Utility Computing

Going back and forth between centralised and distributed

Adrien Lebre
STACK Research Group

Computation

1950/1990 - Mainframes

1975 -Personal Computers

1950 - Batchmode
1960 - Interactive
1967 - First virtualisation attempt
1970 - Terminals (clients/server concepts)

ENIAC
1946

1999 - Salesforces SaaS Concept

2002 - Virtualised Infrastructure

2010 - Cloud democratisation

openstack

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2002- Amazon Initial Compute/Storage services
2006 - Amazon EC2 (IaaS)

amazon web services EC2

2015
Network/Computers Convergence
Software Defined XXX

Transistor
1947

micro processor
1971

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1985 - TCP/IP Adoption
1973 - Ethernet
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1876 - Telephone

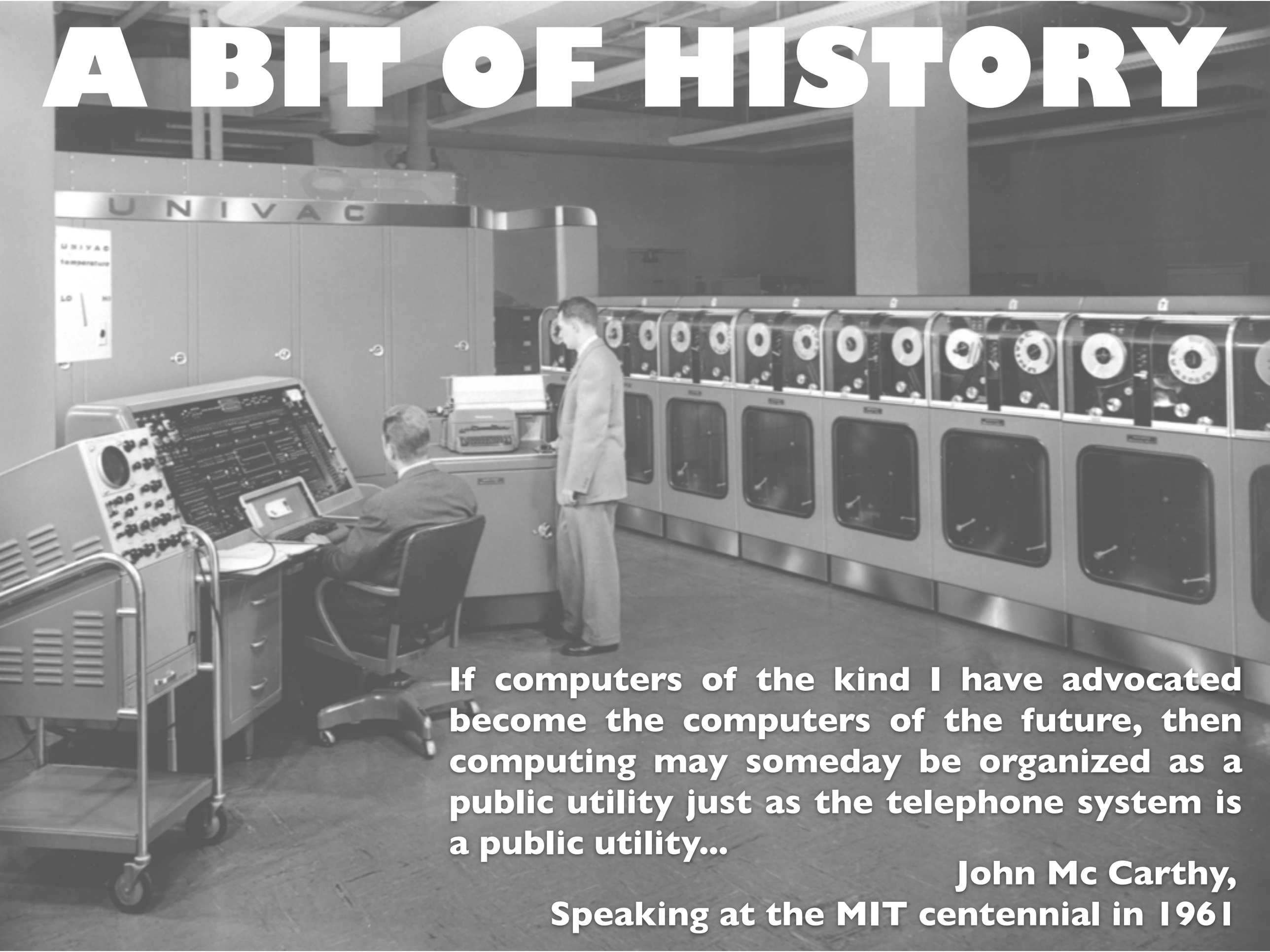
1896 - Radio

SmartPhones
2007

Communication


SKEPTICISM
RENTED
ORGANIZATIONS
COMPUTATION
VIRTUALIZATION
CLUSTER
CENTERS
RESOURCES
SERVICE
ANNOUNCED
SINGLE
SPECIFICALLY
KIND
UTILITY
COMPUTATIONAL
DISTRIBUTED
ADVOCATED
LAUNCHED
SHIFT
TASKS
BEHESTPROPAGATED
WORKLOADSTORAGE
INDUSTRY
SOFTWARE
METERING
COMPUTING
REPACKAGING
COMPUTING
FORM
NODES
BUSINESS
PURPOSE
ENVISIONED
INITIAL
APPLICATION
ARCHITECTURE
GRID
SERVER
DECENTRALIZED
DATA
SEISMIC
DEMAND
PUBLIC
SUPERCOMPUTER
MAINFRAME
PROCESS
NEEDED
METERED
LARGE
COMPUTER
GEOGRAPHICALLY
WEB
HARDWARE
OPERATING
MULTIPLE

A BIT OF HISTORY



If computers of the kind I have advocated become the computers of the future, then computing may someday be organized as a public utility just as the telephone system is a public utility...

John Mc Carthy,
Speaking at the MIT centennial in 1961

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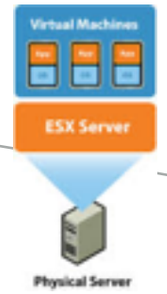

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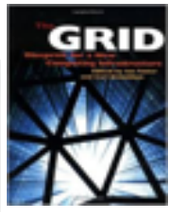

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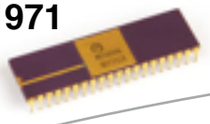

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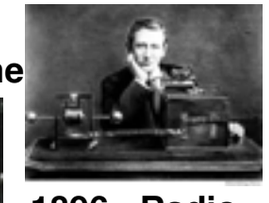

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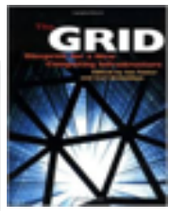

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Communication

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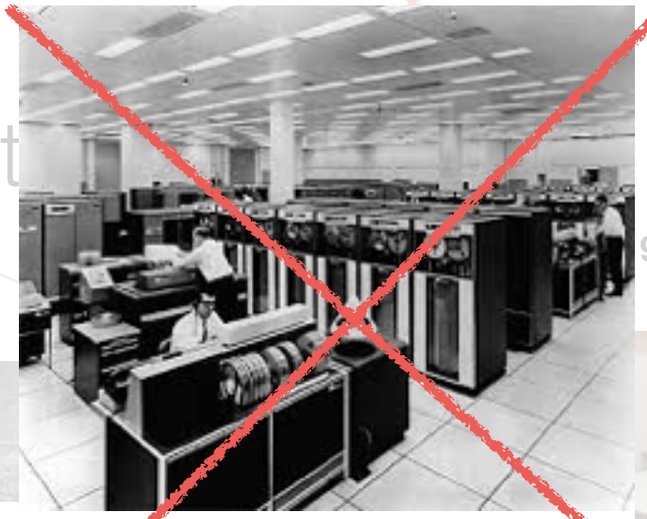

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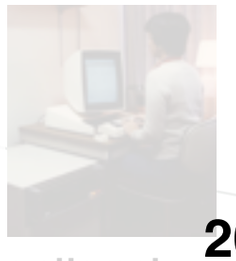

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amazon web services™ | EC2

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2015
Network/Computers Convergence
Software Defined XXX

Communication

Looking back…

- xxx Computing
  Meta / Cluster / Grid / Desktop / "Hive" / Cloud / Sky …

  ⇒ xxx as Utility Computing

- A common objective: provide computing resources (both hardware and software) in a flexible, transparent, secure, reliable, ... way

- Challenges

  Software/Hardware heterogeneity

  Security (Isolation between applications, ...)

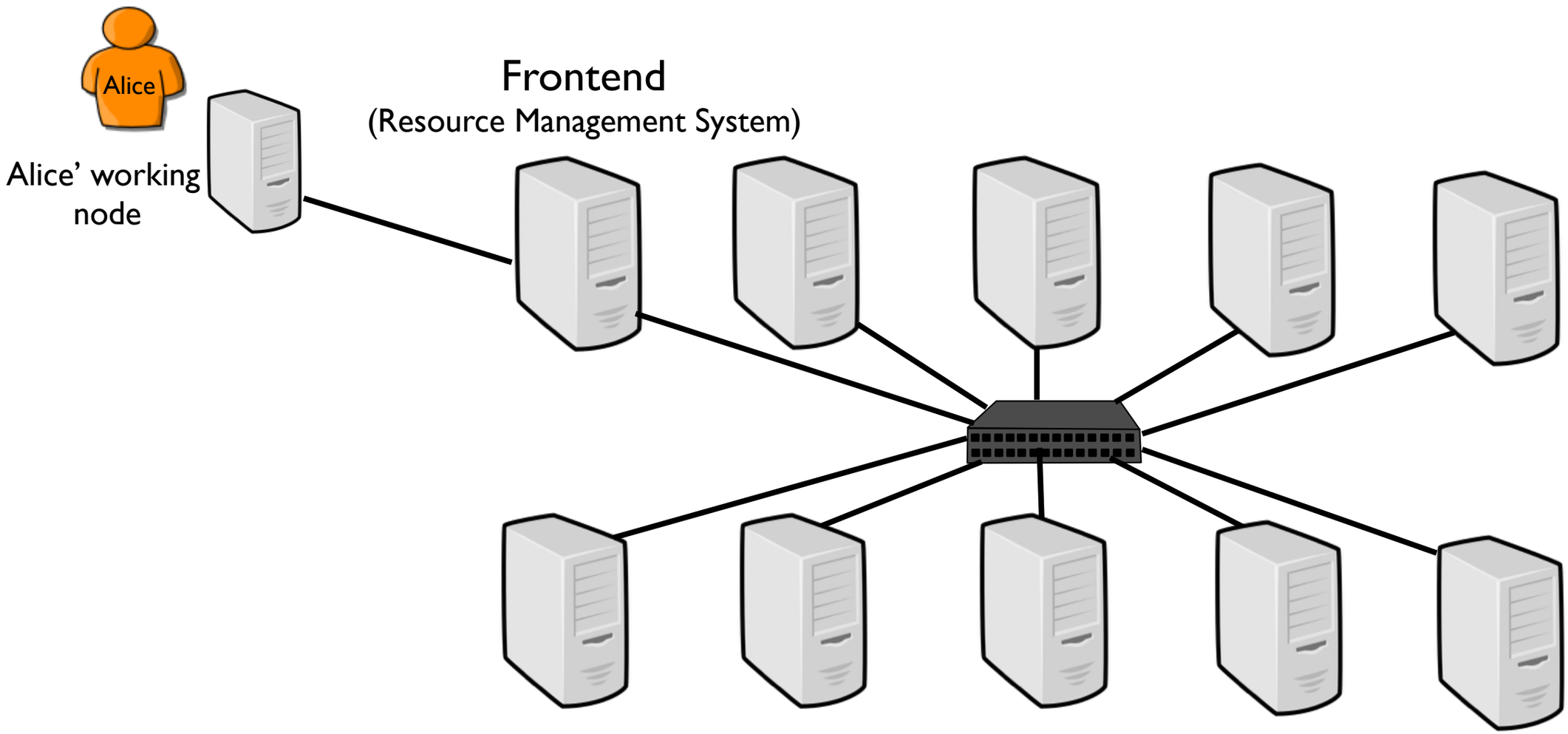
  Reliability / Resiliency

  Data Sharing

  Performance guarantees...

Looking back…

- Network of Workstations 1990 / 20**xx**



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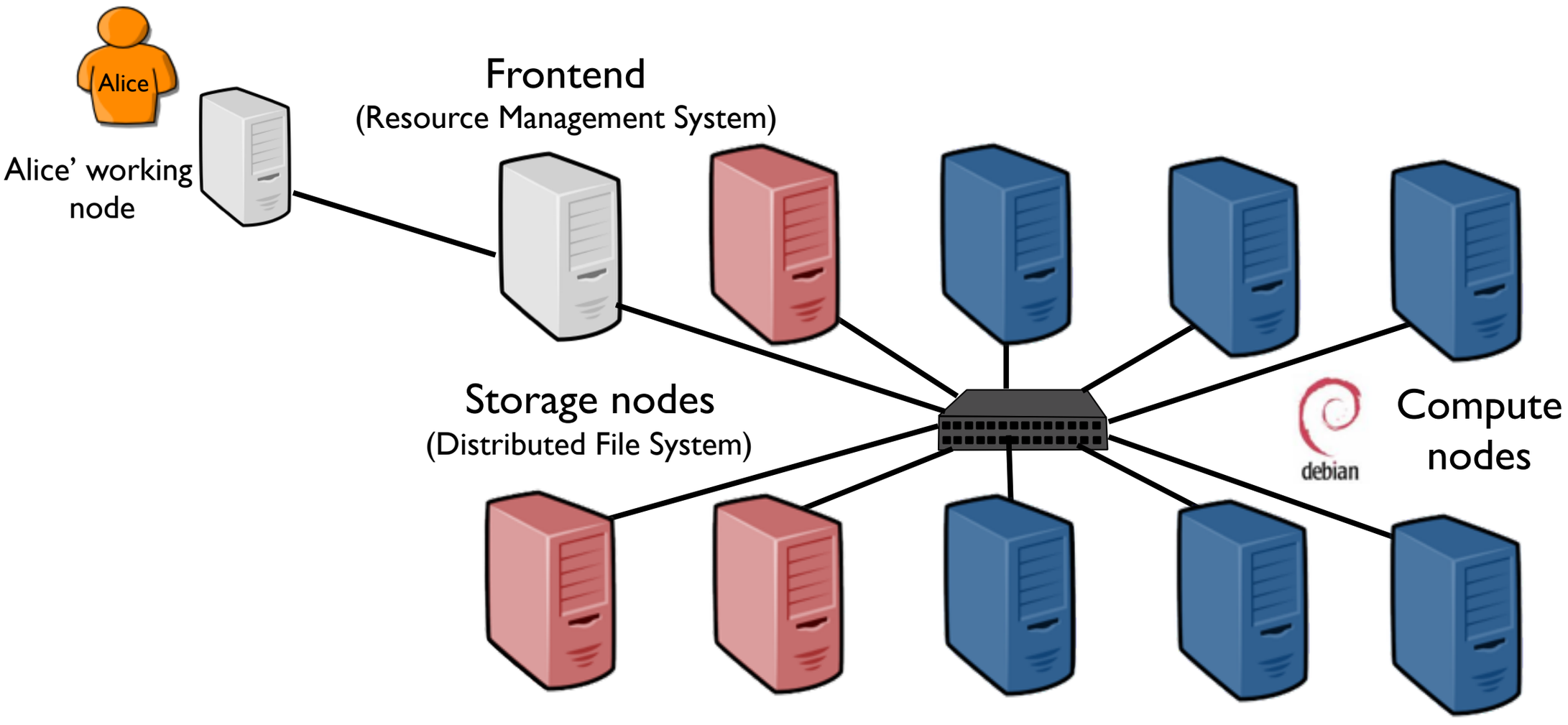

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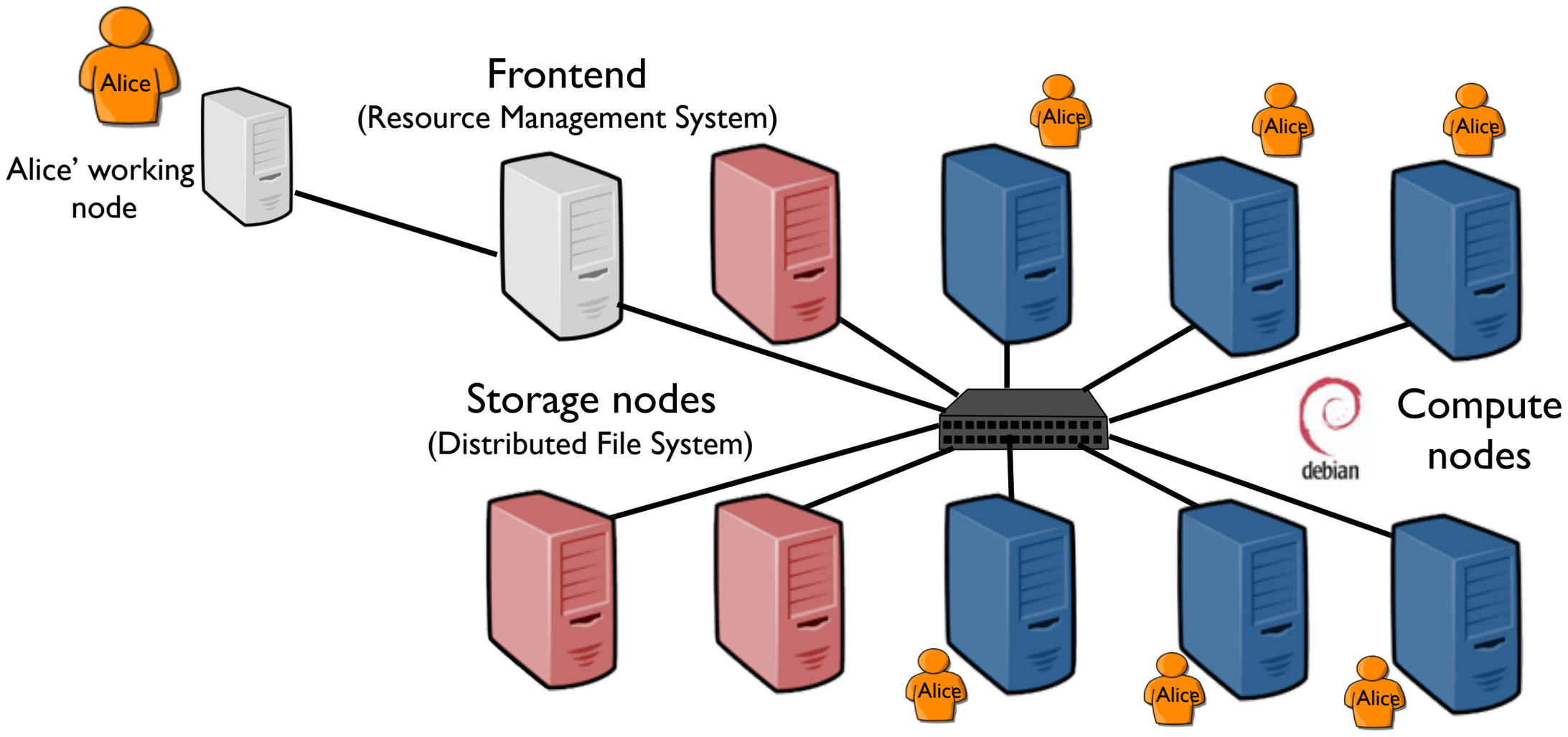

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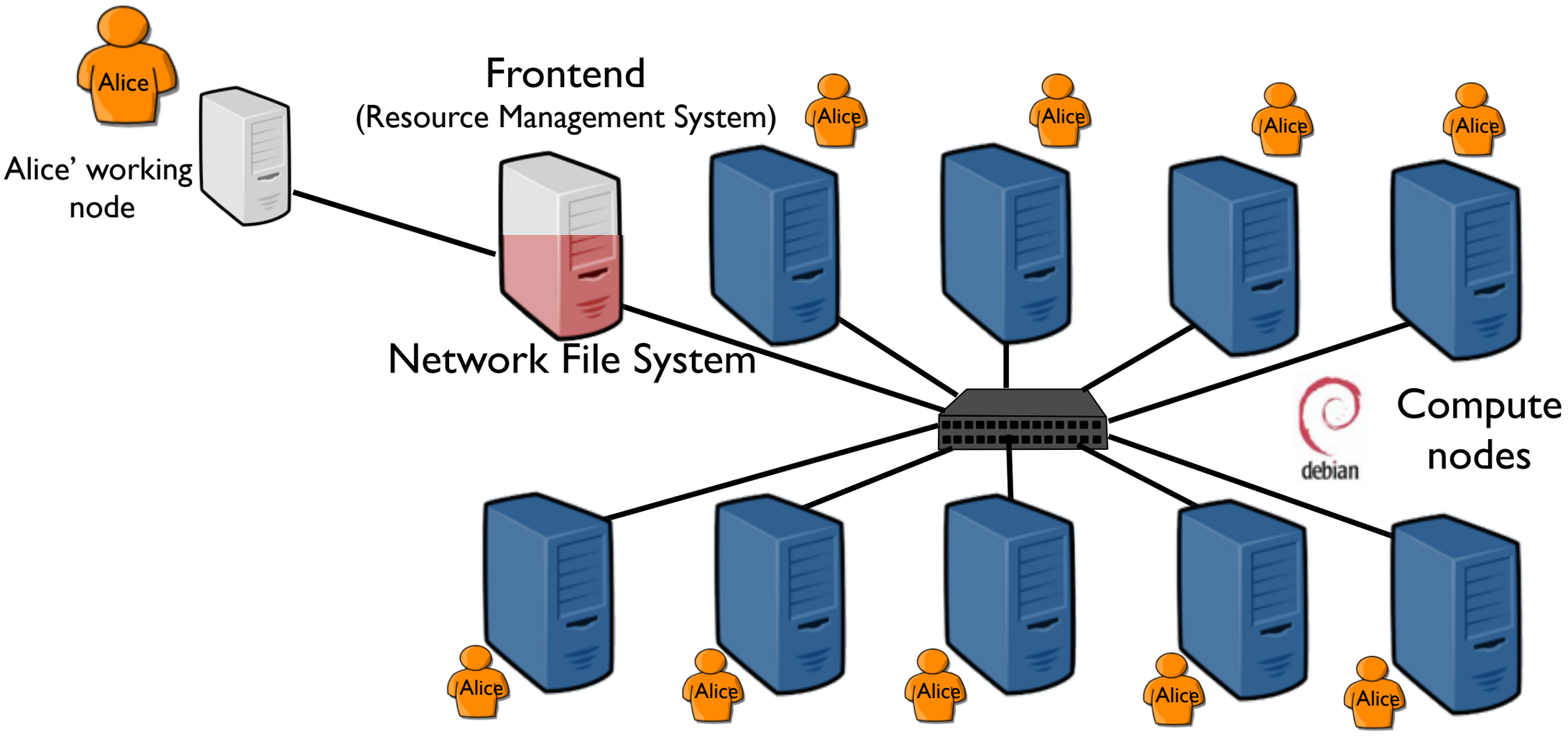

