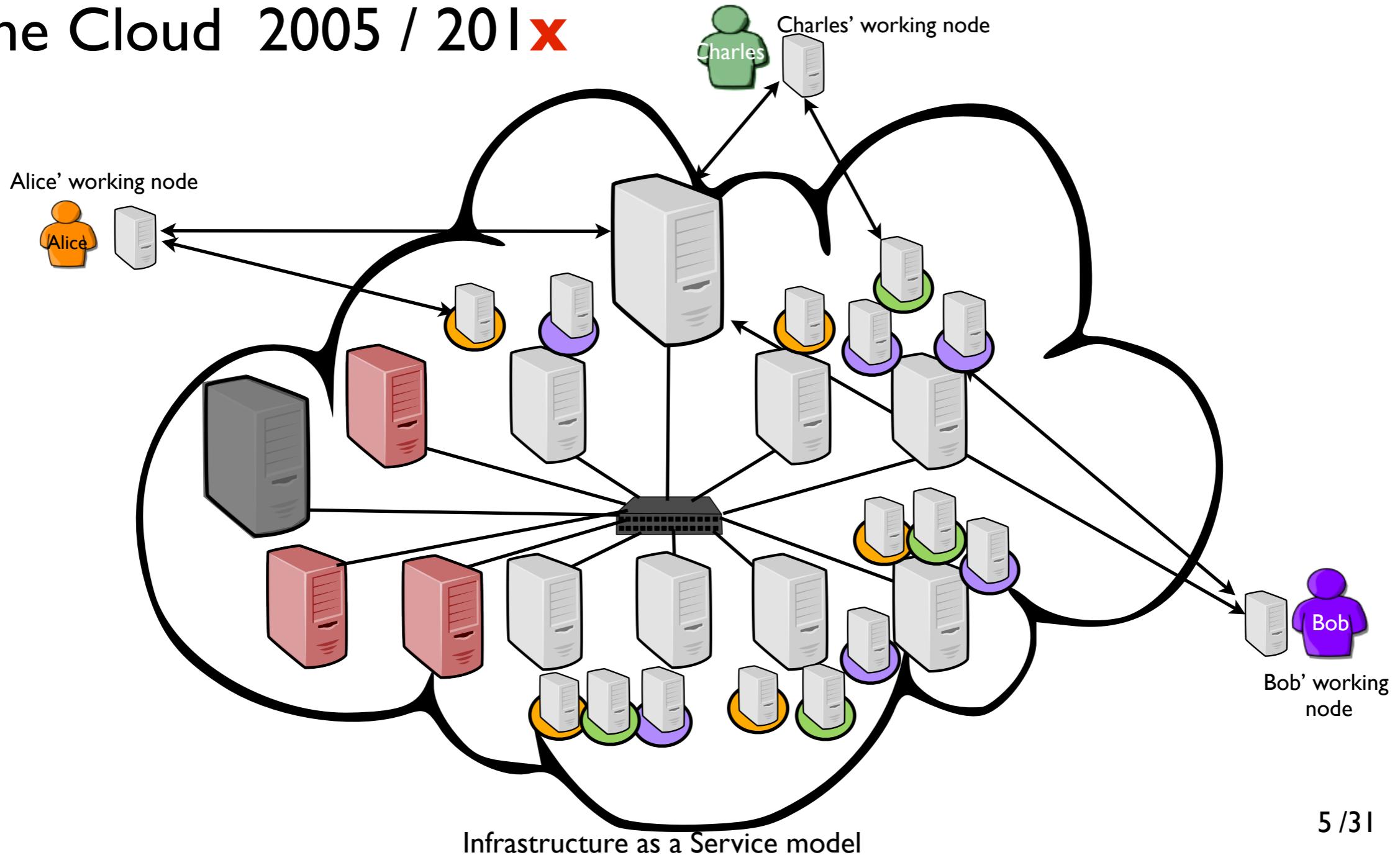
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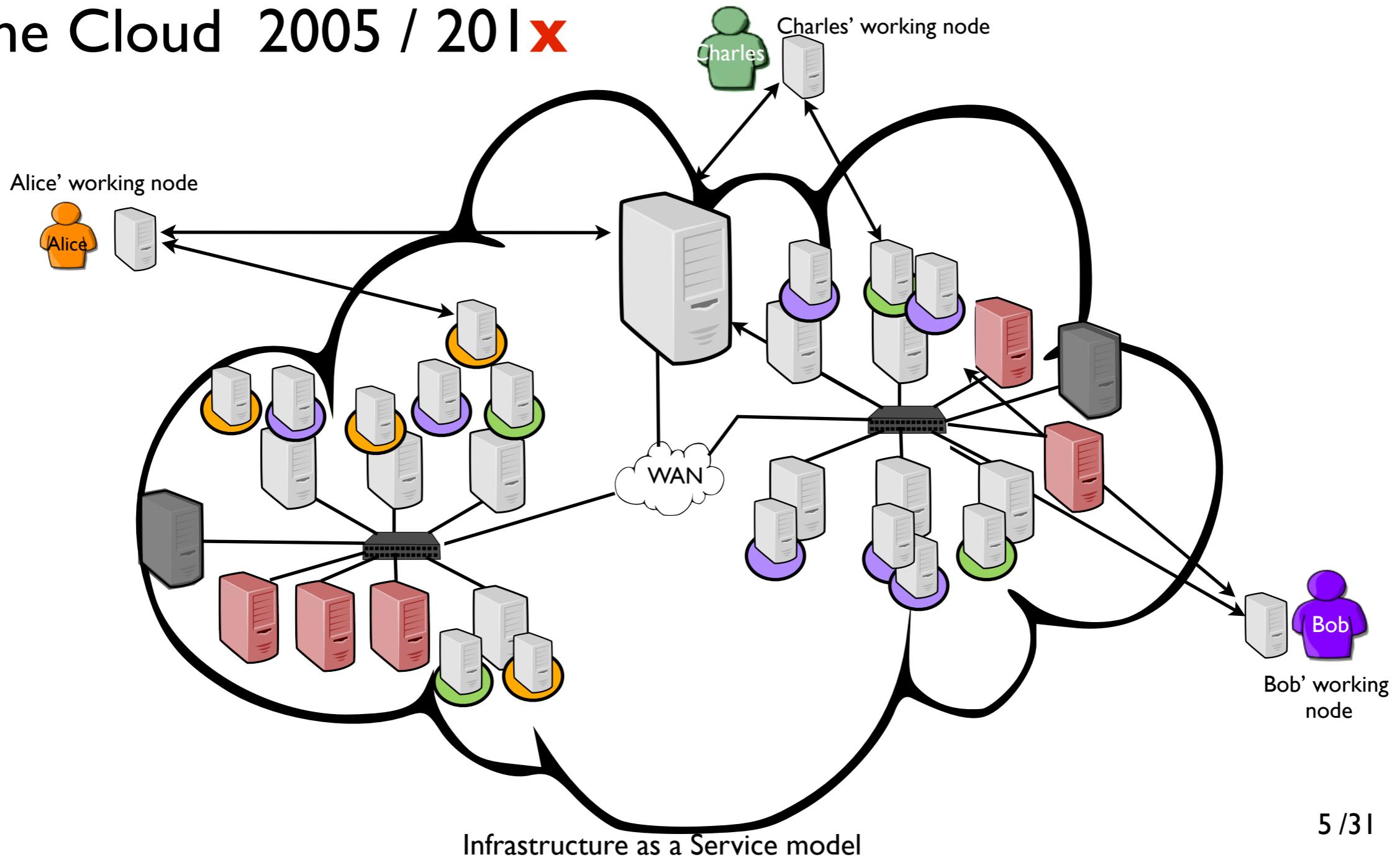
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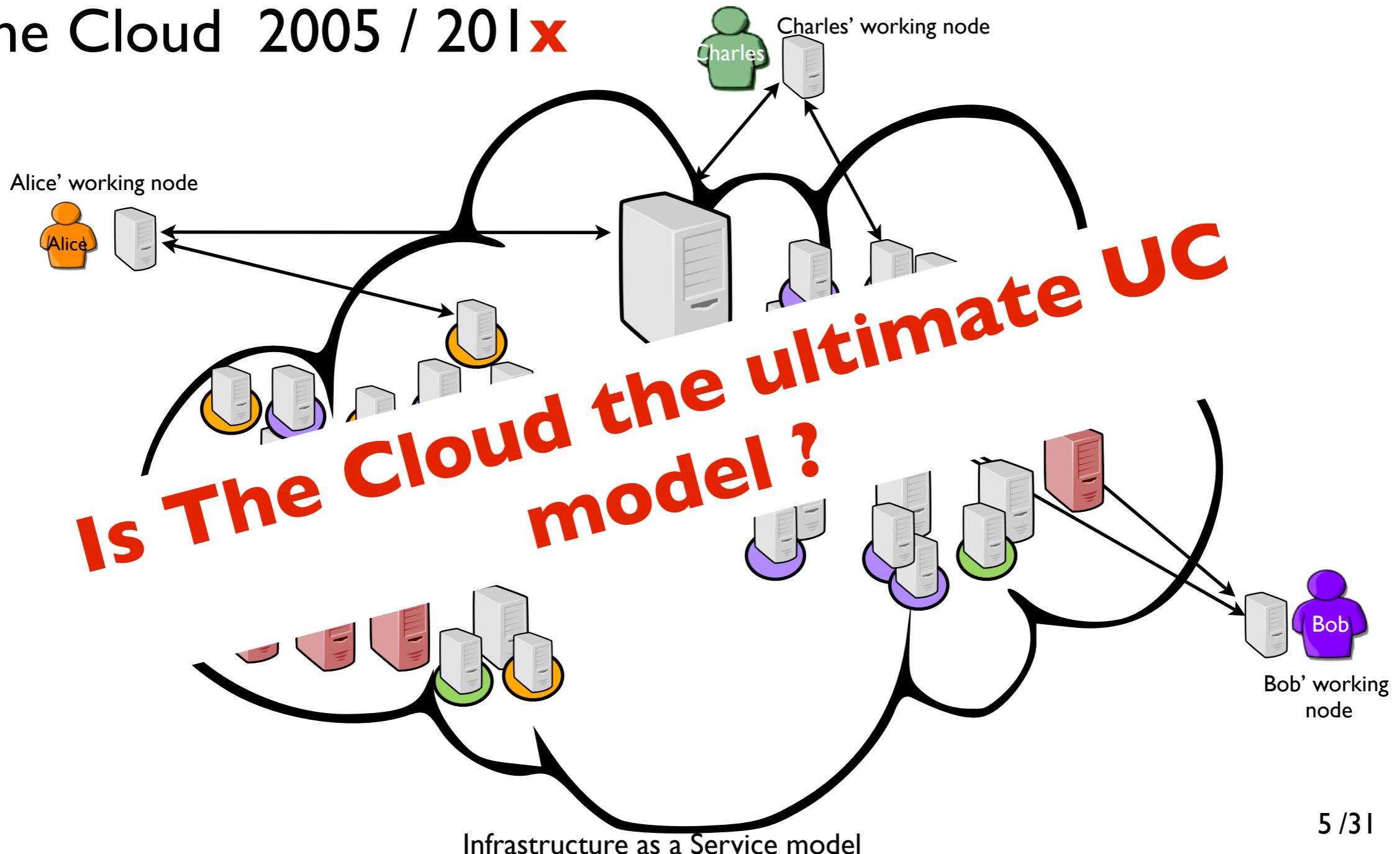
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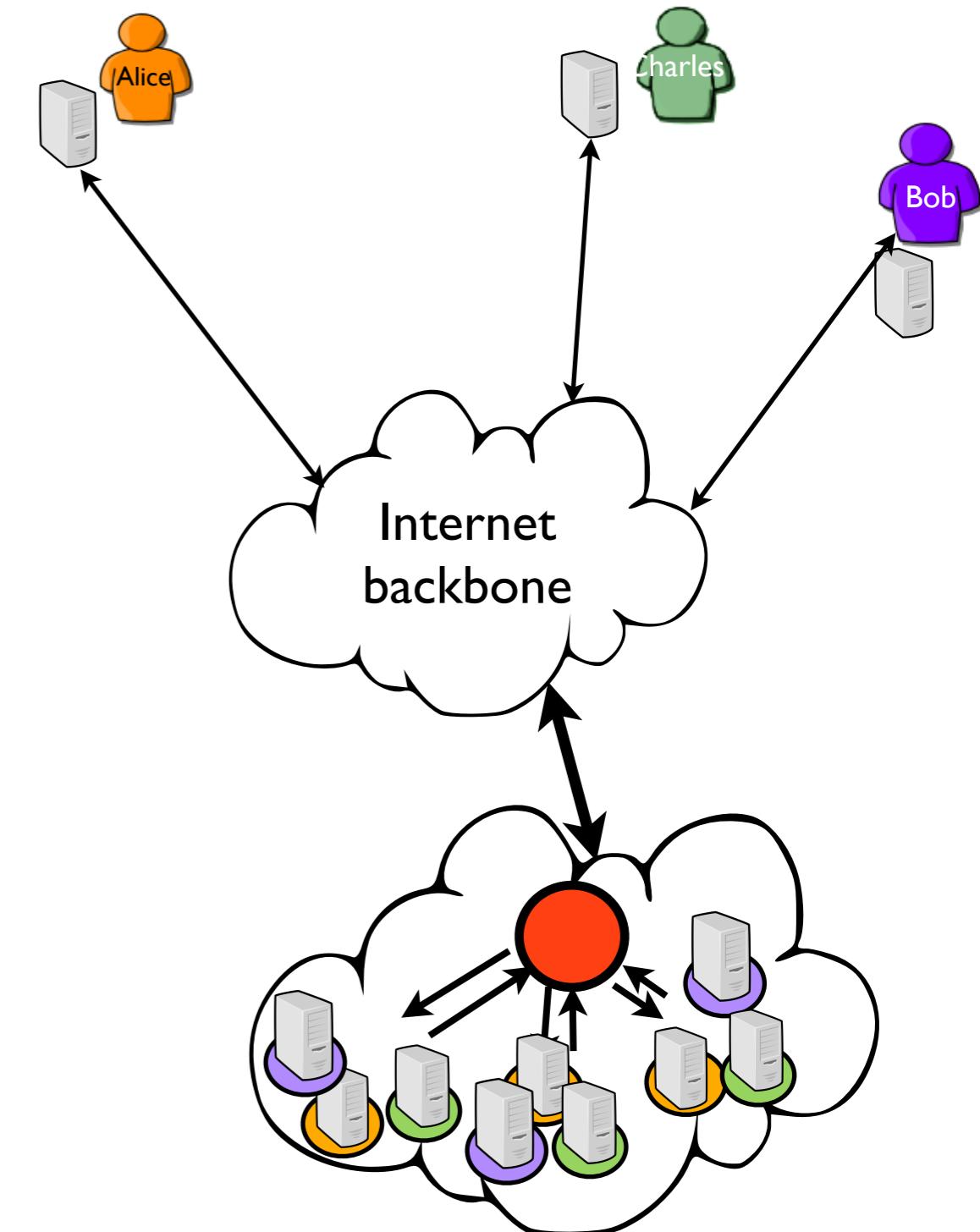
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# Putting everything into the cloud

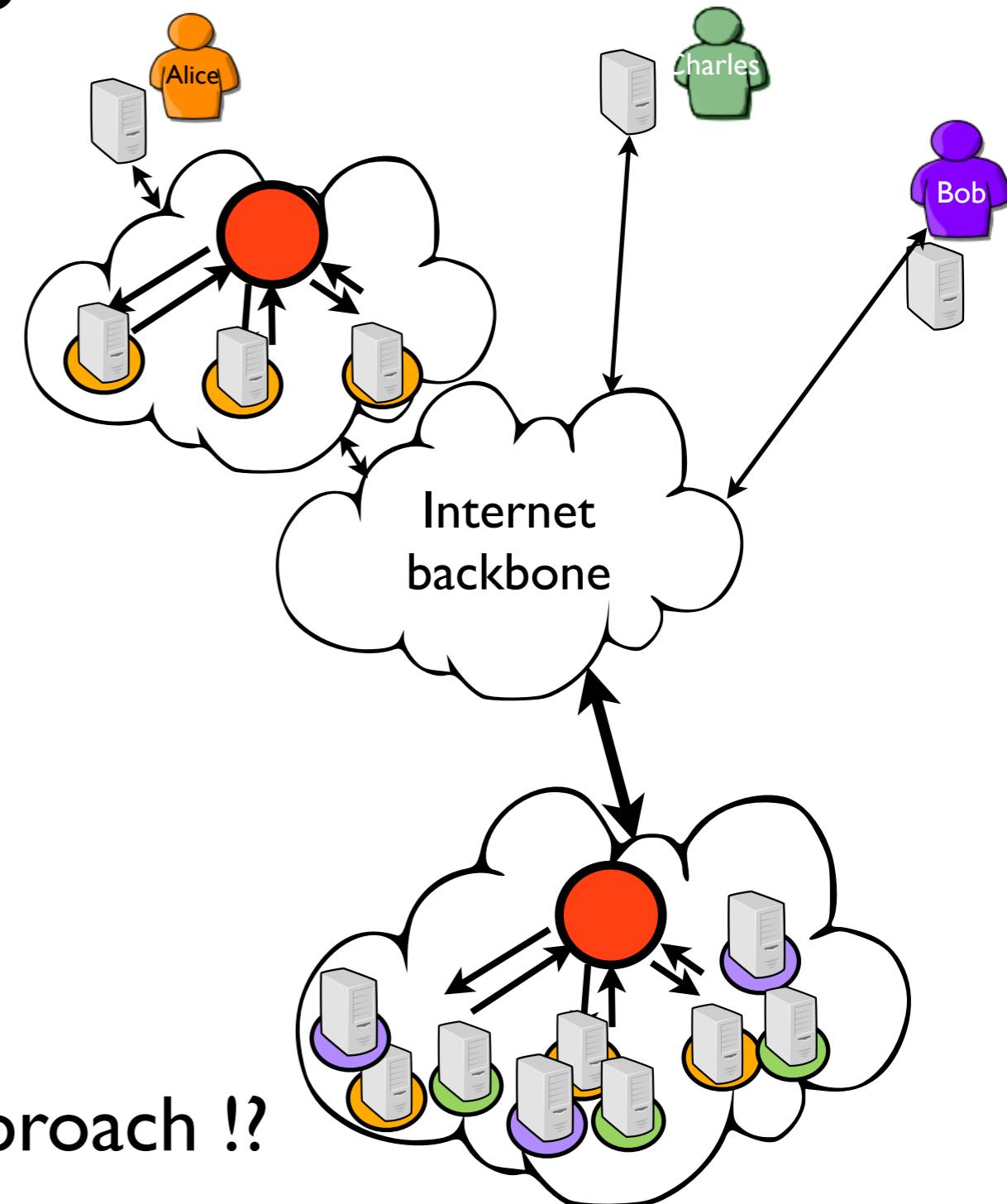
- Inherent limitations of the cloud computing model w.r.t data concerns and public offers

1. Externalization of private applications/ data (jurisdiction concerns)
2. Overhead implied by the unavoidable use of the Internet to reach distant platforms
3. The connectivity to the application/data cannot be insured by centralized dedicated centers (disaster recovery)
4. Energy concerns (footprint but also physical limitations)



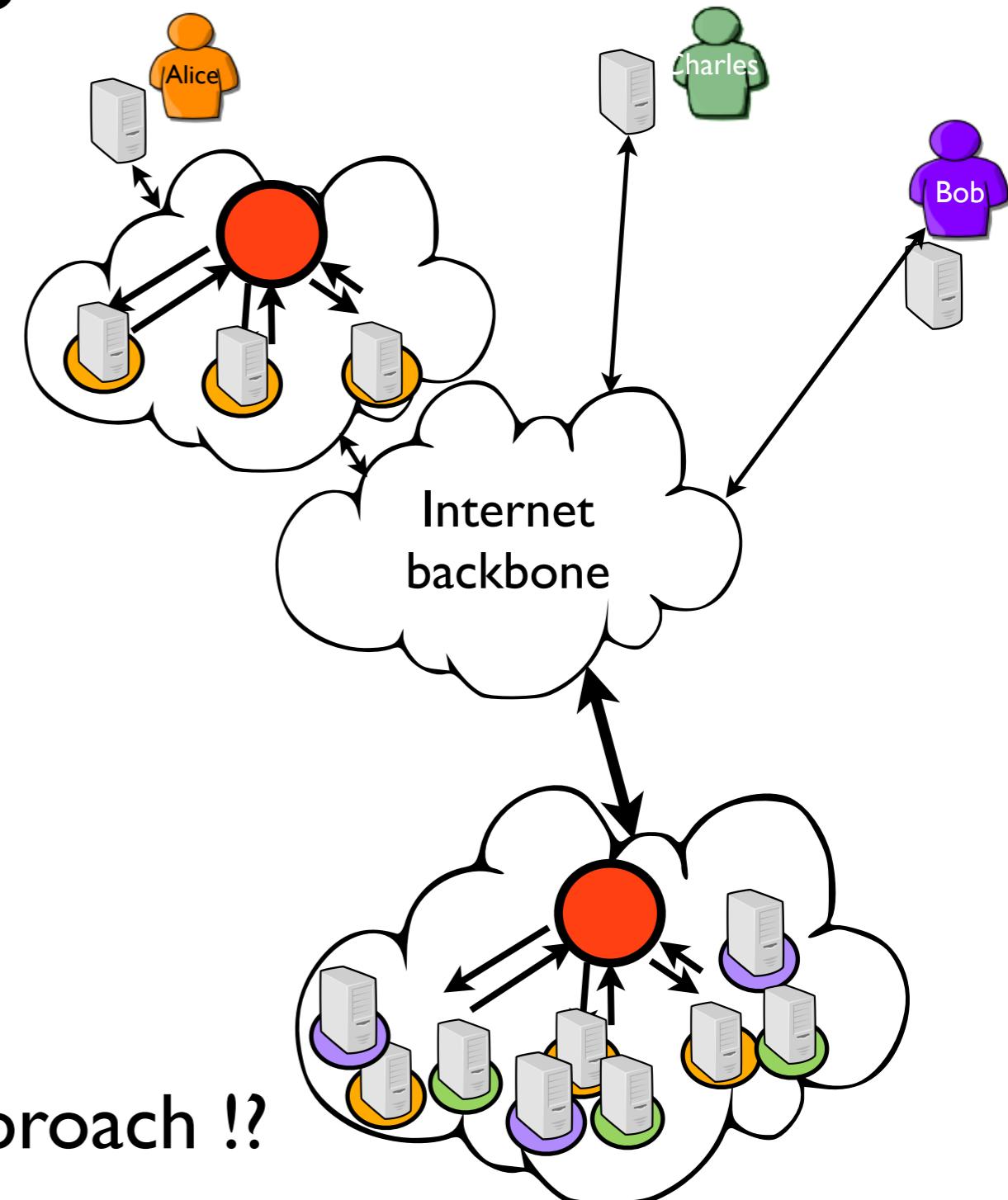
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- Hybrid platforms: a promising approach !?



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- Hybrid platforms: a promising approach !?  
Not really (points 1 and 2 still persist)

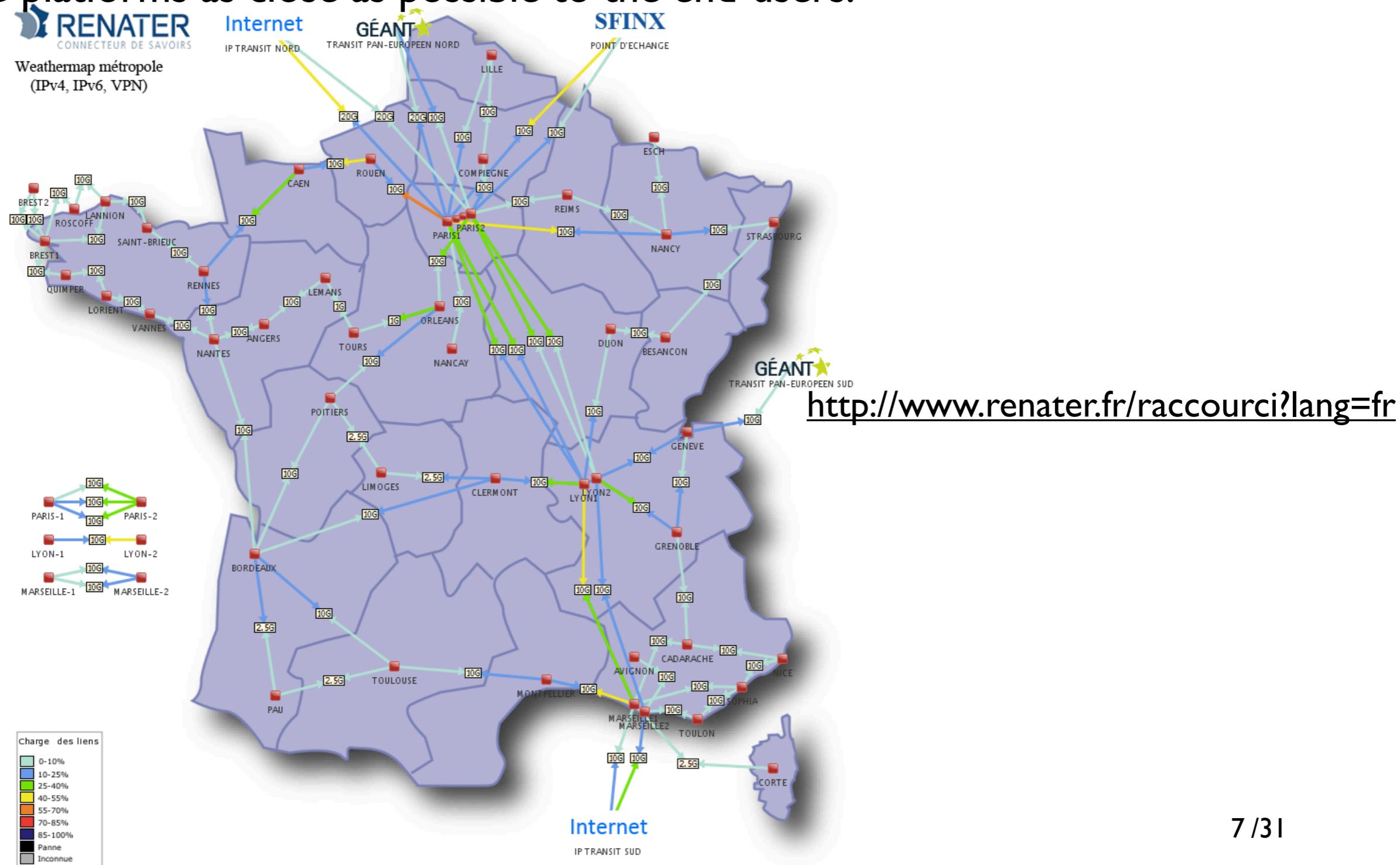


**Can we address these concerns “all in one” ? ?**

# Beyond the Cloud, the DISCOVERY Initiative

## • Locality-based UC infrastructures

The only way to deliver highly efficient and sustainable UC services is to provide UC platforms as close as possible to the end-users.



# Beyond the Cloud, the DISCOVERY Initiative

- Locality-based UC infrastructures

The only way to deliver highly efficient and sustainable UC services is to provide UC platforms as close as possible to the end-users.

- Leveraging network backbones

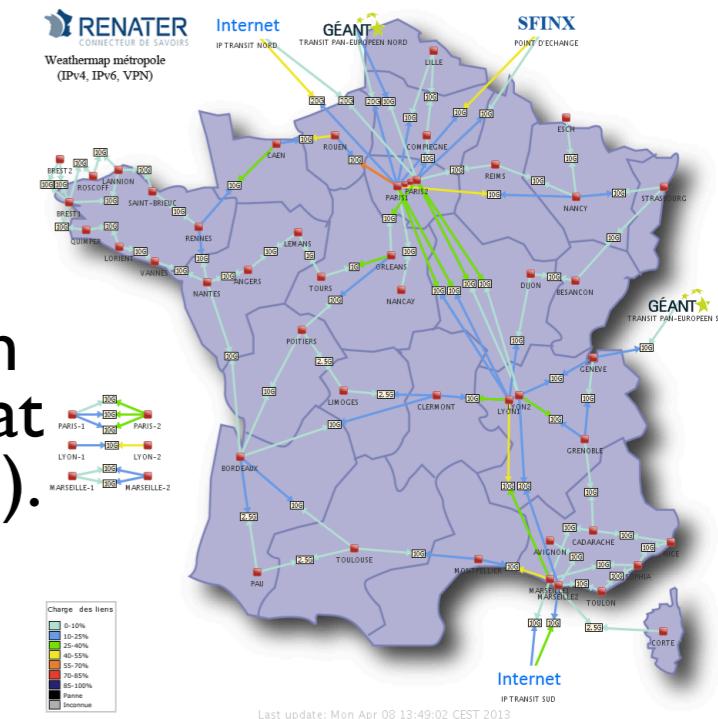
Extend any point of presence of a network backbone with UC servers (from major network hubs up to DSLAMs that are operated by telecom companies/network institutions).

- Leveraging the data furnaces concept

Deploy UC servers in medium and large institutions and use them as sources of heat inside public buildings such as hospitals or universities

- Combining both approaches ! ?

⇒ **Operating such widely distributed resources requires the definition of a fully distributed system**

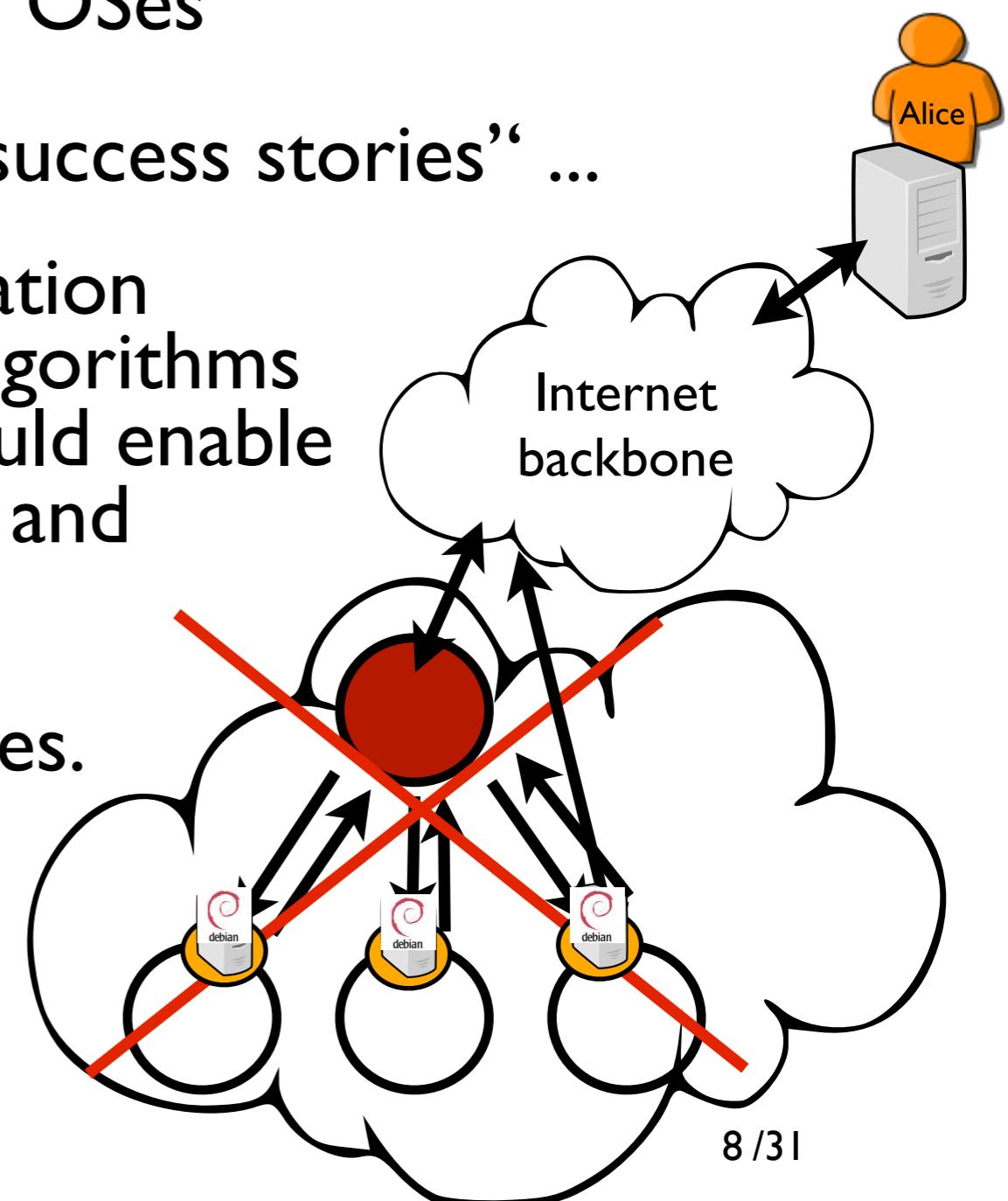


# The DISCOVERY Proposal

- DIStributed and COoperative framework to manage Virtual EnviRonments autonomicallyY
- Designing/implementing Distributed OSes

Deeply investigated with no “real success stories” ...

... But maturity of system virtualization capabilities as well as large scale algorithms and autonomous mechanisms should enable to design and implement a unified and autonomic system manipulating virtual environments (VEs) like traditional OS manipulate processes.