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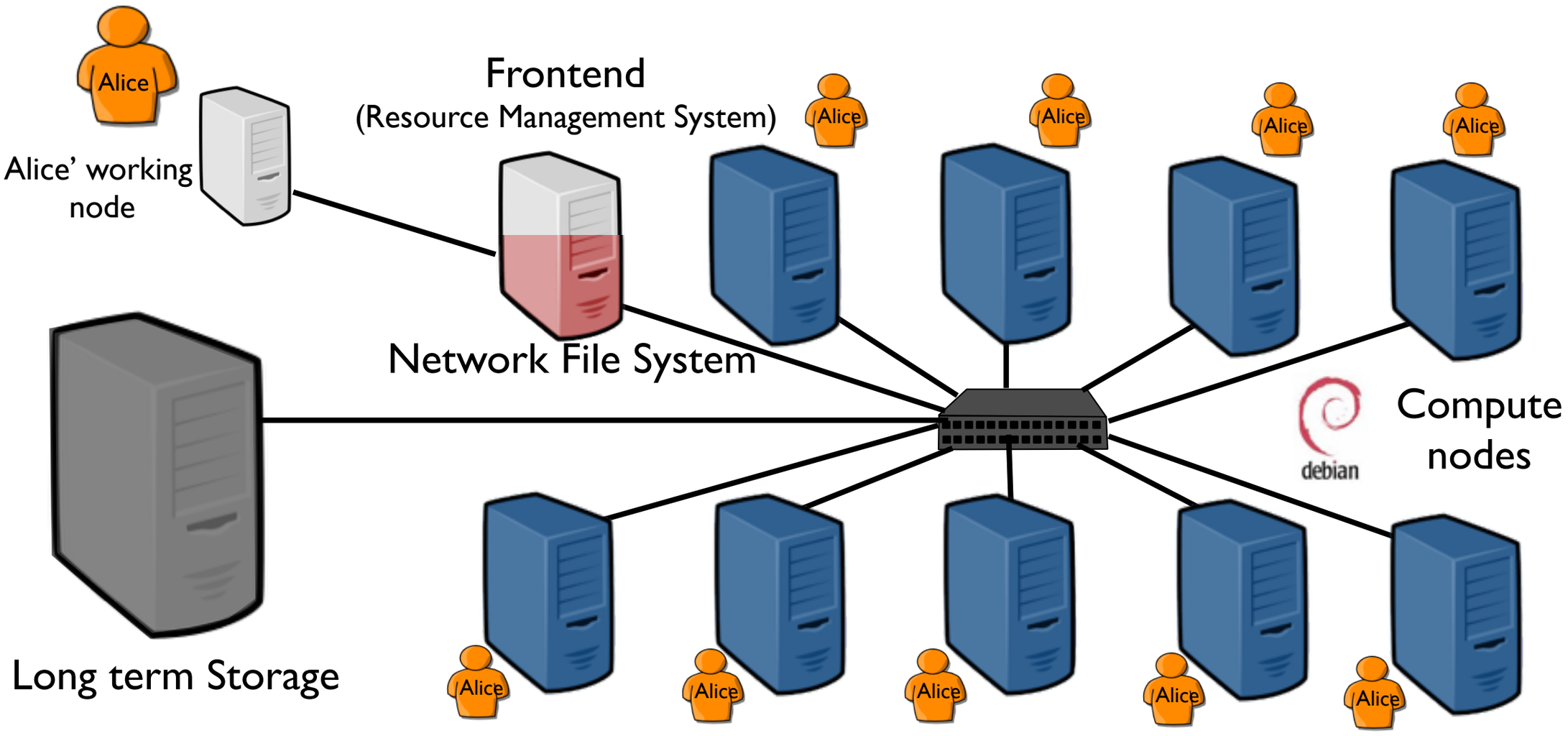

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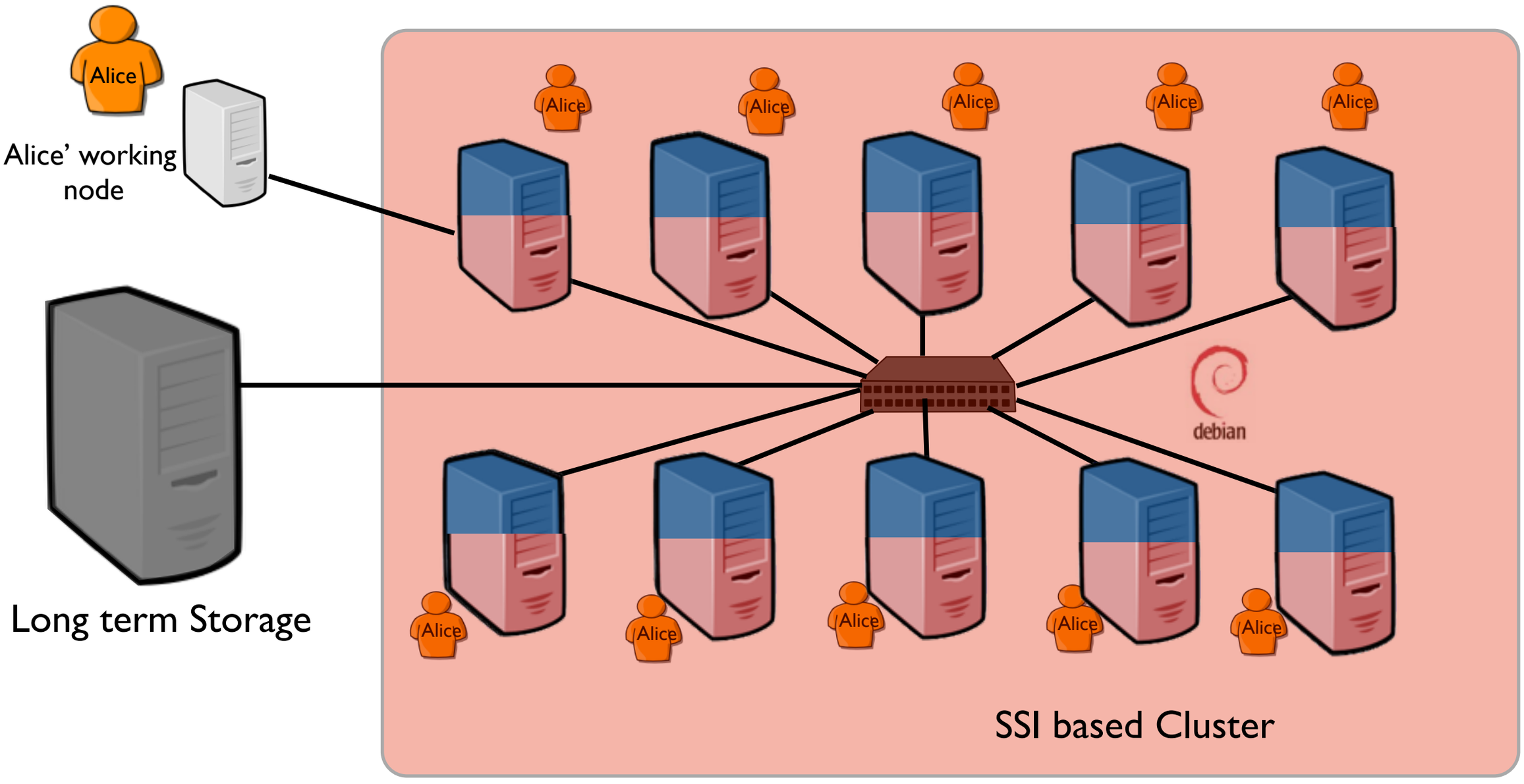

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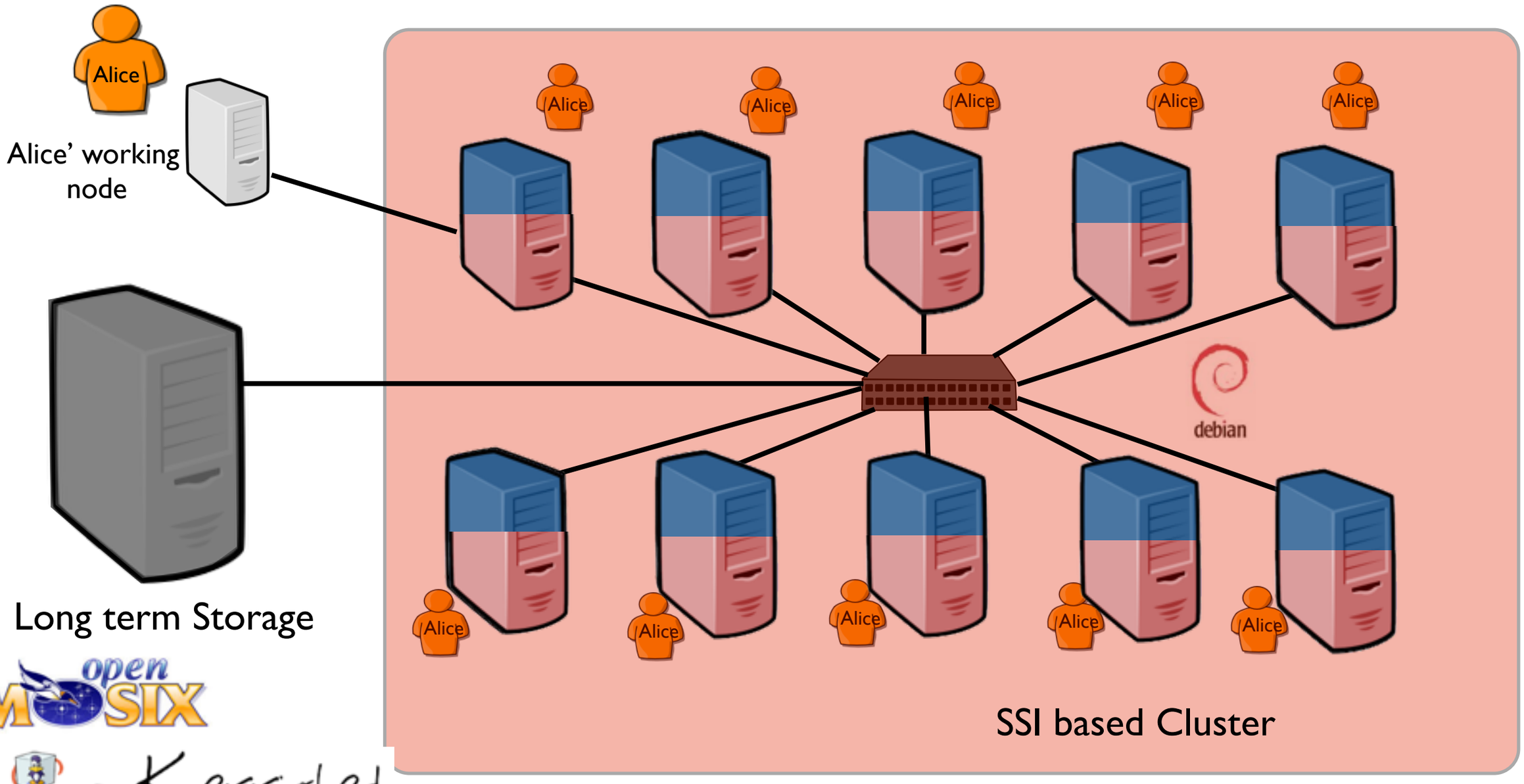

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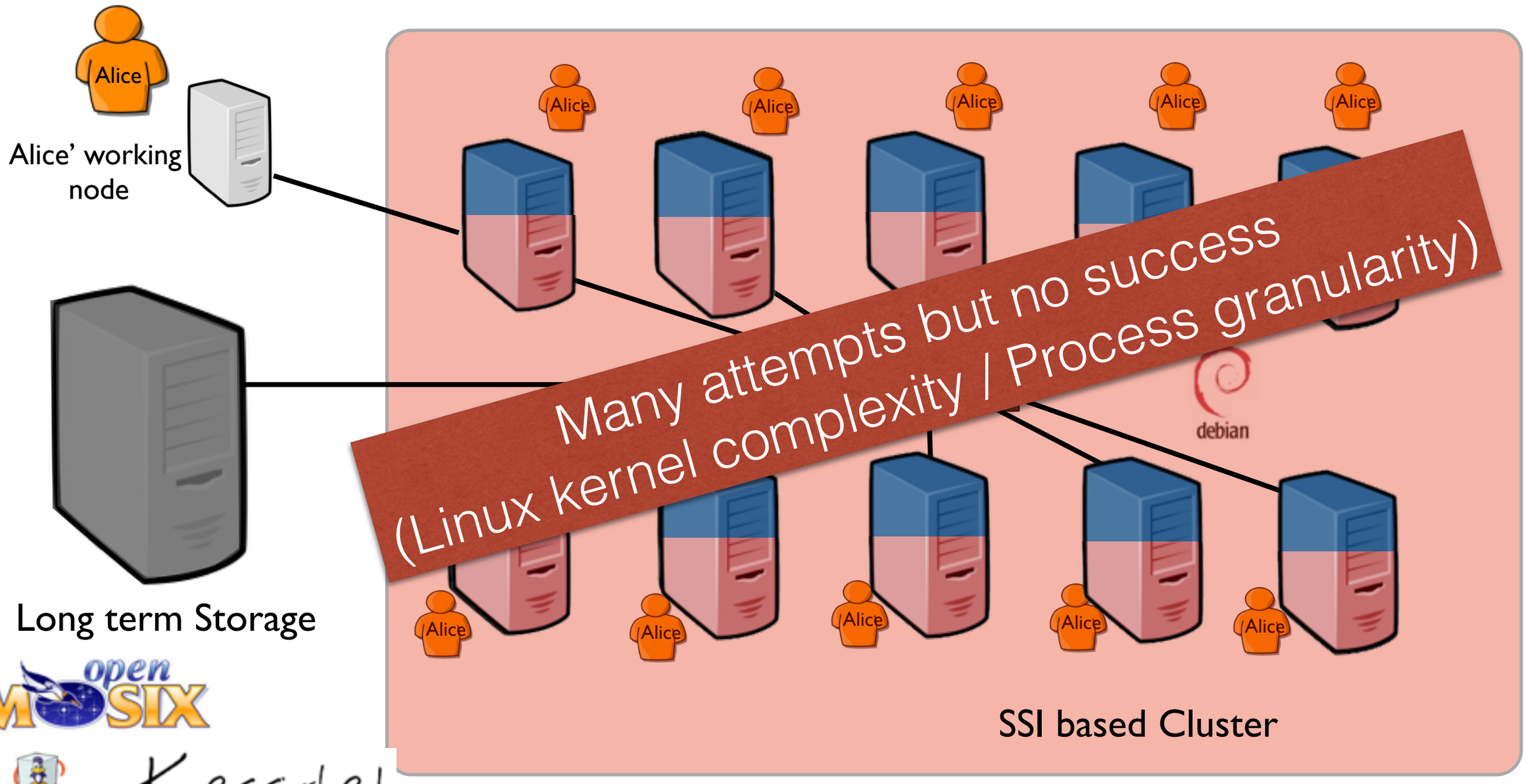

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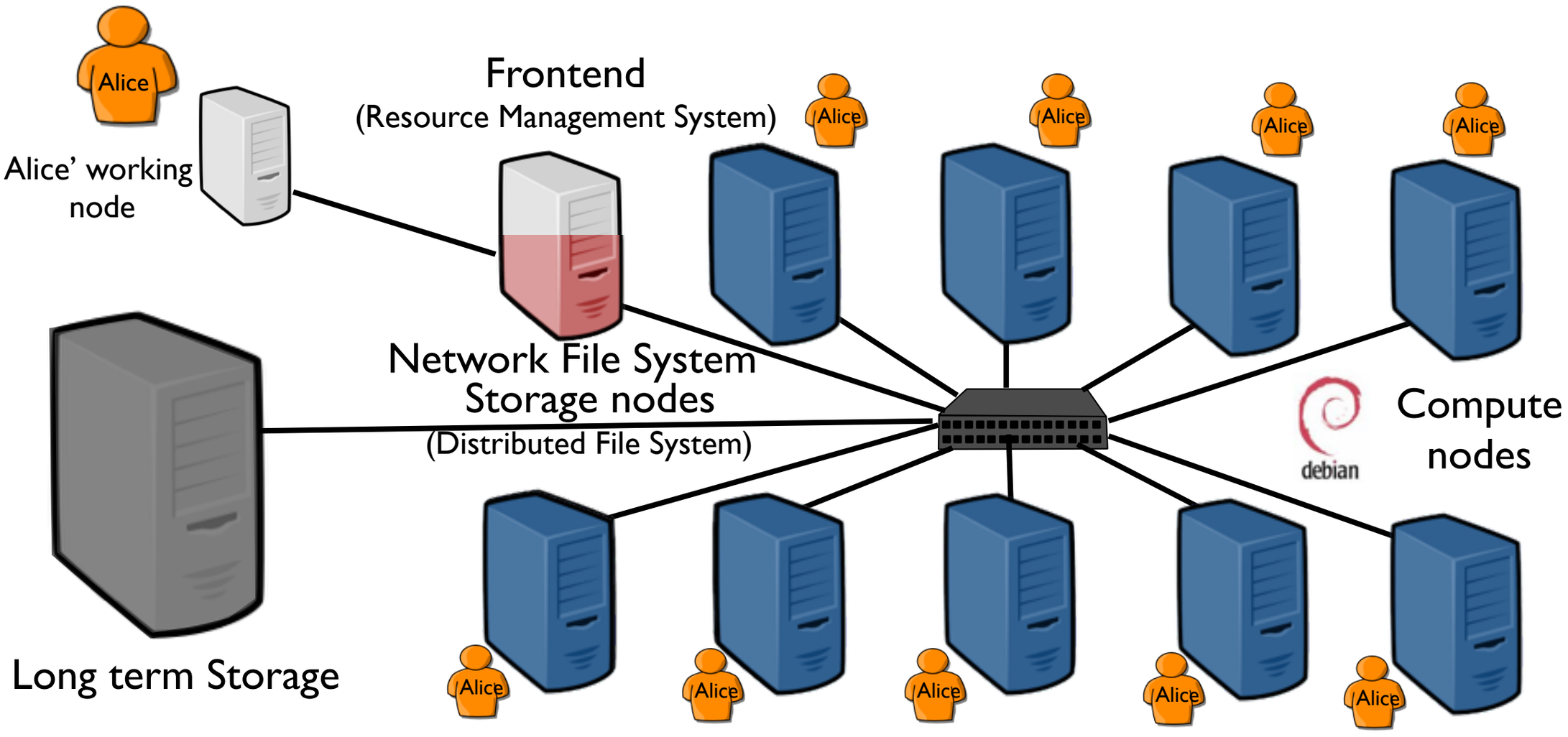

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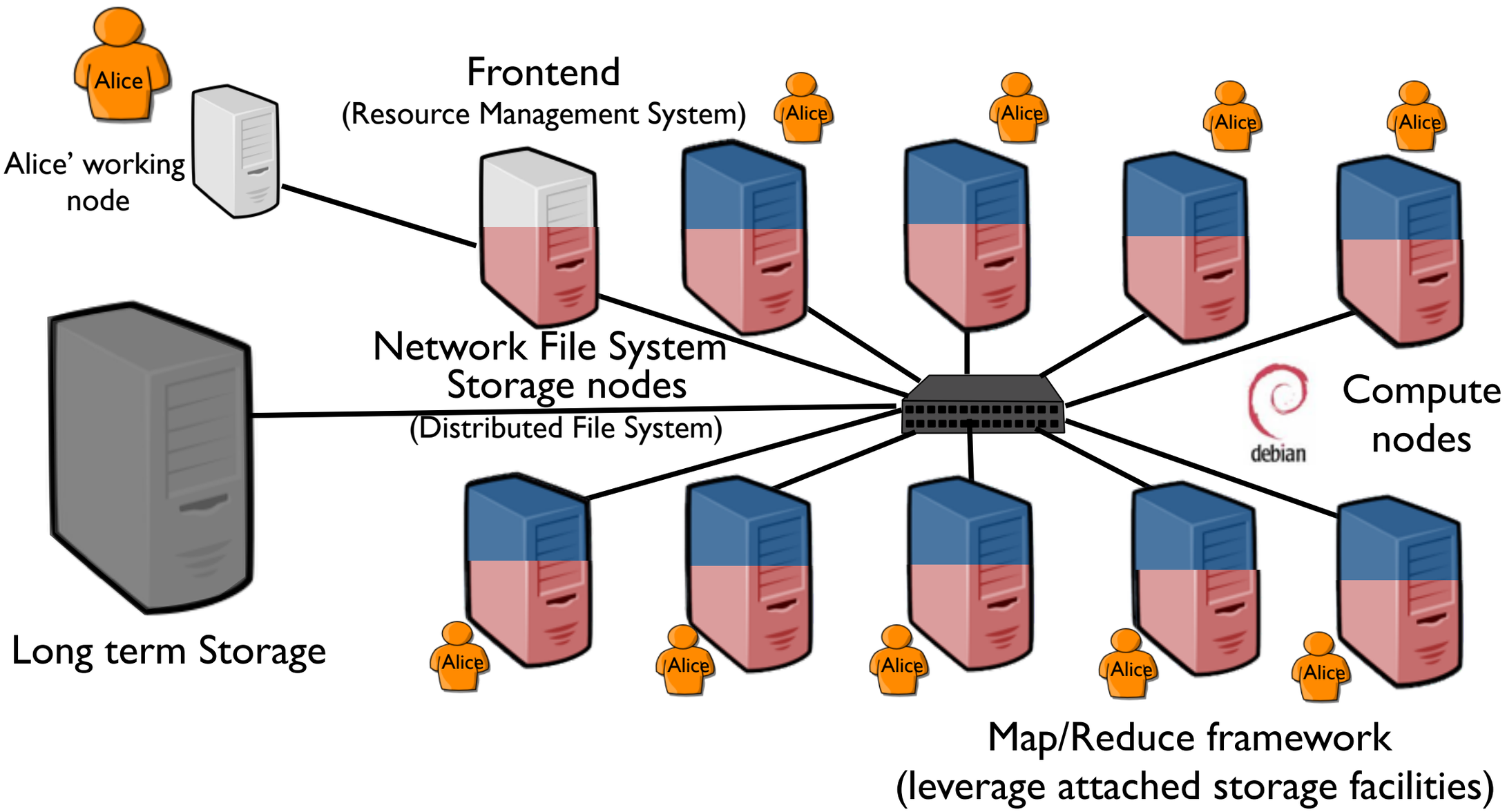
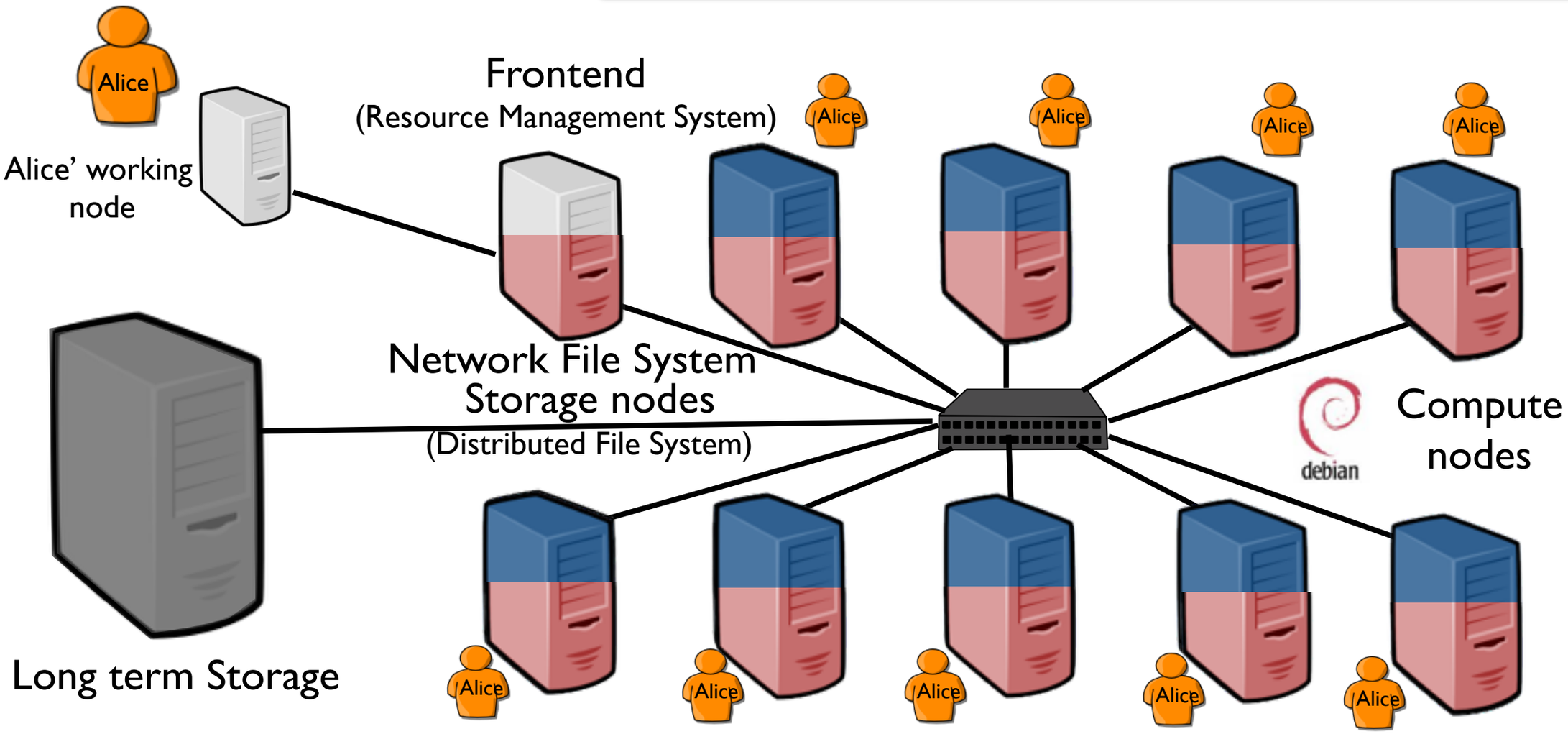


Looking back…

- Network of Workstations 1990 / 20**xx**

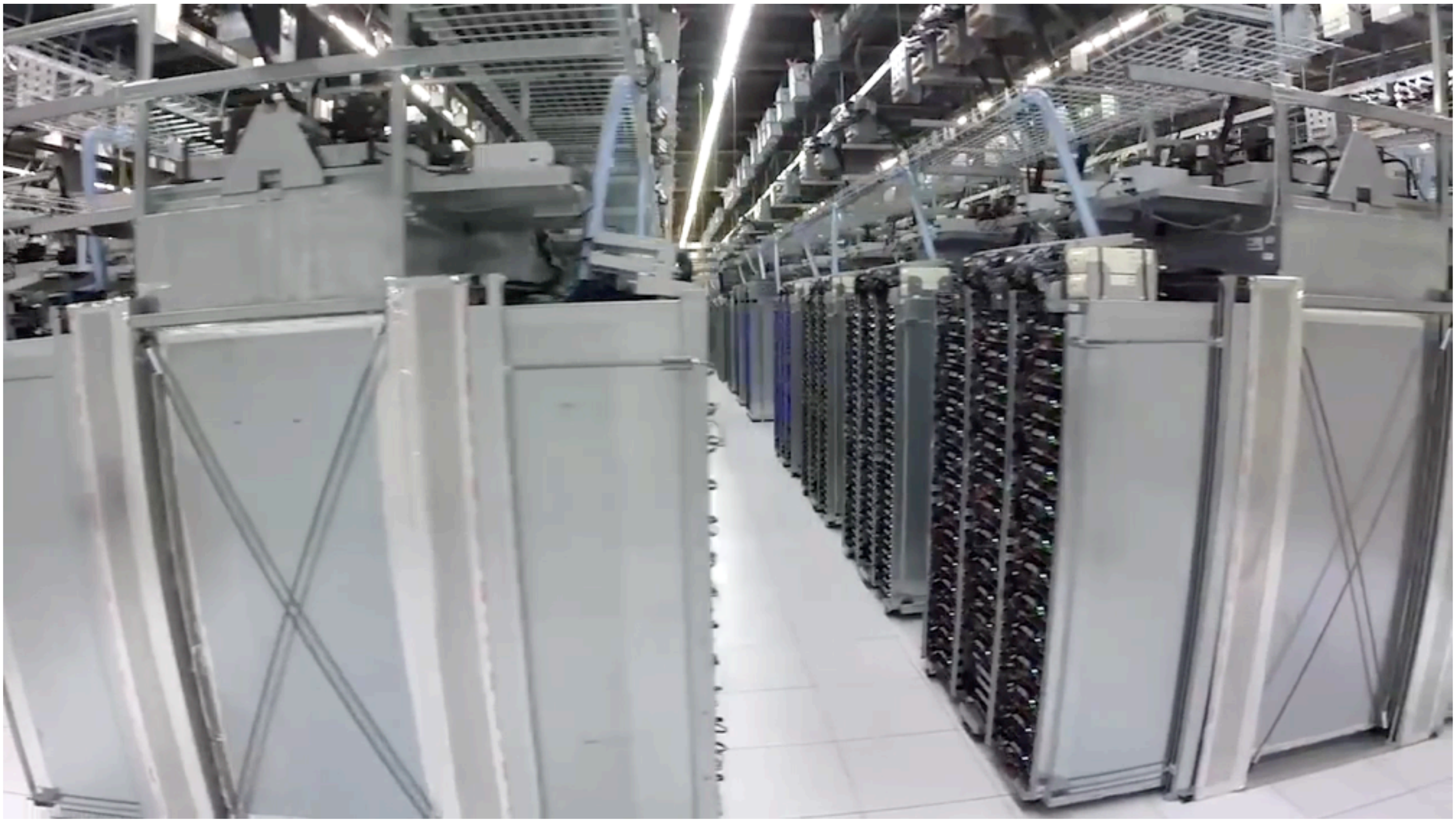
Map/Reduce - S. Ibrahim



Cluster in pictures

Google cluster, 1998

Cluster in pictures



credits: A. Simonet, Introduction to Cloud Computing

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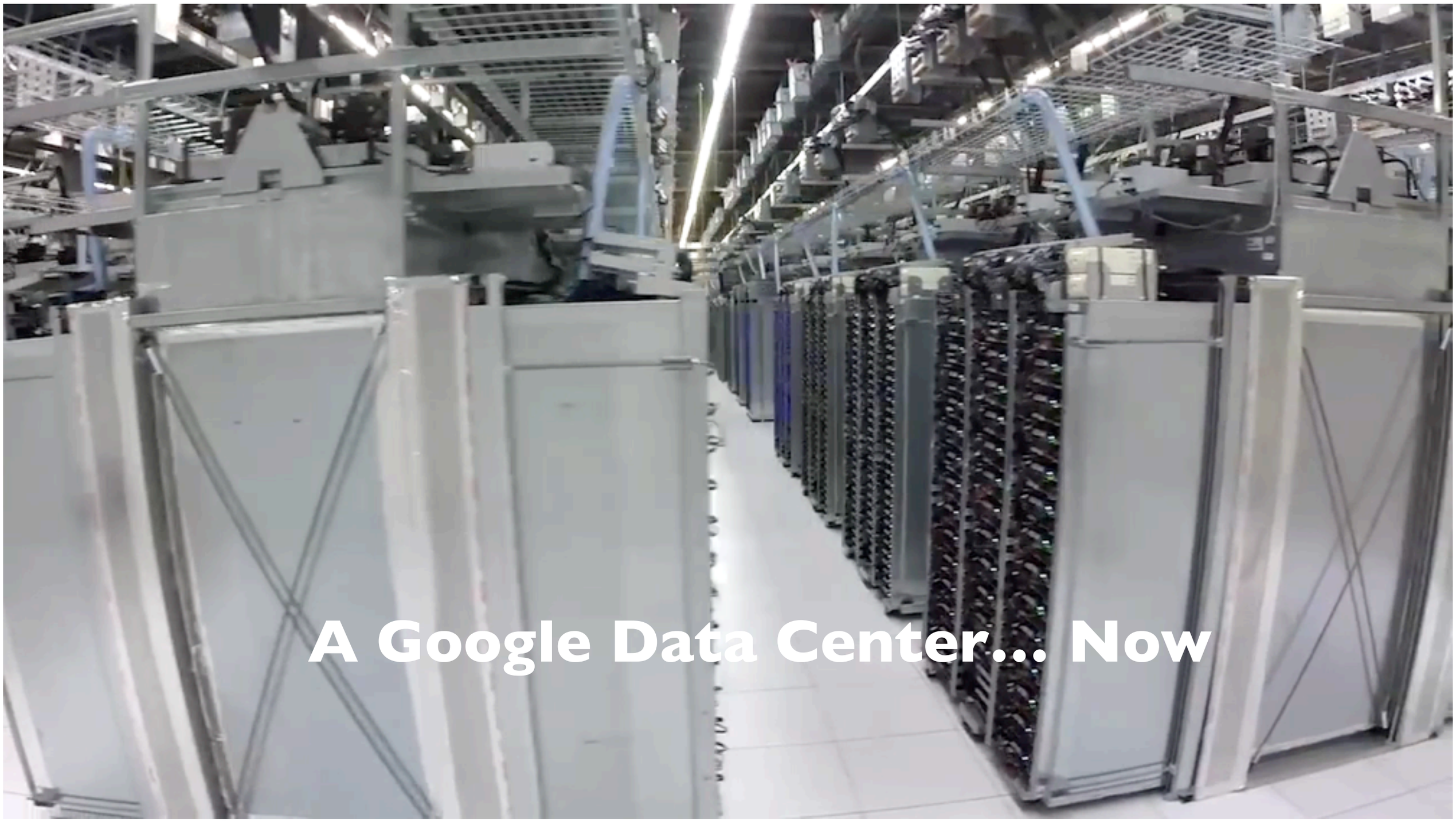

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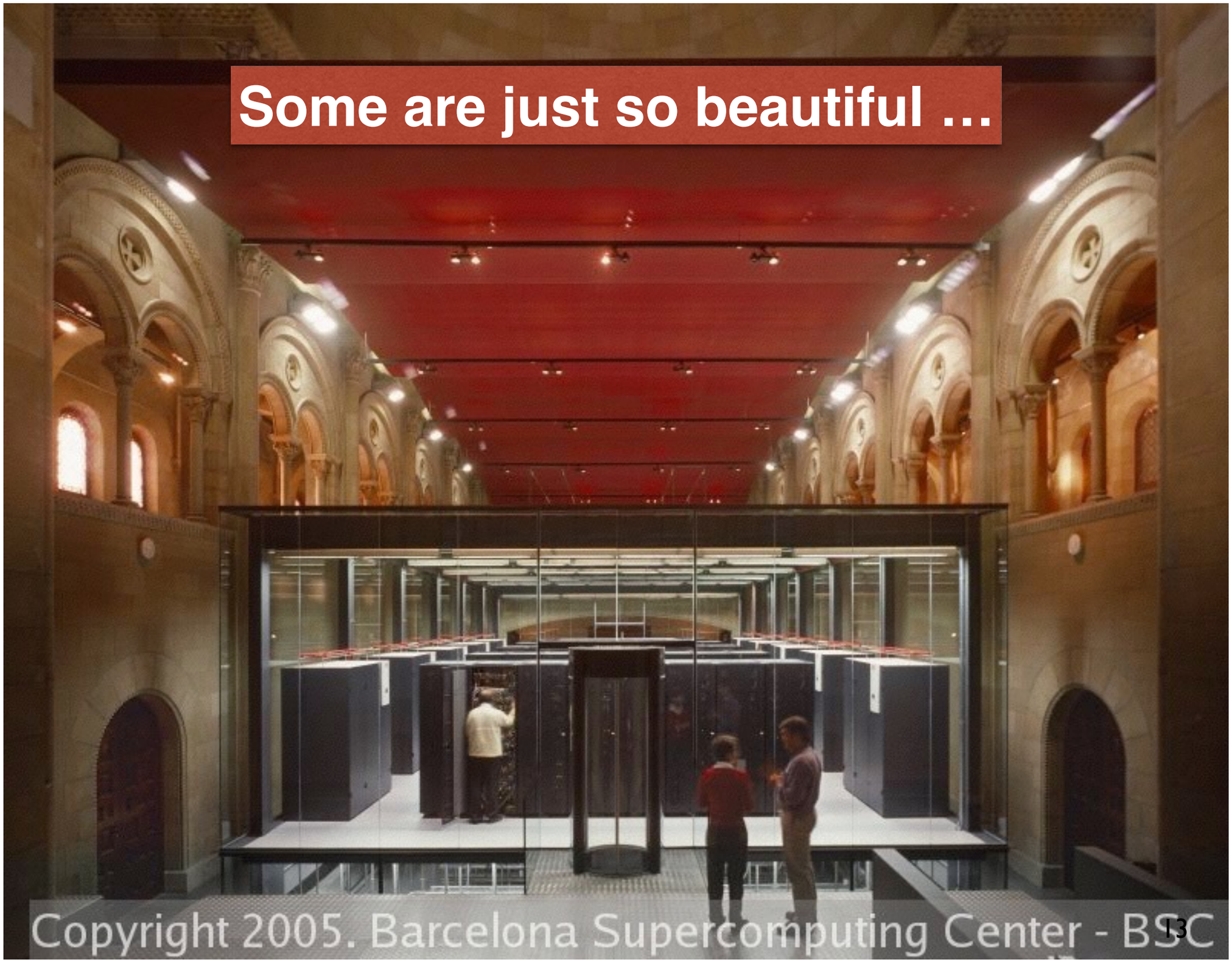

Cluster in pictures

credits: datacentertalk.com - Microsoft DC, Quincy, WA state

Cluster in pictures

Some are just prospective …

Cluster in pictures

Some are just prospective …

Lesson 3: G. Pierre

Looking back …

- Network of Workstations 1990 / 20xx
- Desktop 1998 / 201x

Exploit inactive time of machines interconnected to the Internet
(Volunteers distributed computing)

Famous examples

SETI@home: *Search for Extra-Terrestrial Intelligence (*May 1999*)*
BOINC: Berkeley Open Infrastructure for Network Computing

Clients/server model

Security is the main issue

Strong limitations (SPMD model)

Looking back…

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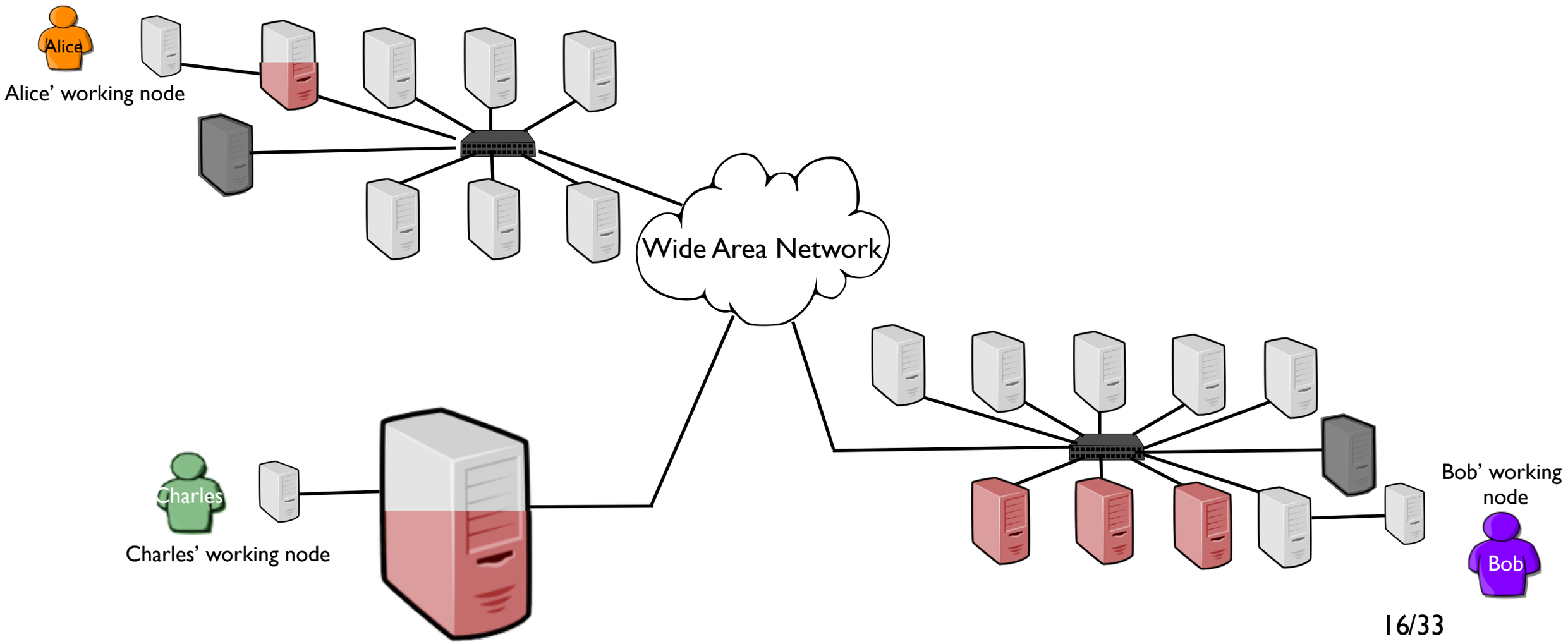
- Desktop 1998 / 201**x**
- Grid 1998 / 201**x**