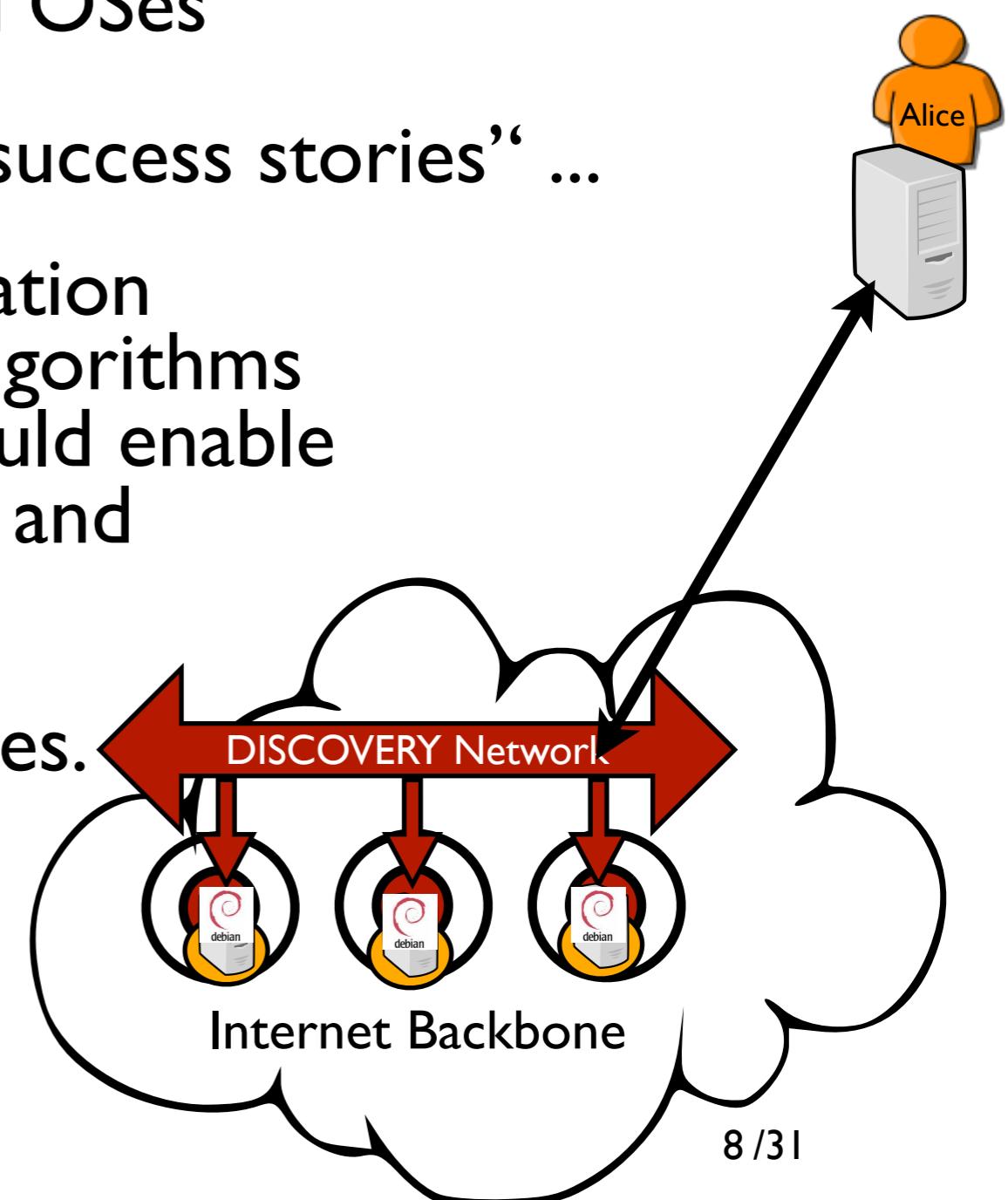


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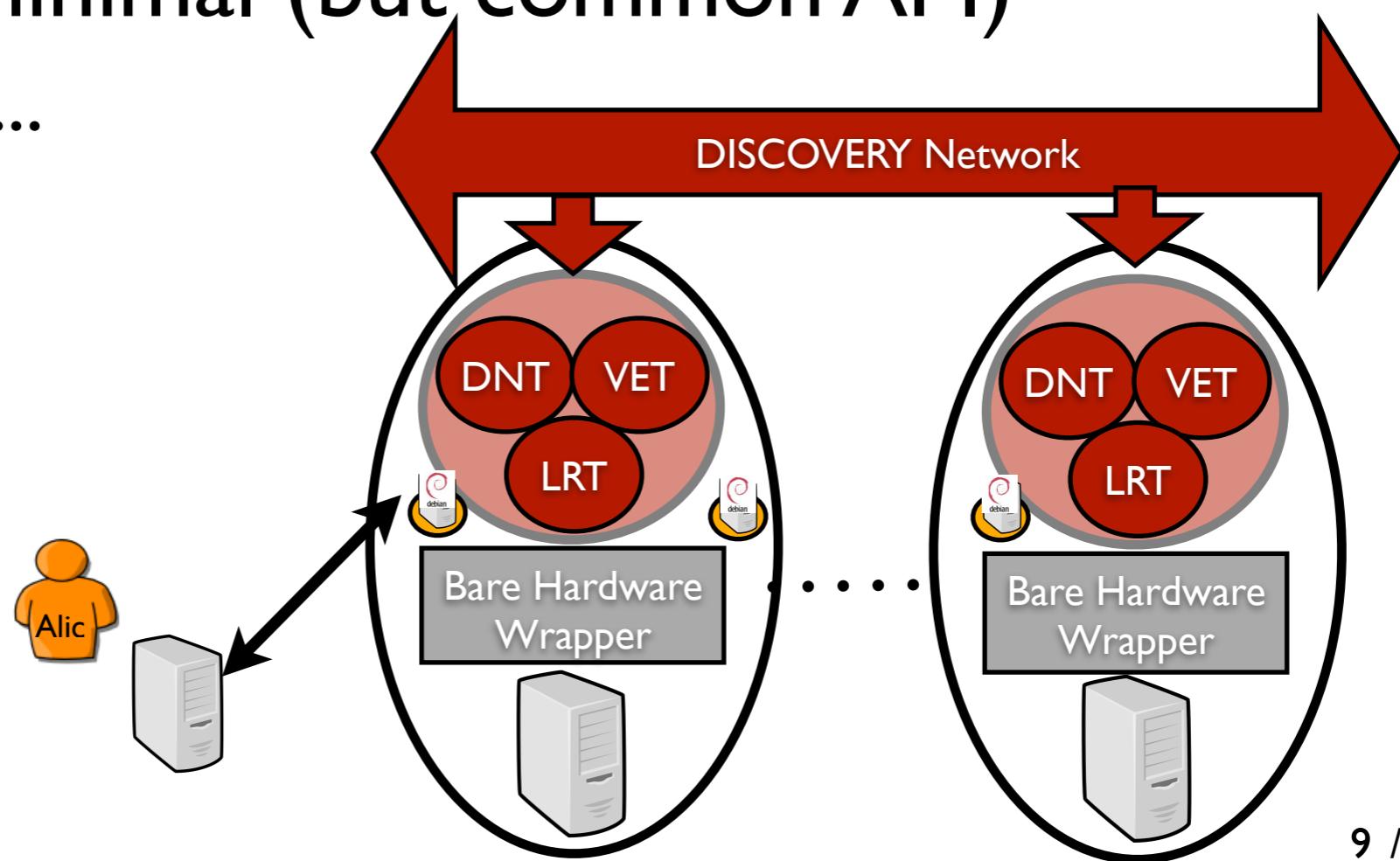
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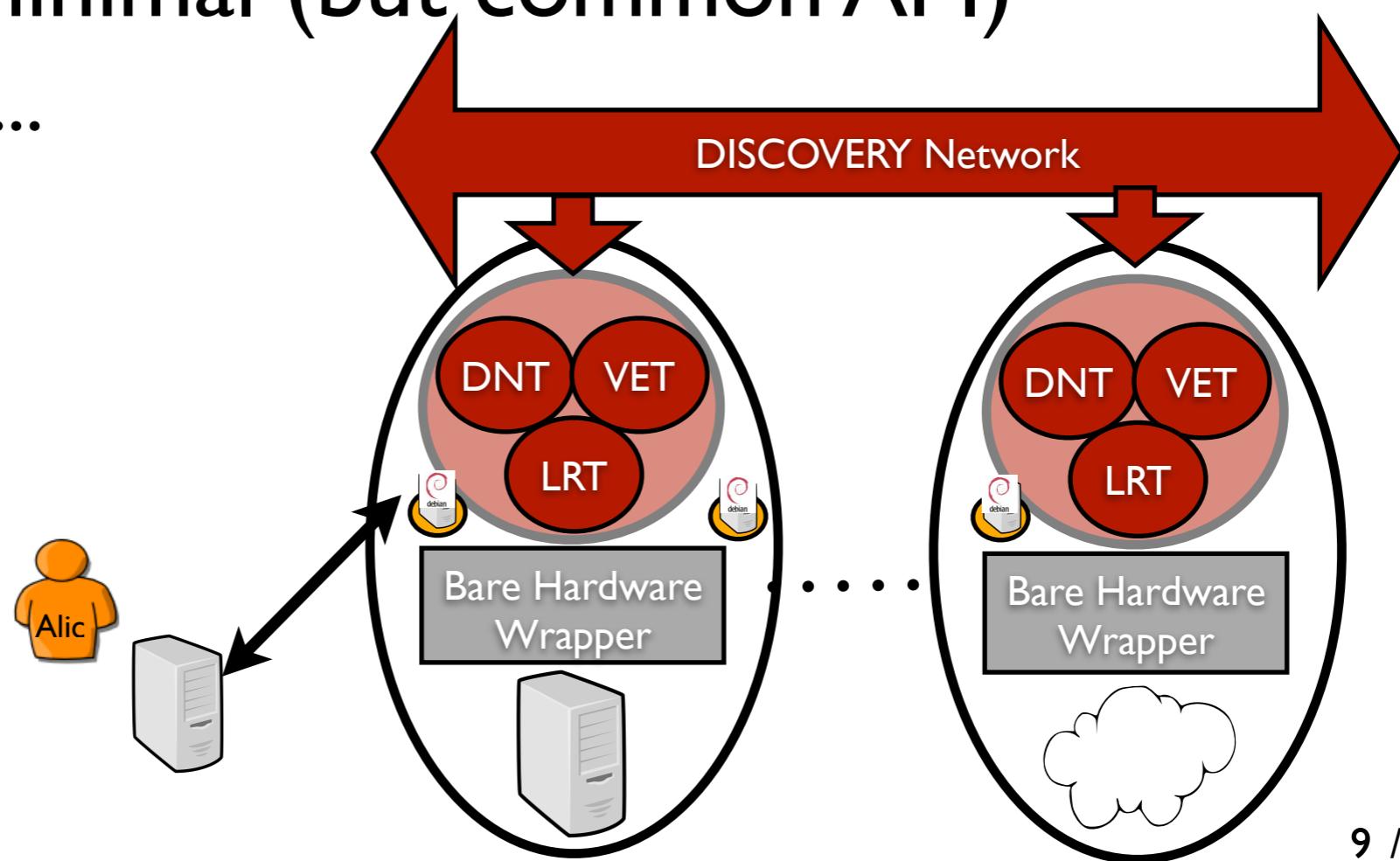
# The LUC OS Agent - Overview

- 3 services  
Discovery Network Tracker (DNT)  
Virtual Environments Tracker (VET)  
Local Resources Tracker (LRT)
- Relying on a minimal (but common API)  
libvirt / OCCI / ...



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# The DISCOVERY Initiative

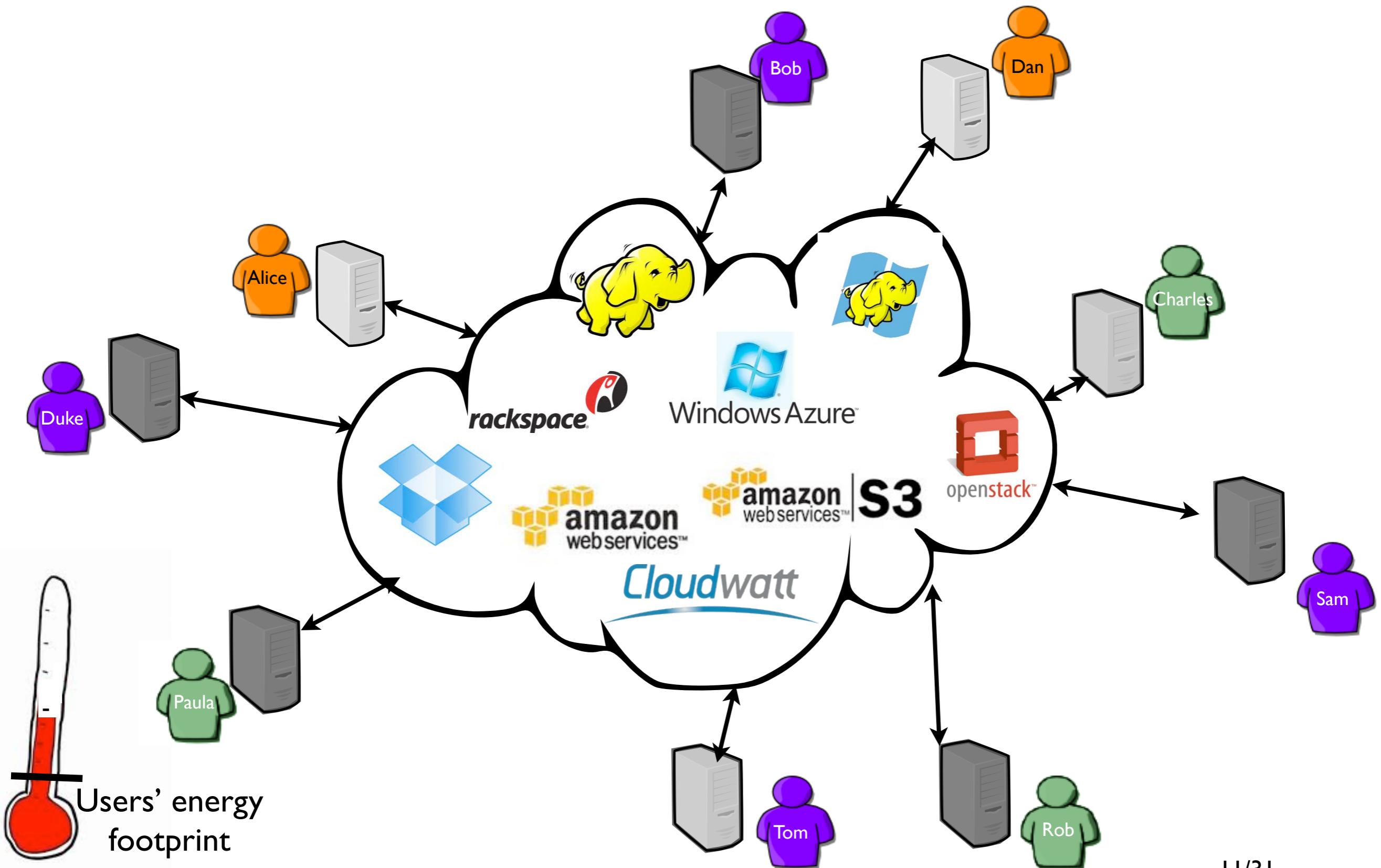
- Focusing on the design and the implementation of a complete OS for IaaS platforms based on VMs and VEs (group of VMs) as the fundamental granularity
  - Scalability**, targeting the management of hundred thousands of VMs upon thousands of physical machines (PMs)
  - Reliability**, considering “hardware failures as the norm rather the exception”
  - Reactivity**, handling each reconfiguration event as swiftly as possible to maintain VEs' QoS.
- May look simple but lots of scientific/technical challenges

Cost of the DISCOVERY network !? partial view of the system !?

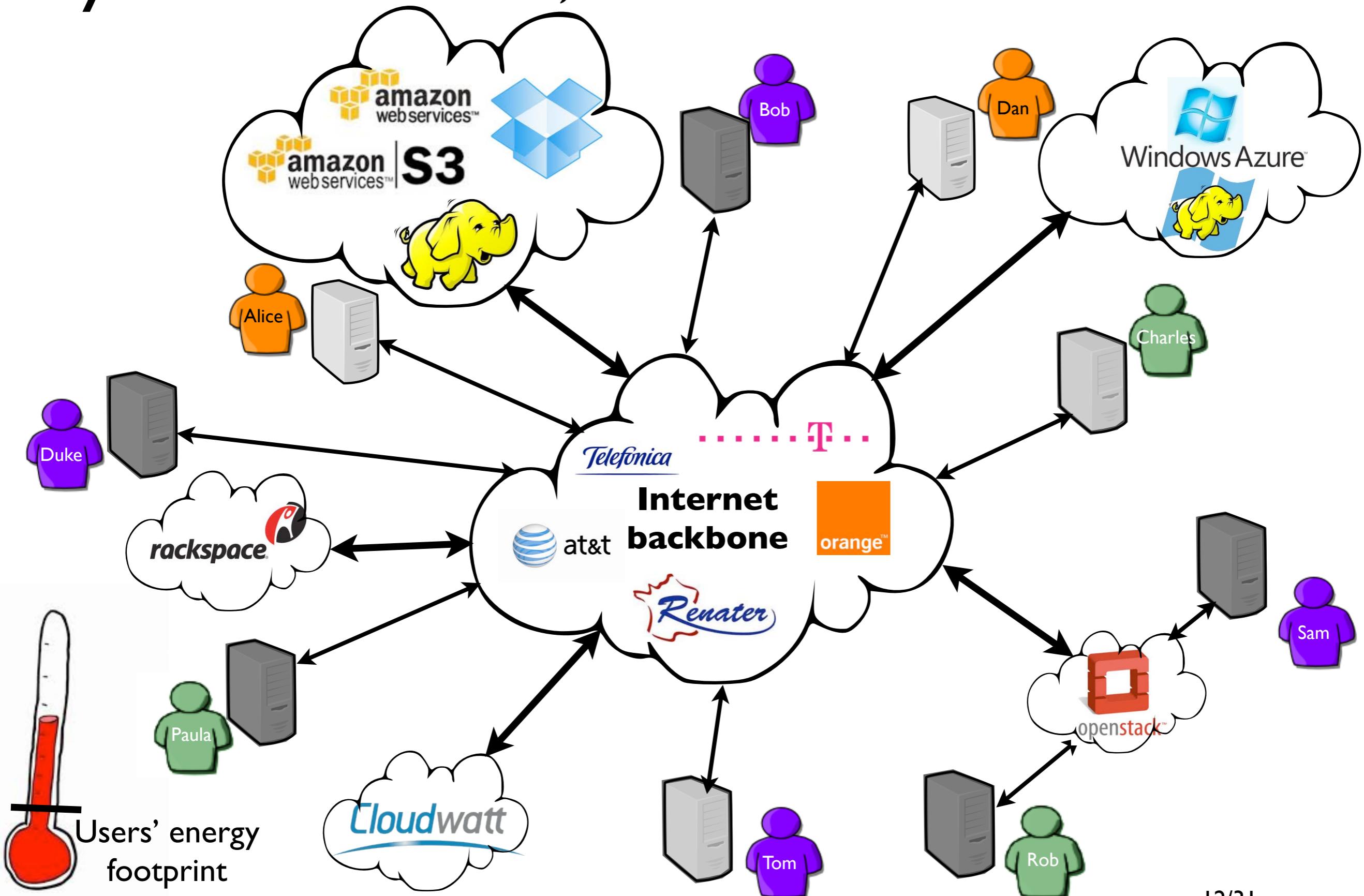
Impact on the others VMs !?, management of VM images !?

Which software abstractions to make the development easier and more reliable (distributed event programming) ?

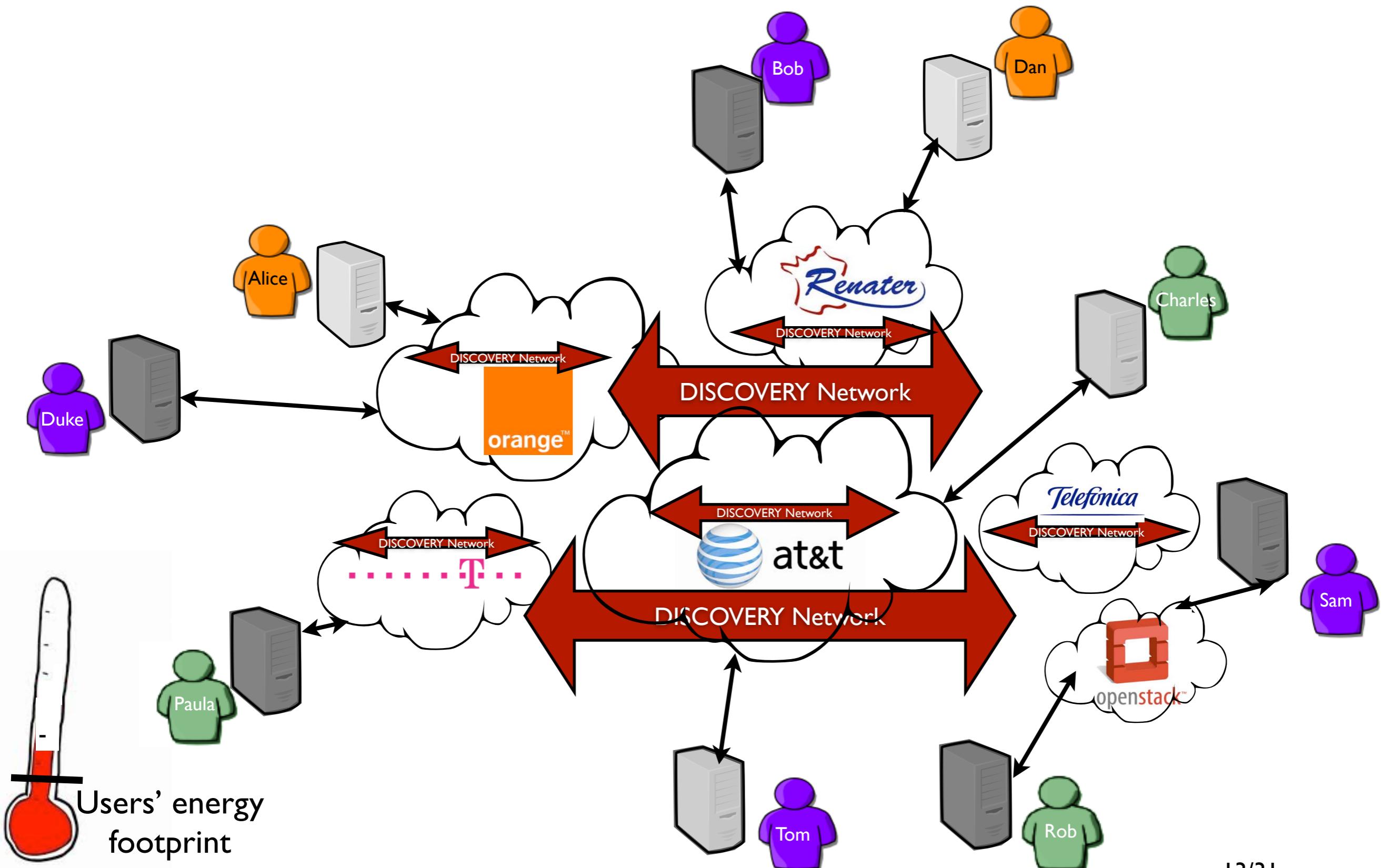
# Beyond the Cloud, the DISCOVERY Initiative



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# The DISCOVERY Initiative

- Leveraging former projects but still on the starting blocks!
- Strong interests of large companies  
(SAP, Orange Lab, Citrix, ...)
- RENATER
- An important actor to follow: Akamai
- Preliminary works with promising results  
(especially on the LRT: a first POC)
- Long term objective: impact on the design of distributed applications in order to take advantage of the locality  
(building S3 like system)

# The DISCOVERY Initiative

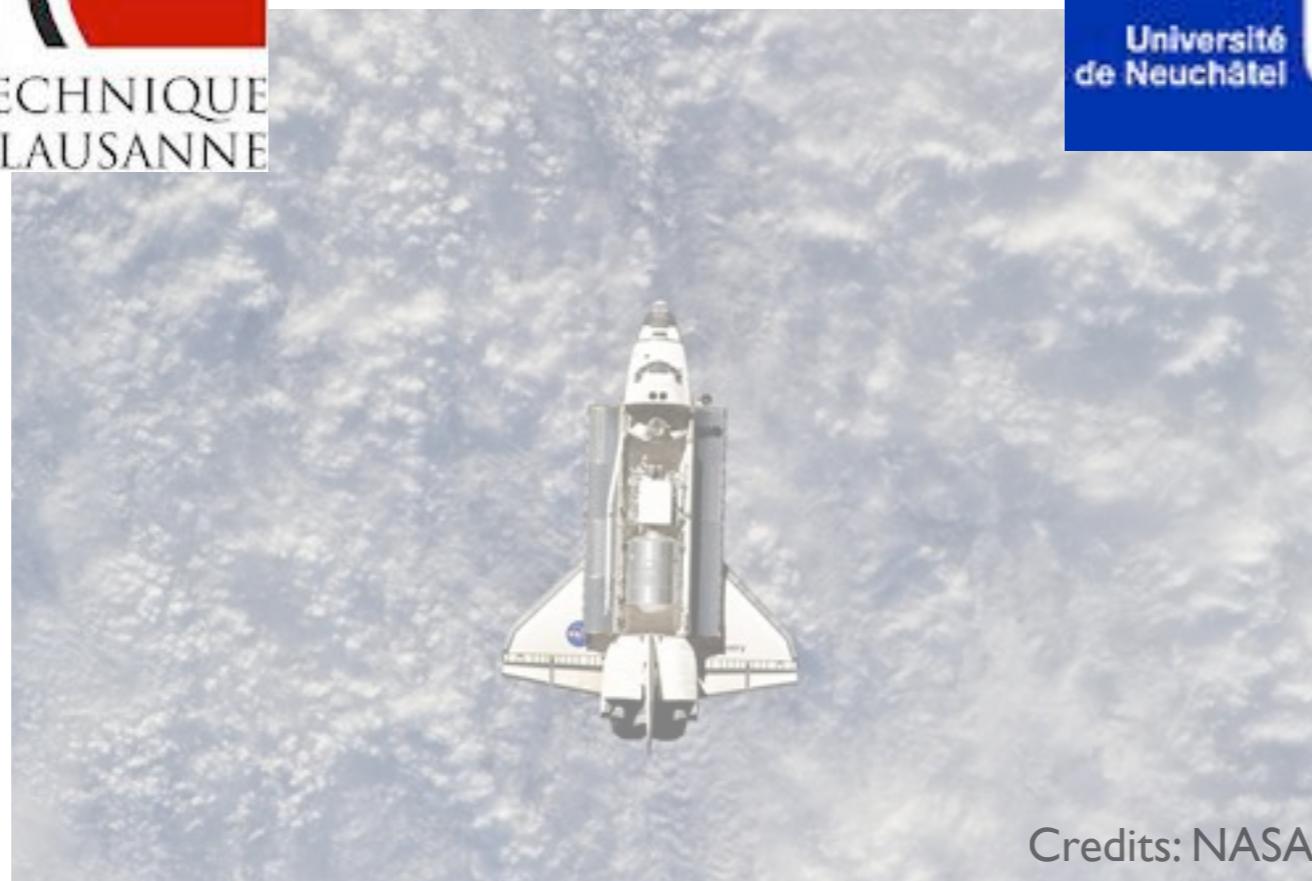
- Thank you / Questions ?
- Want more ?
  - Focus on LRT  
(Flavien Quesnel's Phd, ended in Feb 2013)
  - See Discovery internals in a nutshell



# Beyond the Clouds, the DISCOVERY Initiative



ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE



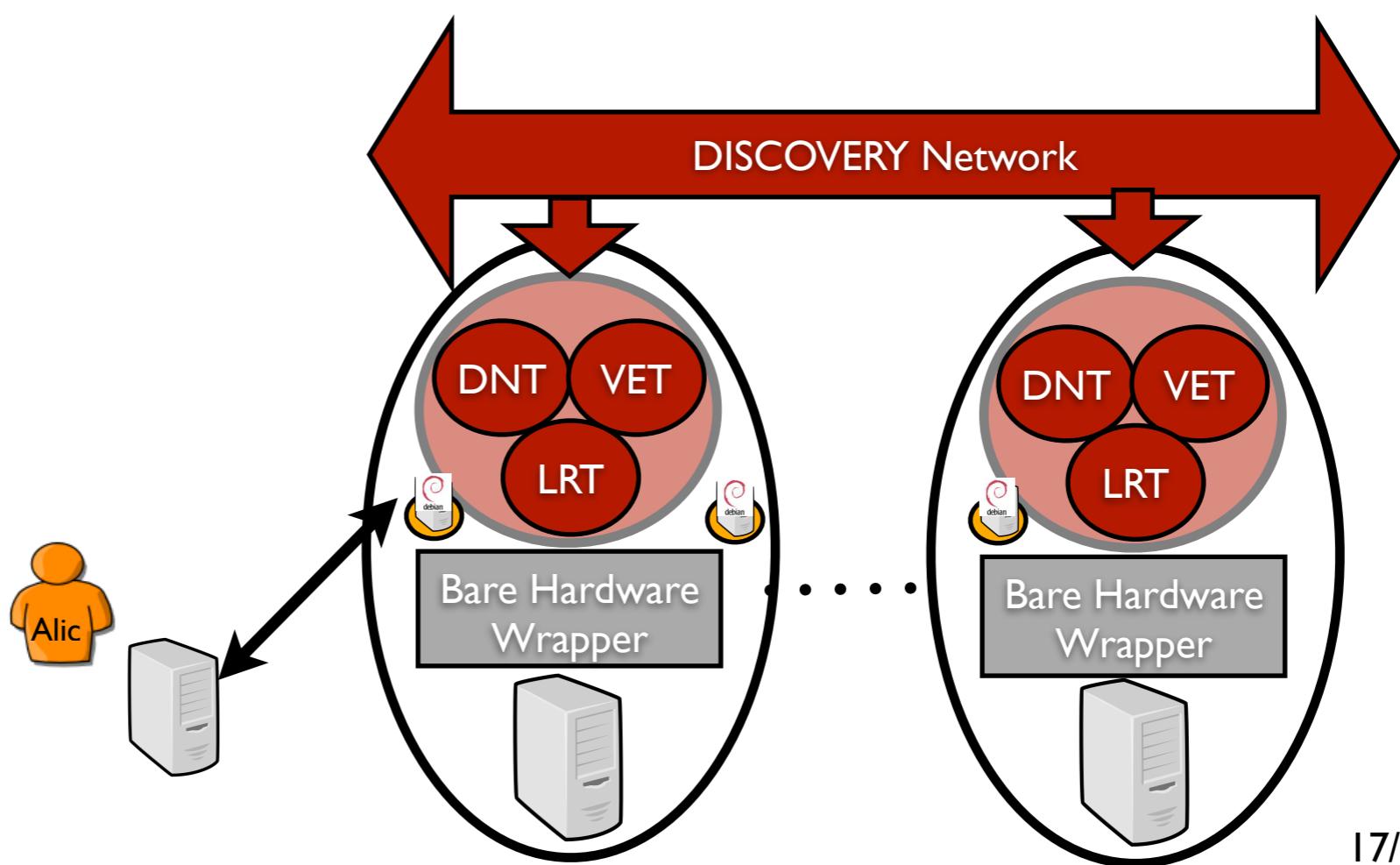
Credits: NASA



Adrien Lèbre / Ascola Research Group

# The LUC OS Agent - Overview

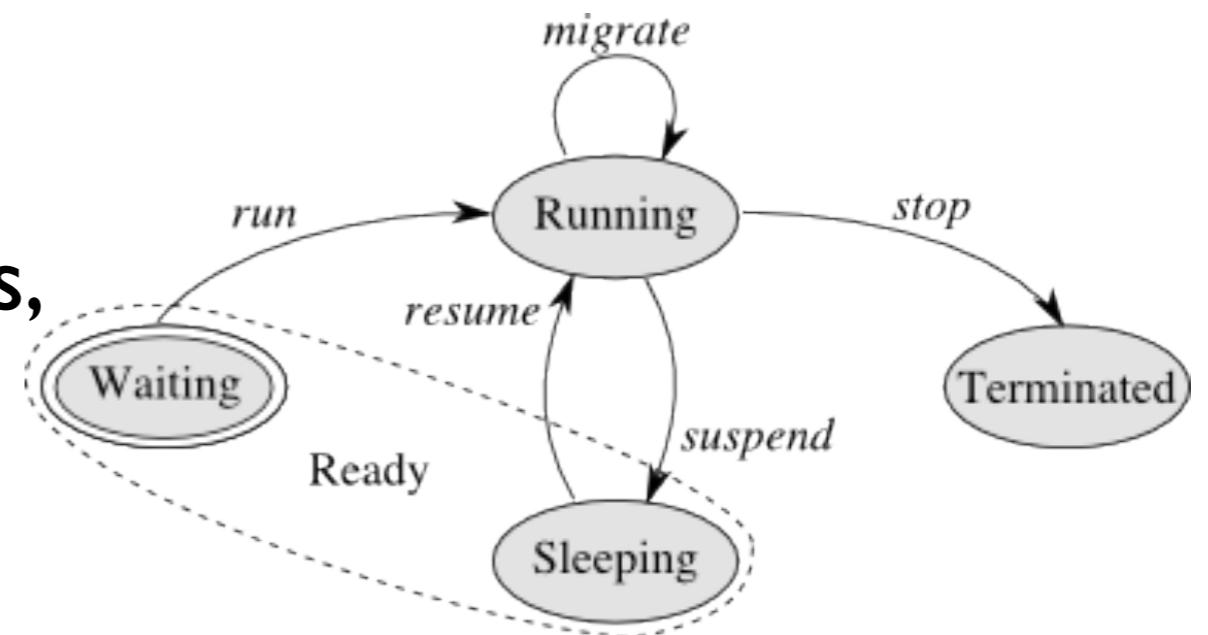
- FOCUS on the LRT and a part of the VET  
Dynamic scheduling of VMs