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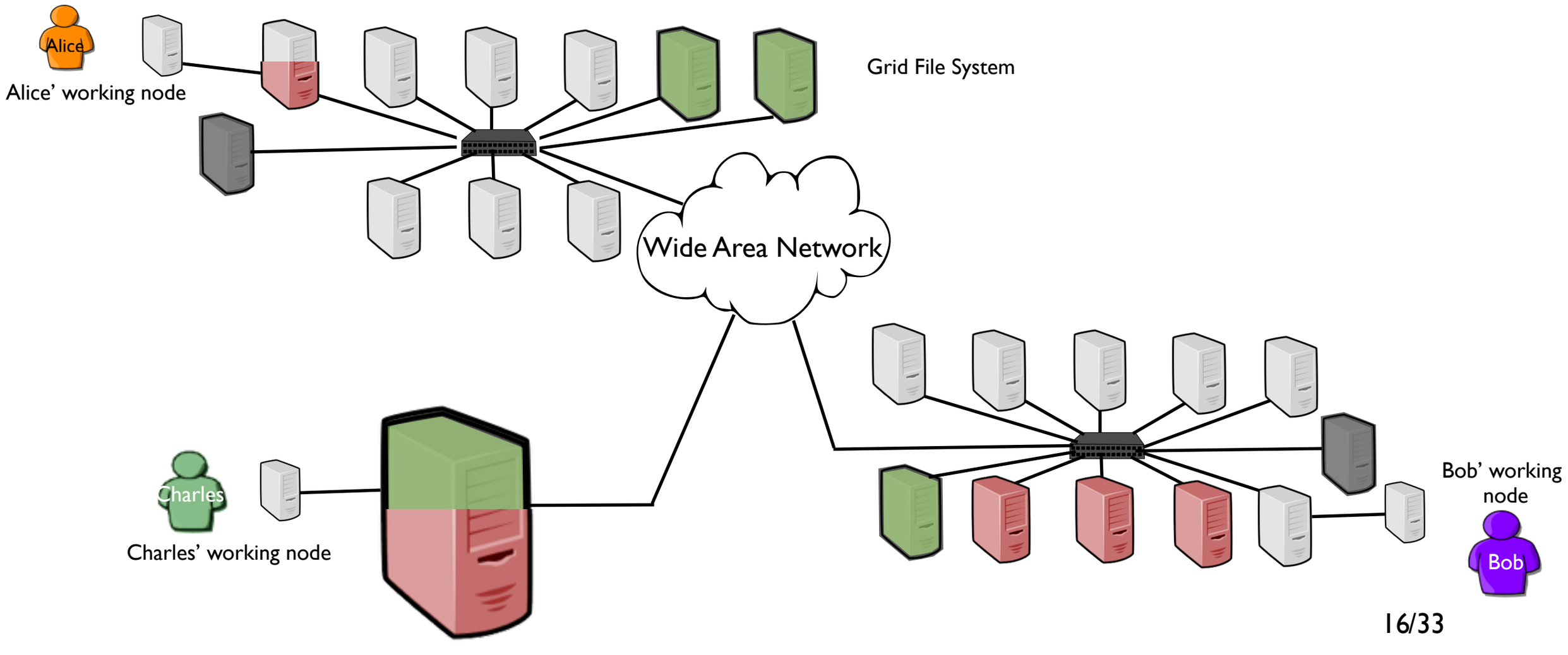

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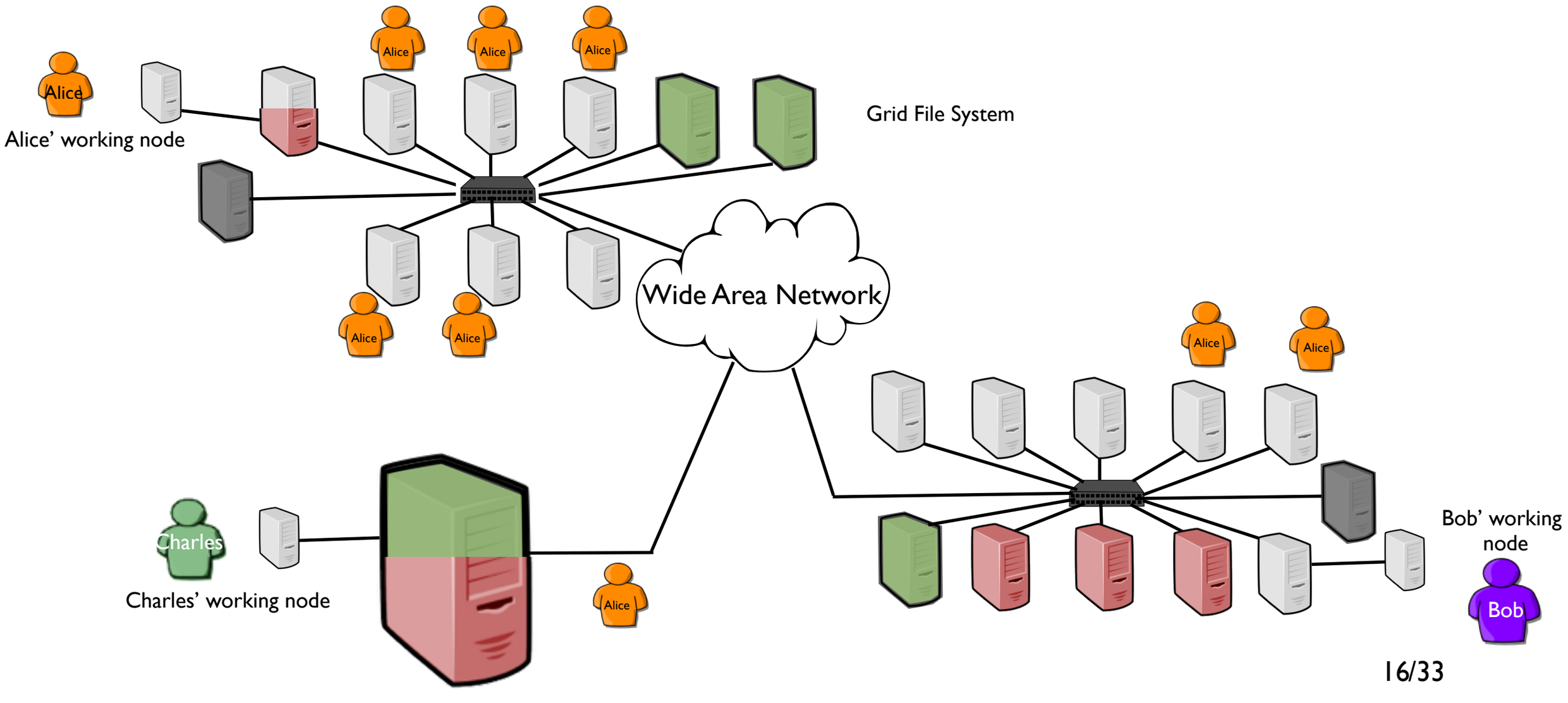

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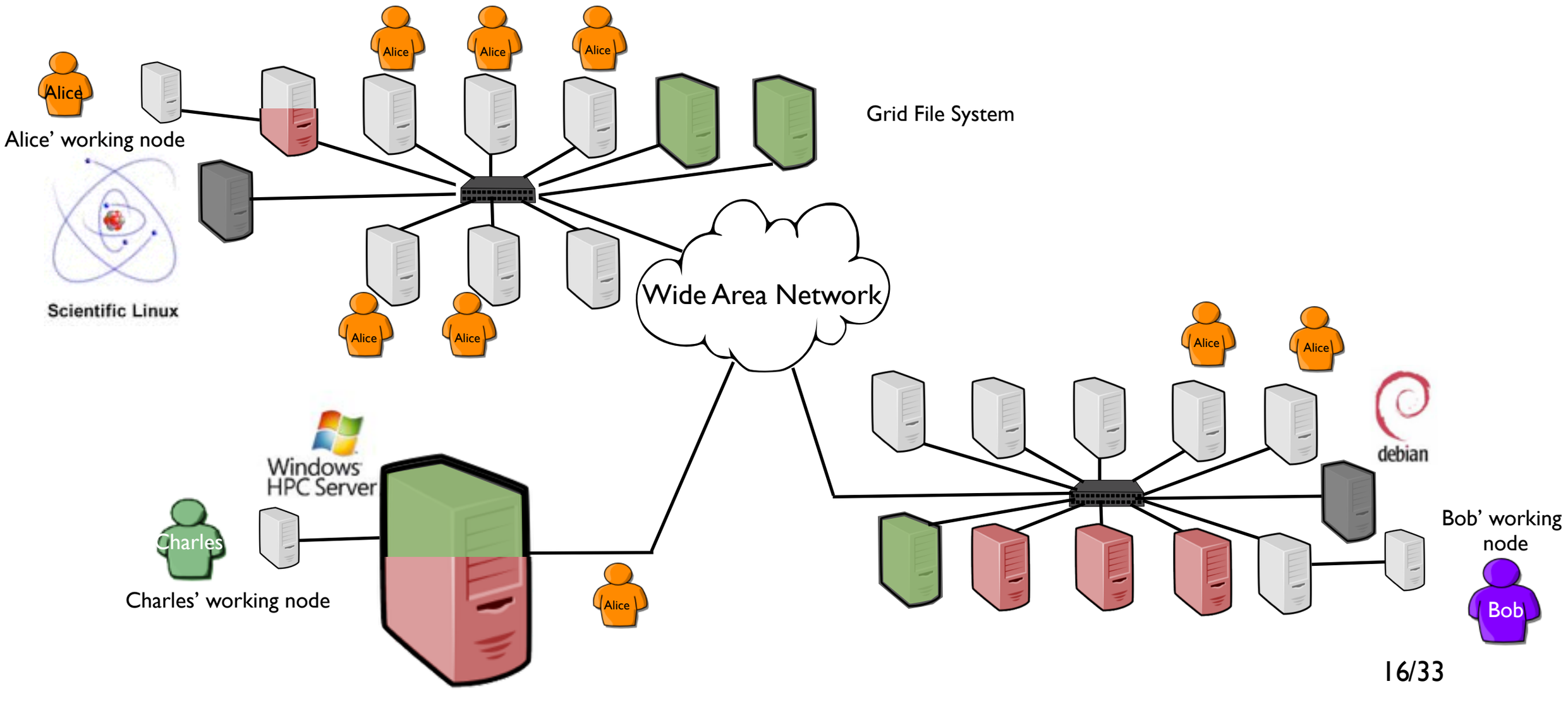

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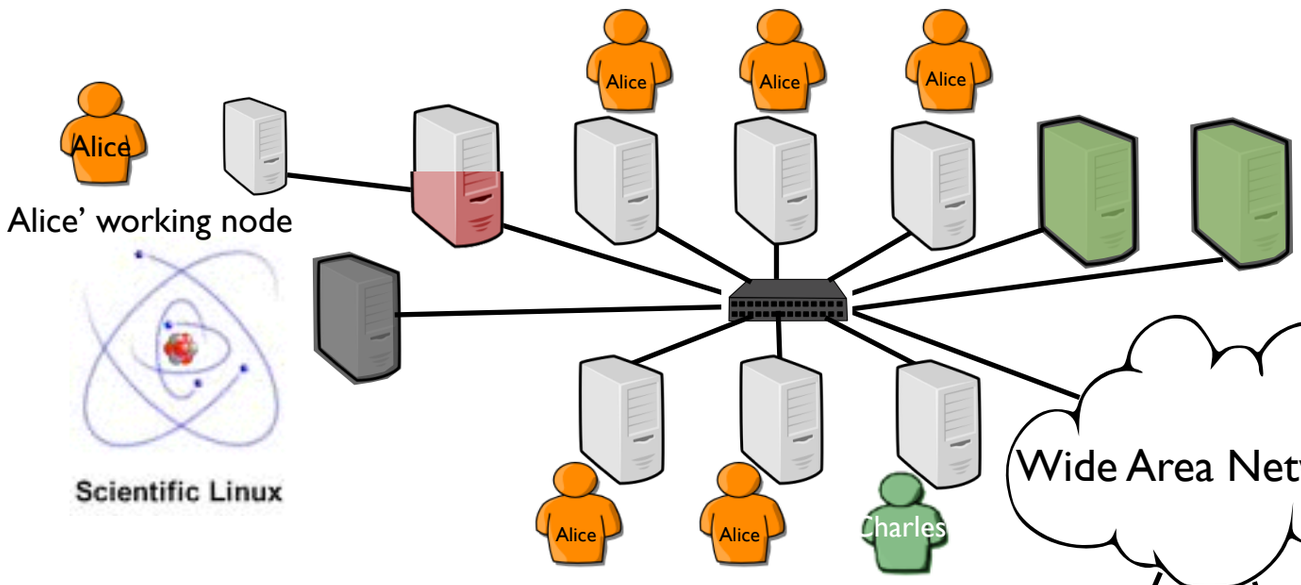

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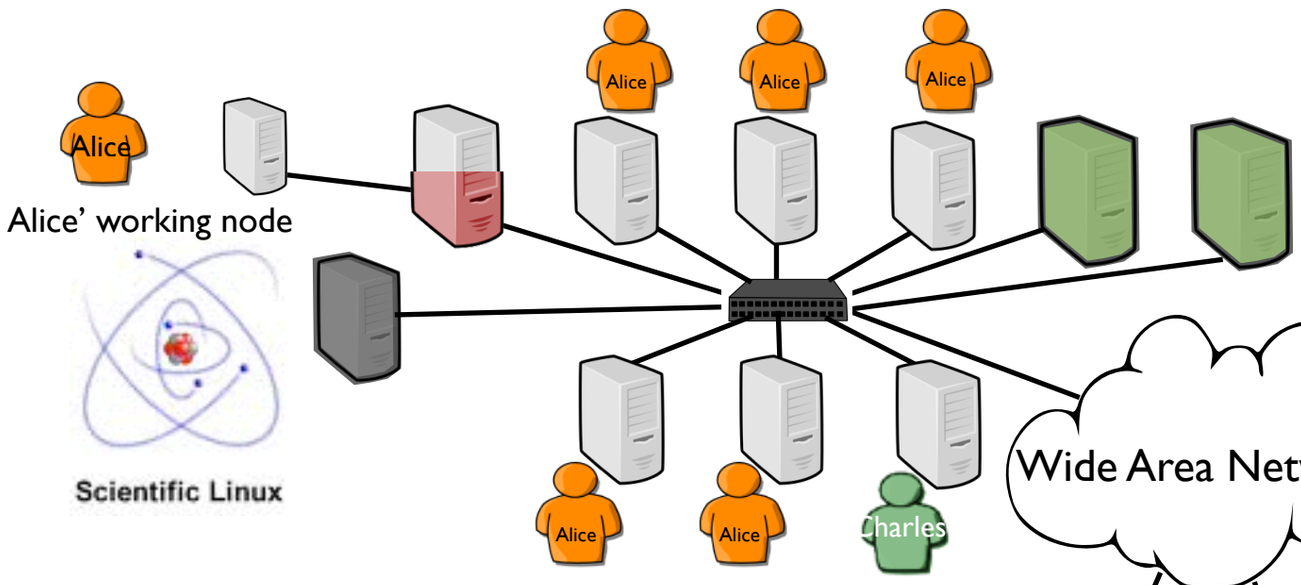

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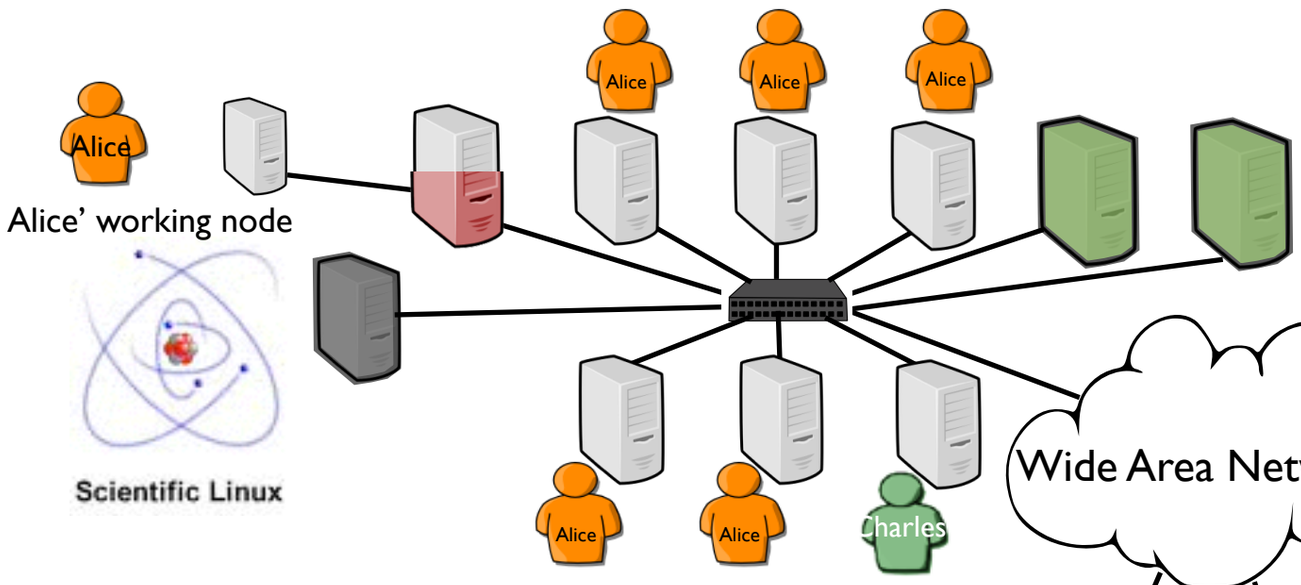

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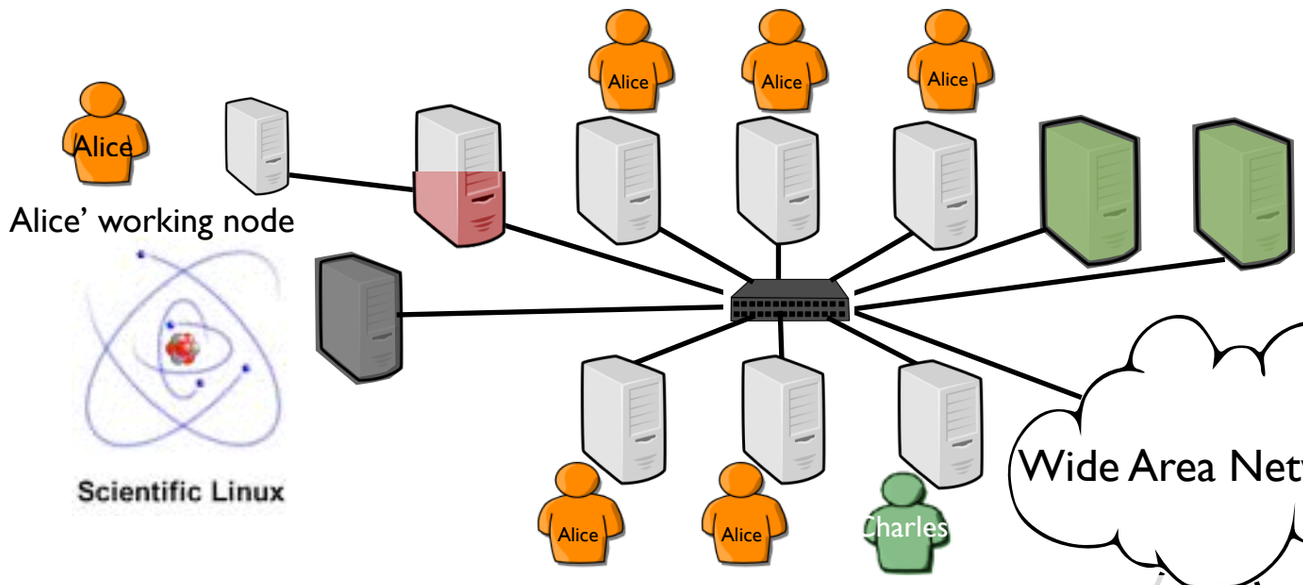

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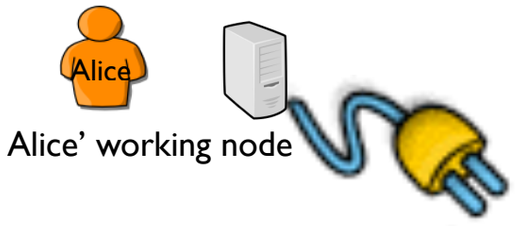
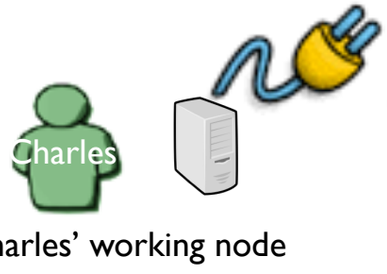
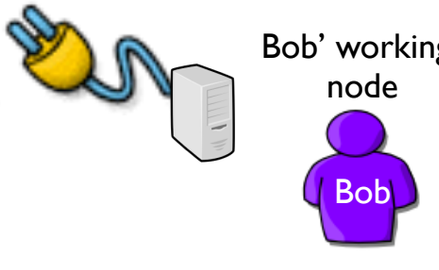


Resource booking (based on user's estimates)
Security concerns (job isolation)
Heterogeneity concerns (hardware and software)
Scheduling limitations (a job cannot be easily relocated)
Fault tolerance issues
…





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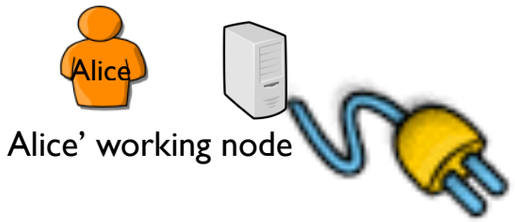
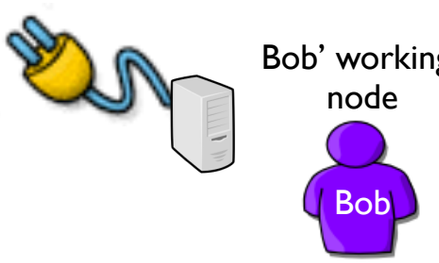
What a Grid ! ? !