# Background - a VE-based OS

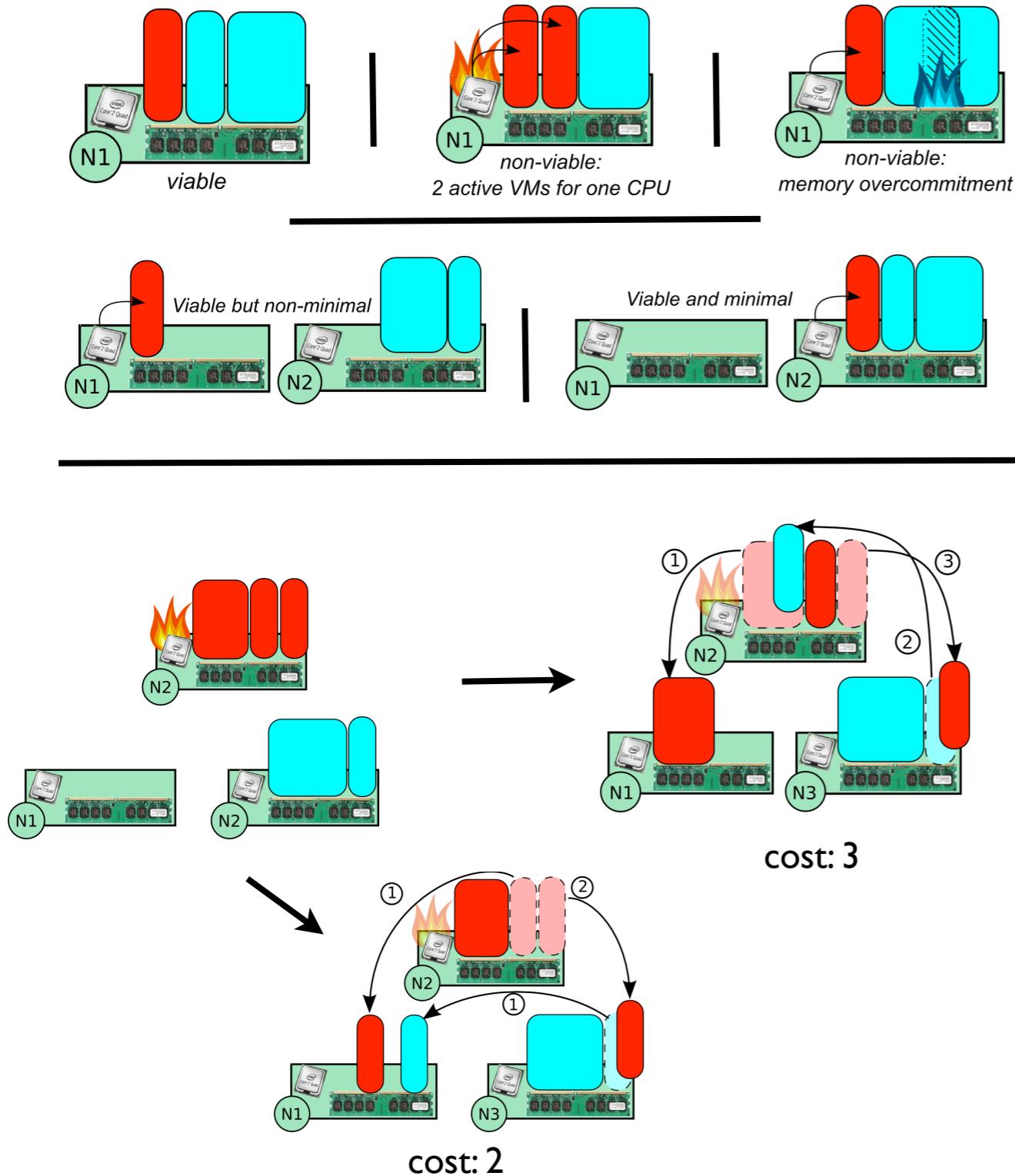
- General idea: manipulate **VEs** instead of processes  
(a VE is a users' working environment, possibly composed of several interconnected VMs)

- In a similar way of usual processes, each VE is in a particular state:

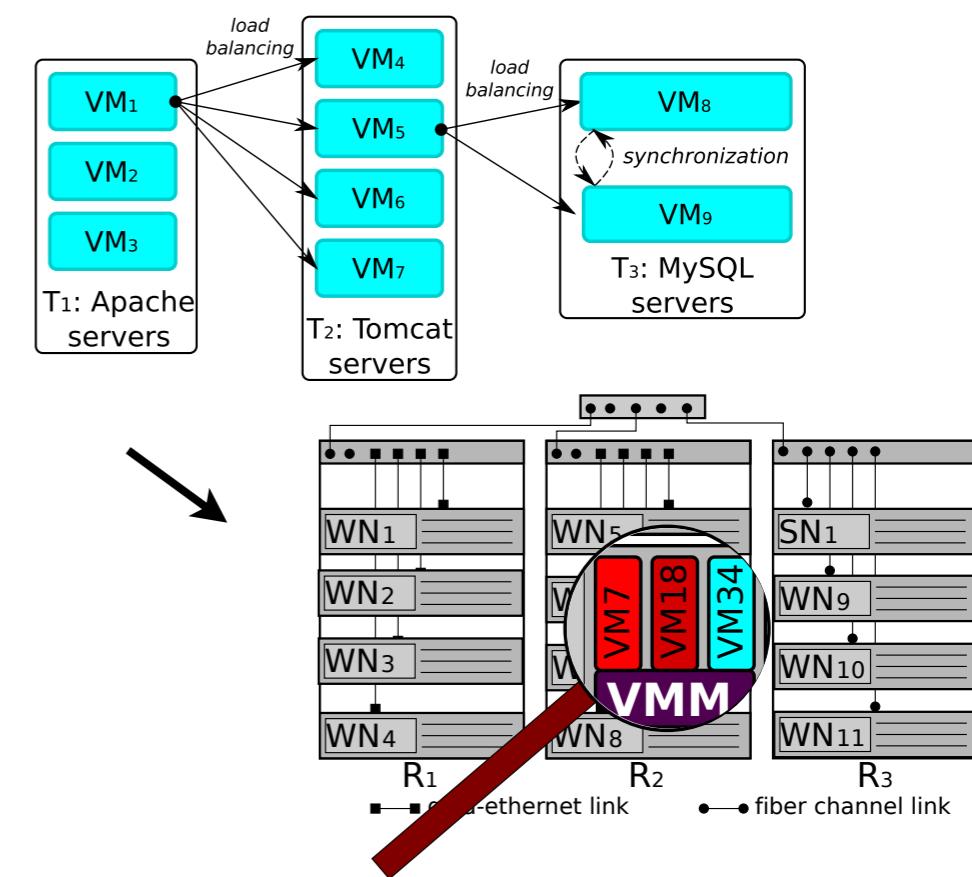


- Perform VE context switches (a set of VM context switches) to rebalance the LUC infrastructure according to the: scheduler objectives / available resources / waiting queue / ...

# Background - the Entropy Proposal

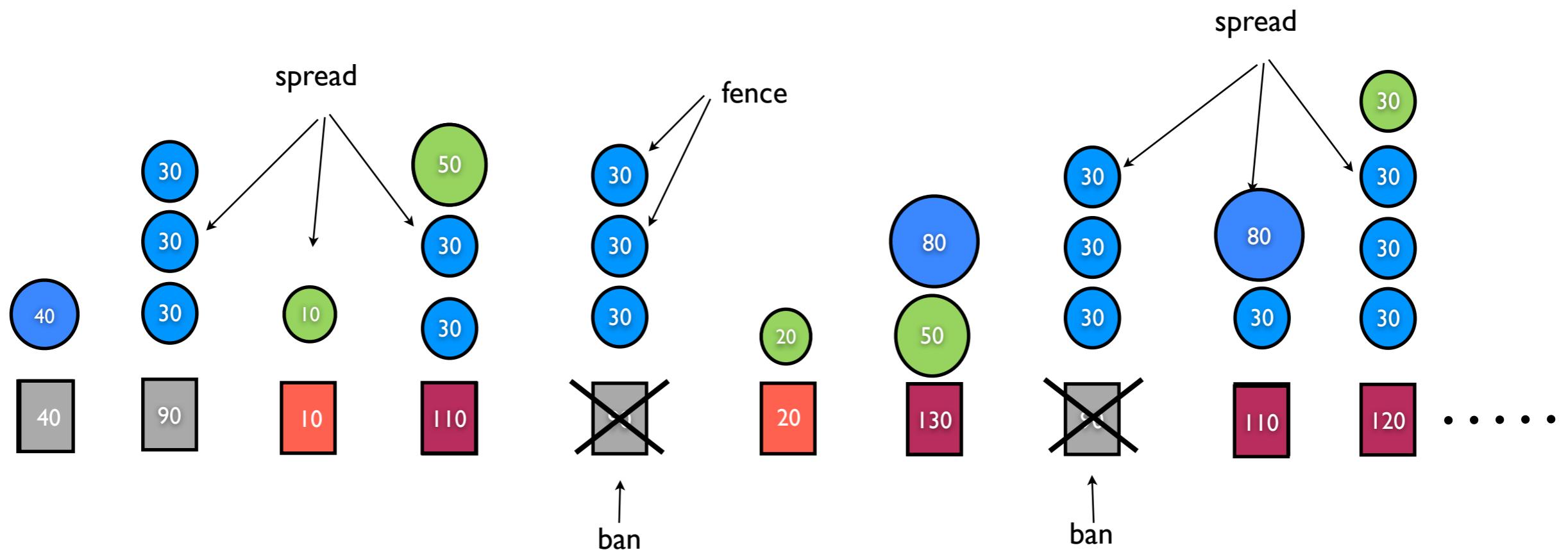


- Find the “right” mapping between needs of VMs, their constraints and resources provided by PMs



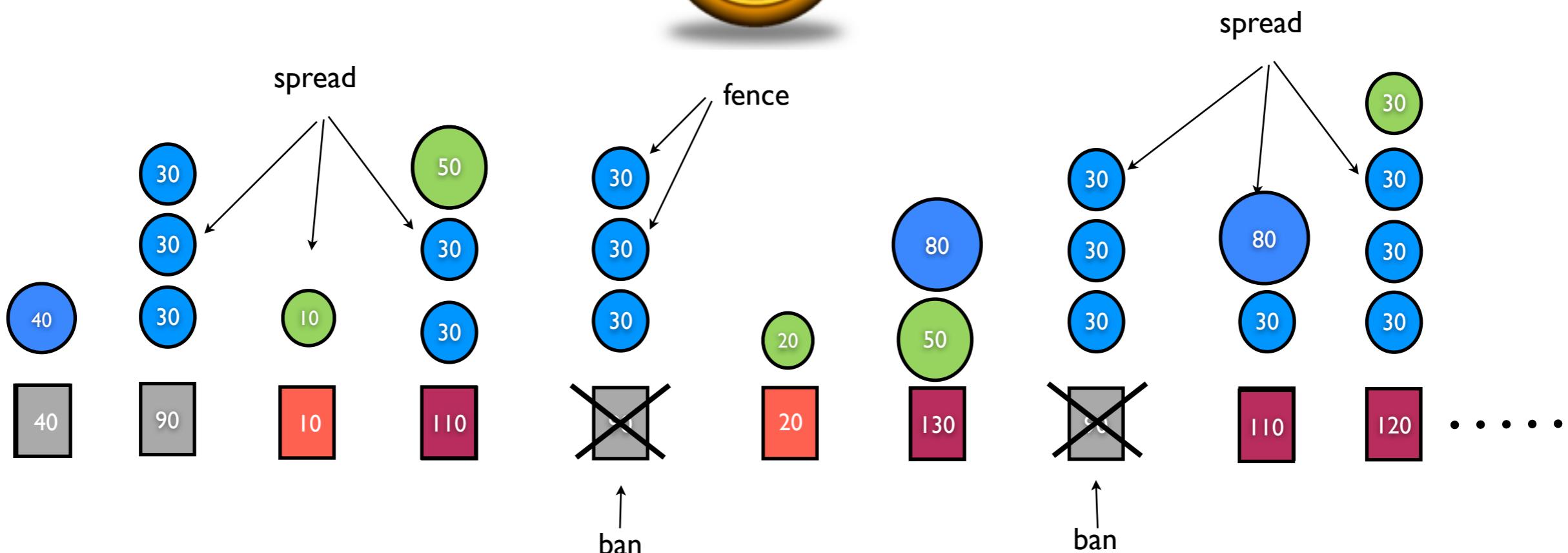
credits: F. Hermenier

# Background - a Small Example



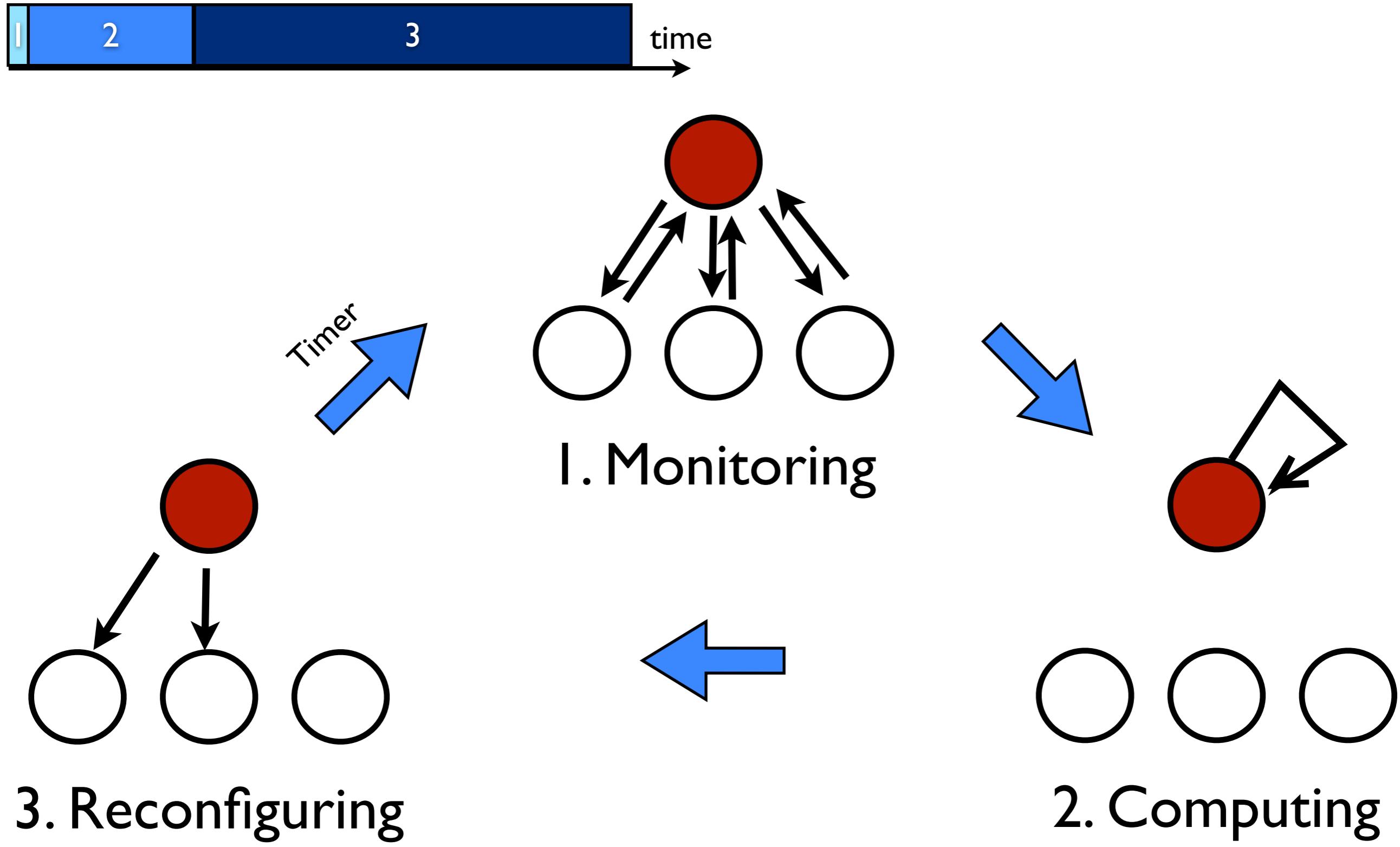
# Background - a Small Example

# Only CPU is considered in this simple example



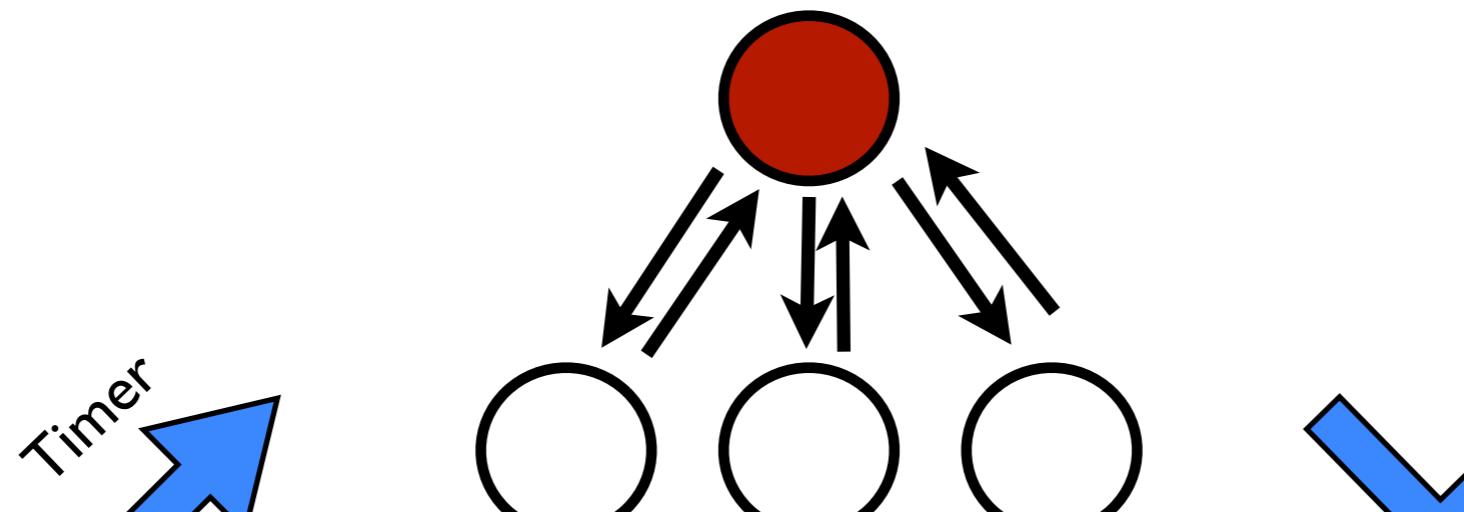
# Dynamic Scheduling of VMs

## Centralized approach

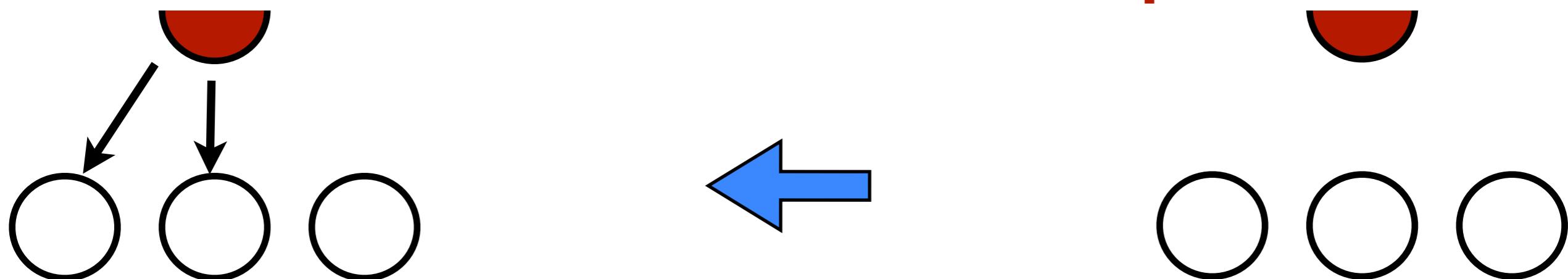


# Dynamic Scheduling of VMs

## Centralized approach



⇒ Not suited for a LUC platform



3. Reconfiguring

2. Computing

# The LUC OS - VEs Scheduling

- Make cooperation between hypervisors
- Main characteristics

Event driven

Peer to peer, no service node

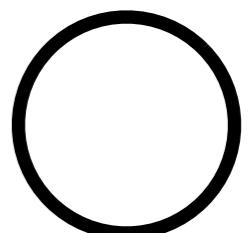
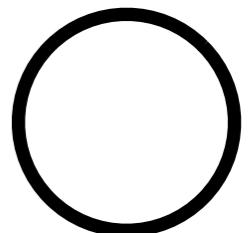
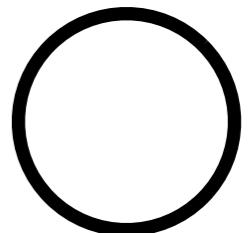
Local interactions between nodes

Scheduling performed on partitions of the system, created dynamically (nodes are reserved for exclusive use by a scheduler, to prevent several schedulers from migrating the same VMs)

# The LUC OS - VEs Scheduling

Event occurs on node<sub>i</sub>

Event



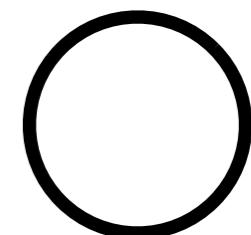
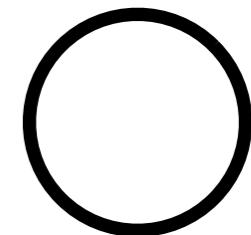
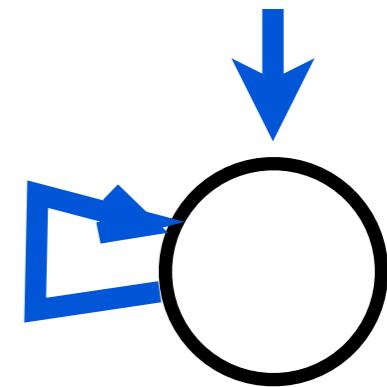
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Event occurs on node<sub>i</sub>



Can current node scheduler  
calculate valid schedule?

Event



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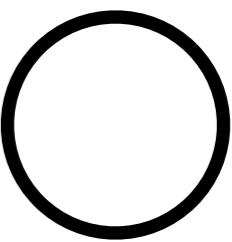
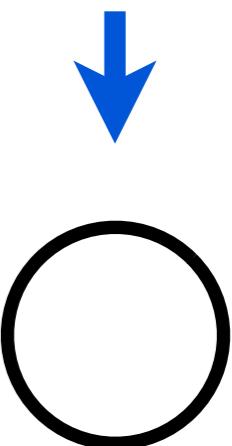
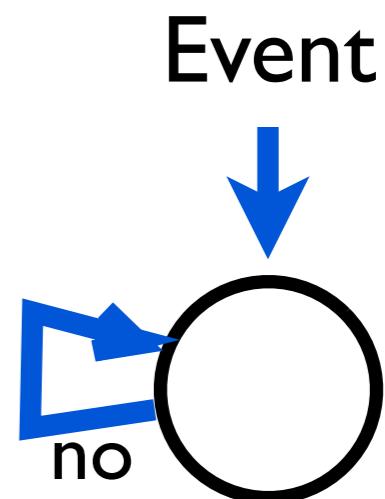
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Contact neighbor  
and ask it to solve  
the problem



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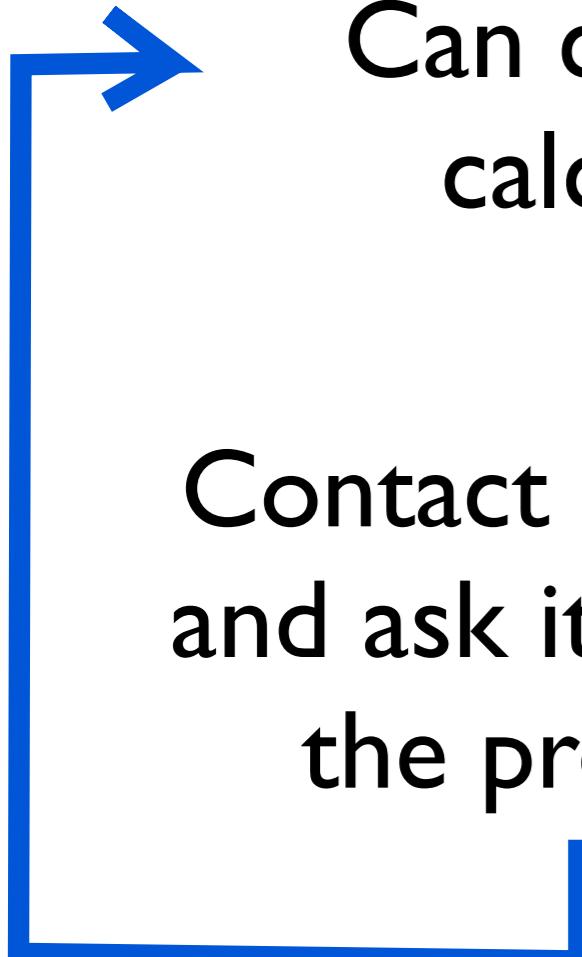
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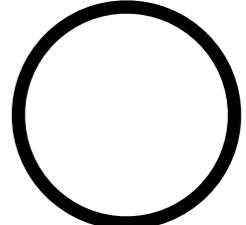
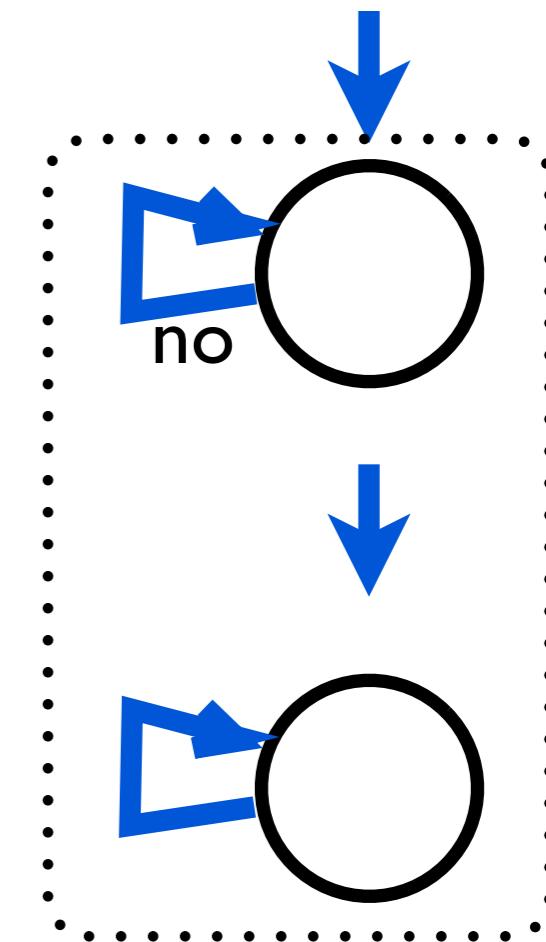
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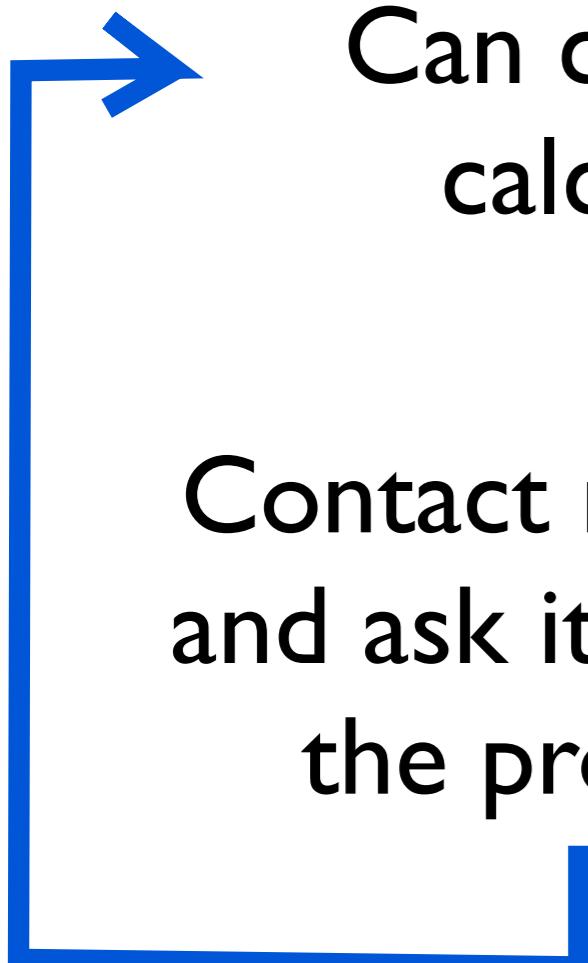
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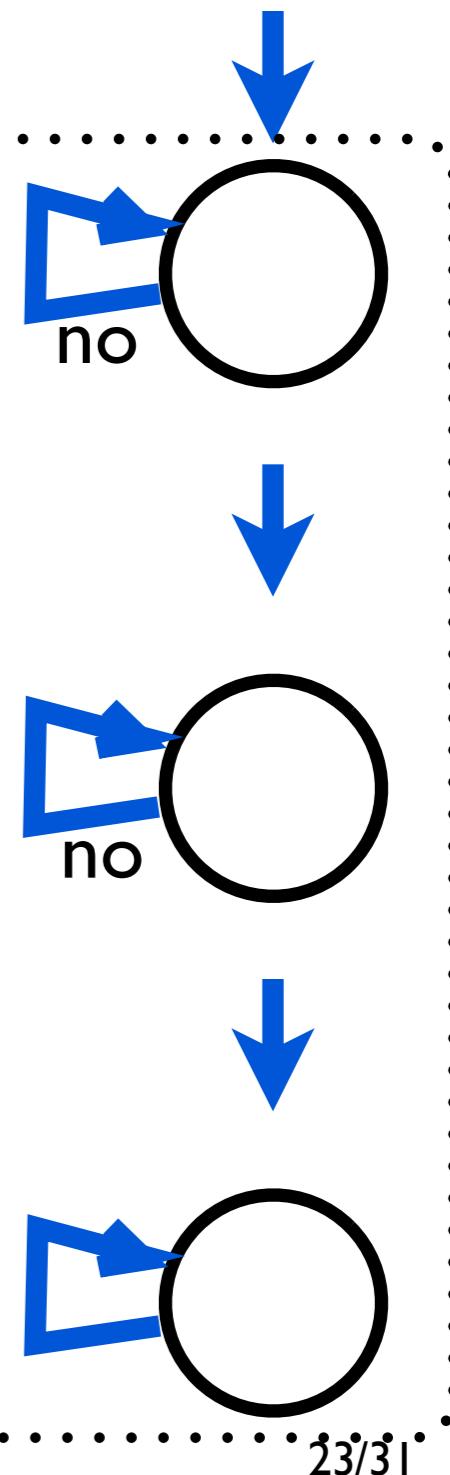
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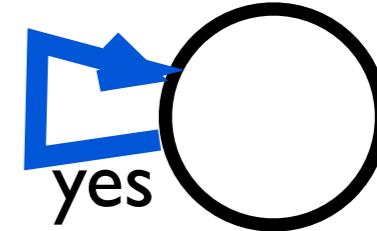
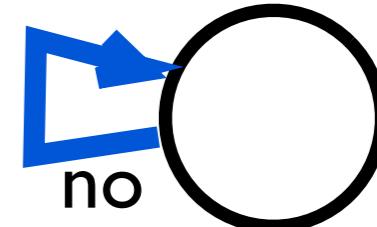
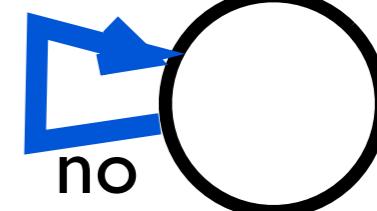
no