A lot of progress has been done since the 90's and several proposals partially addressed these concerns.





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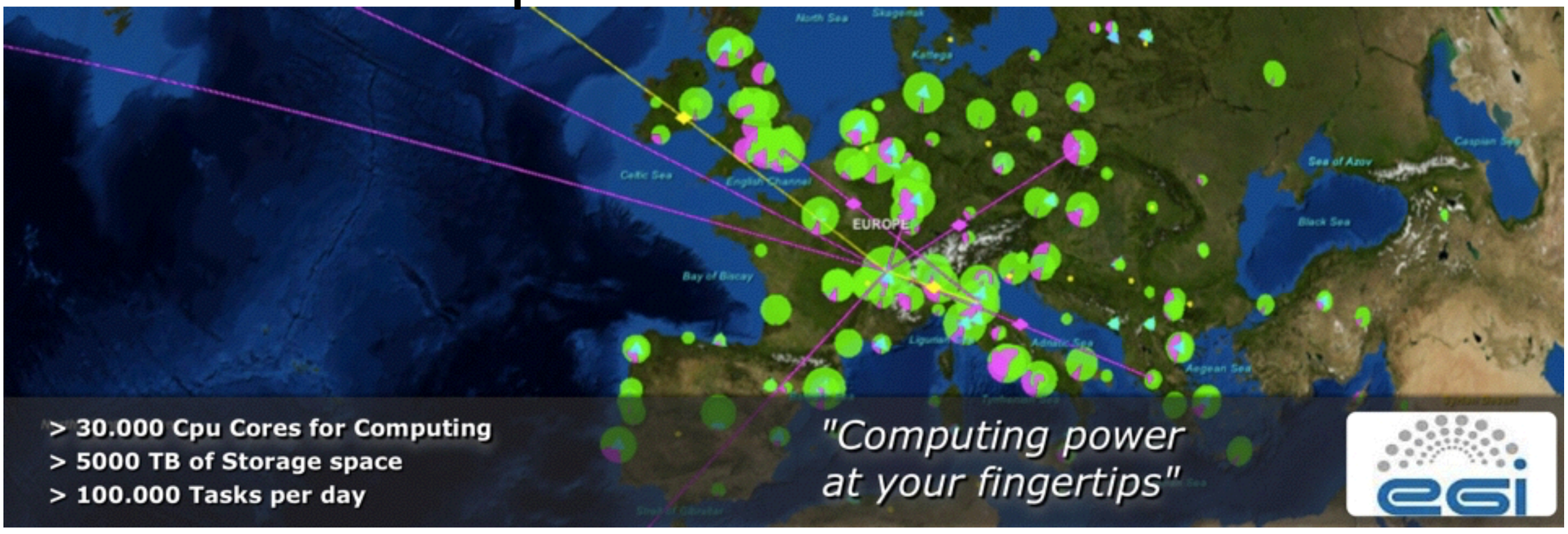
European Grid Infrastructure



EGI enables access to computing resources for European researchers from all fields of science, from high energy physics to humanities.

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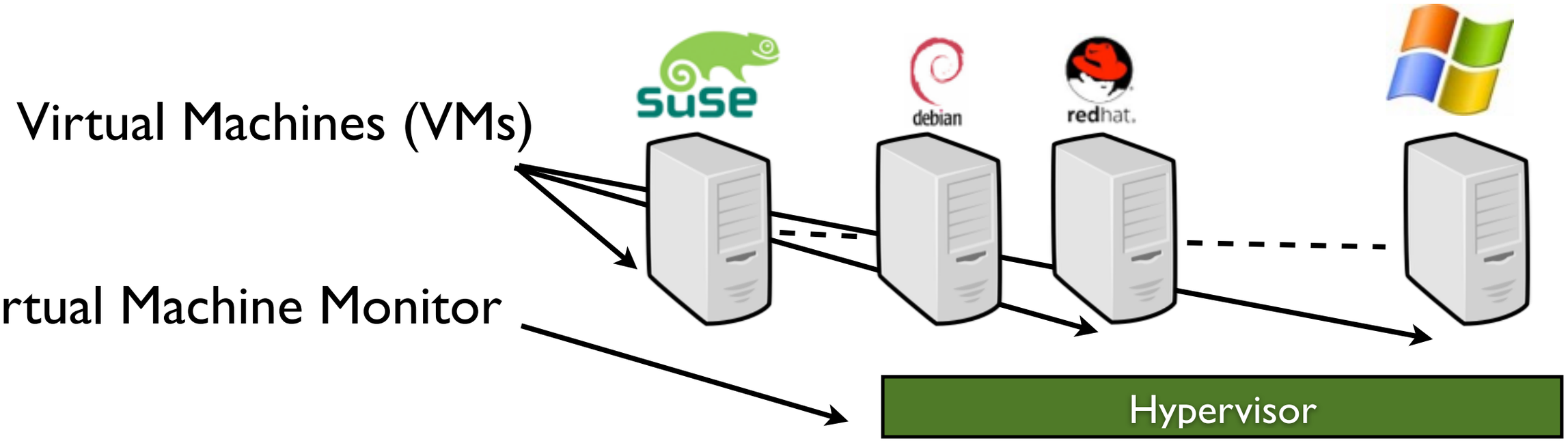

"A ***virtual machine*** (VM) provides a faithful implementation of a physical processor's hardware running in a protected and isolated environment.
Virtual machines are created by a software layer called the ***virtual machine monitor*** (VMM) that runs as a privileged task on a physical processor."

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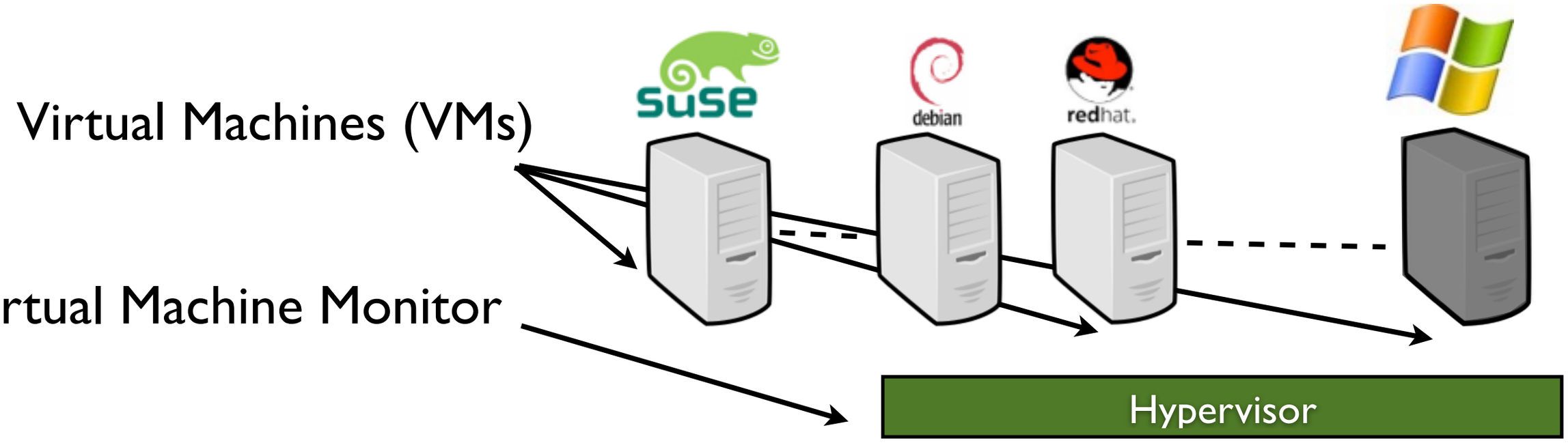

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A BIT OF HISTORY

Proposed in the 60's by IBM
More than 70 publications between 66 and 73

"Virtual Machines have finally arrived. Dismissed for a number of years as merely academic curiosities, they are now seen as cost-effective techniques for organizing computer systems resources to provide extraordinary system flexibility and support for certain unique applications" .

Goldberg, Survey of Virtual Machine Research, 1974

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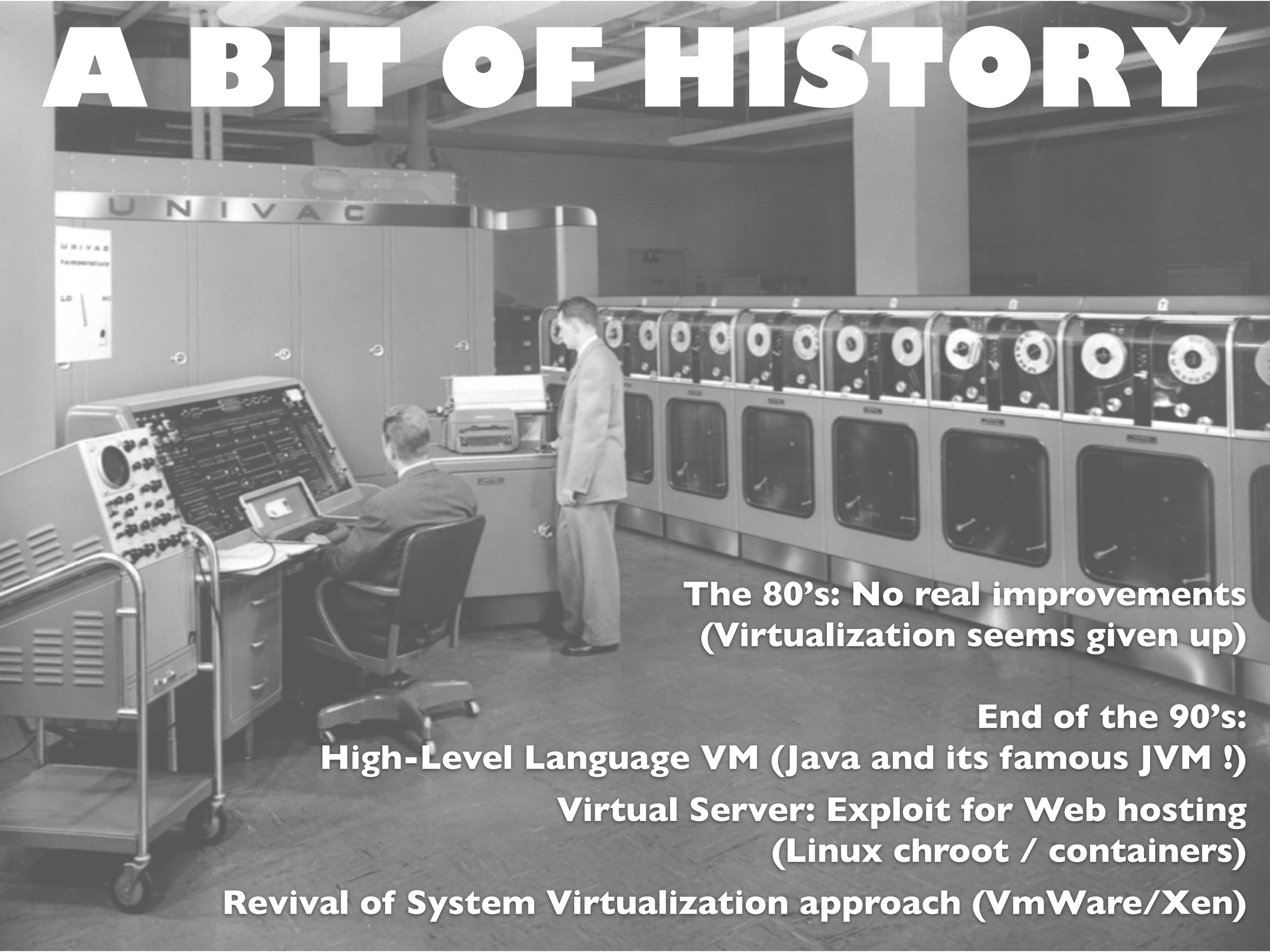


The 80's: No real improvements
(Virtualization seems given up)

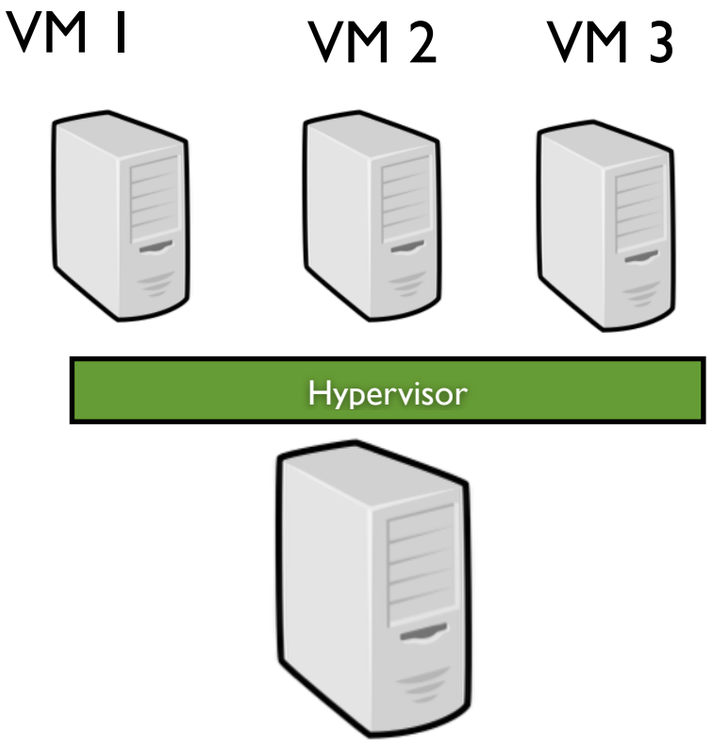
End of the 90's:
High-Level Language VM (Java and its famous JVM !)

Virtual Server: Exploit for Web hosting
(Linux chroot / containers)

Revival of System Virtualization approach (VmWare/Xen)

Looking back…

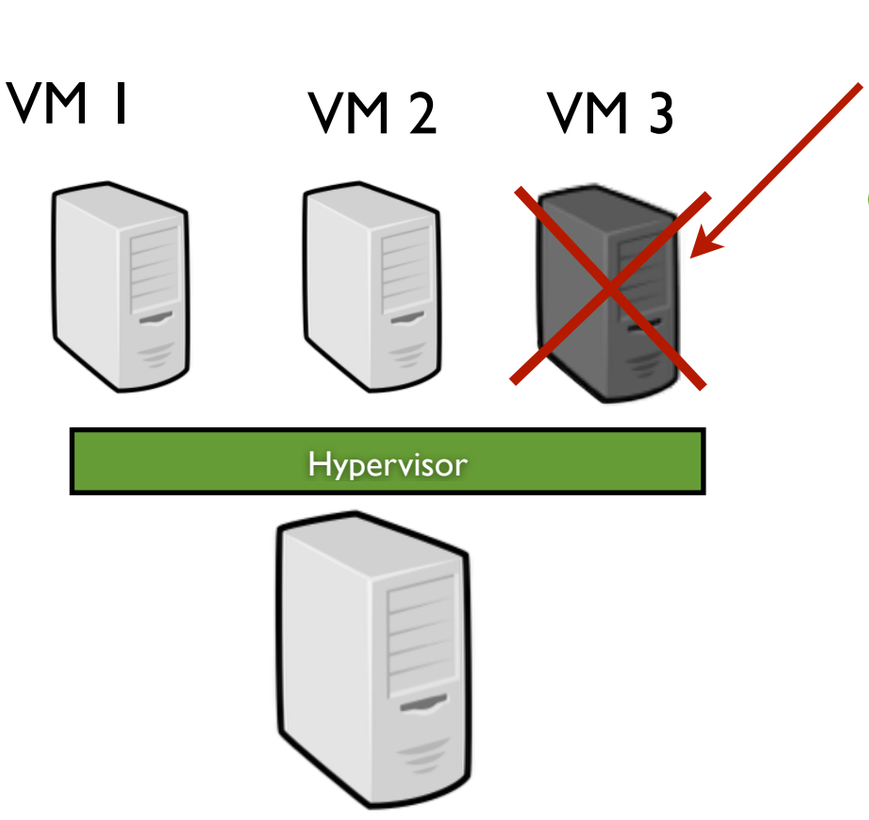
- System virtualization: a great sandbox



- Isolation (“security” between each VM)

Looking back…

- System virtualization: a great sandbox



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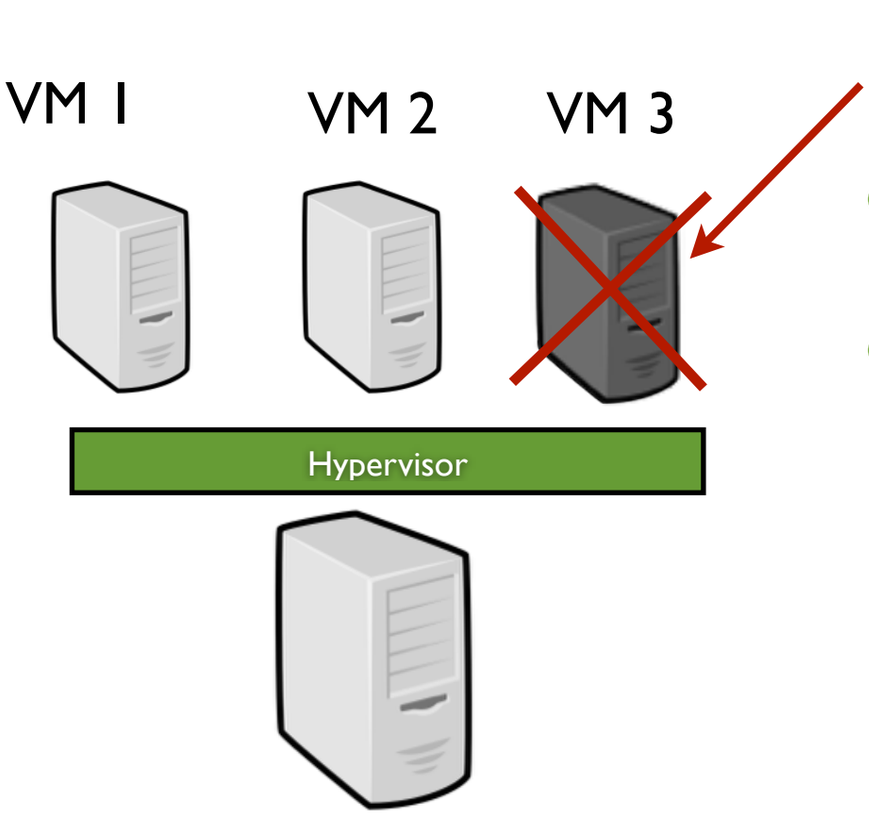

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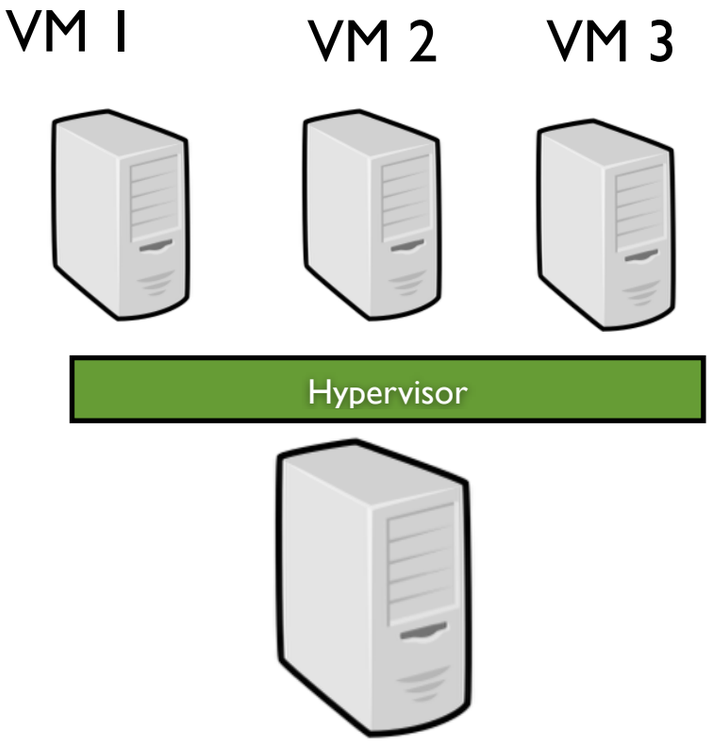