Contact neighbor and ask it to solve the problem

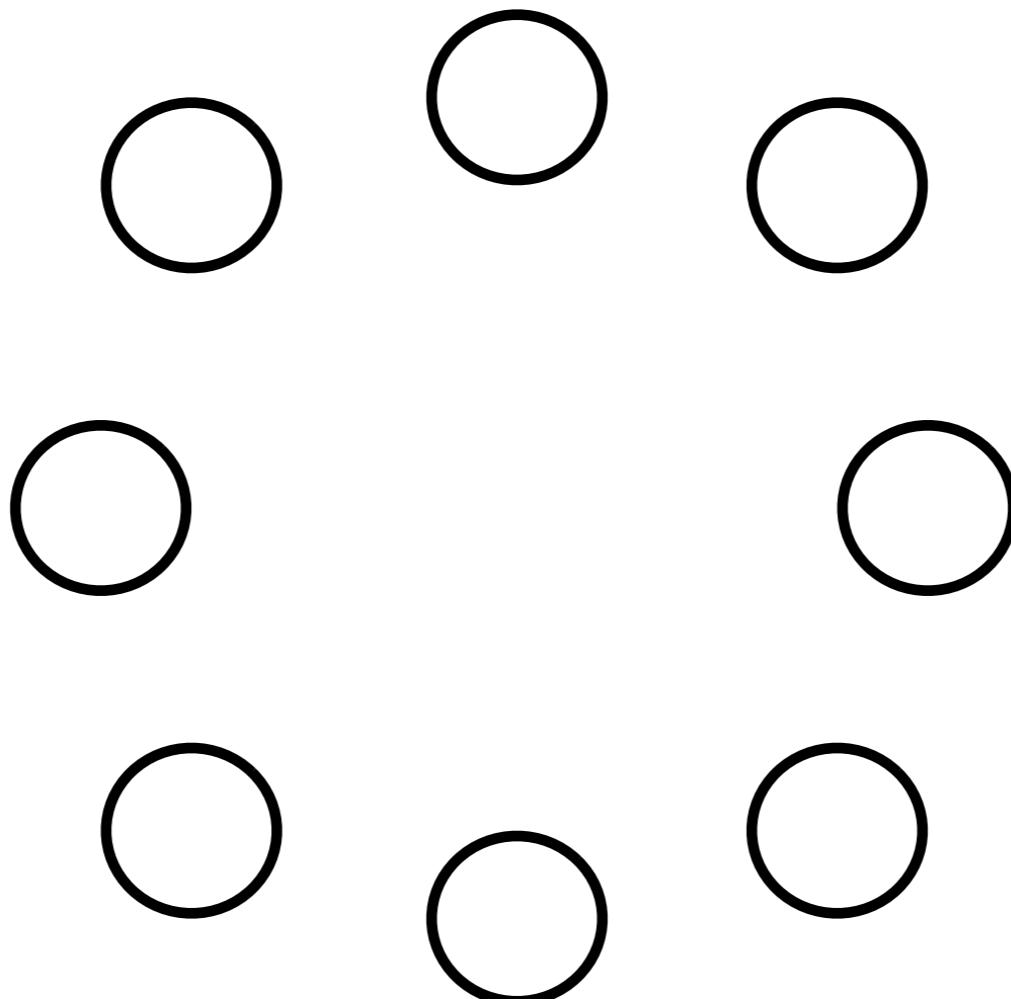
yes

Apply the schedule

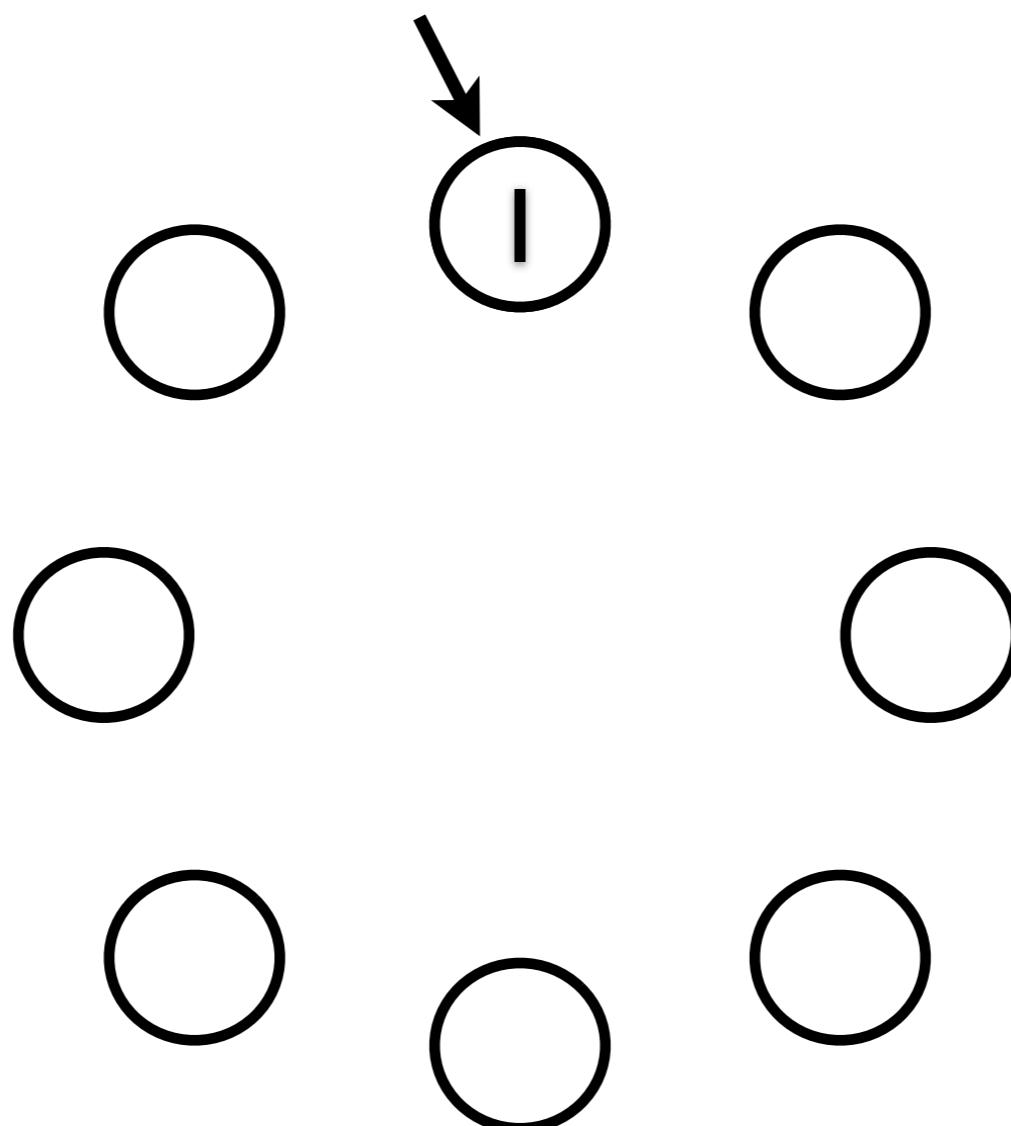
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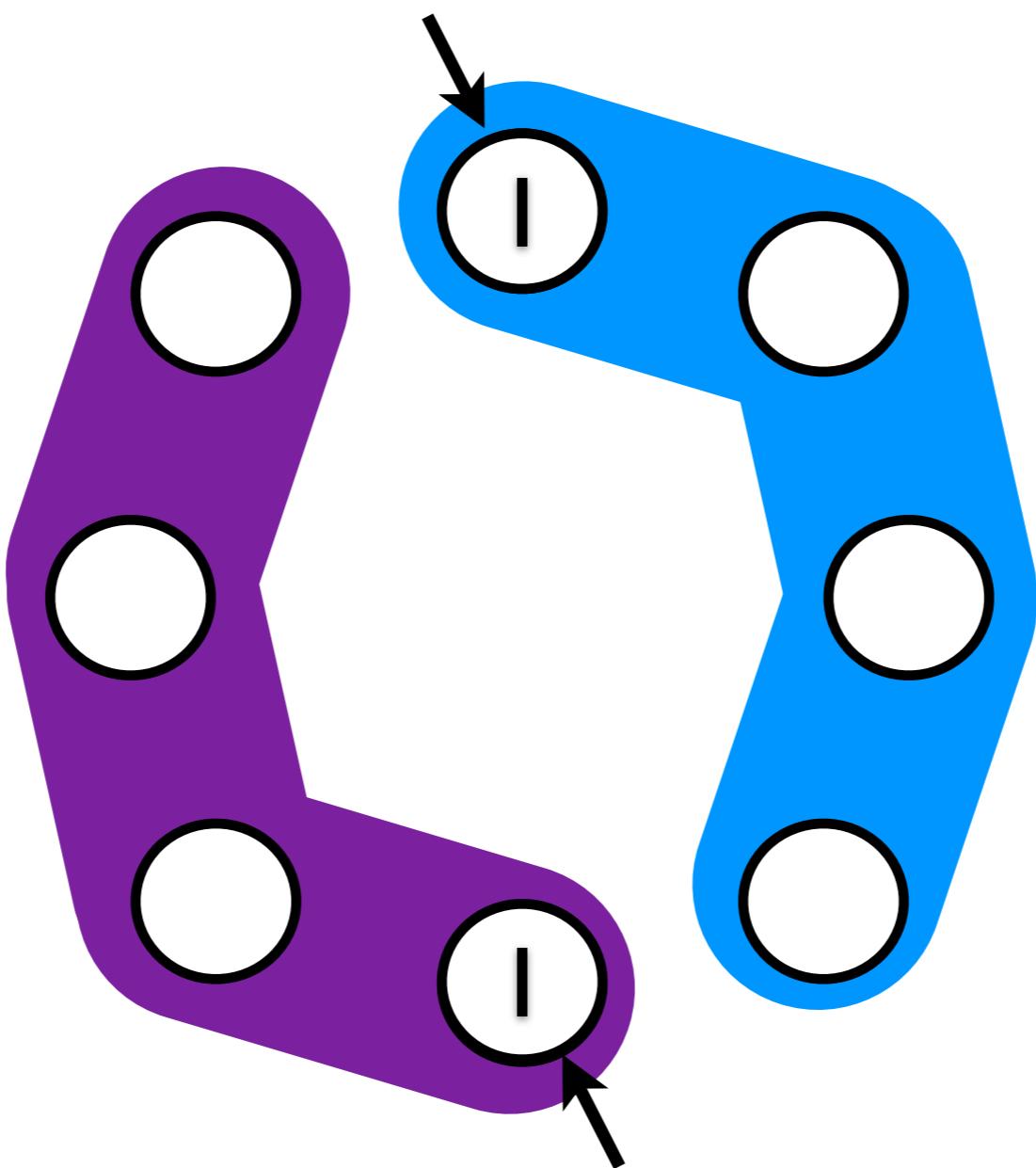
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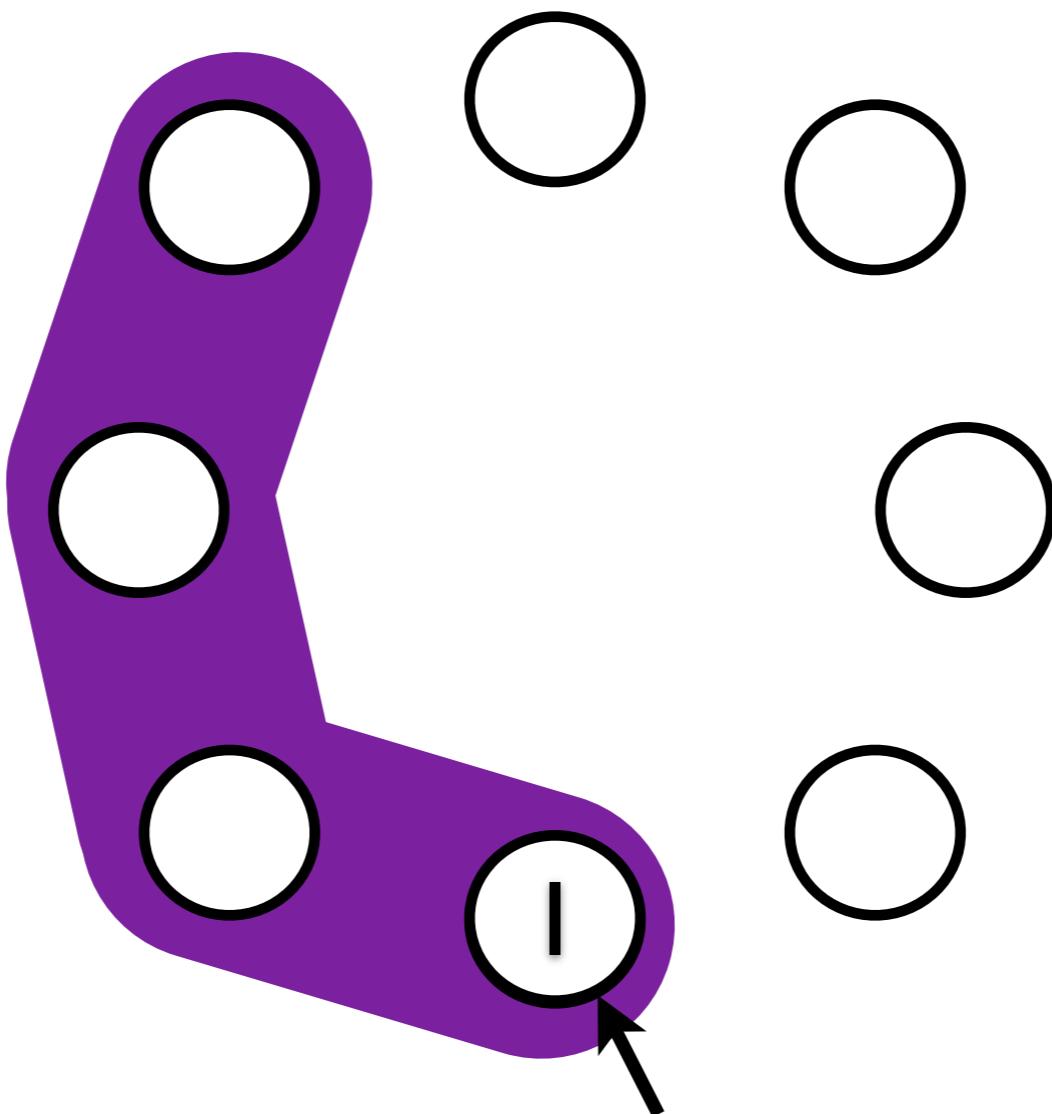
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# The LUC OS - VEs Scheduling

- Published in [CCPE'12]

- Reactivity/scalability

Scheduling started when an event is generated

Few nodes considered for scheduling

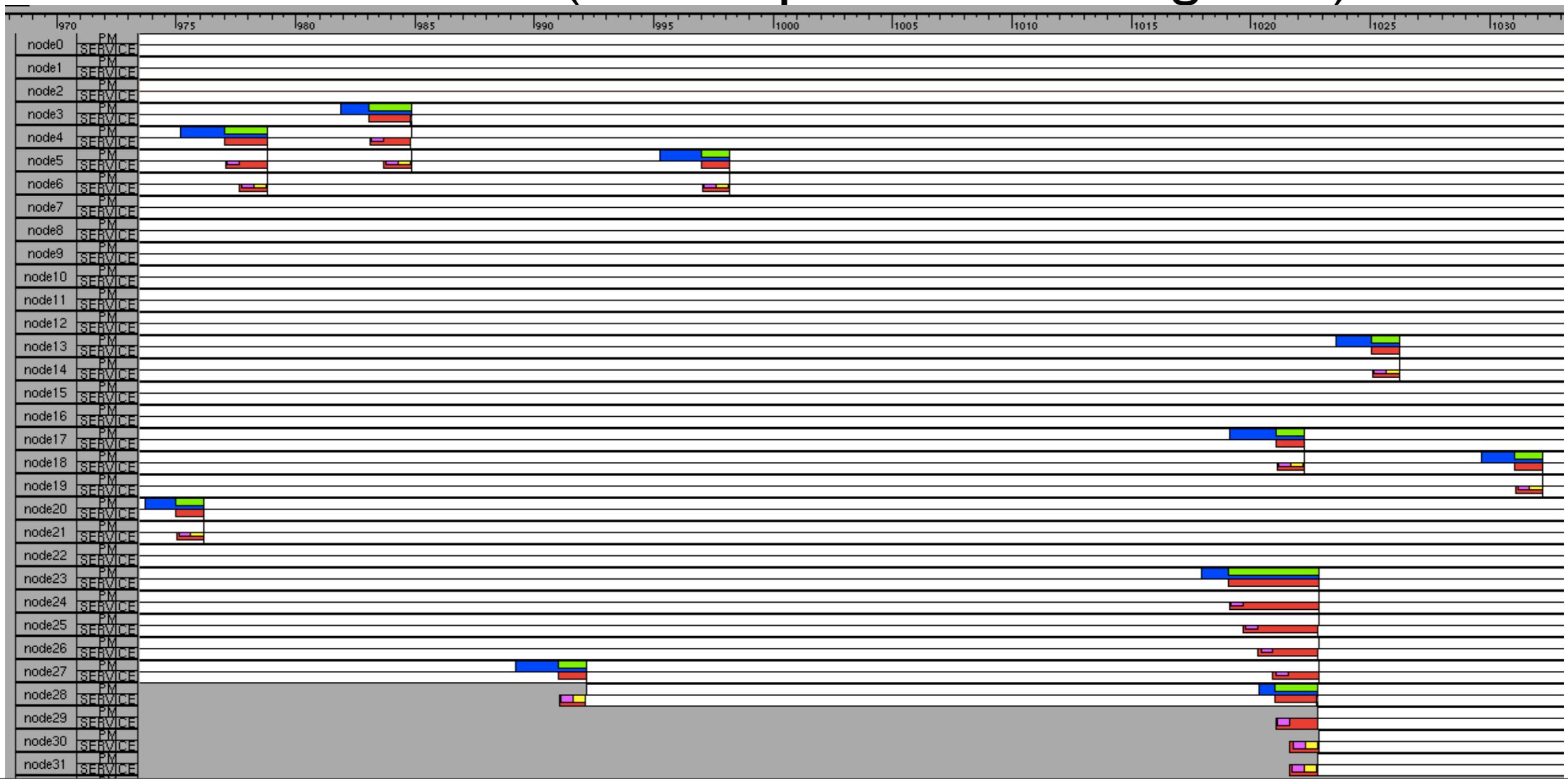
⇒ much faster computation

- Parallelism

Several events can be processed simultaneously and independently

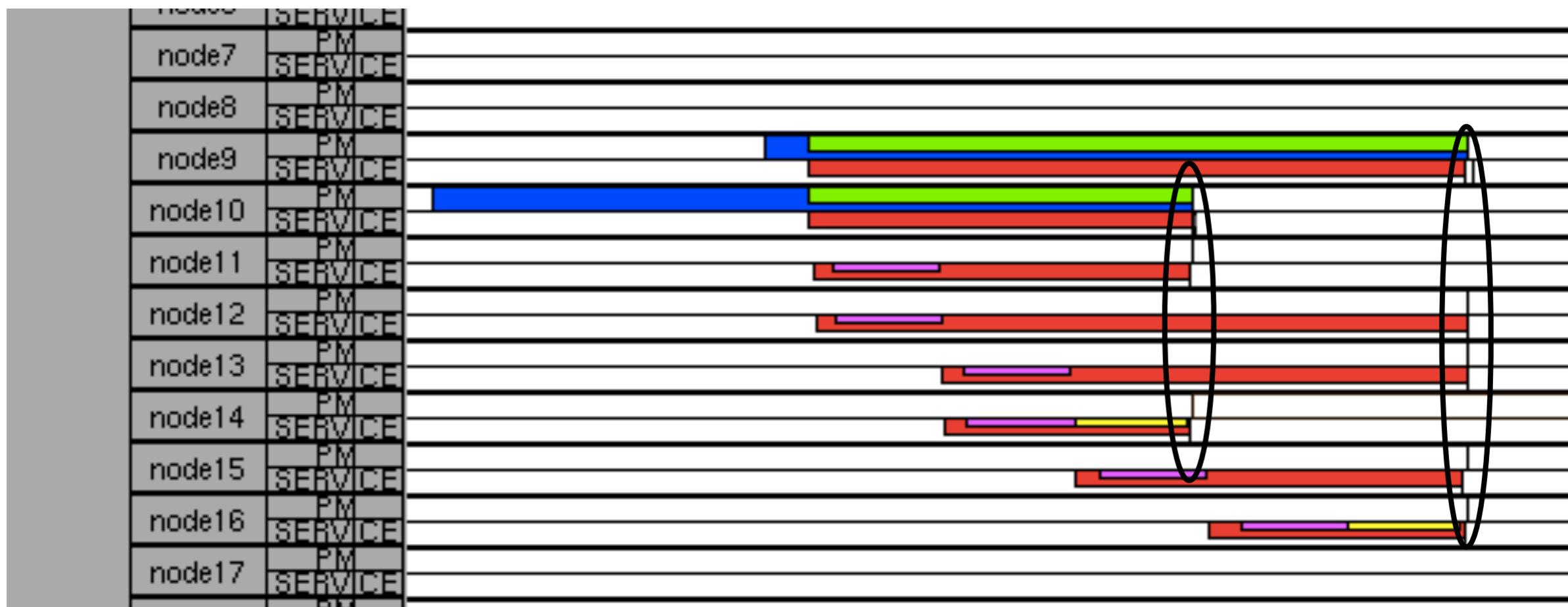
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- POC (leveraging Entropy to solve non viable configuration)
- 100K VMs / 10K PMs (simulation using the SimGrid framework)
- 10K VMs / 512 PMs (“real experiments” using G5K)



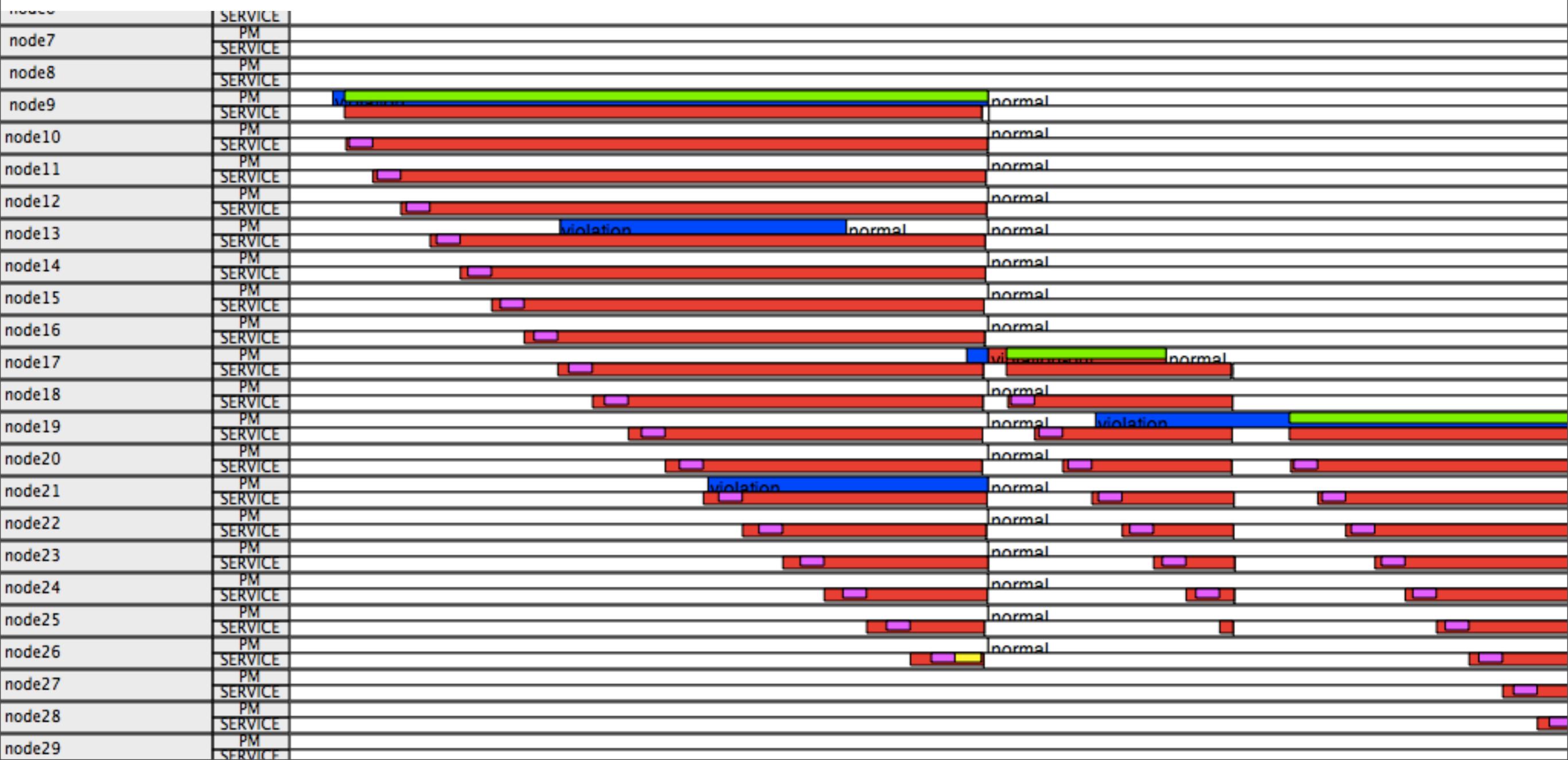
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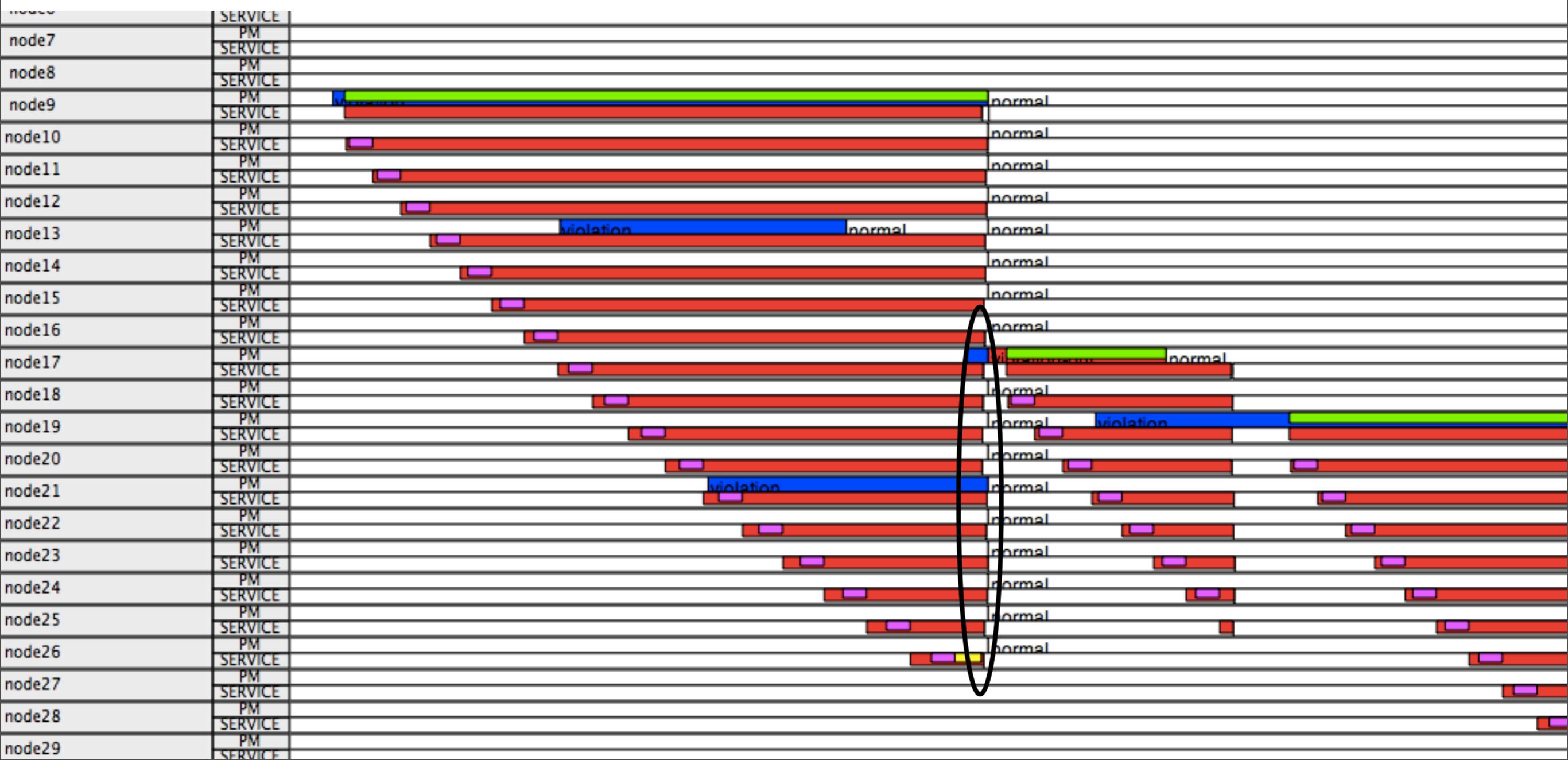
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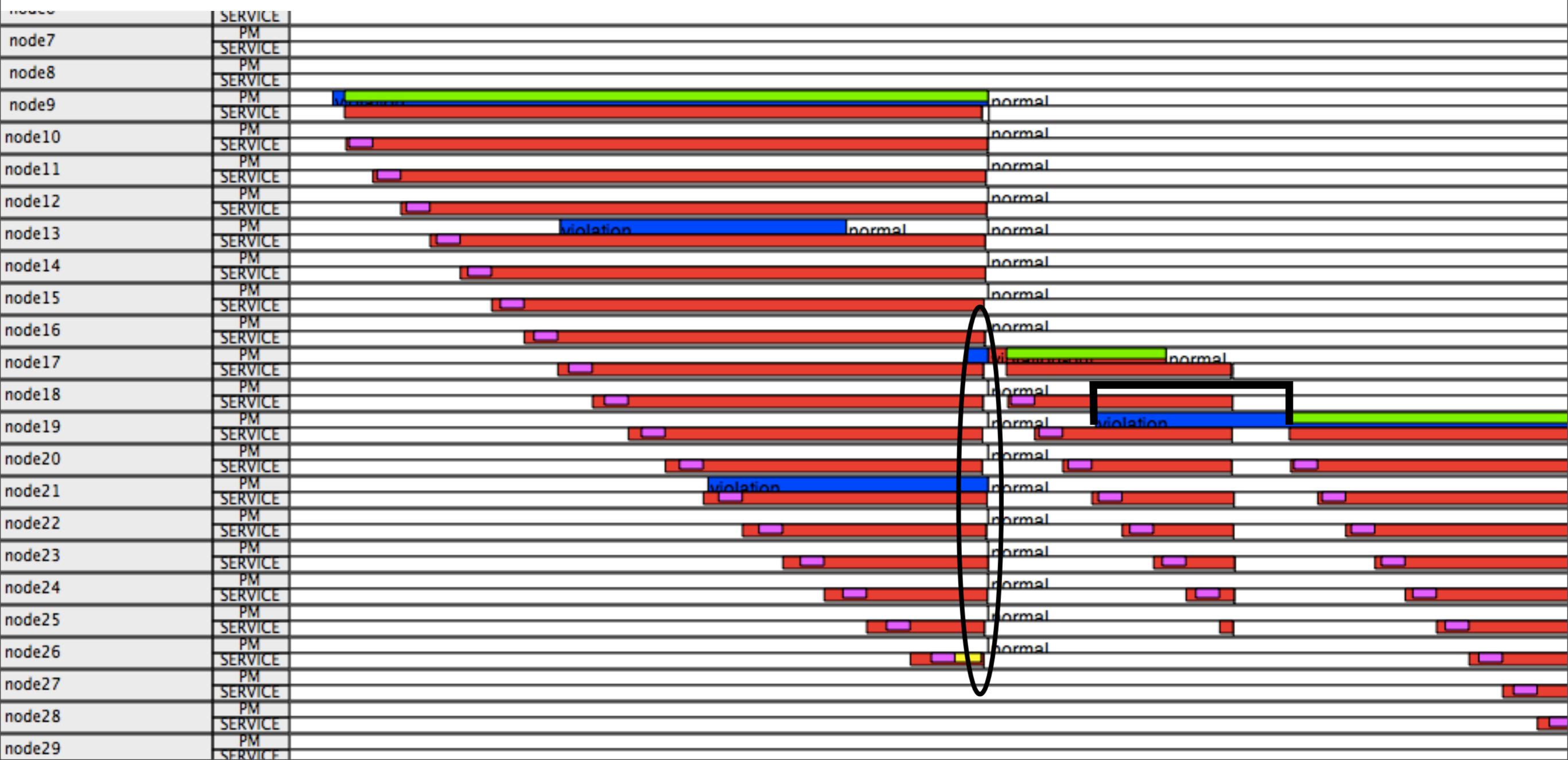
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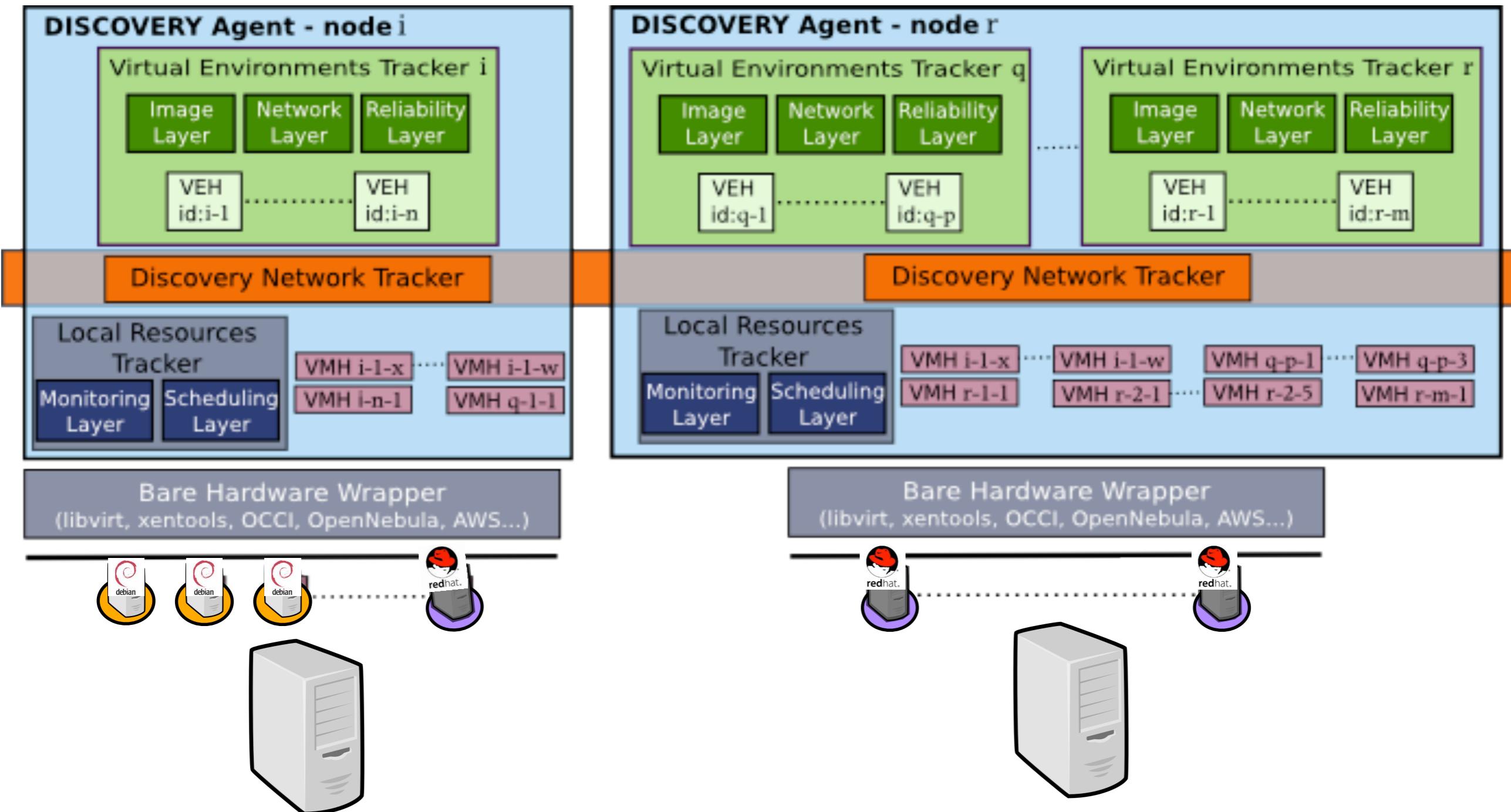