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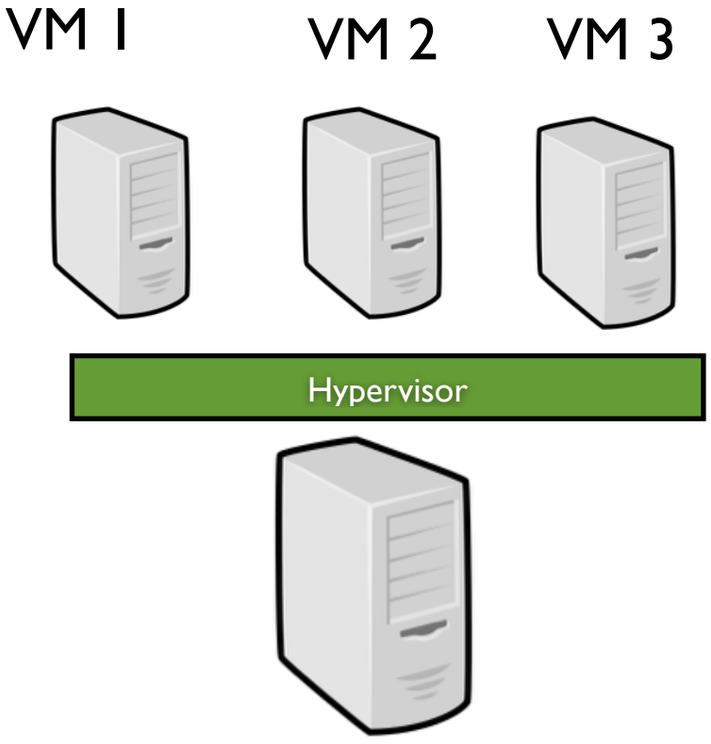

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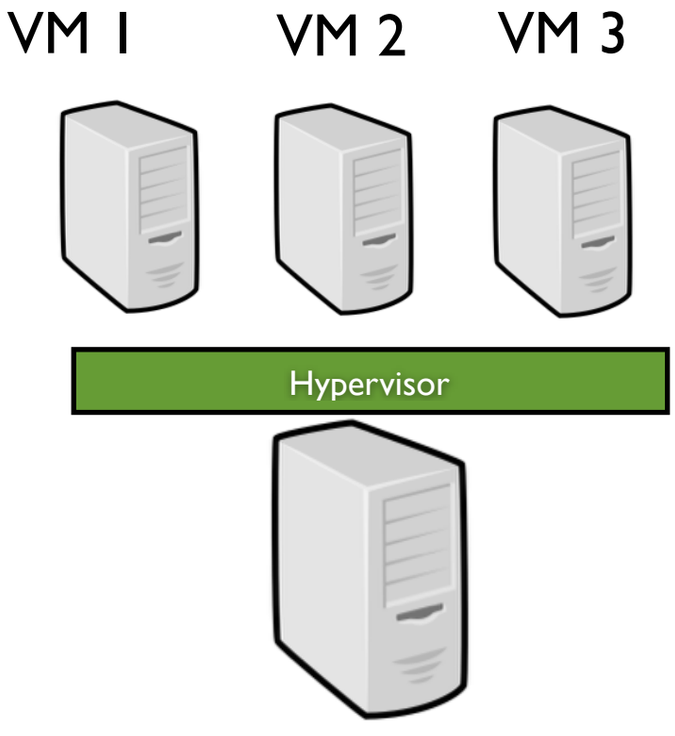

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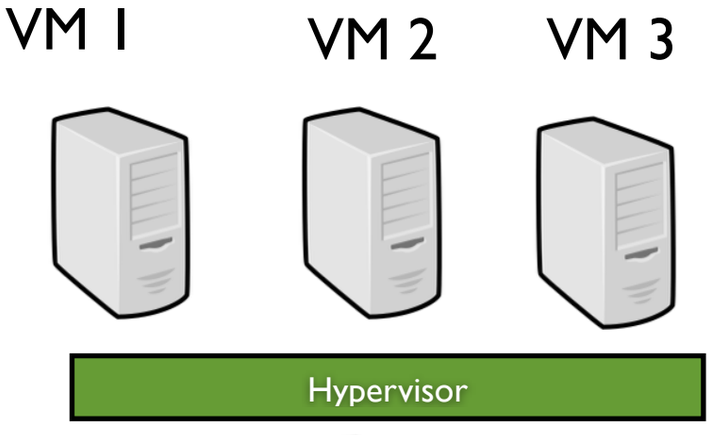

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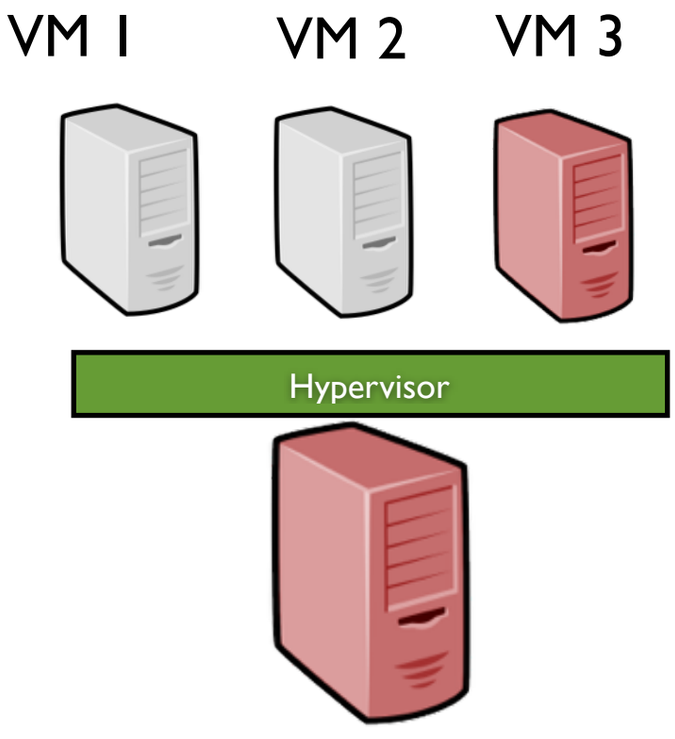

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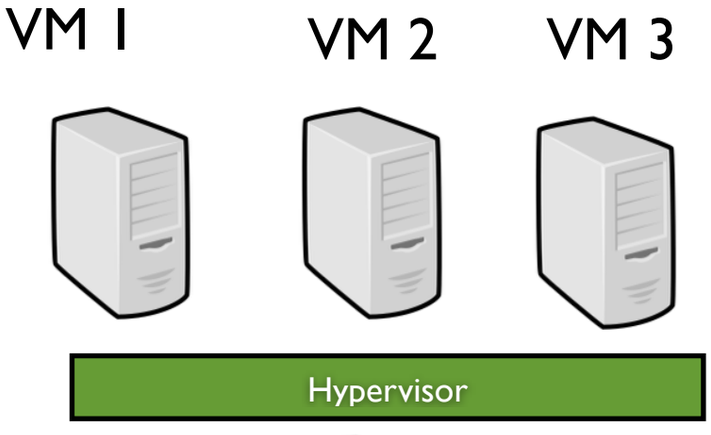

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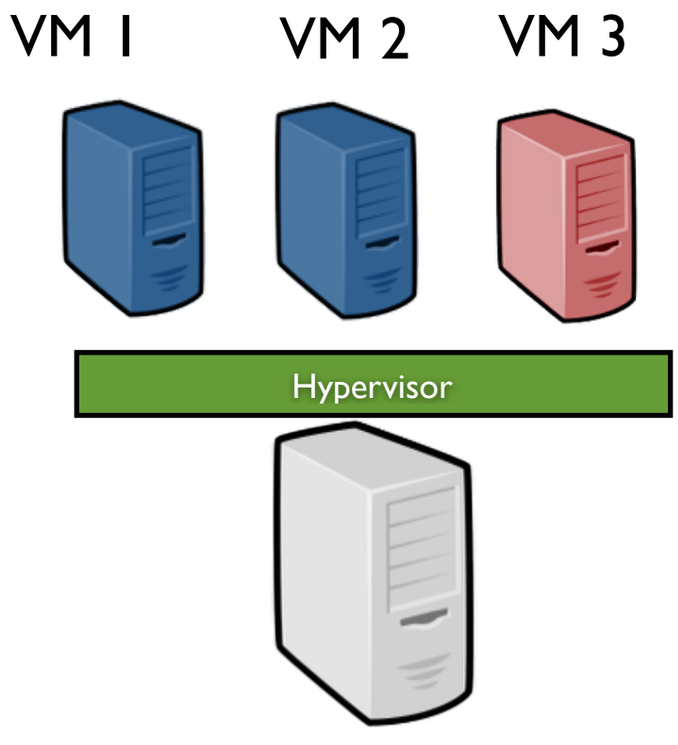

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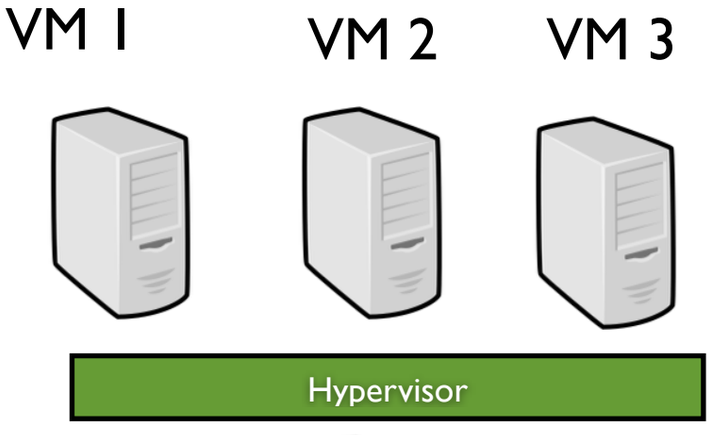

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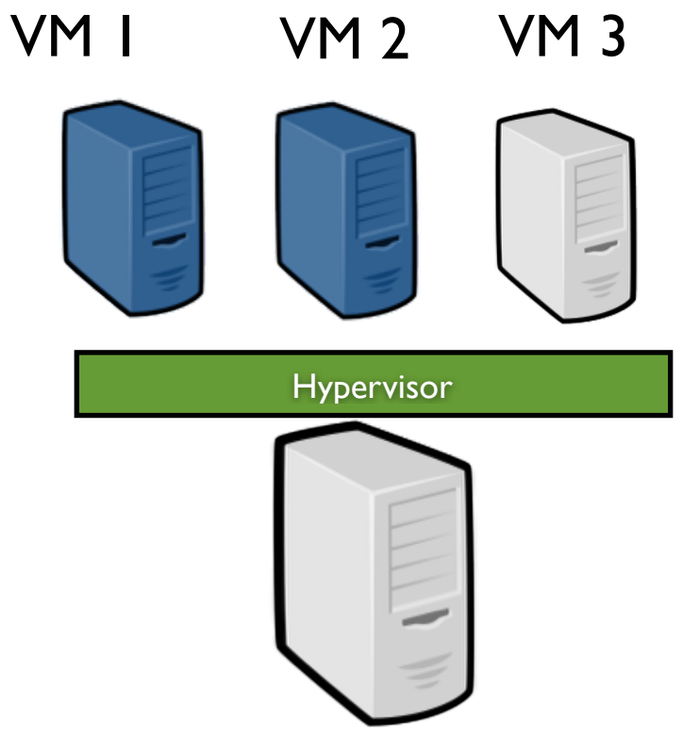

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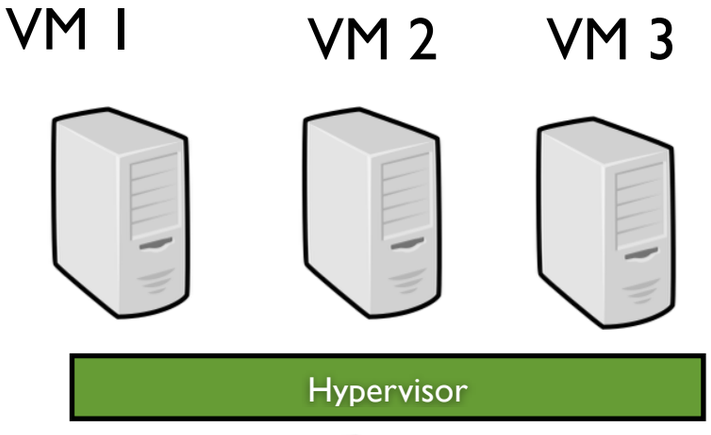

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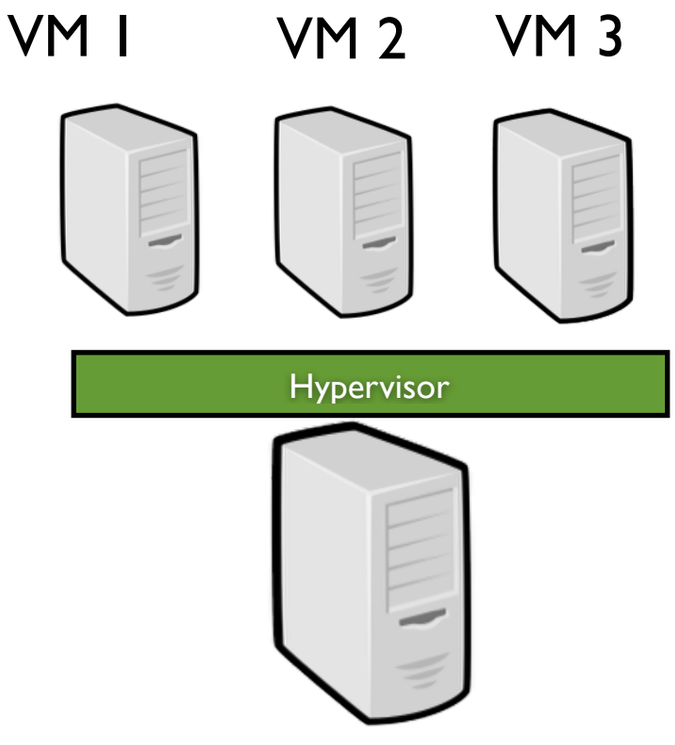

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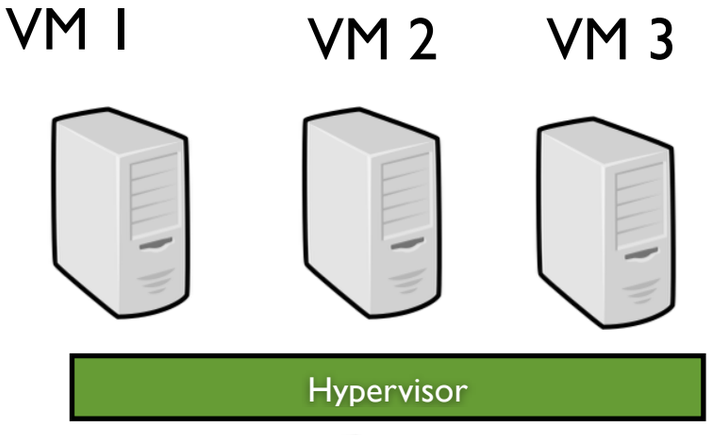

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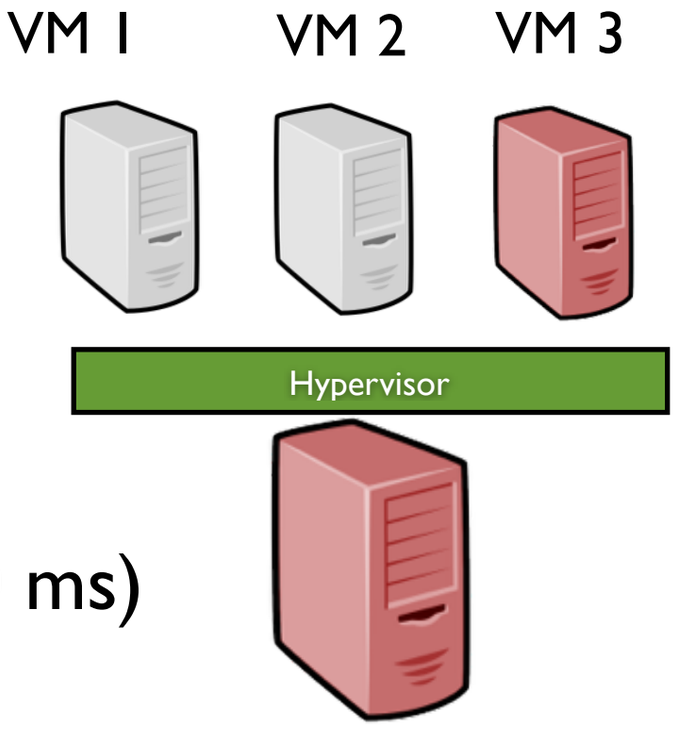

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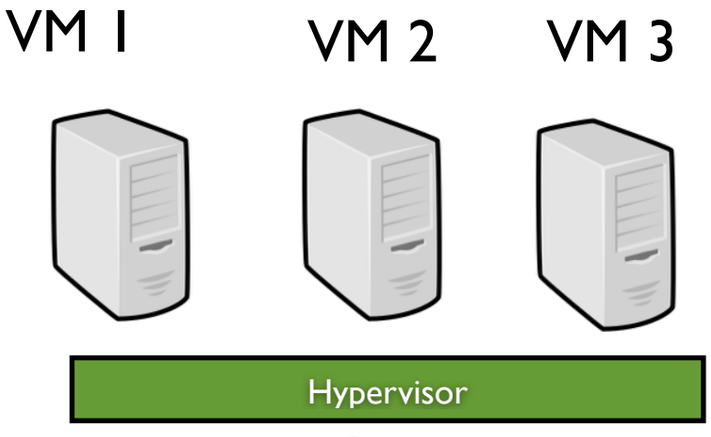

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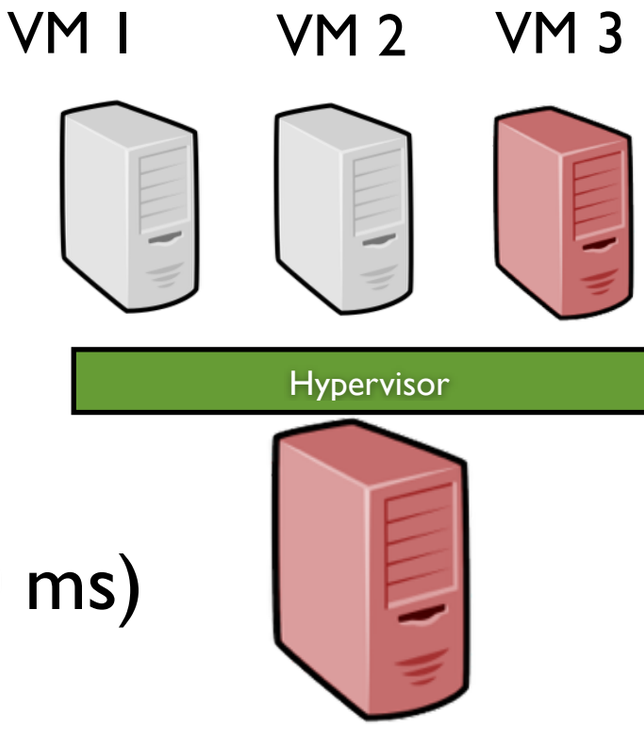

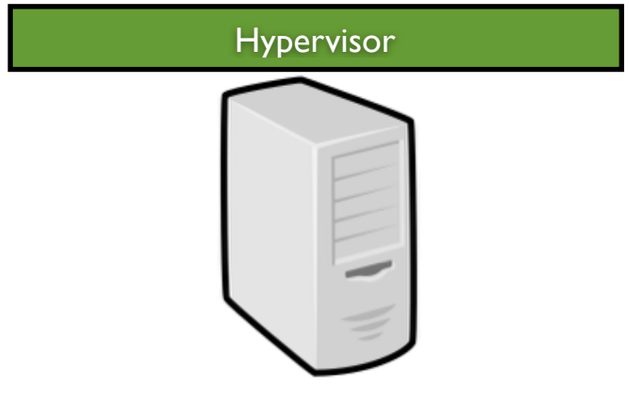

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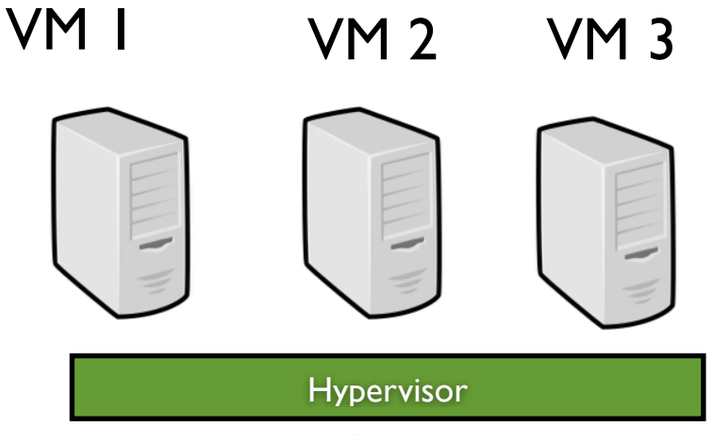