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# Understanding the DISCOVERY Agent



# DISCOVERY - Basic Usage



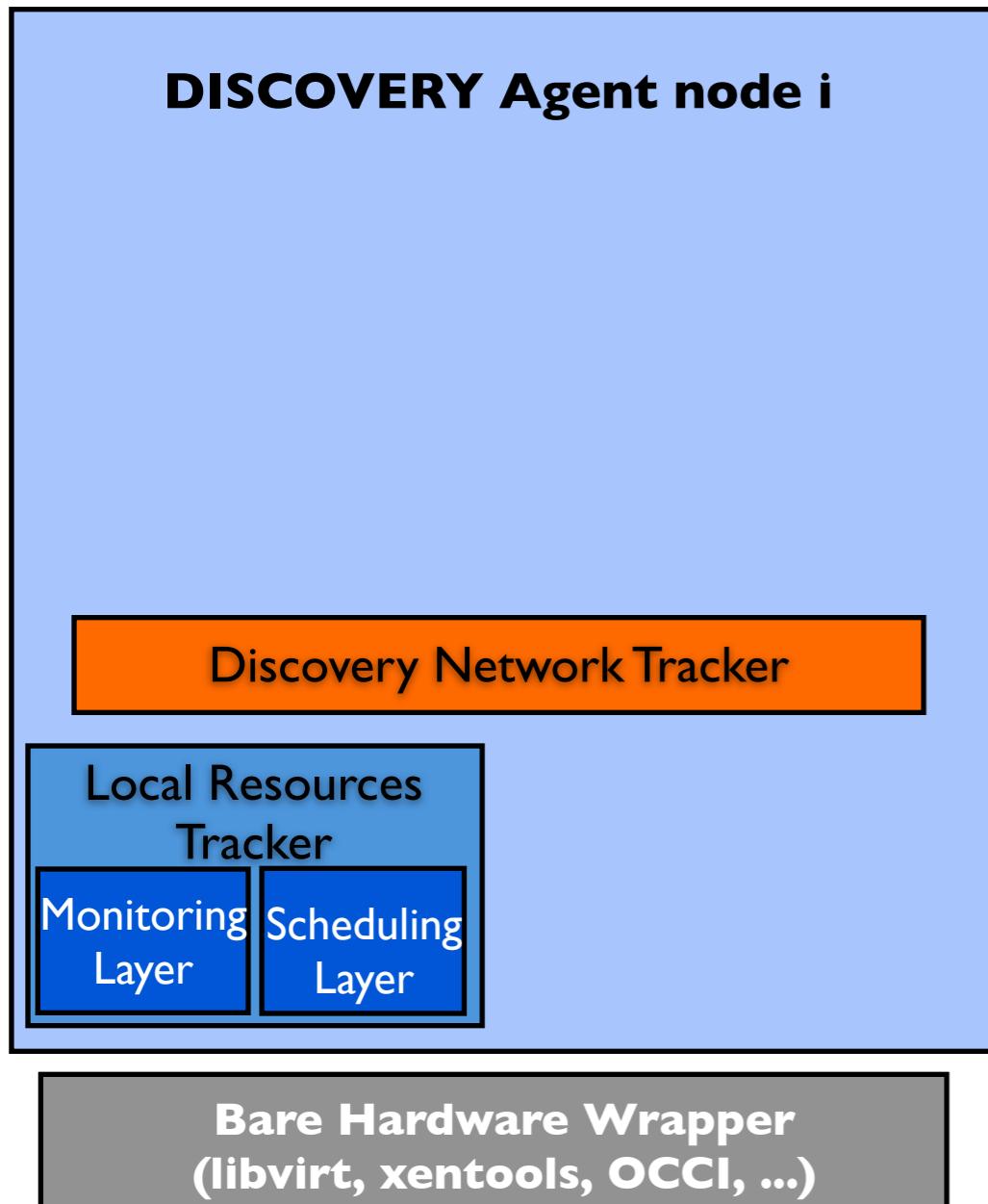
# DISCOVERY - Basic Usage

**DISCOVERY Agent node i**

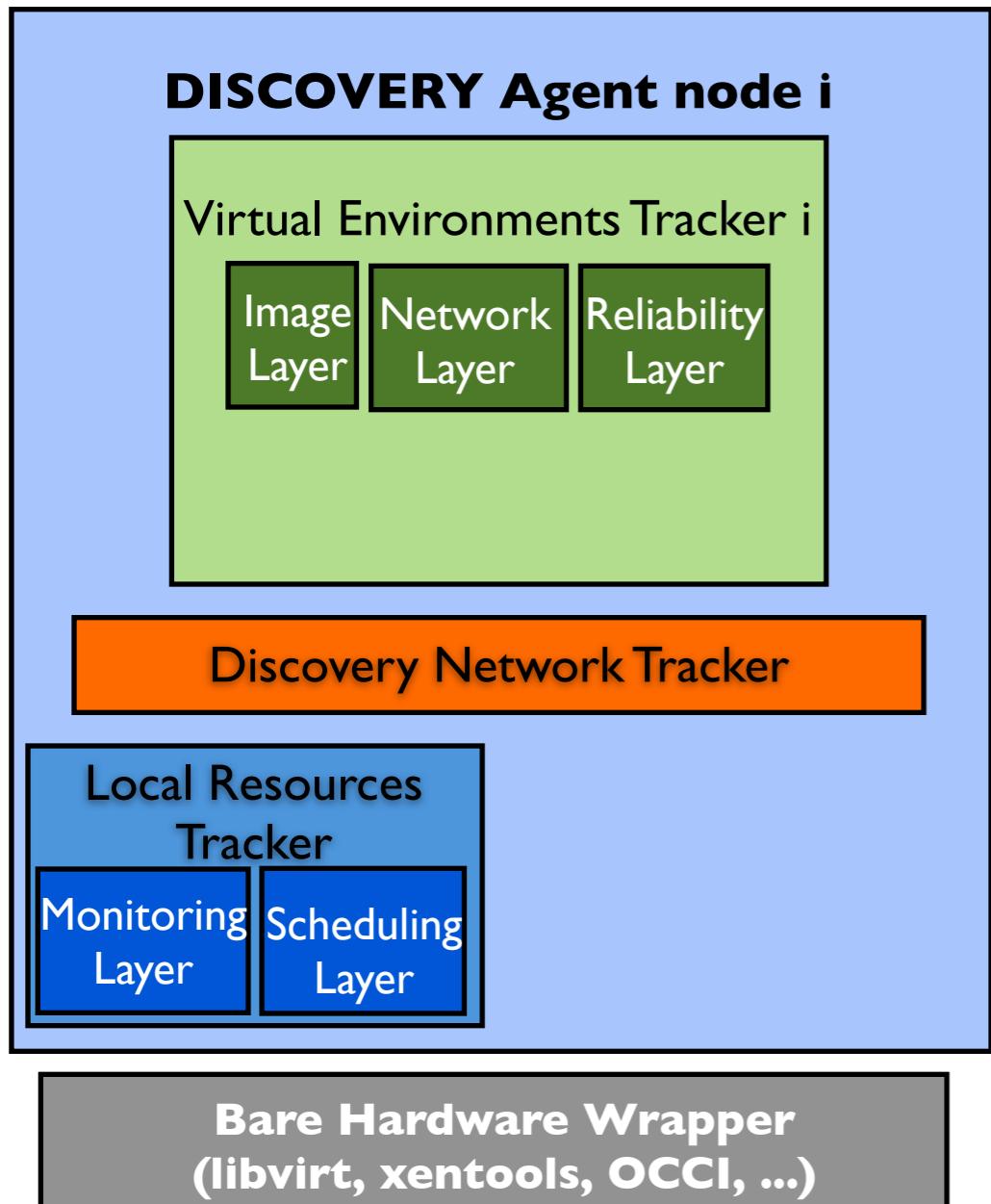
**Bare Hardware Wrapper**  
**(libvirt, xentools, OCCI, ...)**



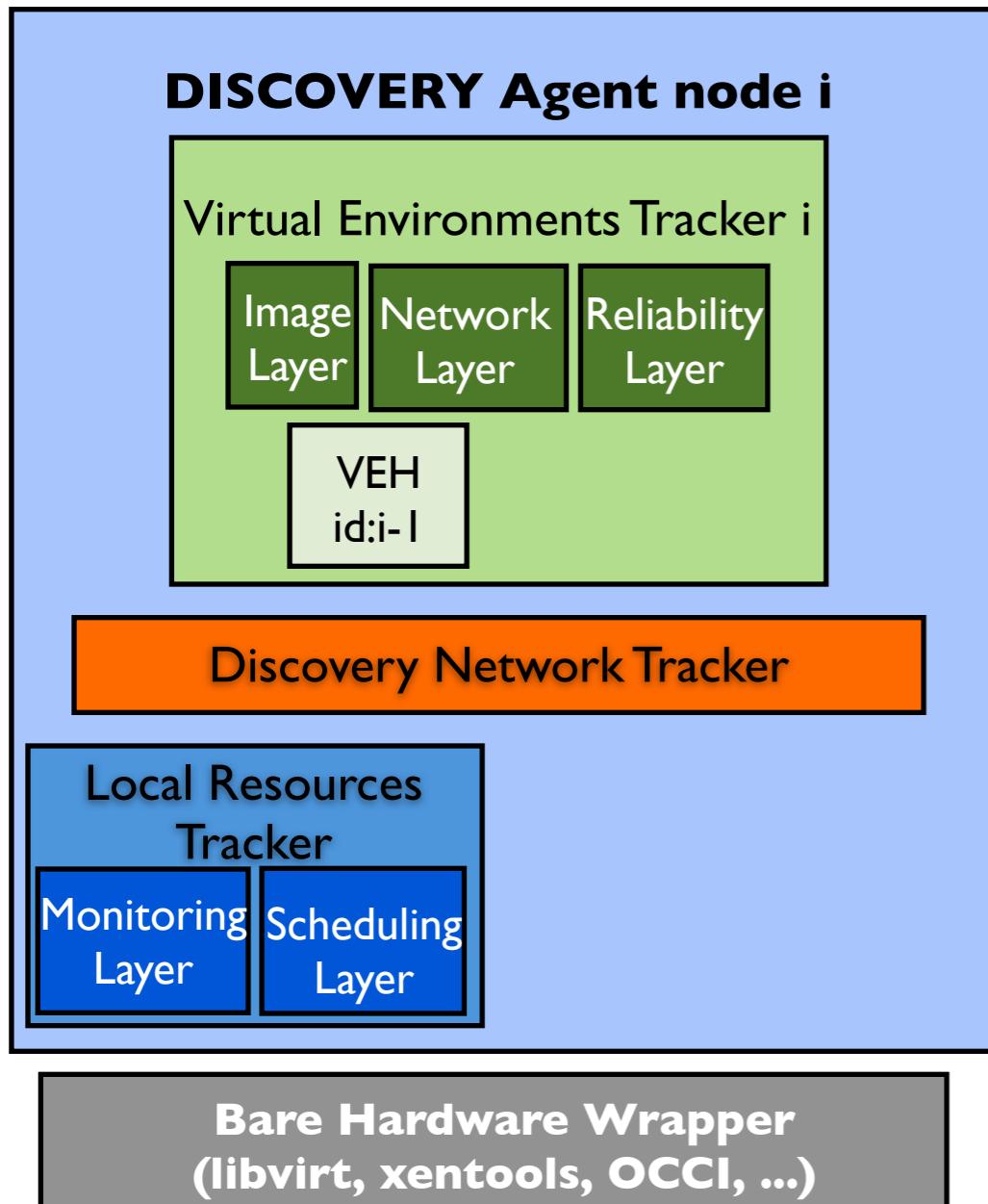
# DISCOVERY - Basic Usage



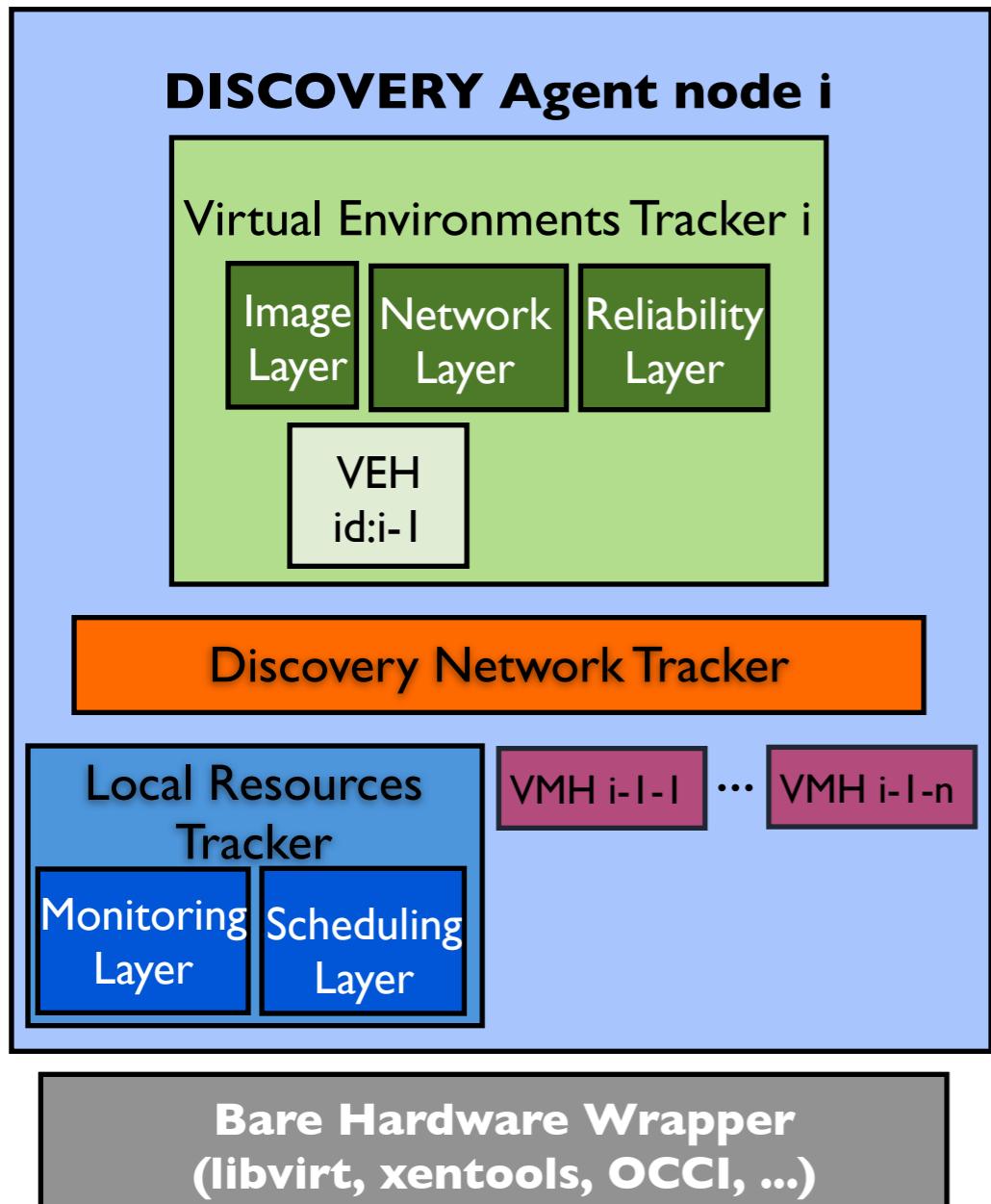
# DISCOVERY - Basic Usage



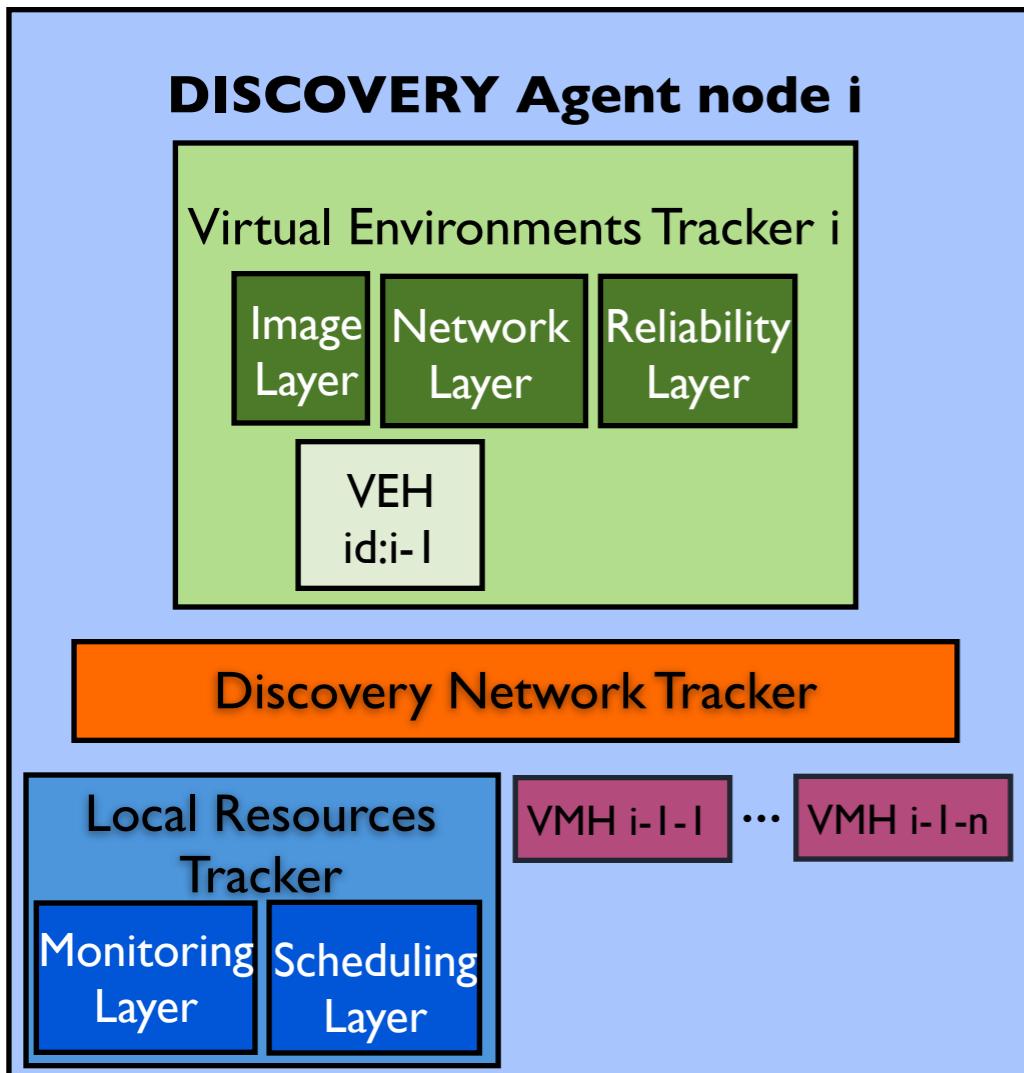
# DISCOVERY - Basic Usage



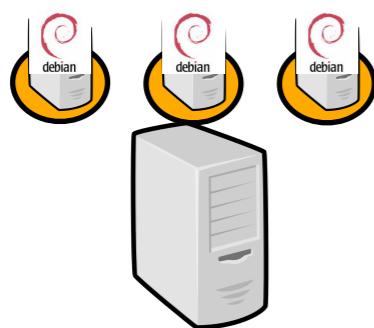
# DISCOVERY - Basic Usage



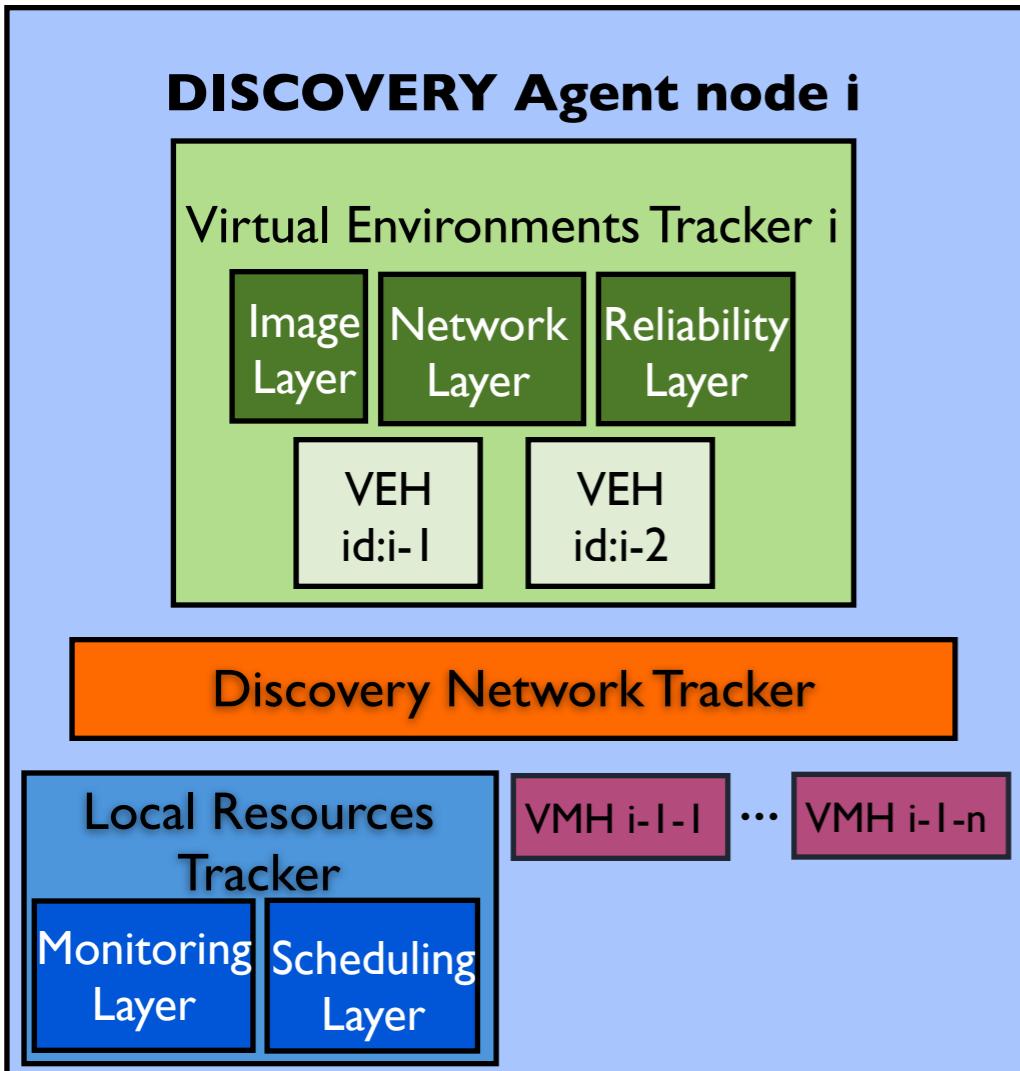
# DISCOVERY - Basic Usage



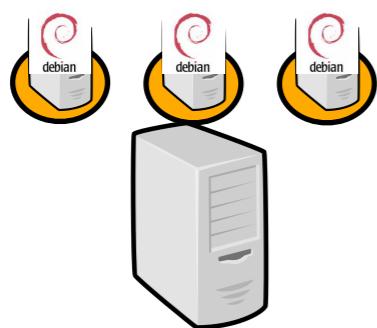
**Bare Hardware Wrapper  
(libvirt, xentools, OCCI, ...)**



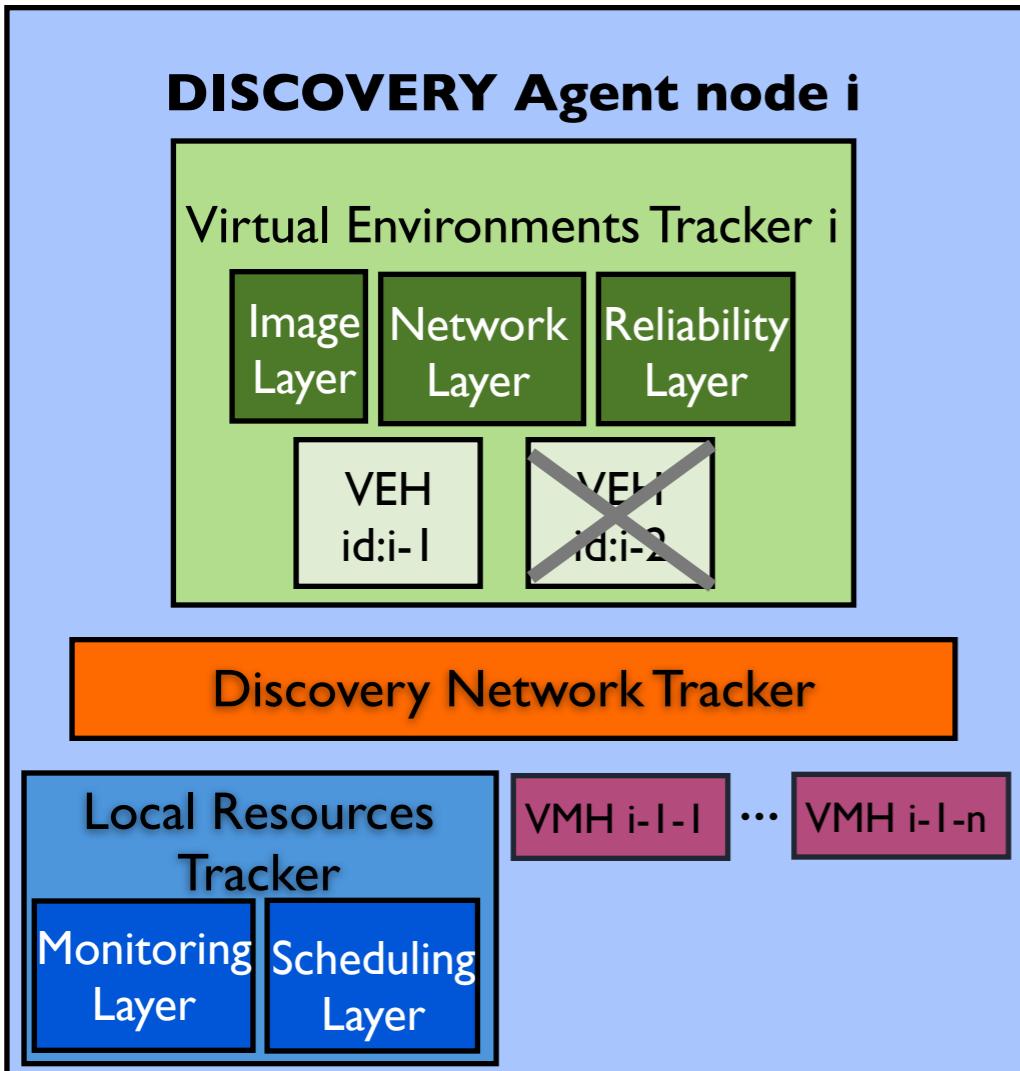
# DISCOVERY - Basic Usage



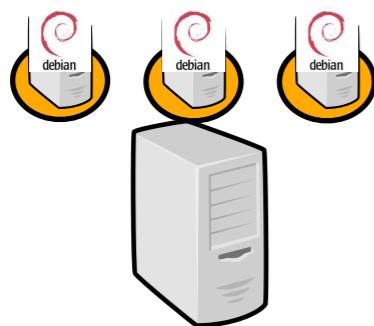
**Bare Hardware Wrapper**  
**(libvirt, xentools, OCCI, ...)**



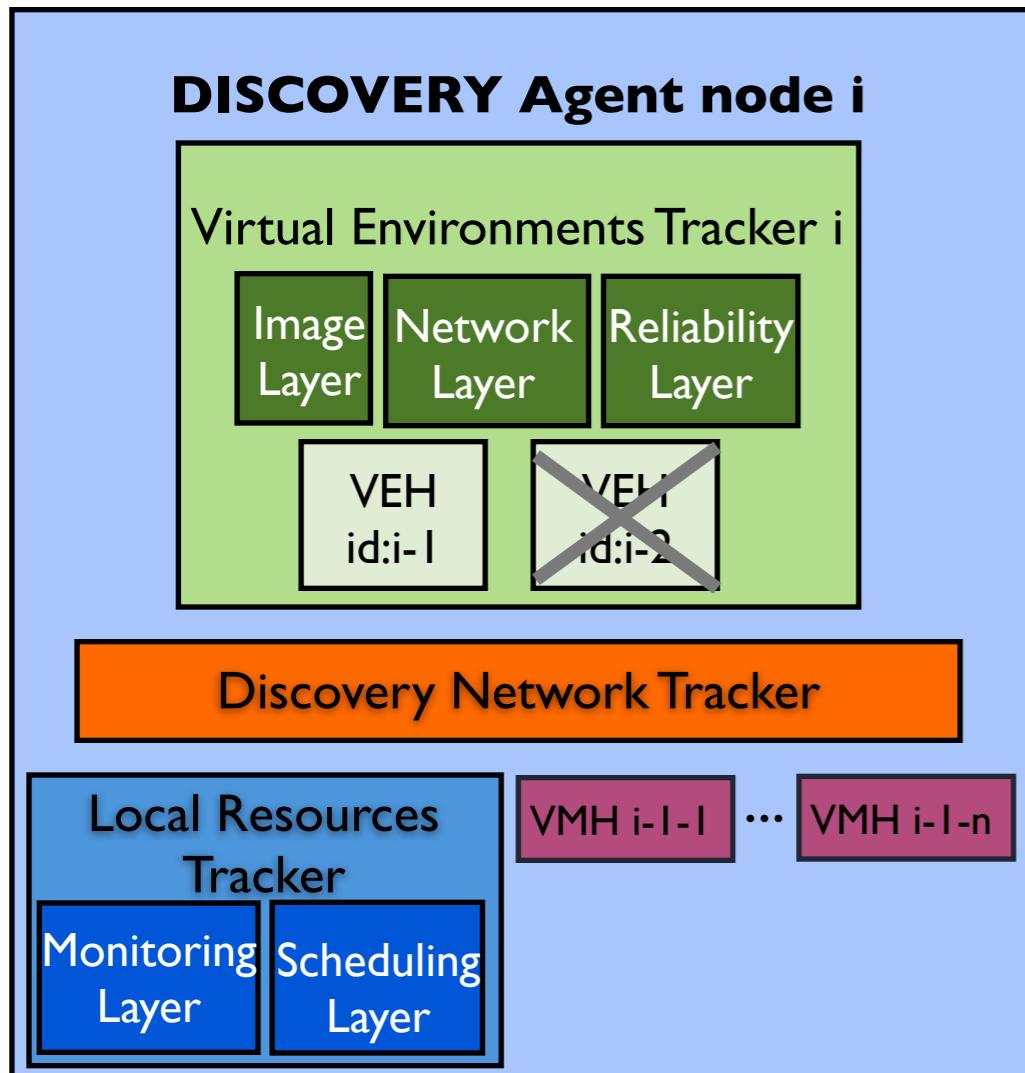
# DISCOVERY - Basic Usage



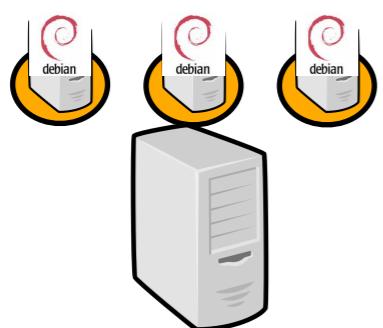
**Bare Hardware Wrapper**  
**(libvirt, xentools, OCCI, ...)**



# DISCOVERY - Basic Usage

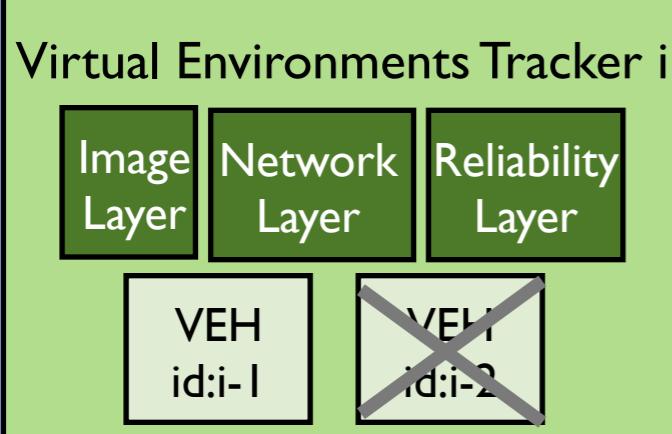


**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



# DISCOVERY - Basic Usage

**DISCOVERY Agent node i**

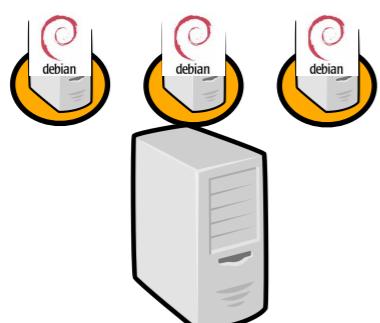


Discovery Network Tracker

Local Resources Tracker

Monitoring Layer      Scheduling Layer

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**

Discovery Network Tracker

Local Resources Tracker

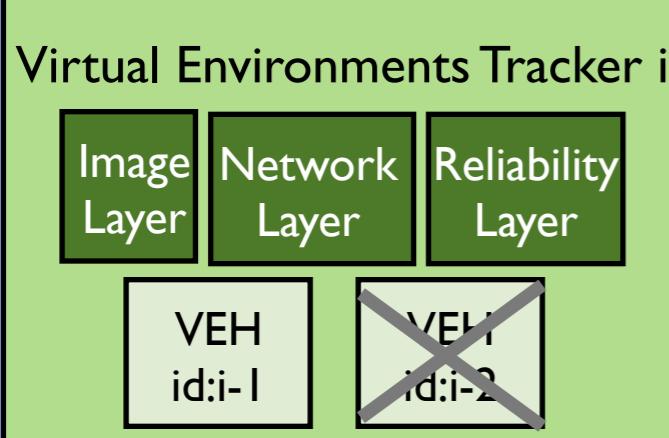
Monitoring Layer      Scheduling Layer

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)

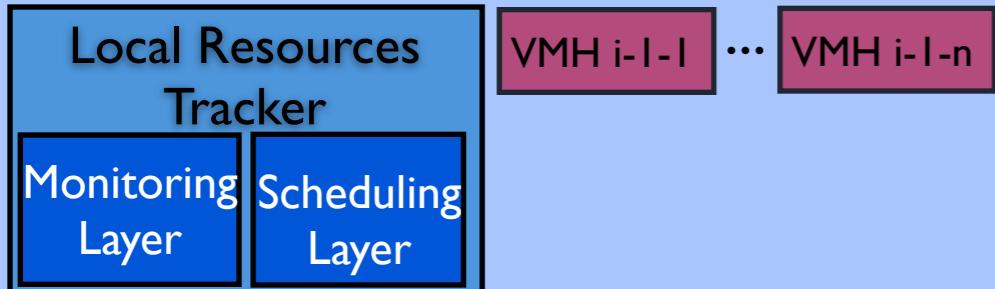


# DISCOVERY - Basic Usage

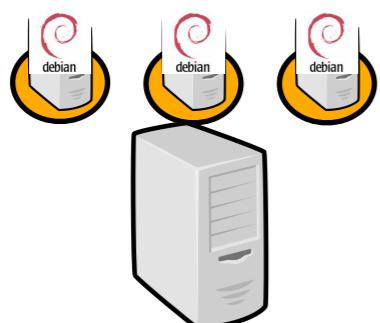
**DISCOVERY Agent node i**



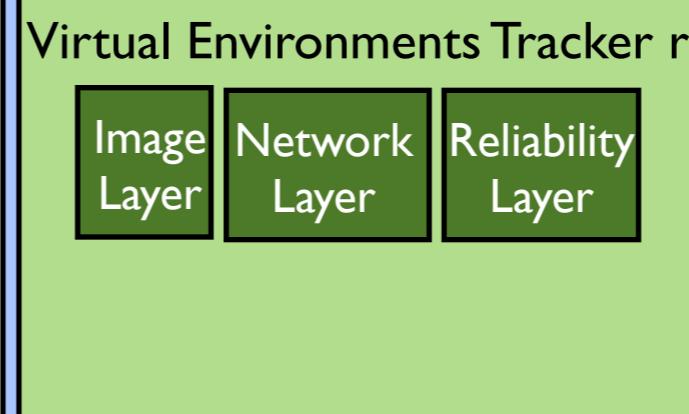
Discovery Network Tracker



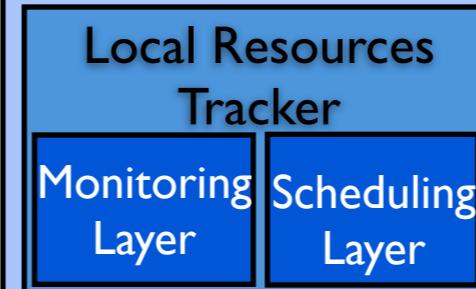
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**



Discovery Network Tracker

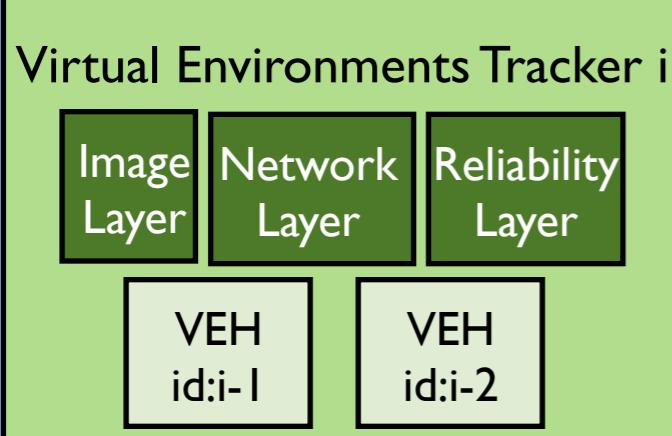


**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)

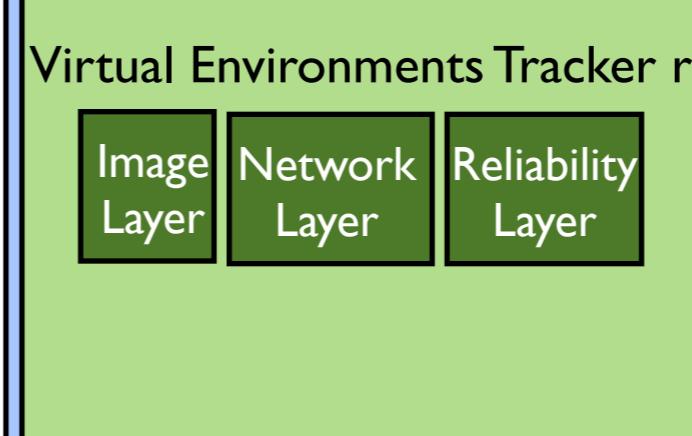


# DISCOVERY - Basic Usage

**DISCOVERY Agent node i**



**DISCOVERY Agent node r**



Discovery Network Tracker

Discovery Network Tracker

Local Resources  
Tracker

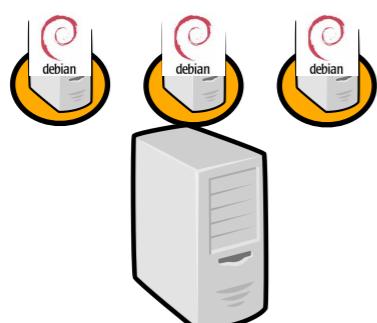
VMH i-1-1 ... VMH i-1-n

Monitoring  
Layer Scheduling  
Layer

Local Resources  
Tracker

Monitoring  
Layer Scheduling  
Layer

**Bare Hardware Wrapper**  
**(libvirt, xentools, OCCI, ...)**

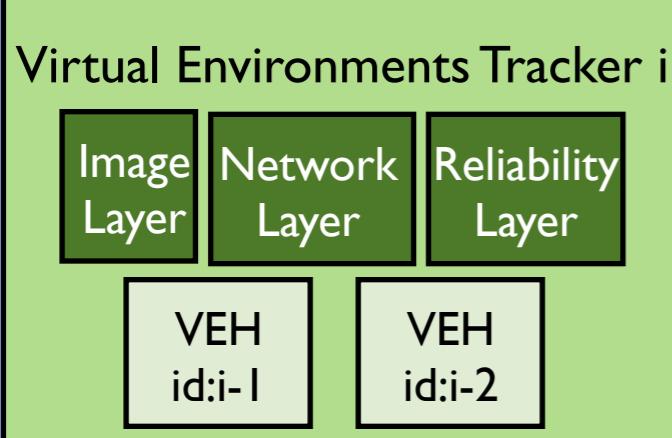


**Bare Hardware Wrapper**  
**(libvirt, xentools, OCCI, ...)**

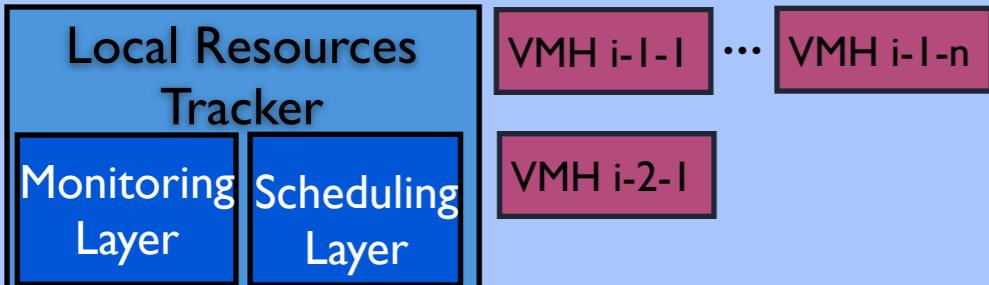


# DISCOVERY - Basic Usage

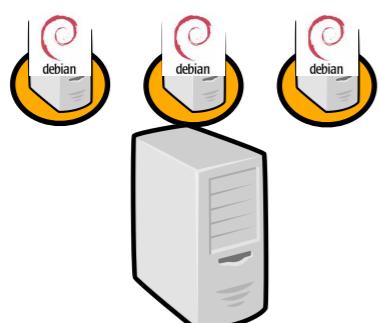
**DISCOVERY Agent node i**



Discovery Network Tracker



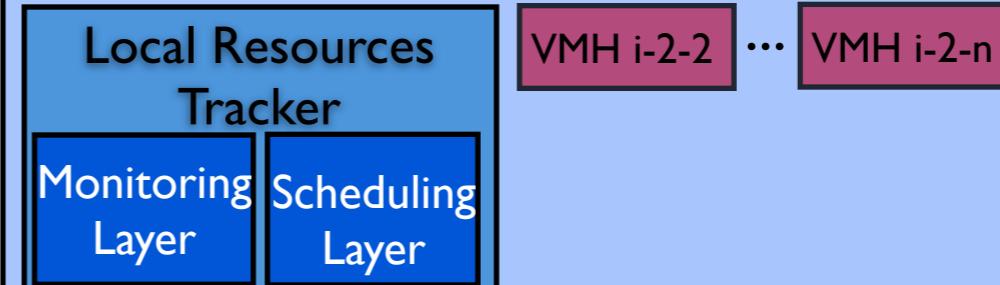
**Bare Hardware Wrapper**  
**(libvirt, xentools, OCCI, ...)**



**DISCOVERY Agent node r**



Discovery Network Tracker

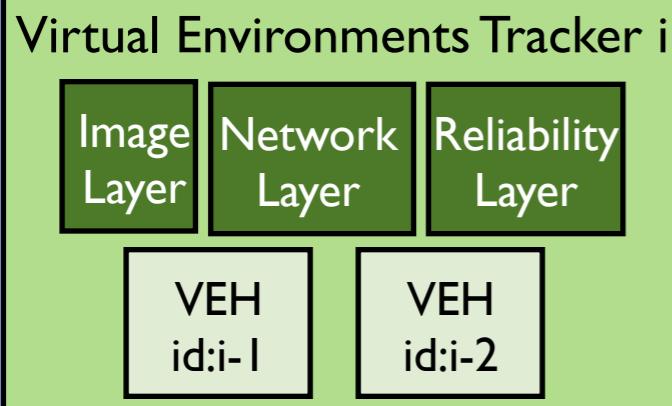


**Bare Hardware Wrapper**  
**(libvirt, xentools, OCCI, ...)**

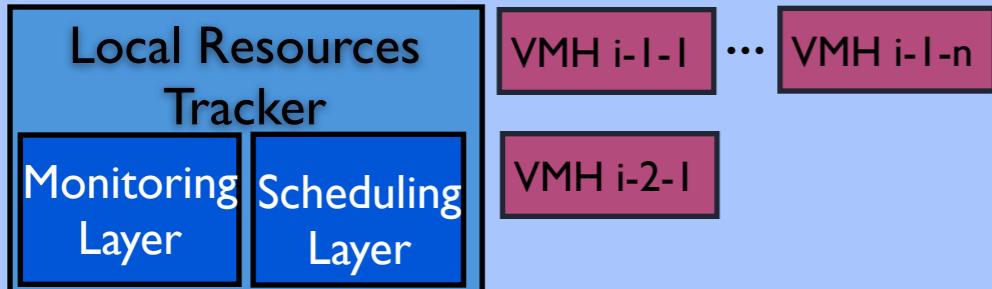


# DISCOVERY - Basic Usage

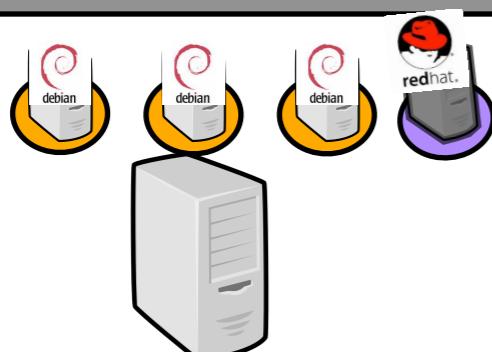
**DISCOVERY Agent node i**



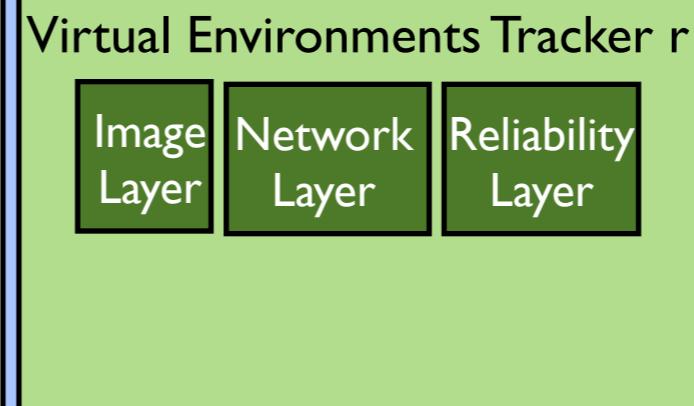
Discovery Network Tracker



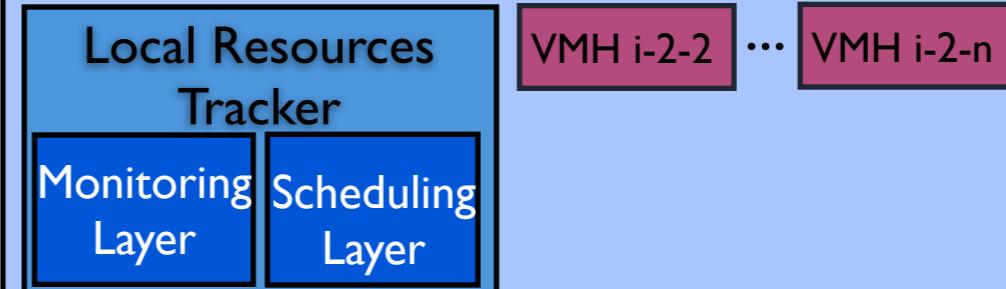
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



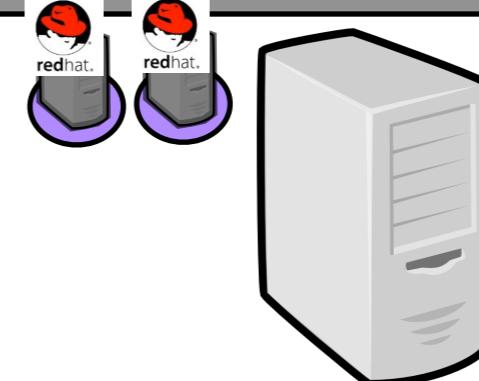
**DISCOVERY Agent node r**



Discovery Network Tracker

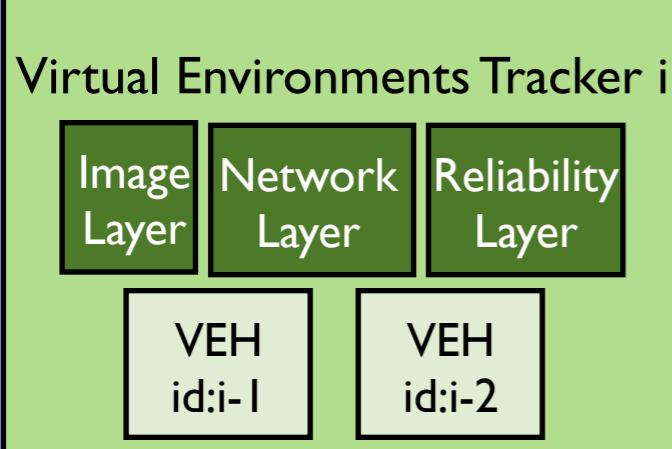


**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)

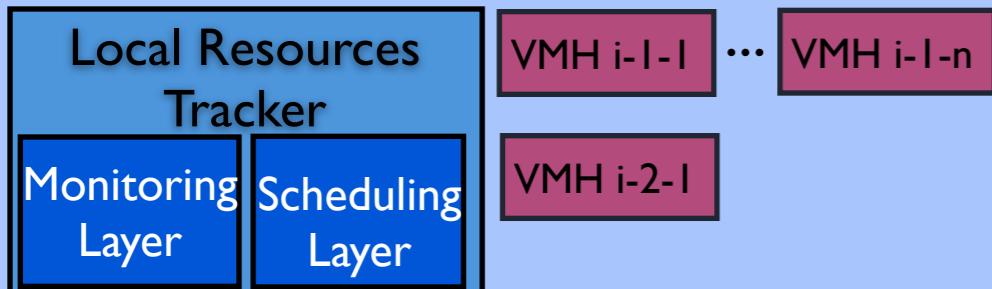


# DISCOVERY - Basic Usage

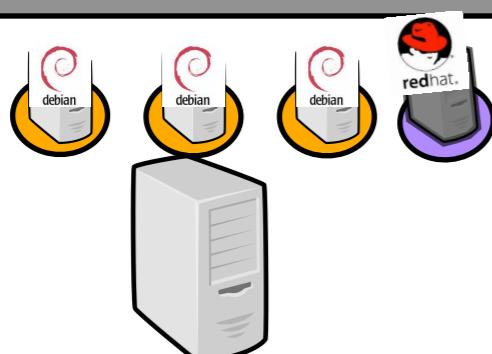
**DISCOVERY Agent node i**



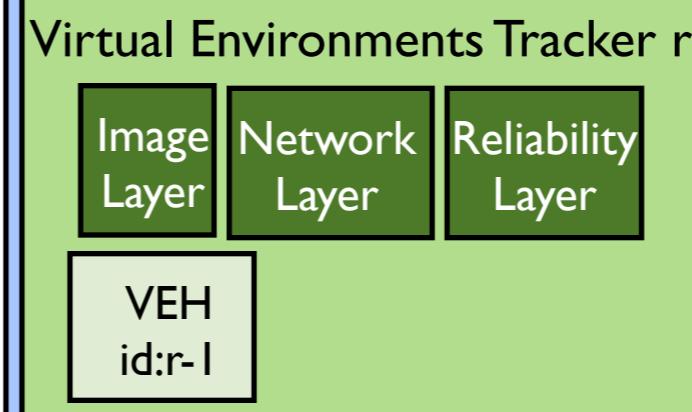
Discovery Network Tracker



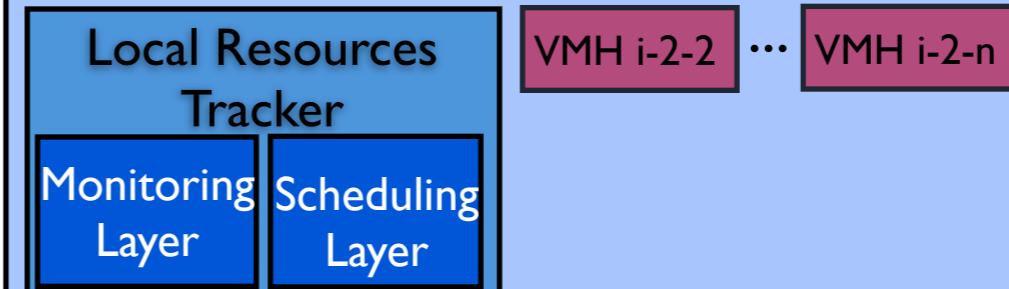
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



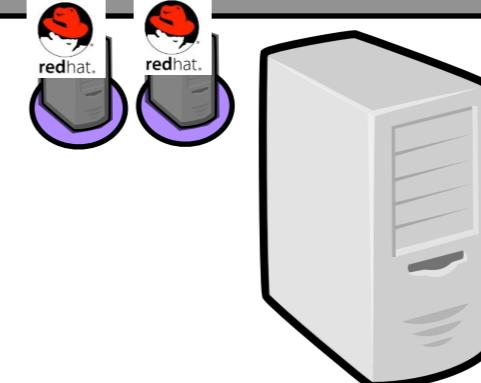
**DISCOVERY Agent node r**



Discovery Network Tracker



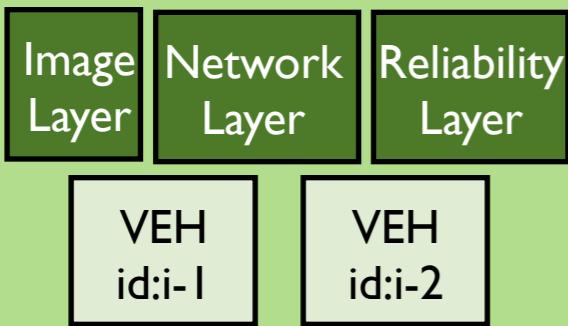
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



# DISCOVERY - Basic Usage

**DISCOVERY Agent node i**

Virtual Environments Tracker i



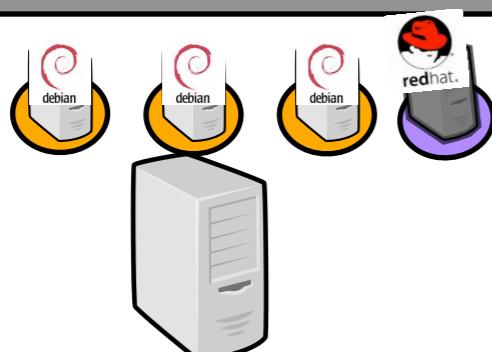
Discovery Network Tracker

Local Resources Tracker  
Monitoring Layer

VMH i-1-1 ... VMH i-1-n  
VMH i-2-1

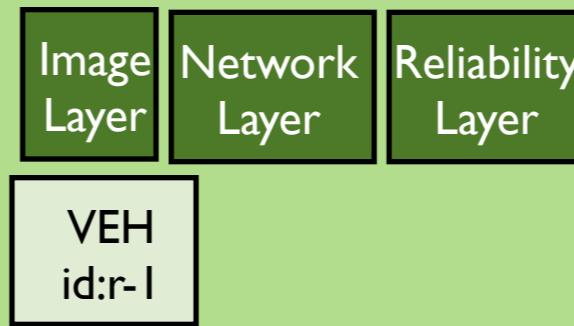
Scheduling Layer

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**

Virtual Environments Tracker r



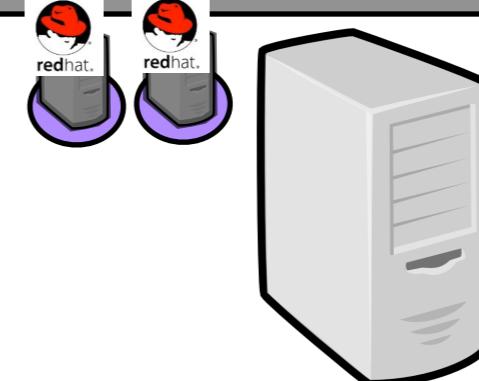
Discovery Network Tracker

Local Resources Tracker  
Monitoring Layer

VMH i-2-2 ... VMH i-2-n  
VMH r-1-1

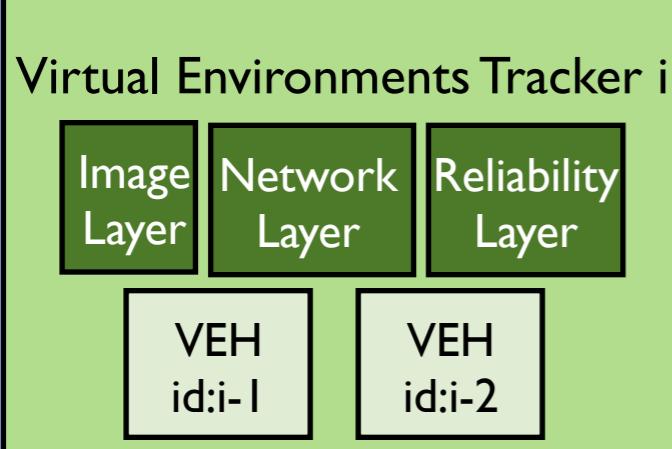
Scheduling Layer

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)

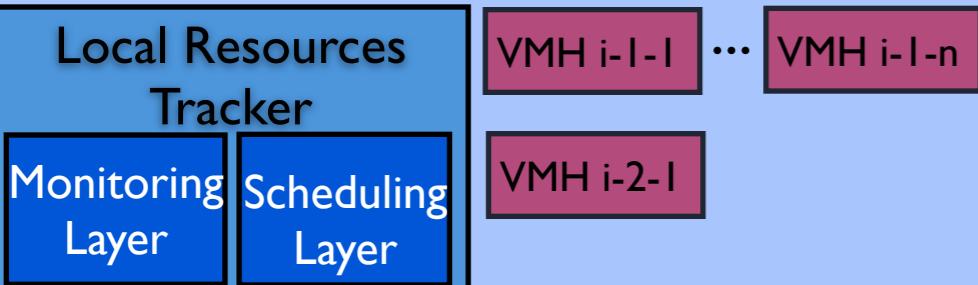


# DISCOVERY - Basic Usage

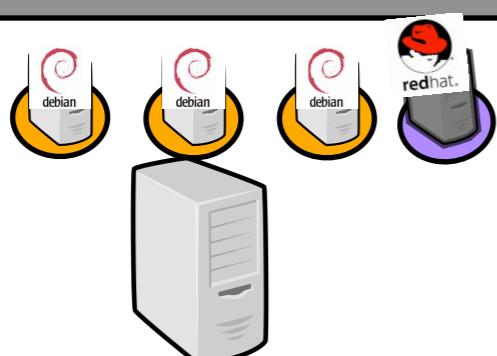
**DISCOVERY Agent node i**



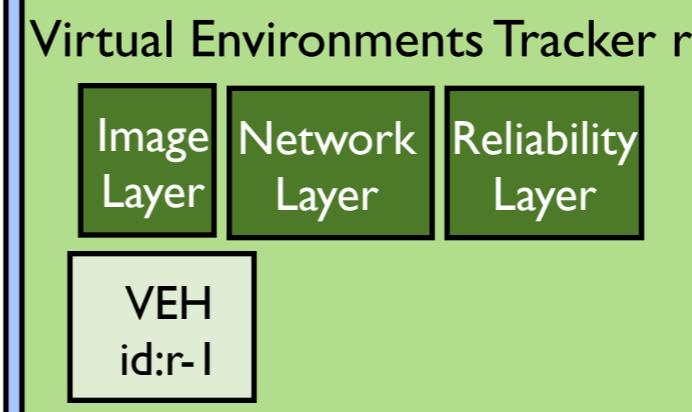
Discovery Network Tracker



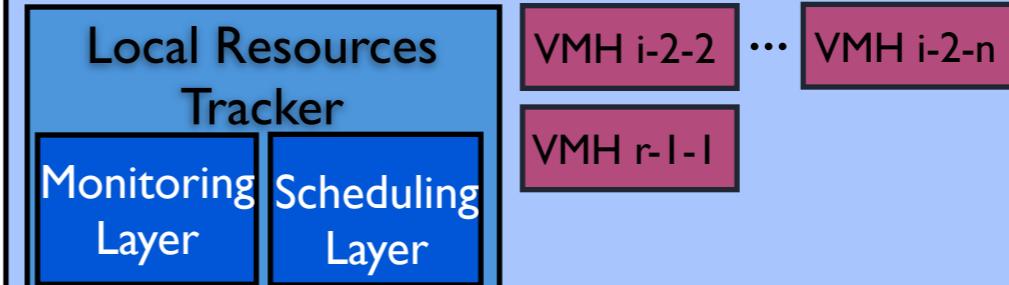
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



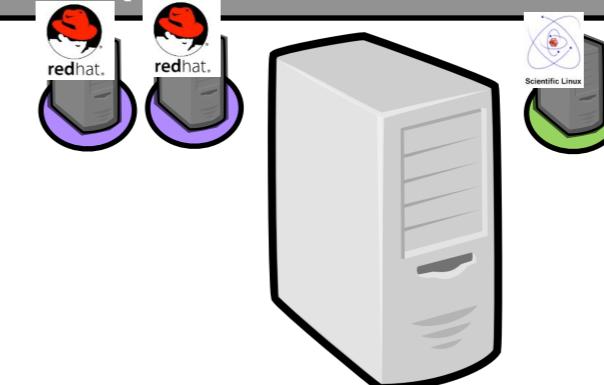
**DISCOVERY Agent node r**



Discovery Network Tracker



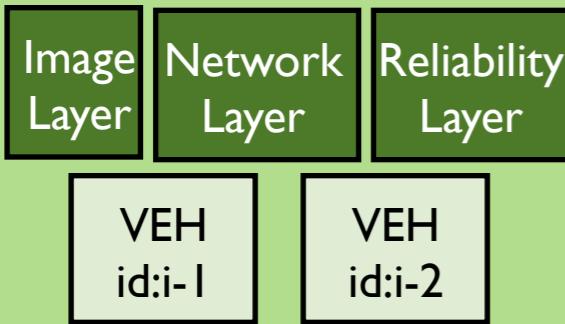
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



# DISCOVERY - Human removals

**DISCOVERY Agent node i**

Virtual Environments Tracker i



Discovery Network Tracker

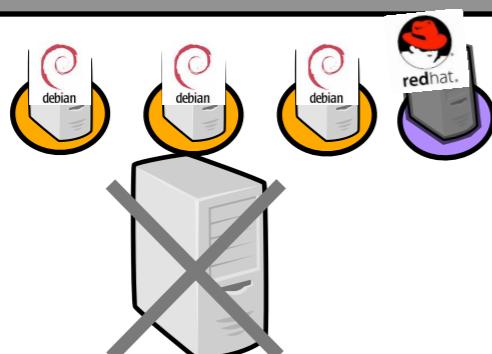
Local Resources Tracker  
Monitoring Layer

VMH i-1-1 ... VMH i-1-n

VMH i-2-1

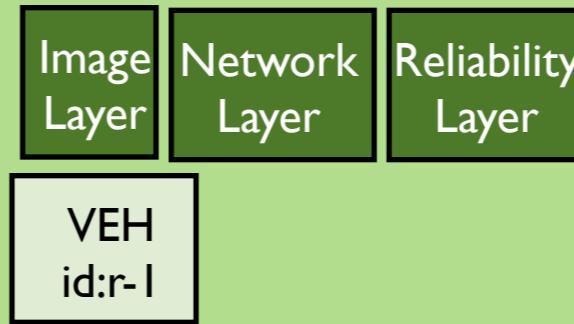
Scheduling Layer

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**

Virtual Environments Tracker r



Discovery Network Tracker

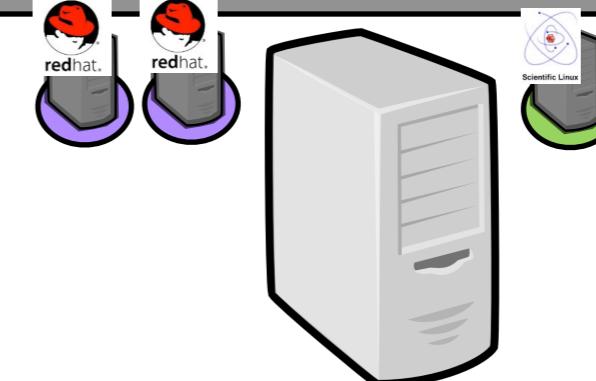
Local Resources Tracker  
Monitoring Layer

VMH i-2-2 ... VMH i-2-n

VMH r-1-1

Scheduling Layer

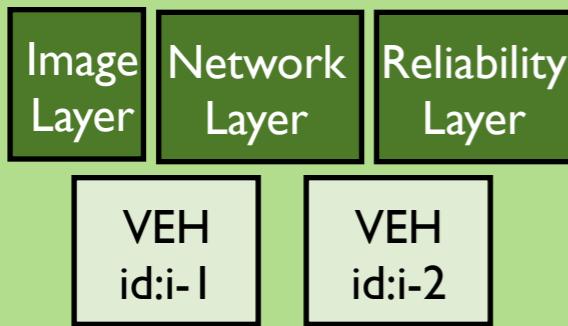
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



# DISCOVERY - Human removals

**DISCOVERY Agent node i**

Virtual Environments Tracker i



Discovery Network Tracker

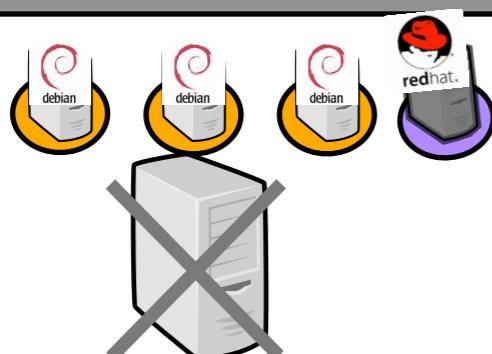
Local Resources Tracker  
Monitoring Layer

Scheduling Layer

VMH i-1-1 ... VMH i-1-n

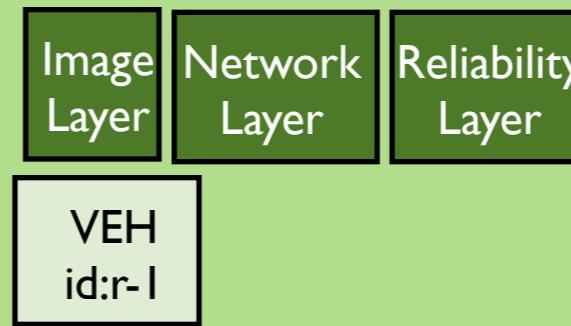
VMH i-2-1

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**

Virtual Environments Tracker r



Discovery Network Tracker

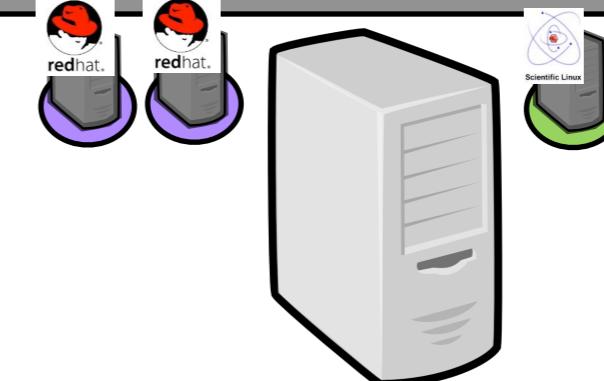
Local Resources Tracker  
Monitoring Layer