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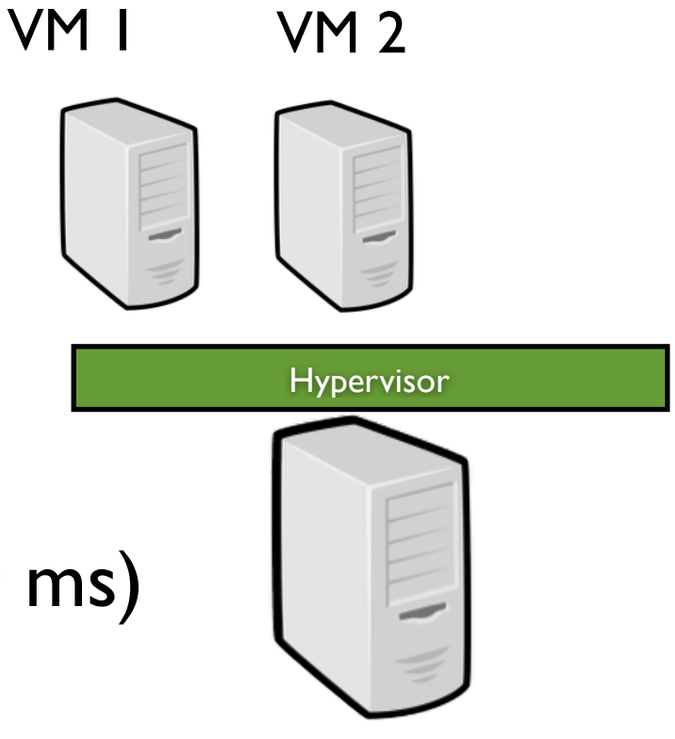

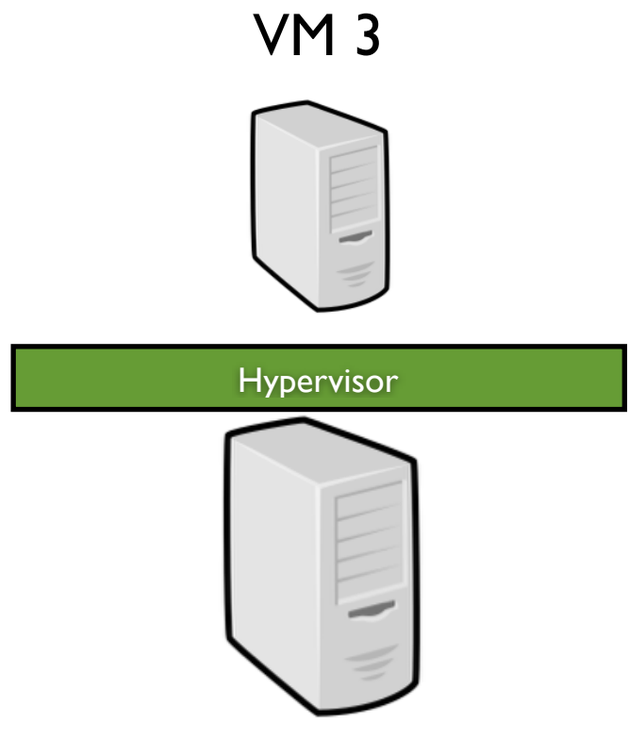

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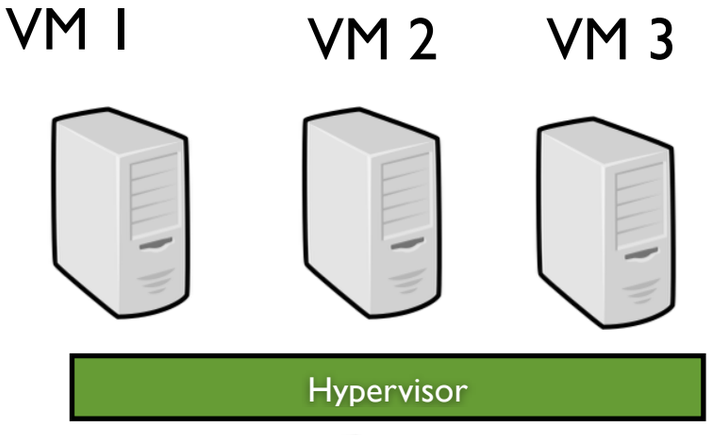

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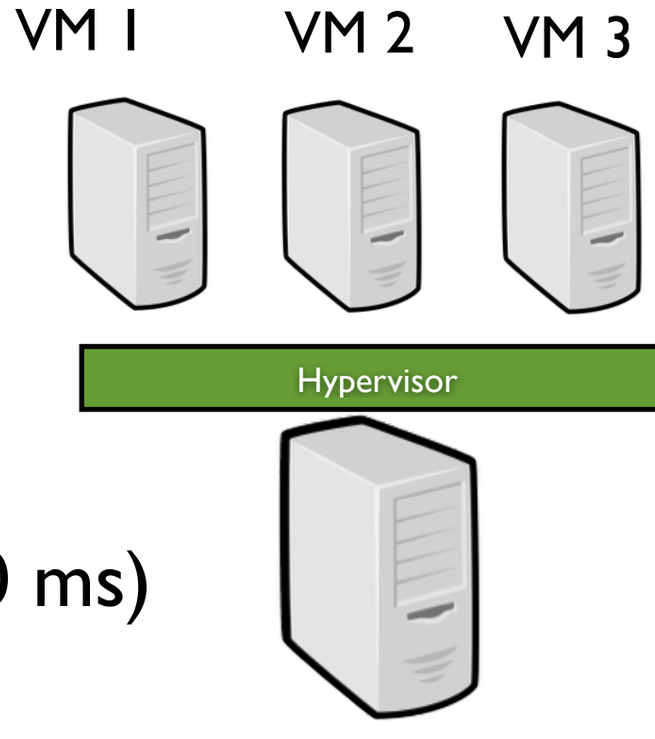

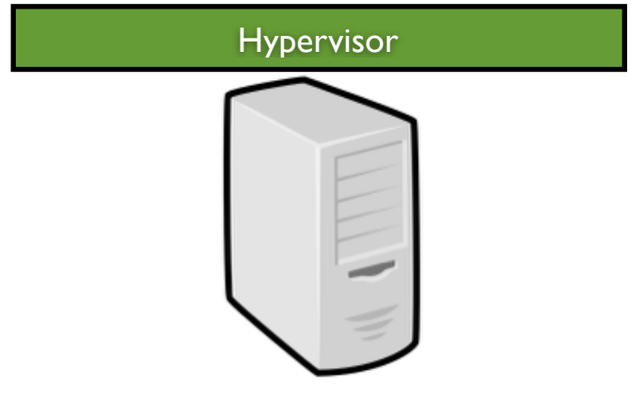

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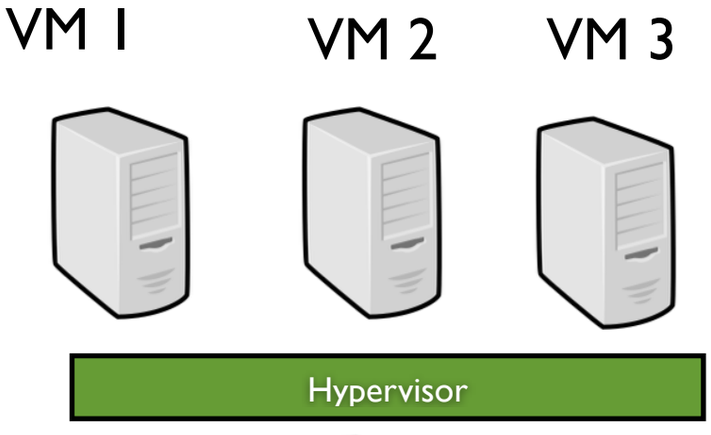

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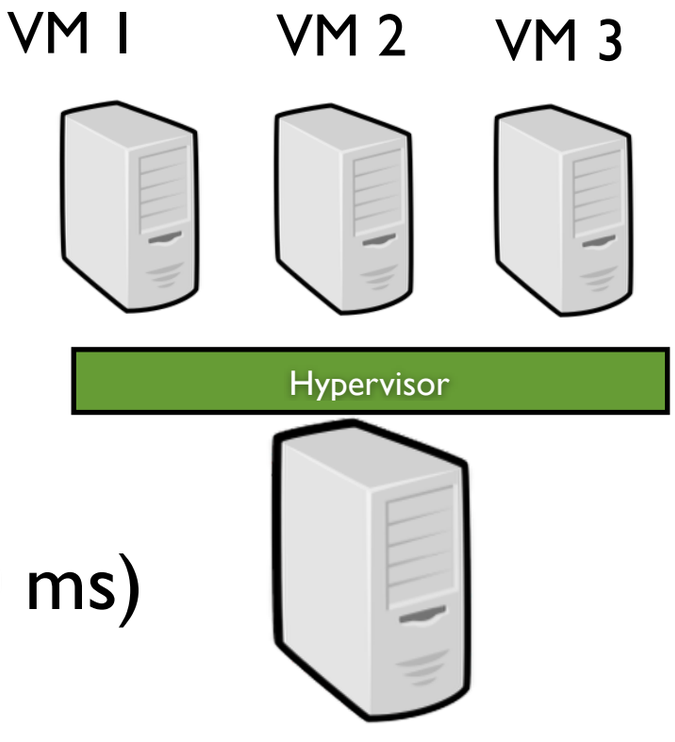

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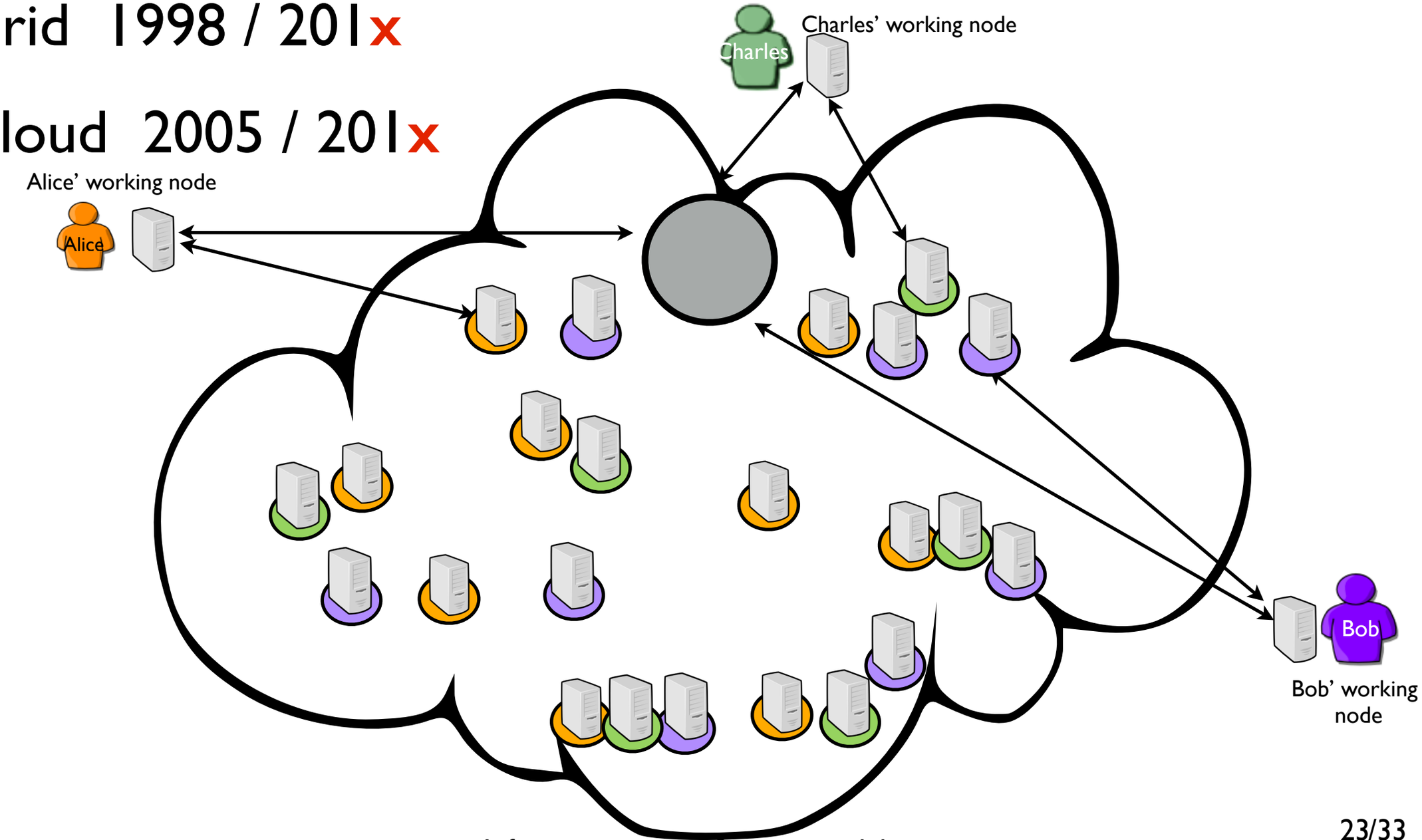

Infrastructure as a Service model

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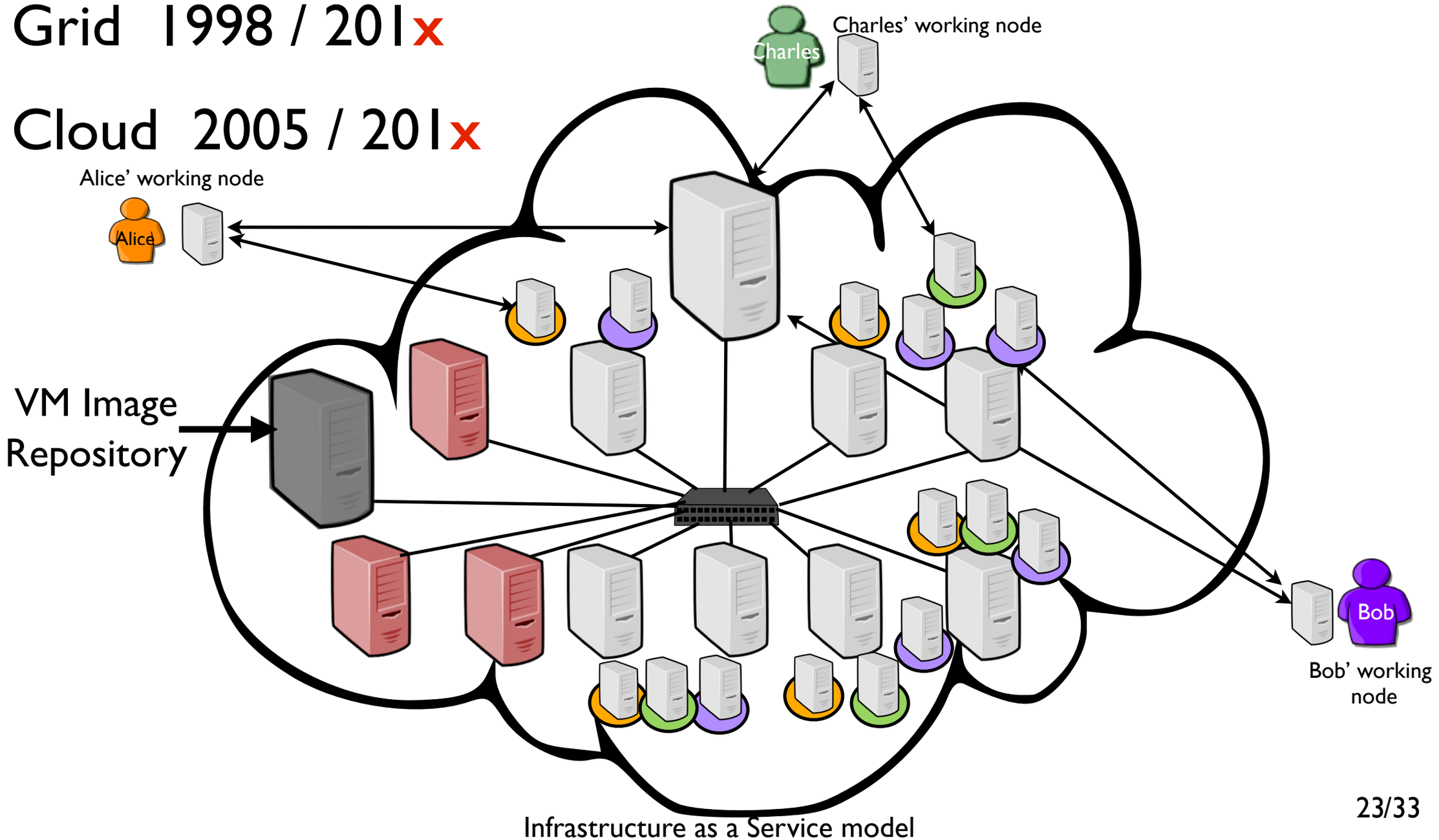

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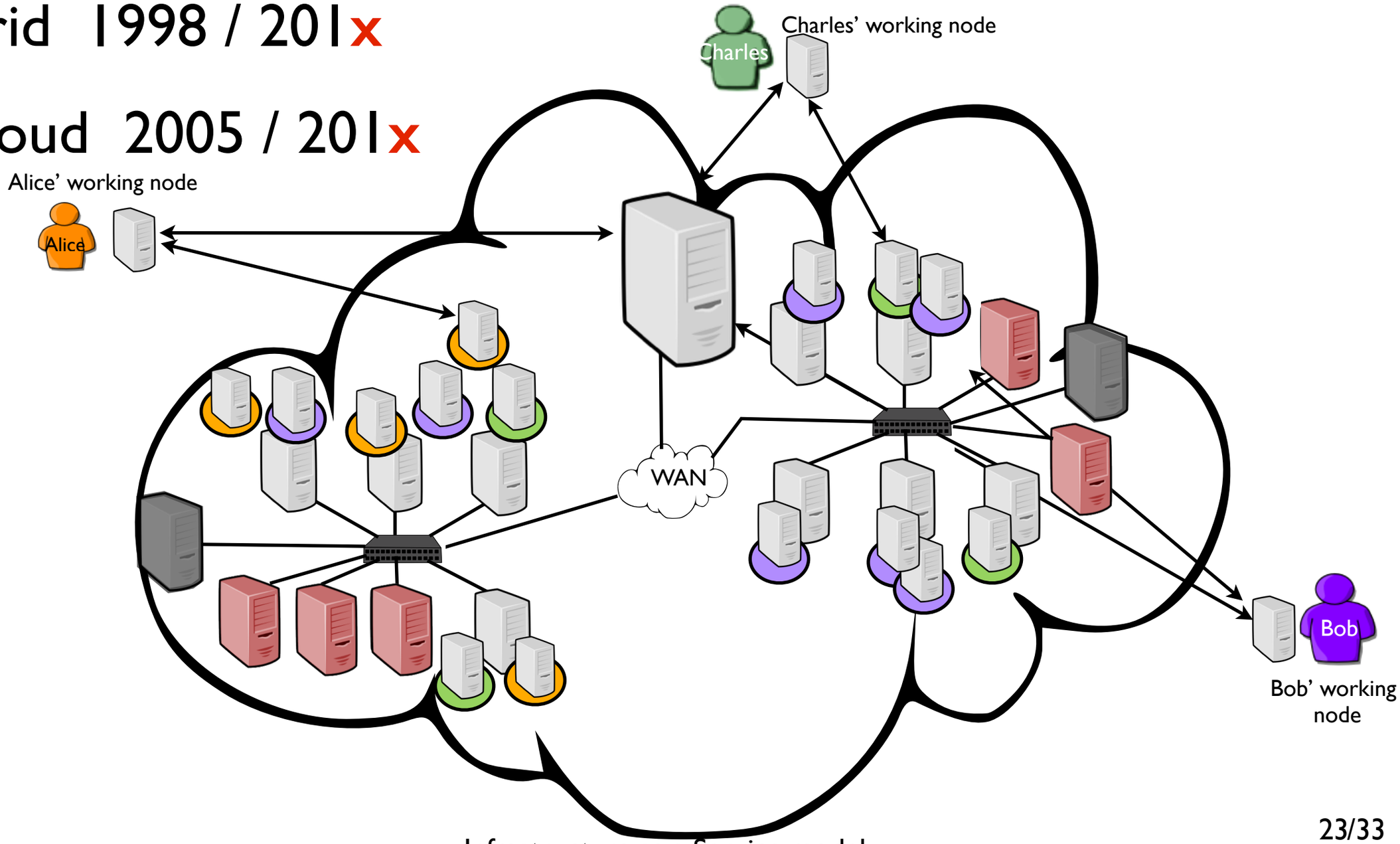