Scheduling Layer

VMH i-2-2 ... VMH i-2-n

VMH r-1-1

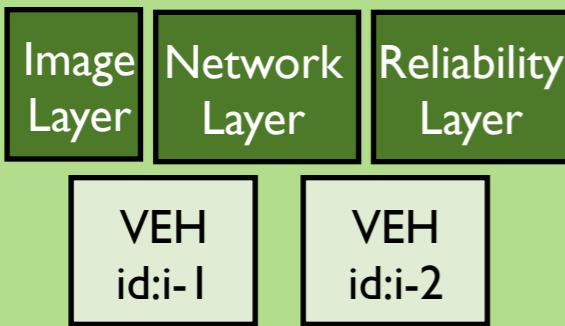
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



# DISCOVERY - Human removals

**DISCOVERY Agent node i**

Virtual Environments Tracker i

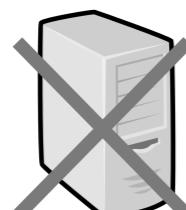


Discovery Network Tracker

Local Resources Tracker  
Monitoring Layer

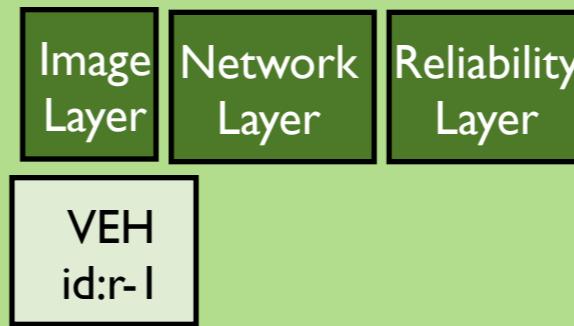
Scheduling Layer

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**

Virtual Environments Tracker r



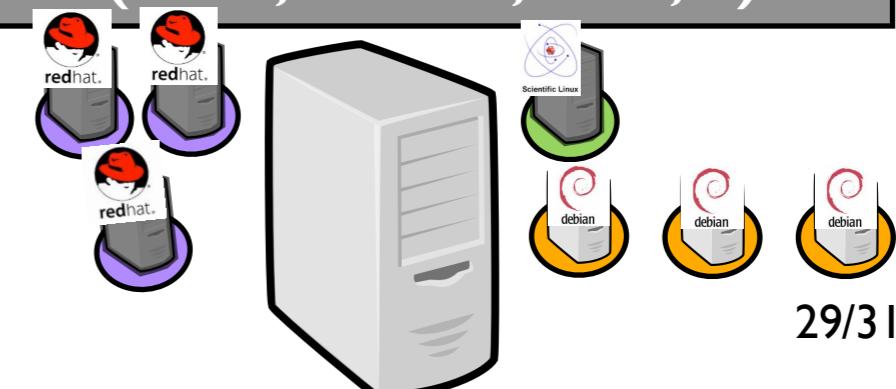
Discovery Network Tracker

Local Resources Tracker  
Monitoring Layer

Scheduling Layer

VMH i-2-2 ... VMH i-2-n VMH i-2-1  
VMH r-1-1 VMH i-1-1 ... VMH i-1-n

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



# DISCOVERY - Human removals

**DISCOVERY Agent node i**

Discovery Network Tracker

Local Resources  
Tracker

Monitoring  
Layer      Scheduling  
Layer

Bare Hardware Wrapper  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**

Virtual Environments Tracker r

Image  
Layer

Network  
Layer

Reliability  
Layer

VEH  
id:r-1

Virtual Environments Tracker i

Image  
Layer

Network  
Layer

Reliability  
Layer

VEH  
id:i-1

VEH  
id:i-2

Discovery Network Tracker

Local Resources  
Tracker

Monitoring  
Layer      Scheduling  
Layer

VMH i-2-2

VMH i-2-n

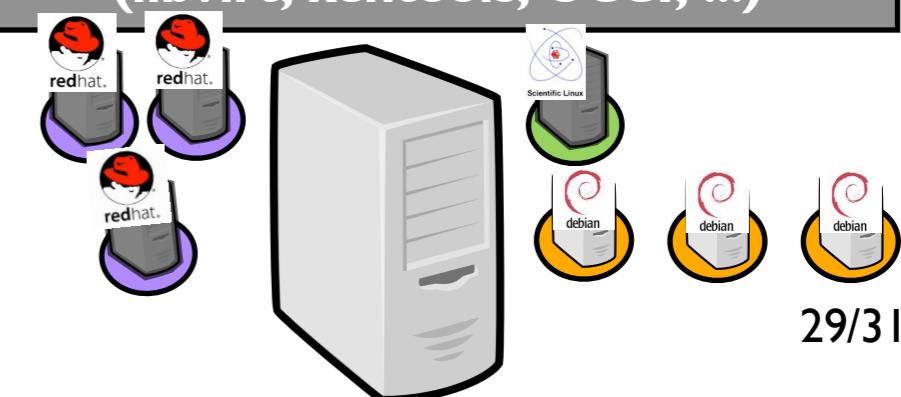
VMH i-2-1

VMH r-1-1

VMH i-1-1

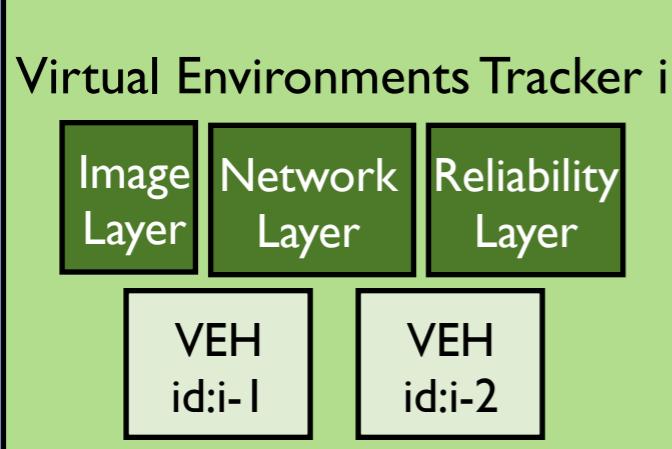
VMH i-1-n

Bare Hardware Wrapper  
(libvirt, xentools, OCCI, ...)

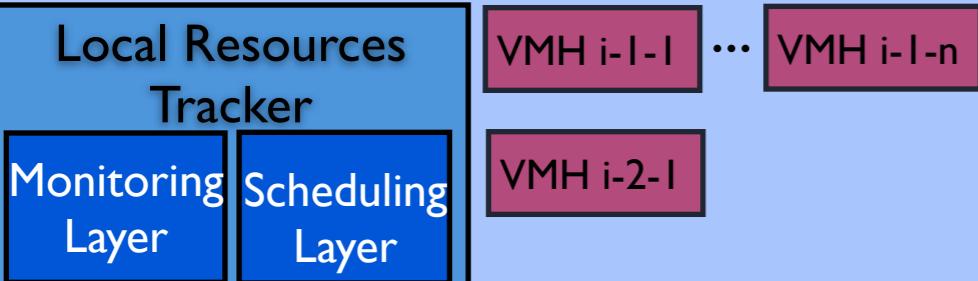


# DISCOVERY - VM Crashes

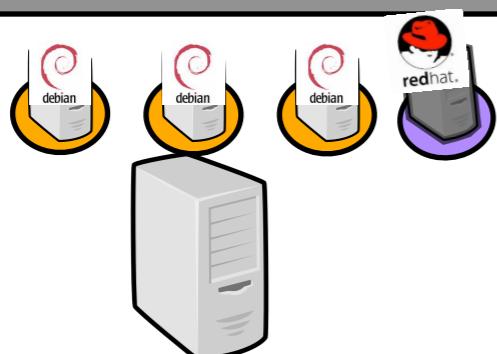
**DISCOVERY Agent node i**



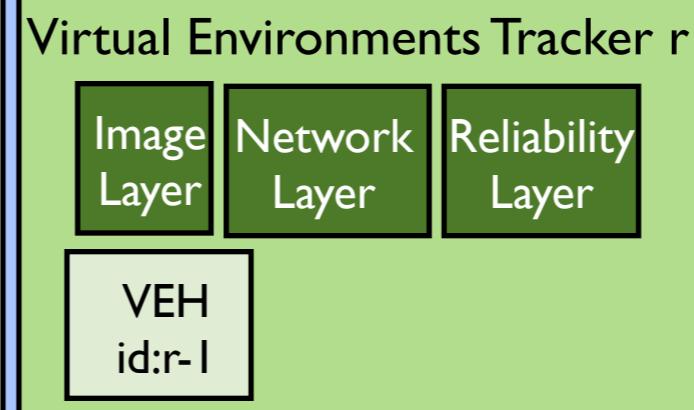
Discovery Network Tracker



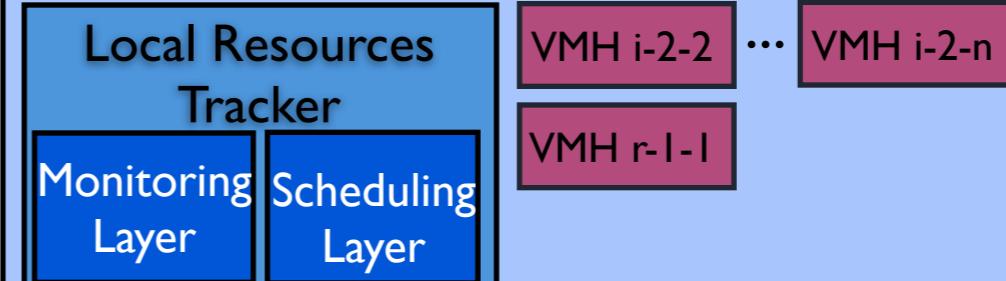
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



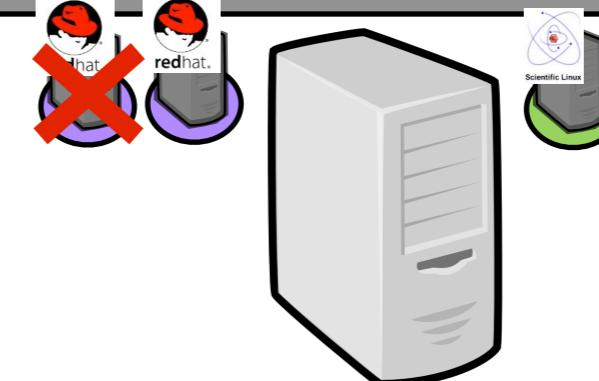
**DISCOVERY Agent node r**



Discovery Network Tracker

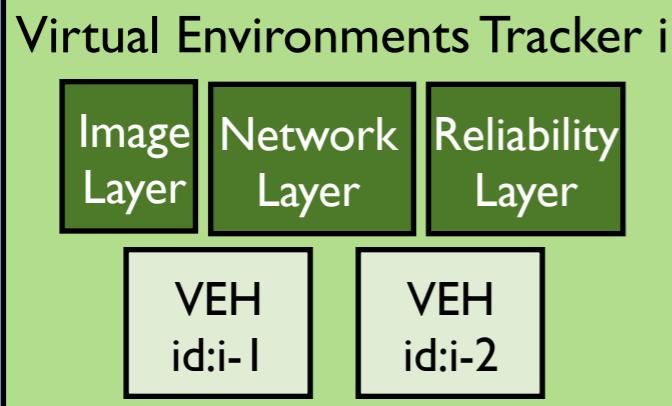


**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)

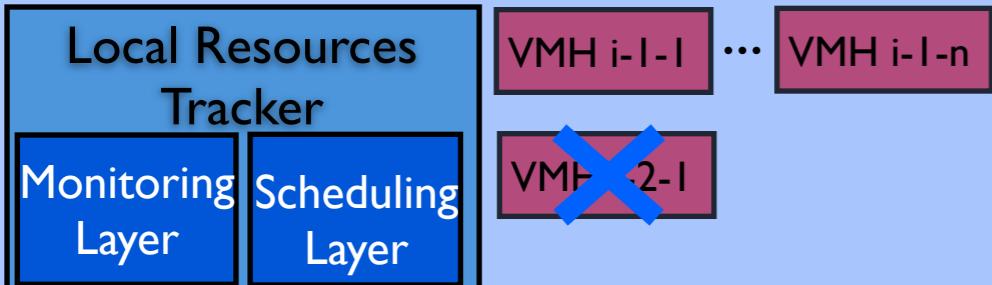


# DISCOVERY - VM Crashes

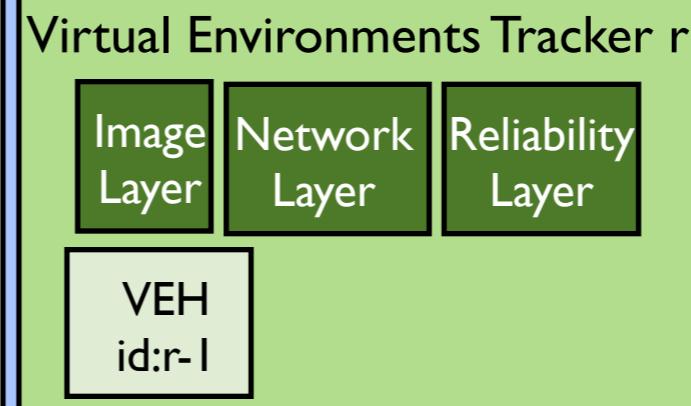
**DISCOVERY Agent node i**



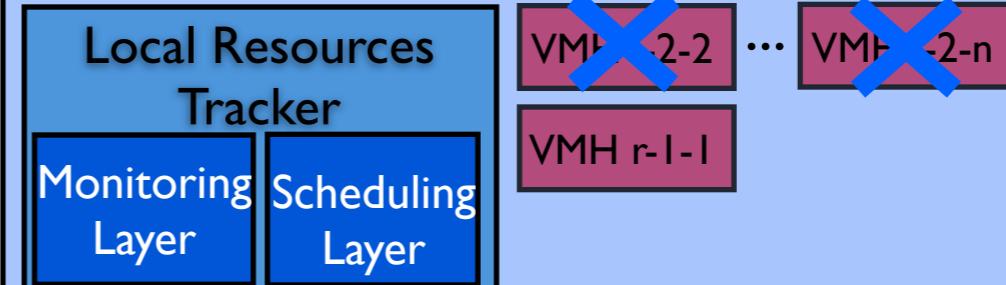
Discovery Network Tracker



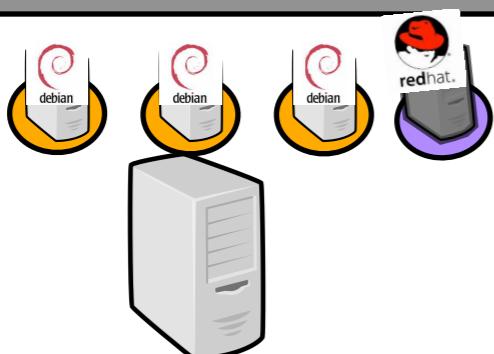
**DISCOVERY Agent node r**



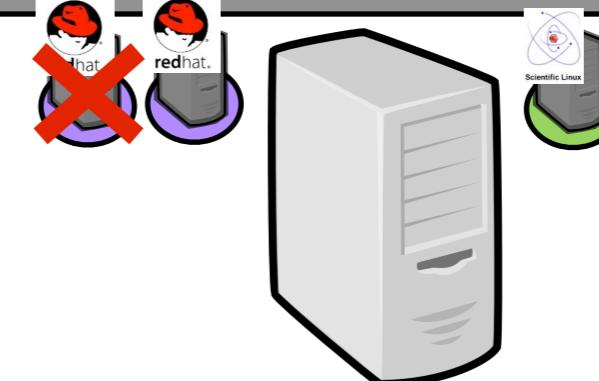
Discovery Network Tracker



**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)

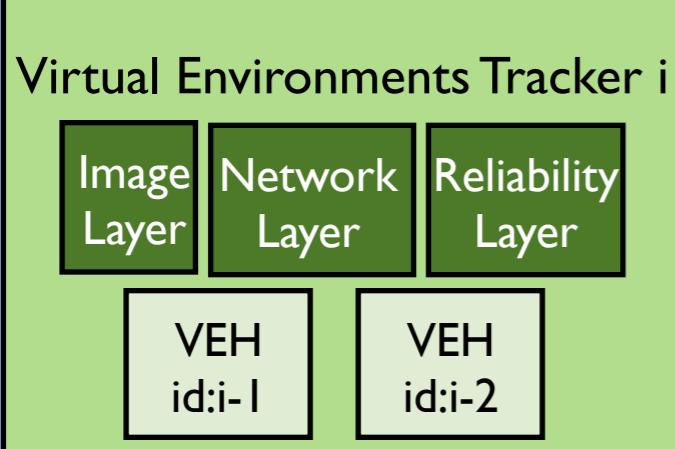


**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)

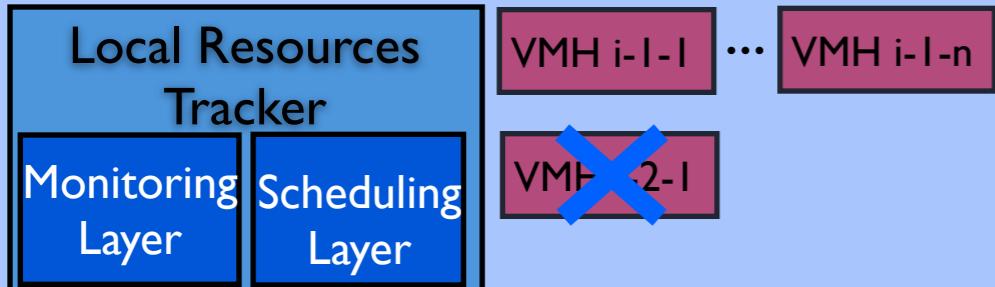


# DISCOVERY - VM Crashes

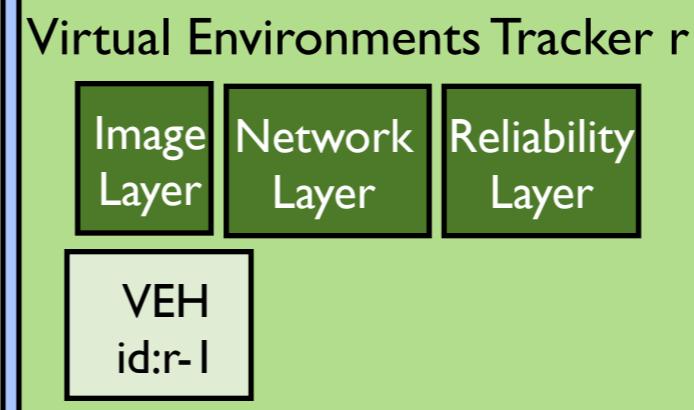
**DISCOVERY Agent node i**



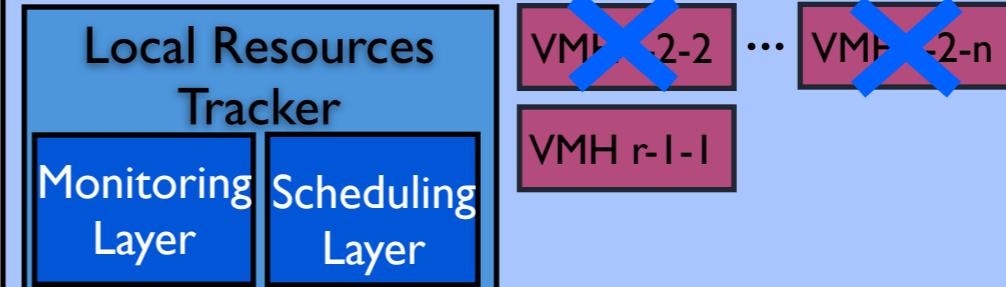
Discovery Network Tracker



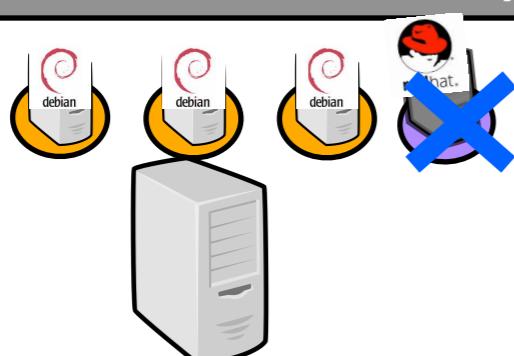
**DISCOVERY Agent node r**



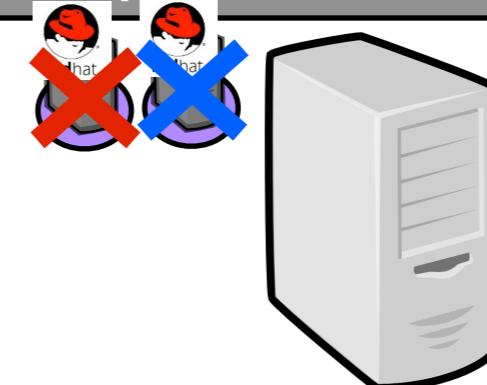
Discovery Network Tracker



**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)

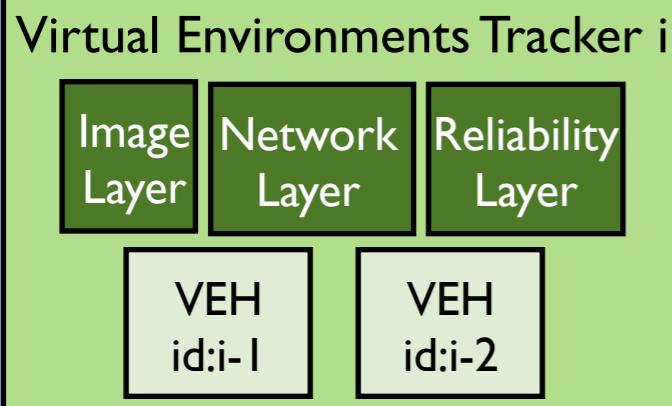


**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)

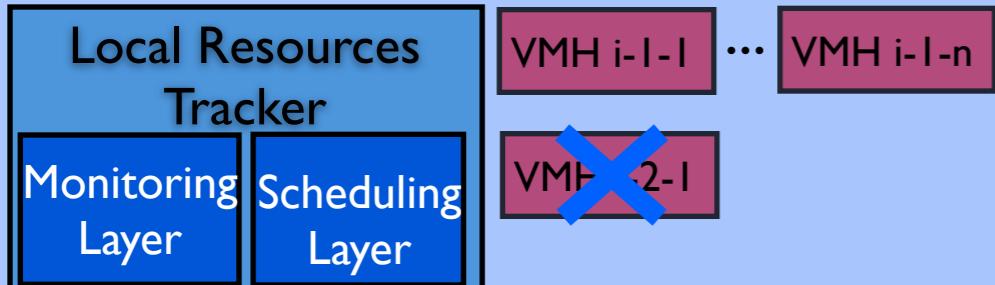


# DISCOVERY - VM Crashes

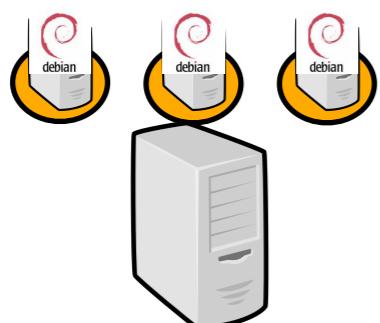
**DISCOVERY Agent node i**



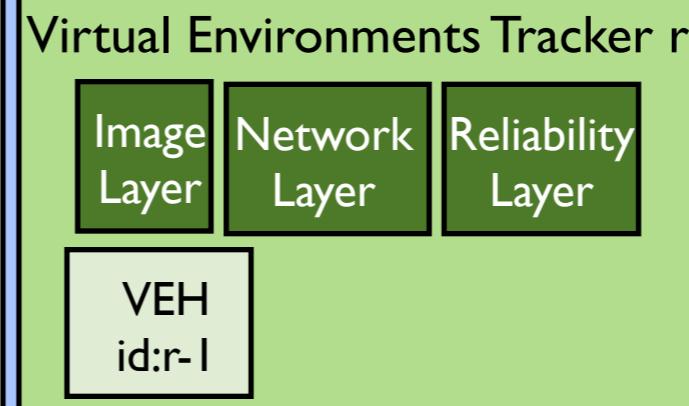
Discovery Network Tracker



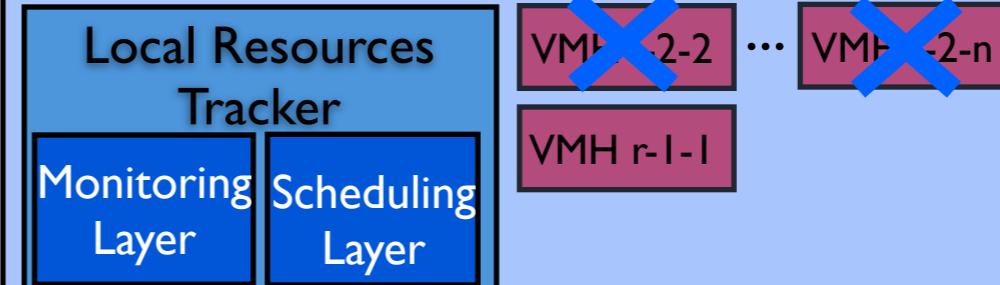
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**



Discovery Network Tracker



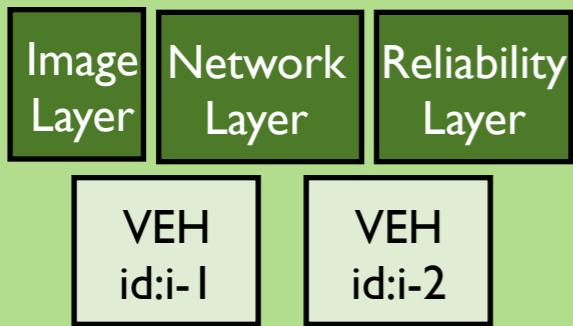
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



# DISCOVERY - VM Crashes

**DISCOVERY Agent node i**

Virtual Environments Tracker i



Discovery Network Tracker

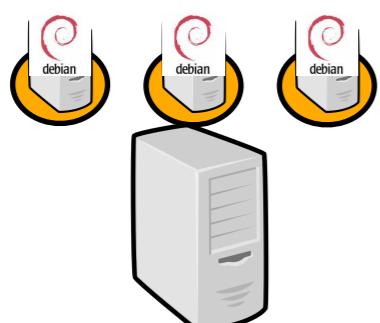
Local Resources Tracker  
Monitoring Layer

VMH i-1-1 ... VMH i-1-n

VMH i-2-1

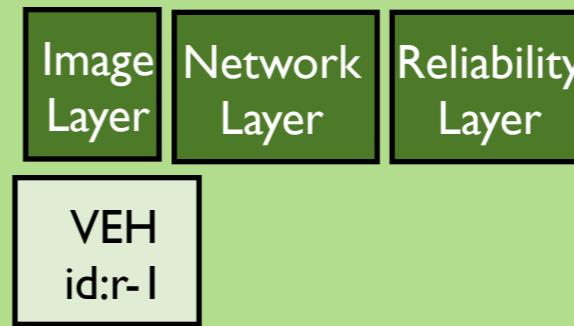
Scheduling Layer

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**

Virtual Environments Tracker r



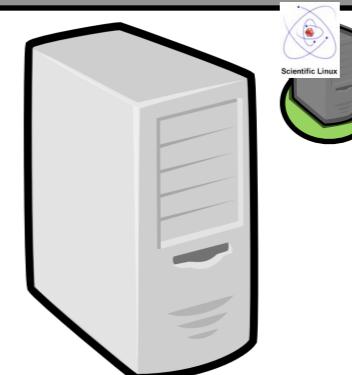
Discovery Network Tracker

Local Resources Tracker  
Monitoring Layer

VMH i-2-2 ... VMH i-2-n

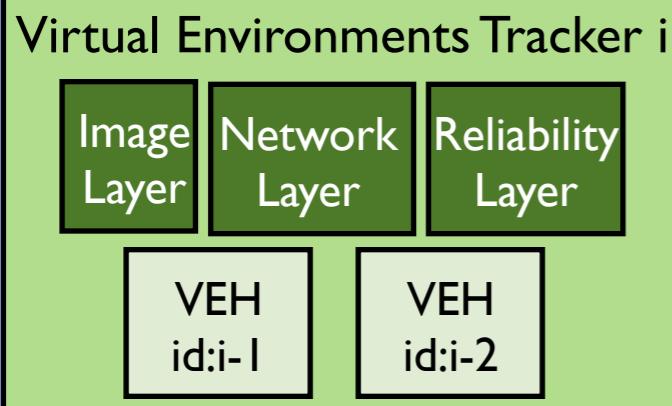
VMH r-1-1

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)

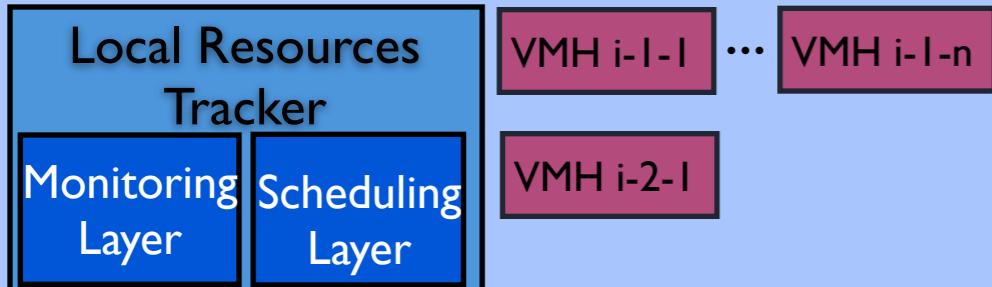


# DISCOVERY - VM Crashes

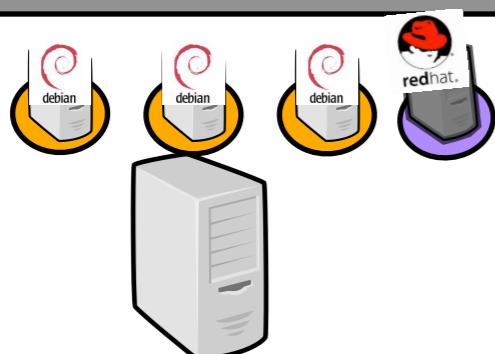
**DISCOVERY Agent node i**



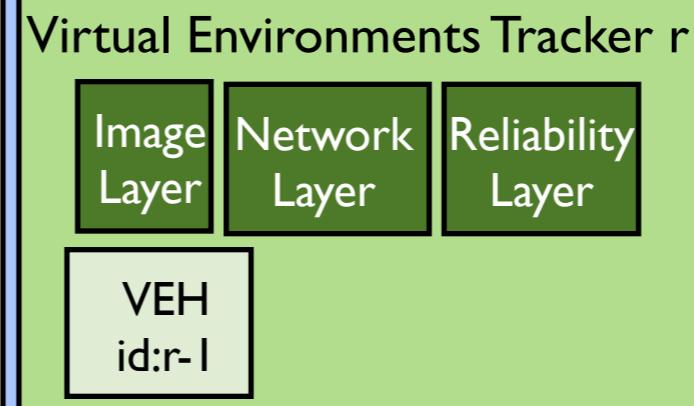
Discovery Network Tracker



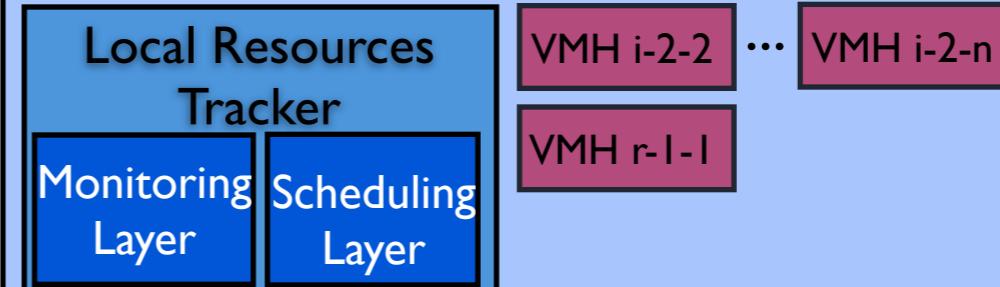
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



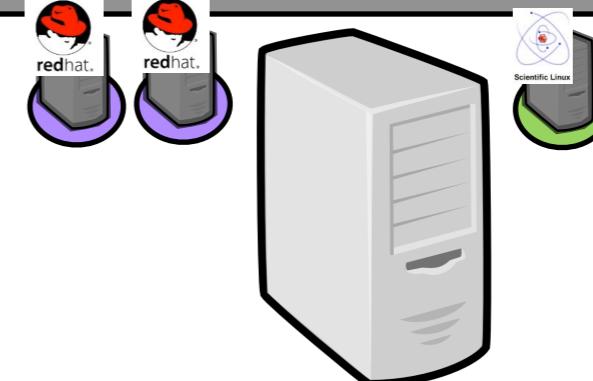
**DISCOVERY Agent node r**



Discovery Network Tracker

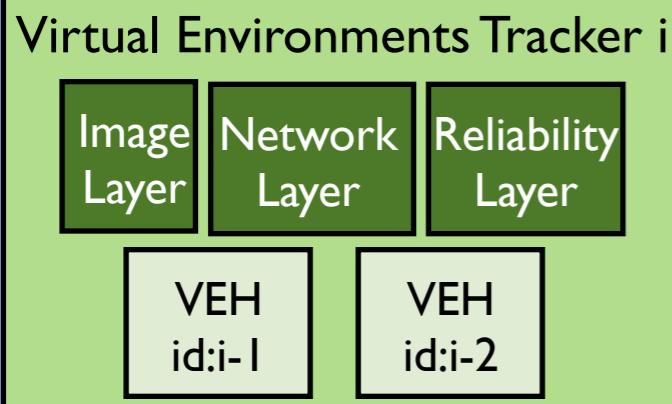


**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)

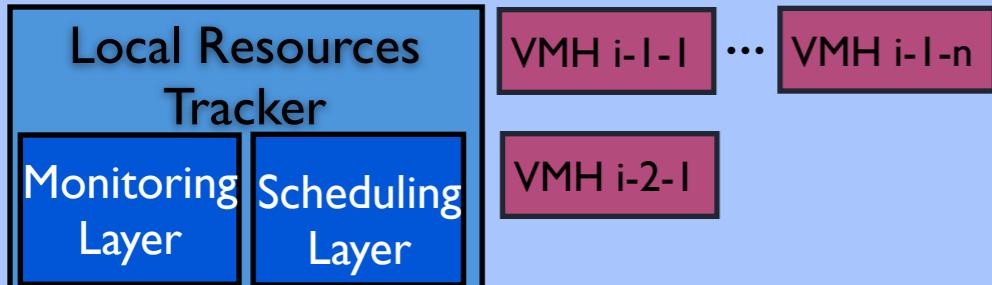


# DISCOVERY - Nodes Crashes

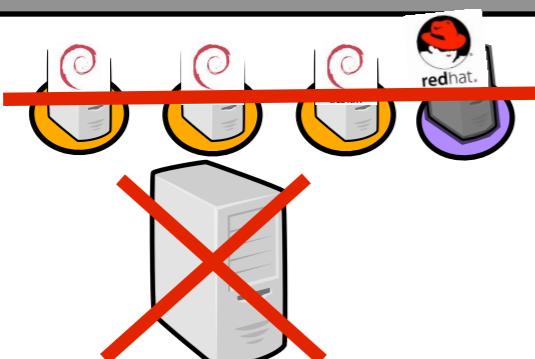
**DISCOVERY Agent node i**



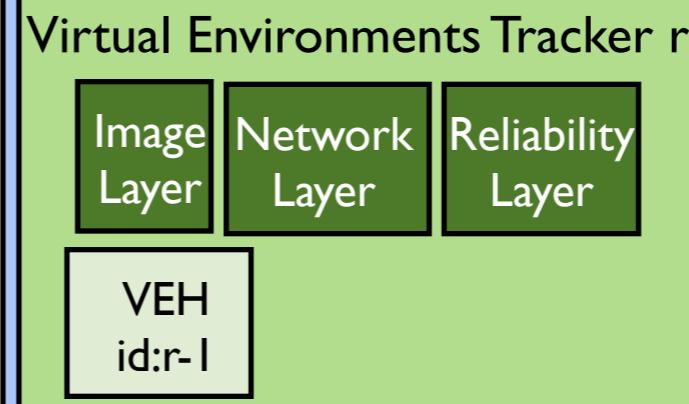
Discovery Network Tracker



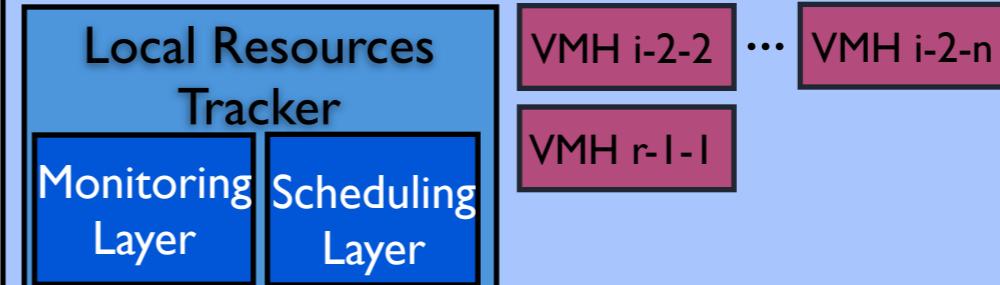
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



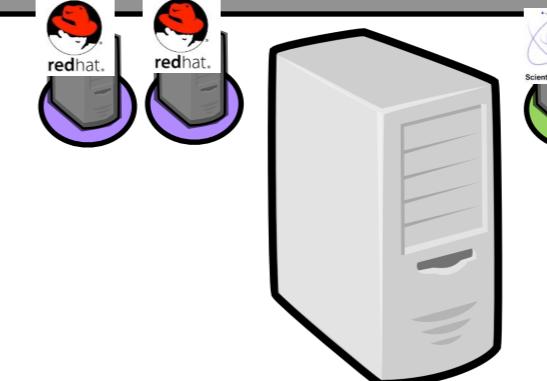
**DISCOVERY Agent node r**



Discovery Network Tracker



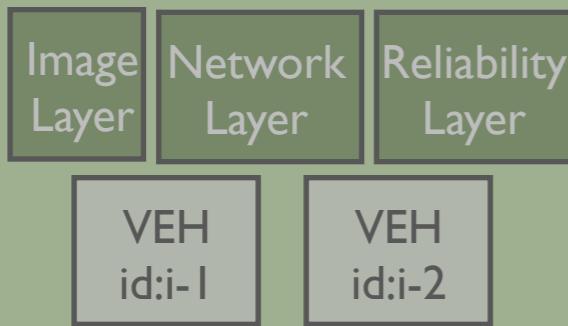
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



# DISCOVERY - Nodes Crashes

**DISCOVERY Agent node i**

Virtual Environments Tracker i



Discovery Network Tracker

Local Resources Tracker

Monitoring Layer      Scheduling Layer

VMH i-1-1 ... VMH i-1-n

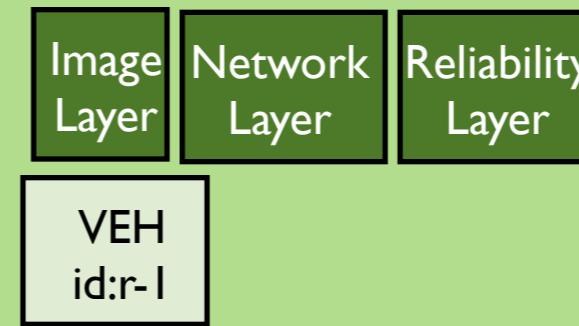
VMH i-2-1

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**

Virtual Environments Tracker r



Discovery Network Tracker

Local Resources Tracker

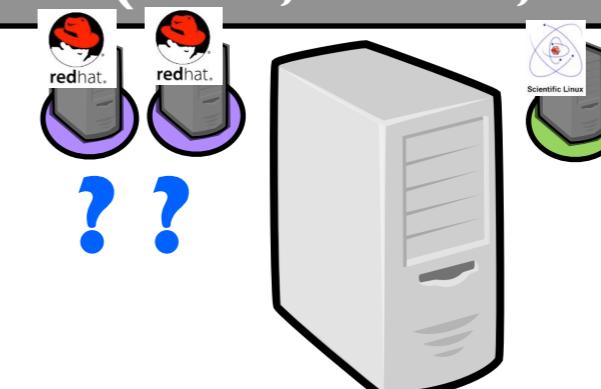
Monitoring Layer      Scheduling Layer

VMH i-2-2 ... VMH i-2-n

VMH r-1-1

?

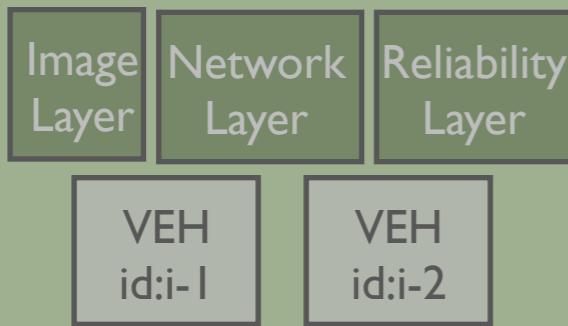
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



# DISCOVERY - Nodes Crashes

**DISCOVERY Agent node i**

Virtual Environments Tracker i



Discovery Network Tracker

Local Resources Tracker

Monitoring Layer      Scheduling Layer

VMH i-1-1 ... VMH i-1-n

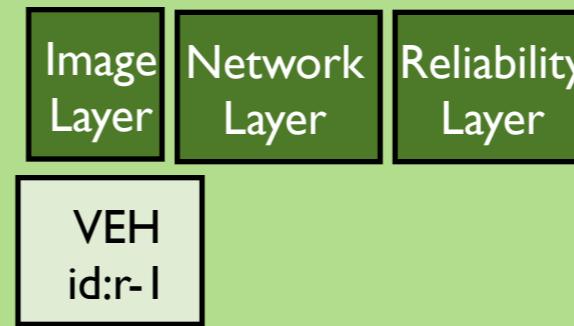
VMH i-2-1

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**

Virtual Environments Tracker r



Discovery Network Tracker

Local Resources Tracker

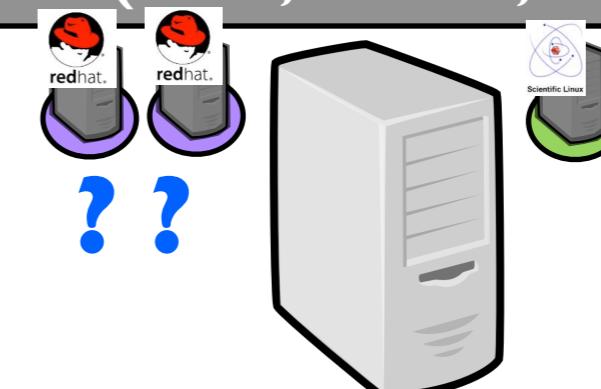
Monitoring Layer      Scheduling Layer

VMH i-2-2 ... VMH i-2-n

VMH r-1-1

?

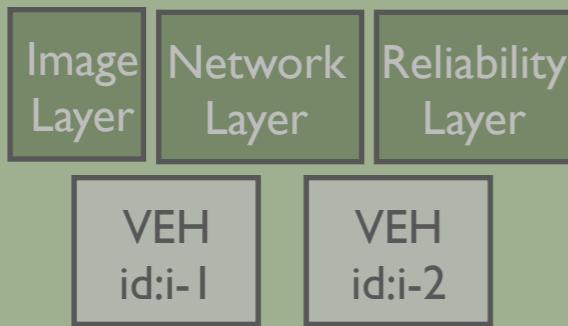
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



# DISCOVERY - Nodes Crashes

**DISCOVERY Agent node i**

Virtual Environments Tracker i



Discovery Network Tracker

Local Resources Tracker

Monitoring Layer      Scheduling Layer

VMH i-1-1 ... VMH i-1-n

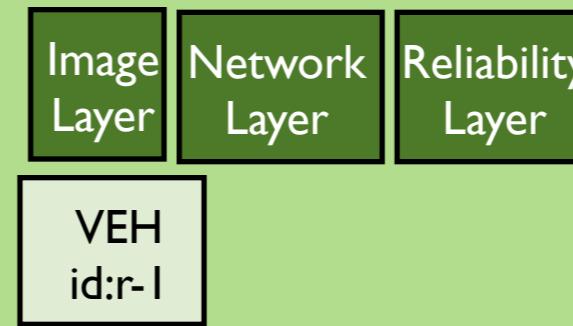
VMH i-2-1

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**

Virtual Environments Tracker r



Discovery Network Tracker

Local Resources Tracker

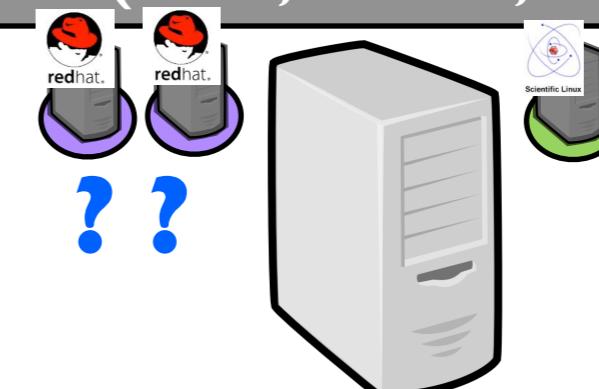
Monitoring Layer      Scheduling Layer

VMH i-2-2 ... VMH i-2-n

VMH r-1-1

?

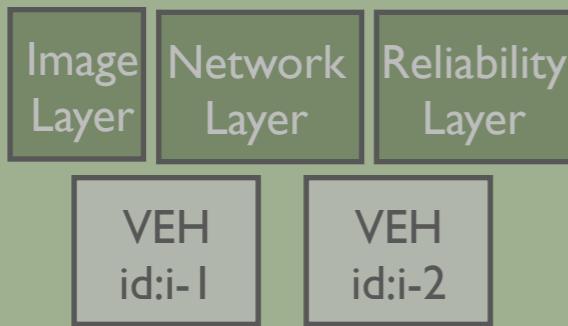
**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



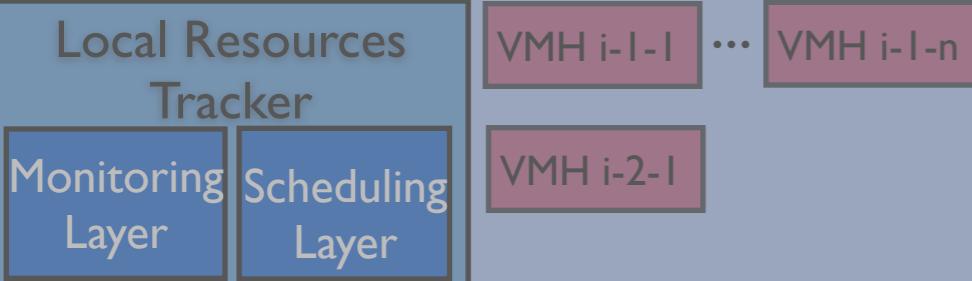
# DISCOVERY - Nodes Crashes

**DISCOVERY Agent node i**

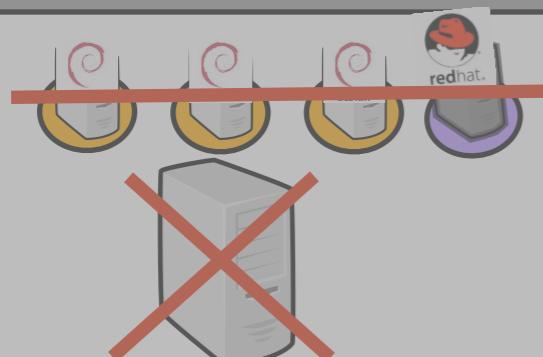
Virtual Environments Tracker i



Discovery Network Tracker

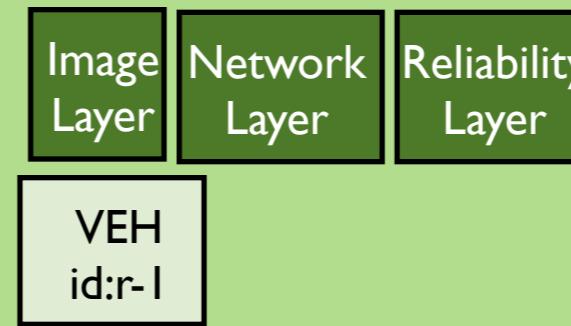


Bare Hardware Wrapper  
(libvirt, xentools, OCCI, ...)

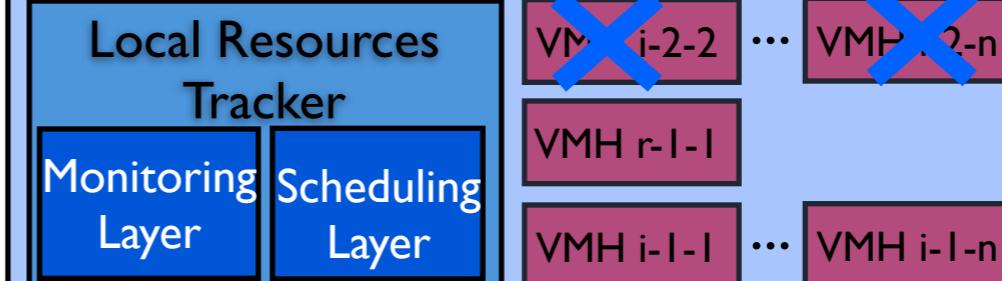


**DISCOVERY Agent node r**

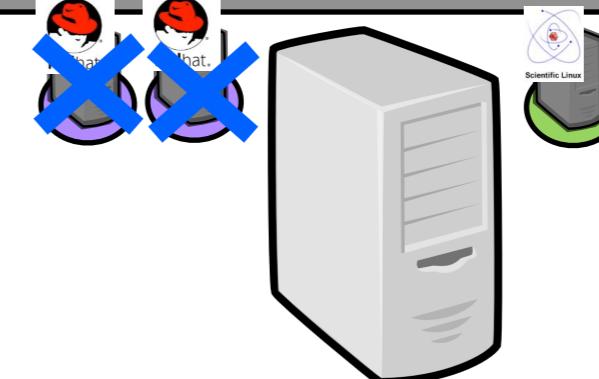
Virtual Environments Tracker r



Discovery Network Tracker



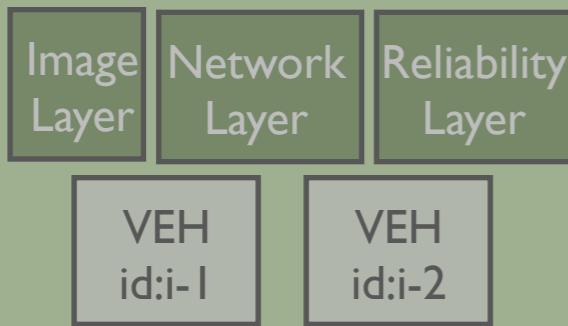
Bare Hardware Wrapper  
(libvirt, xentools, OCCI, ...)



# DISCOVERY - Nodes Crashes

**DISCOVERY Agent node i**

Virtual Environments Tracker i



Discovery Network Tracker

Local Resources Tracker

Monitoring Layer      Scheduling Layer

VMH i-1-1 ... VMH i-1-n

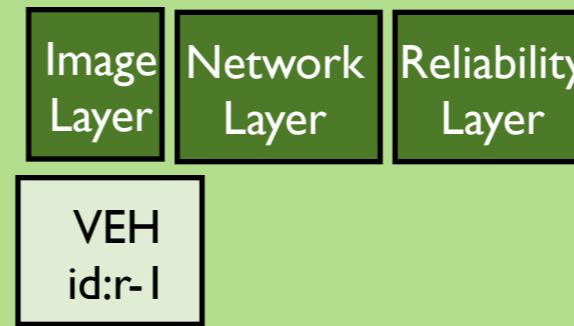
VMH i-2-1

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



**DISCOVERY Agent node r**

Virtual Environments Tracker r



Discovery Network Tracker

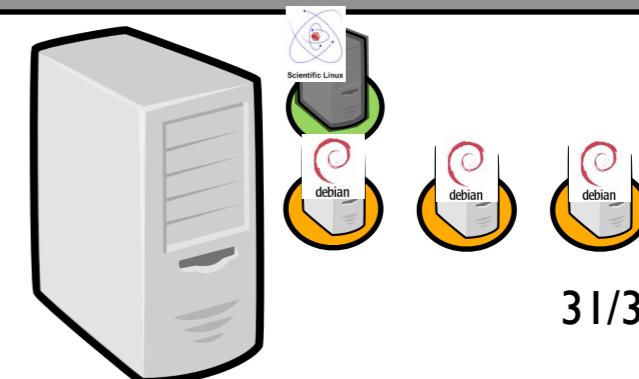
Local Resources Tracker

Monitoring Layer      Scheduling Layer

VMH r-1-1

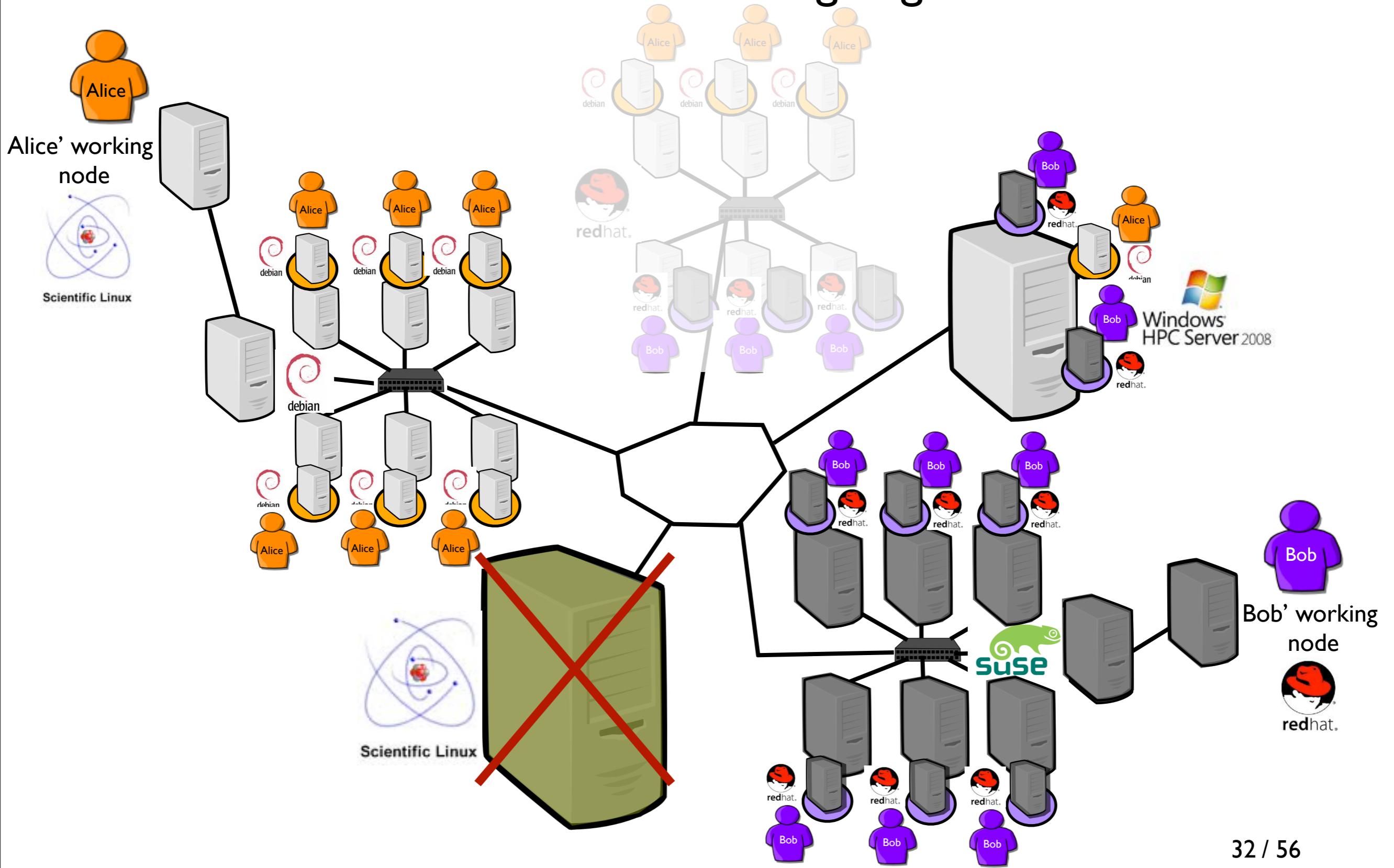
VMH i-1-1 ... VMH i-1-n

**Bare Hardware Wrapper**  
(libvirt, xentools, OCCI, ...)



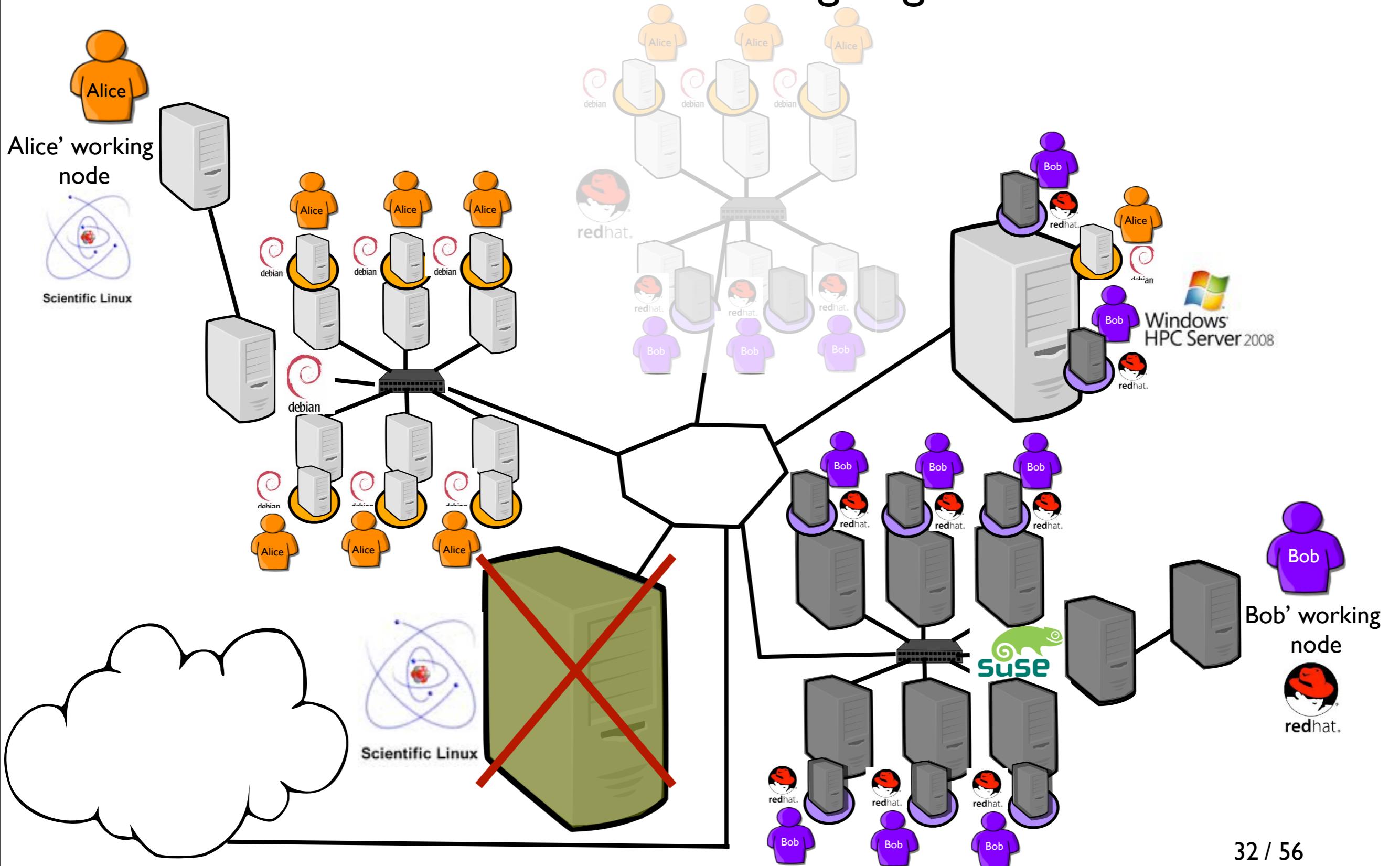
# Alice, Bob and The Cloud

Where we are - going - ?



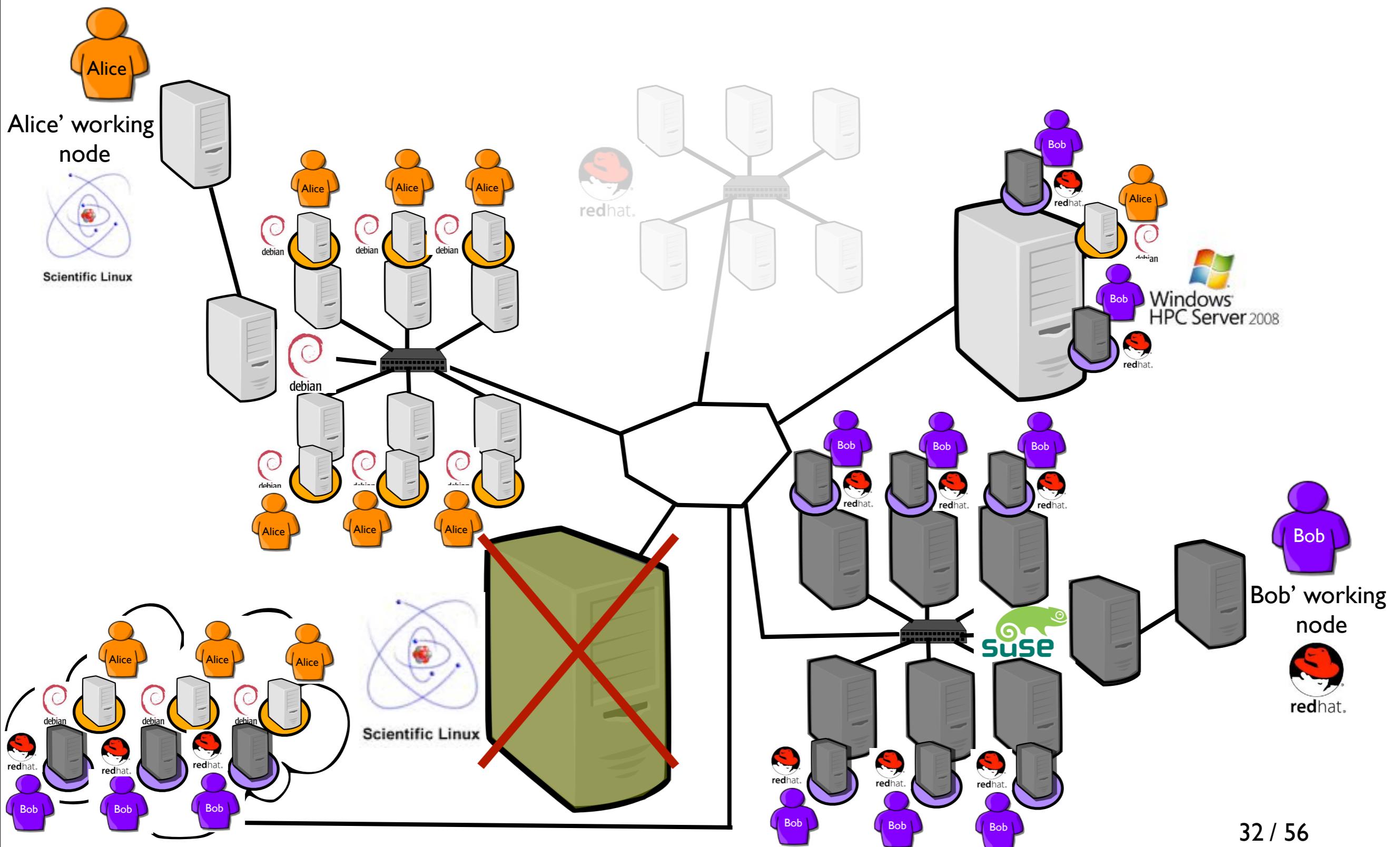
# Alice, Bob and The Cloud

Where we are - going - ?

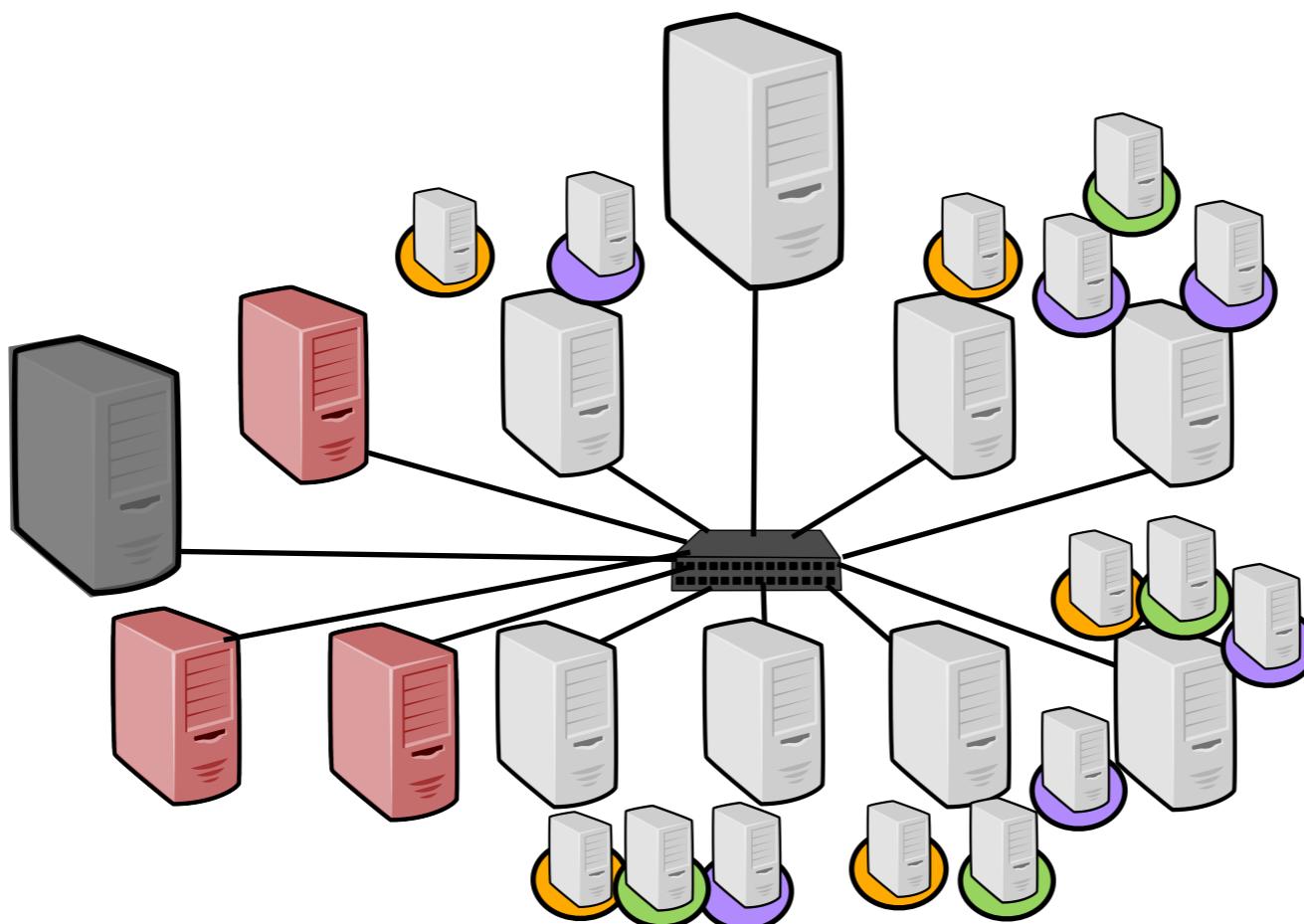


# Alice, Bob and The Cloud

## Where we are - going - ?



# Utility Computing and Data Management



Infrastructure as a Service model

# Utility Computing and Data Management