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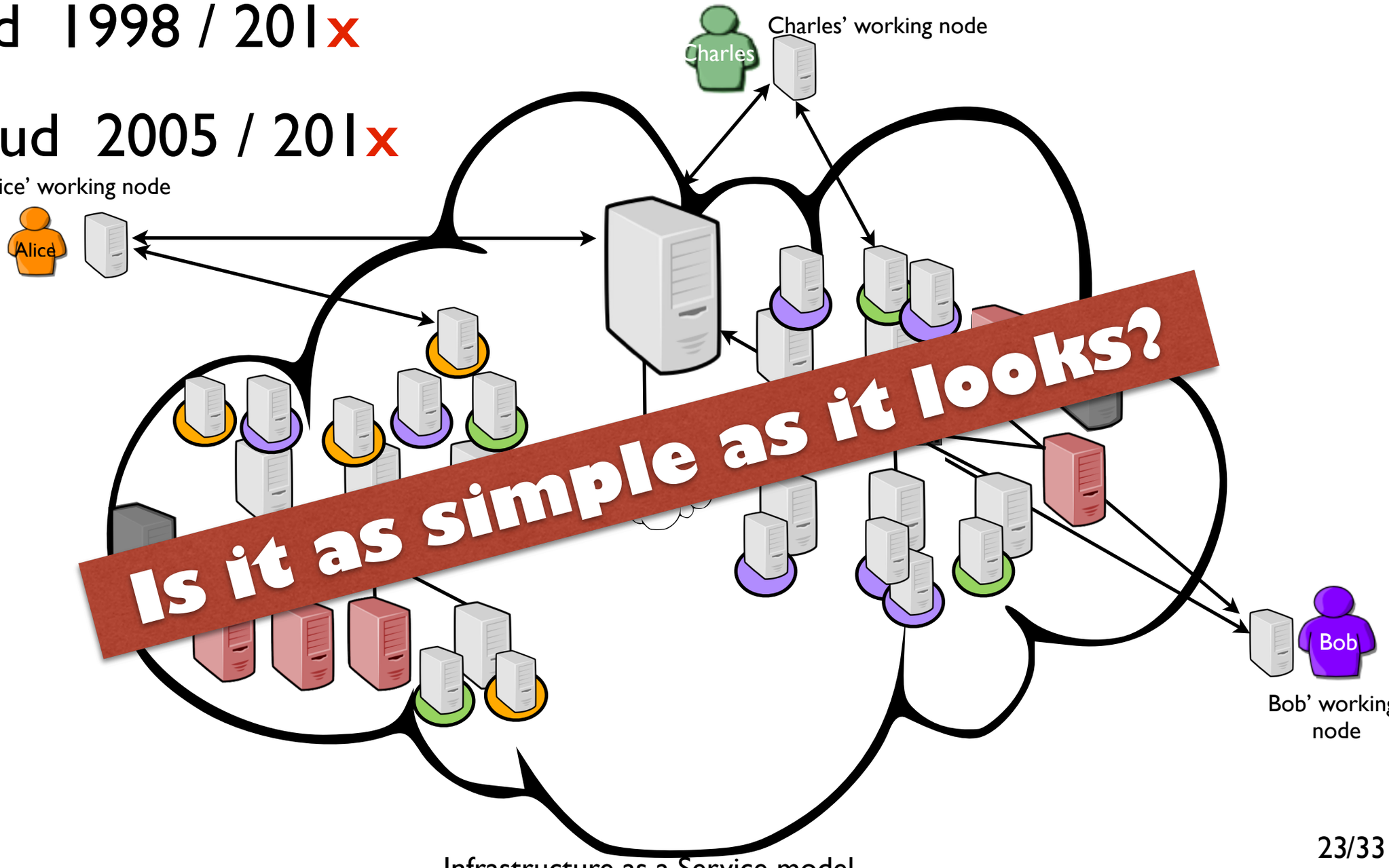
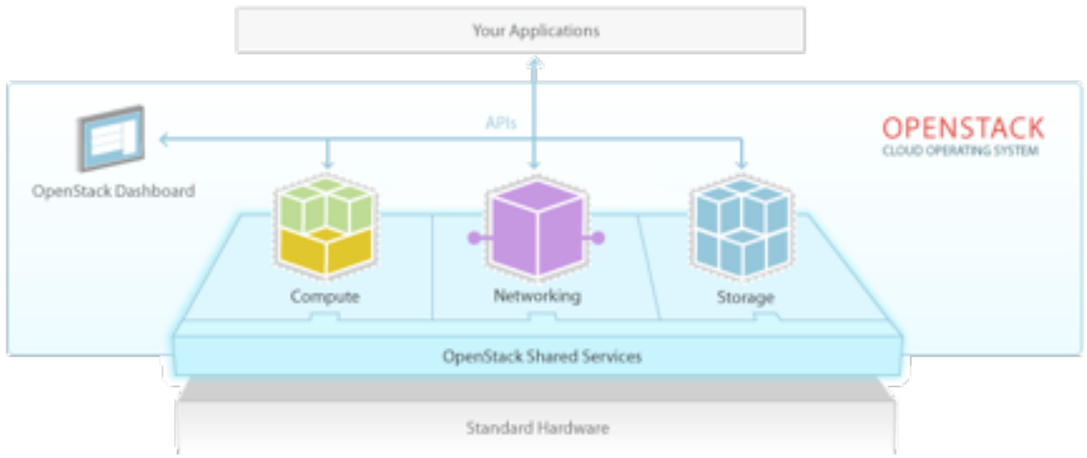
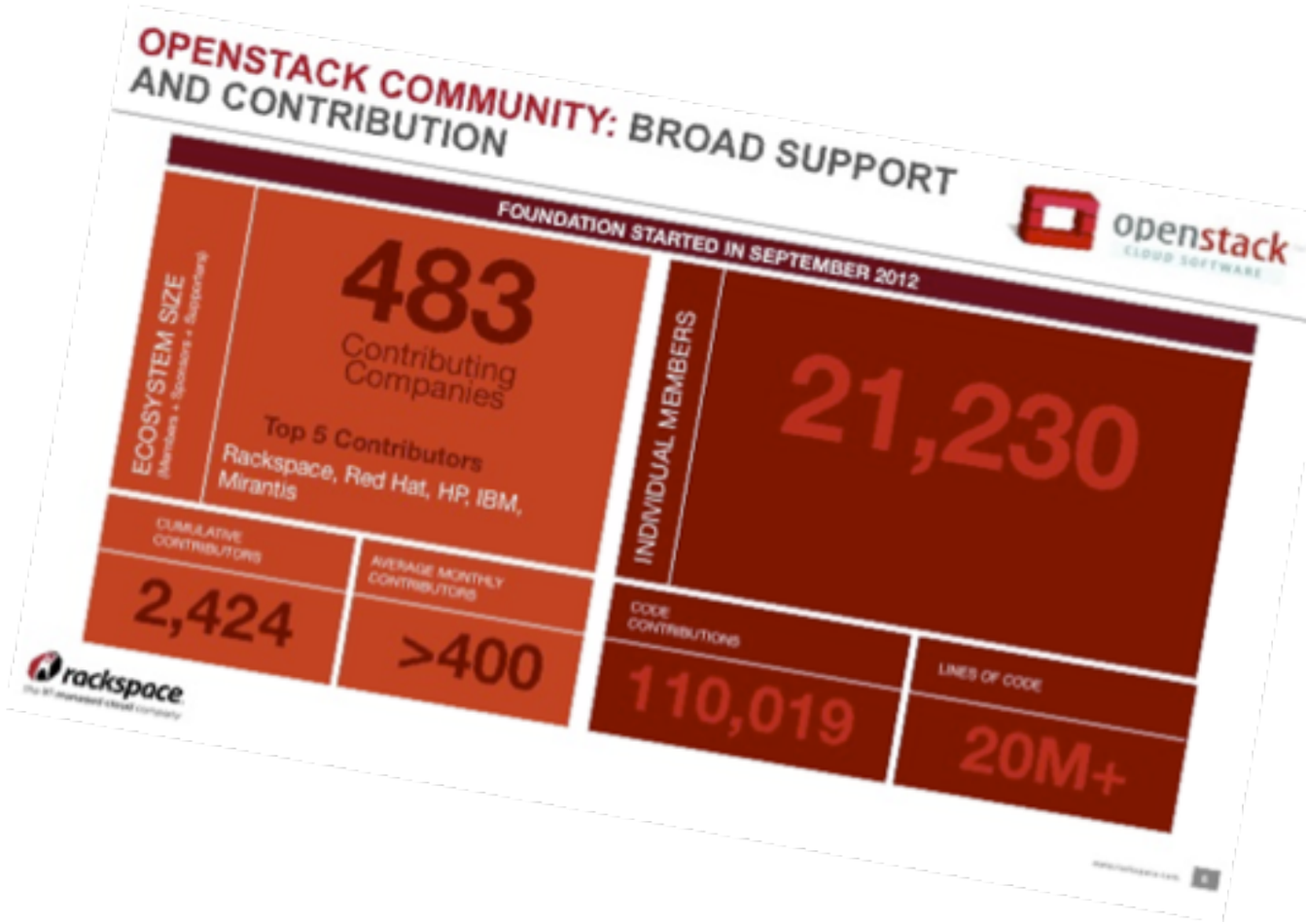


OpenStack

- Industry standard for creating public and private clouds





- A rich (and complex) ecosystem
  - **20 Millions of LoC**, 164 services, some services are composed of sub-services (e.g nova-scheduler, nova-conductor, …)

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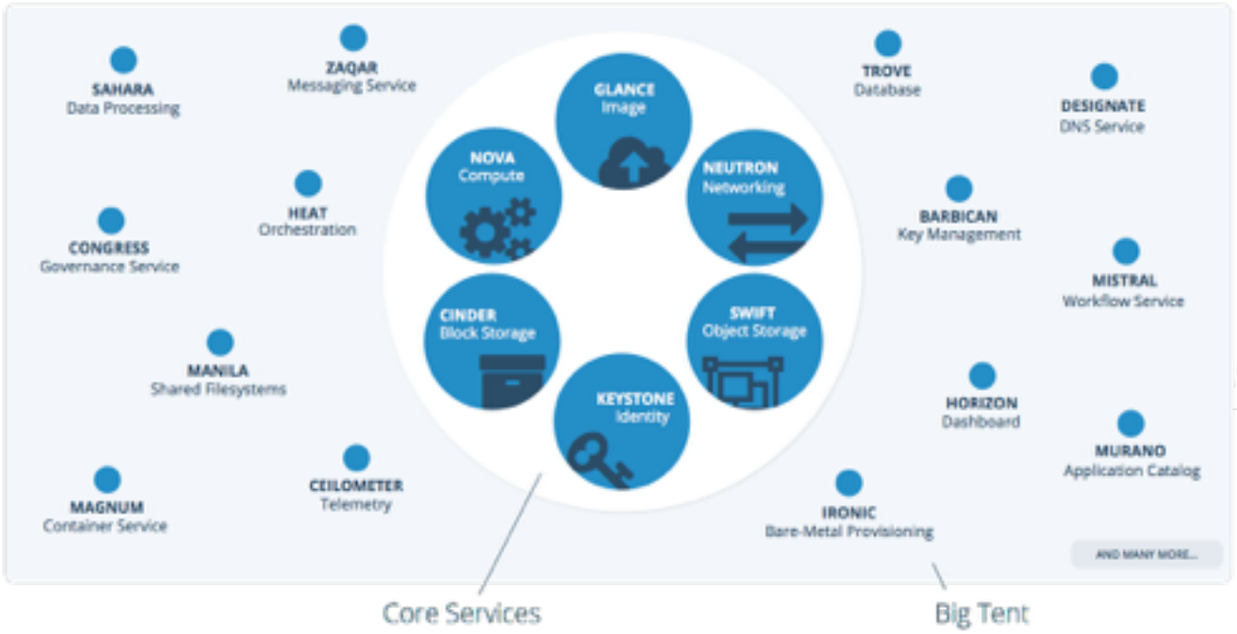

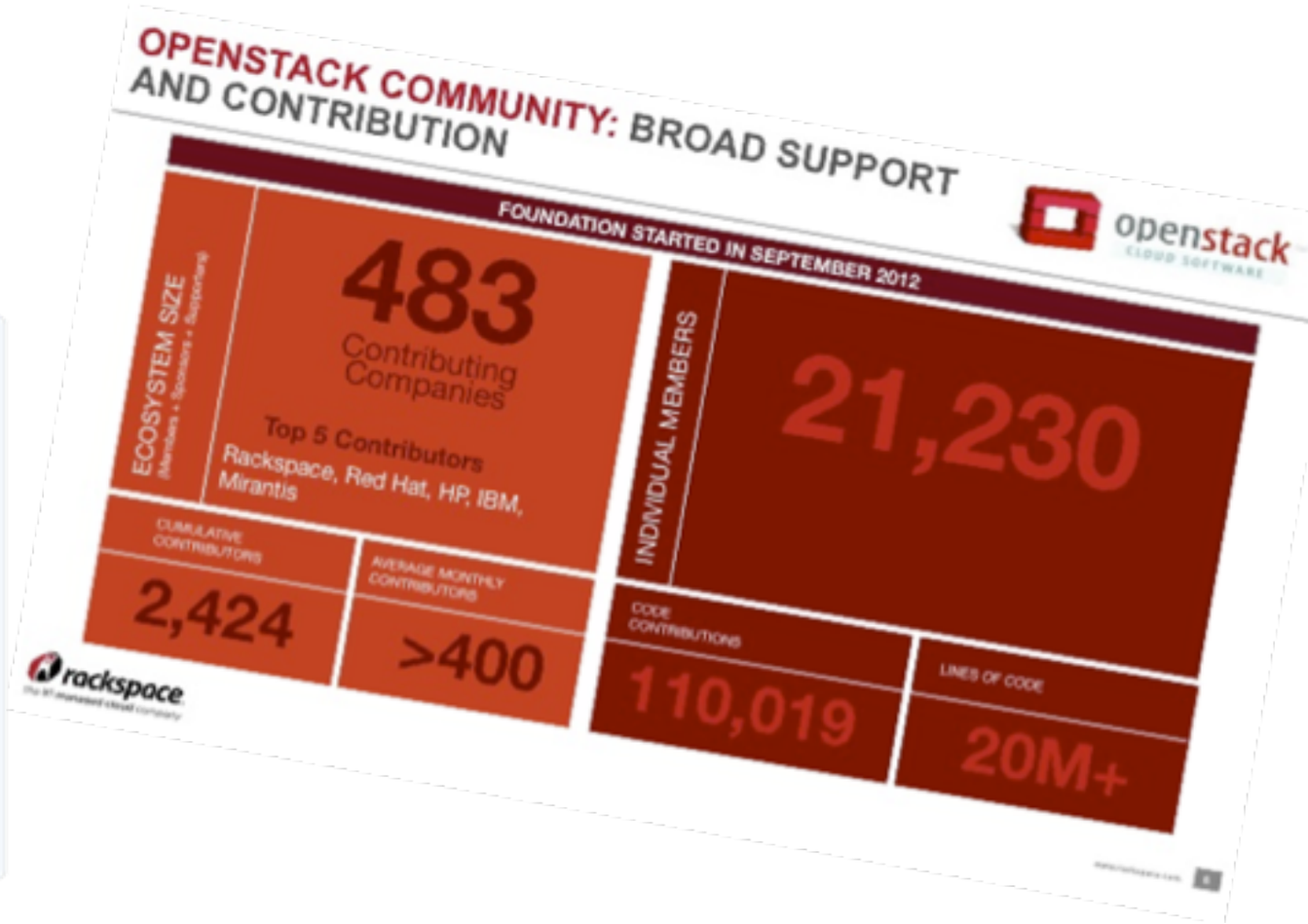

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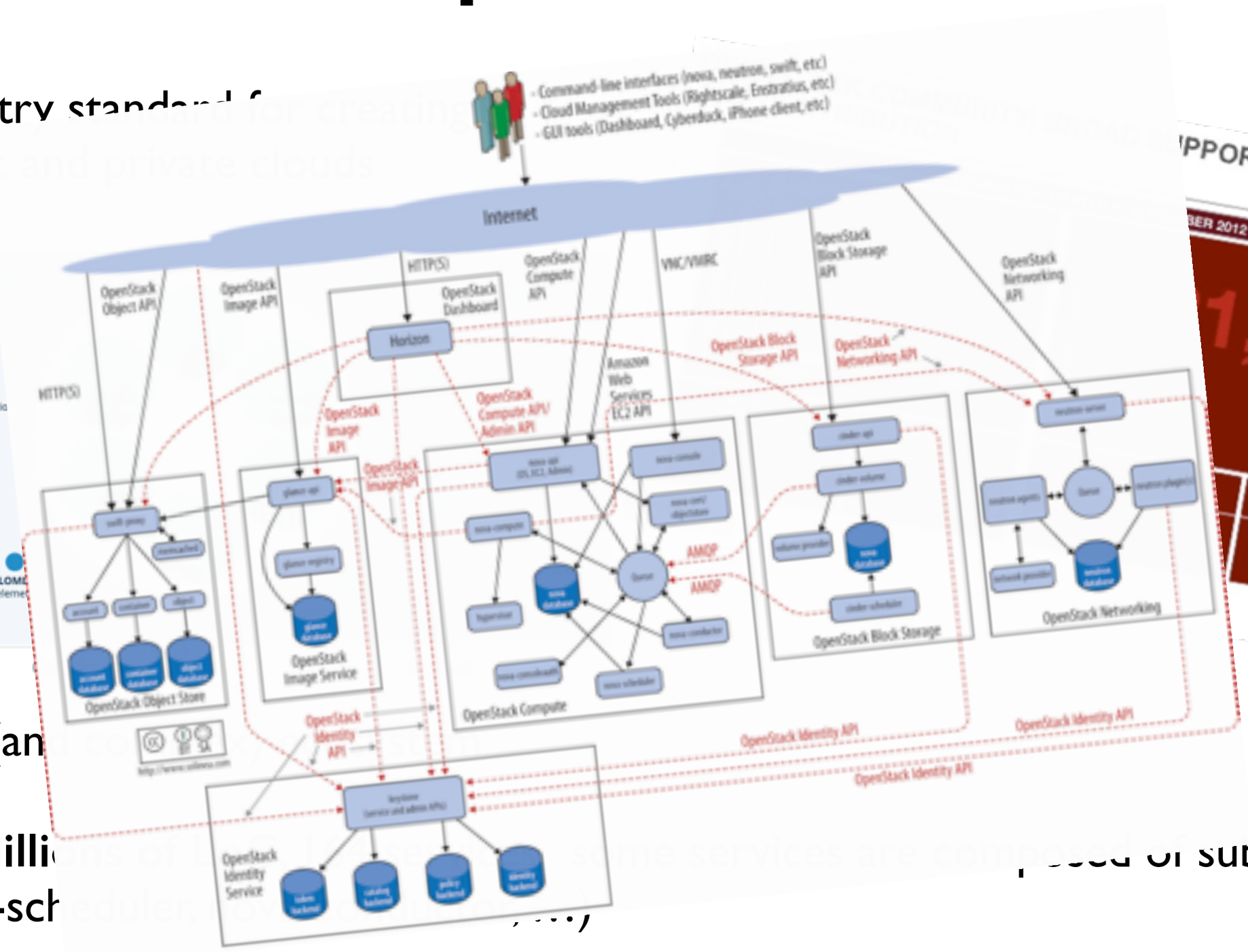

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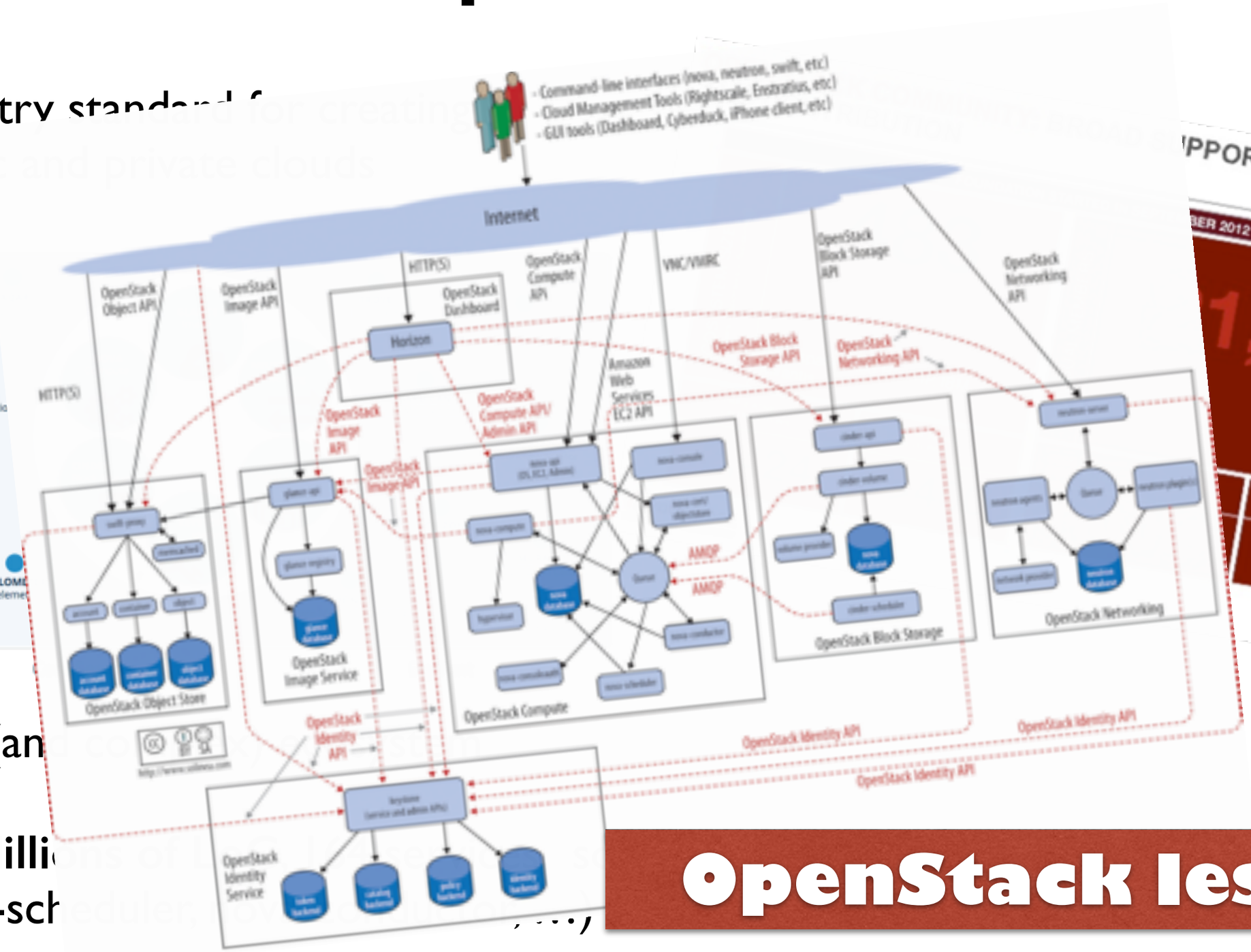

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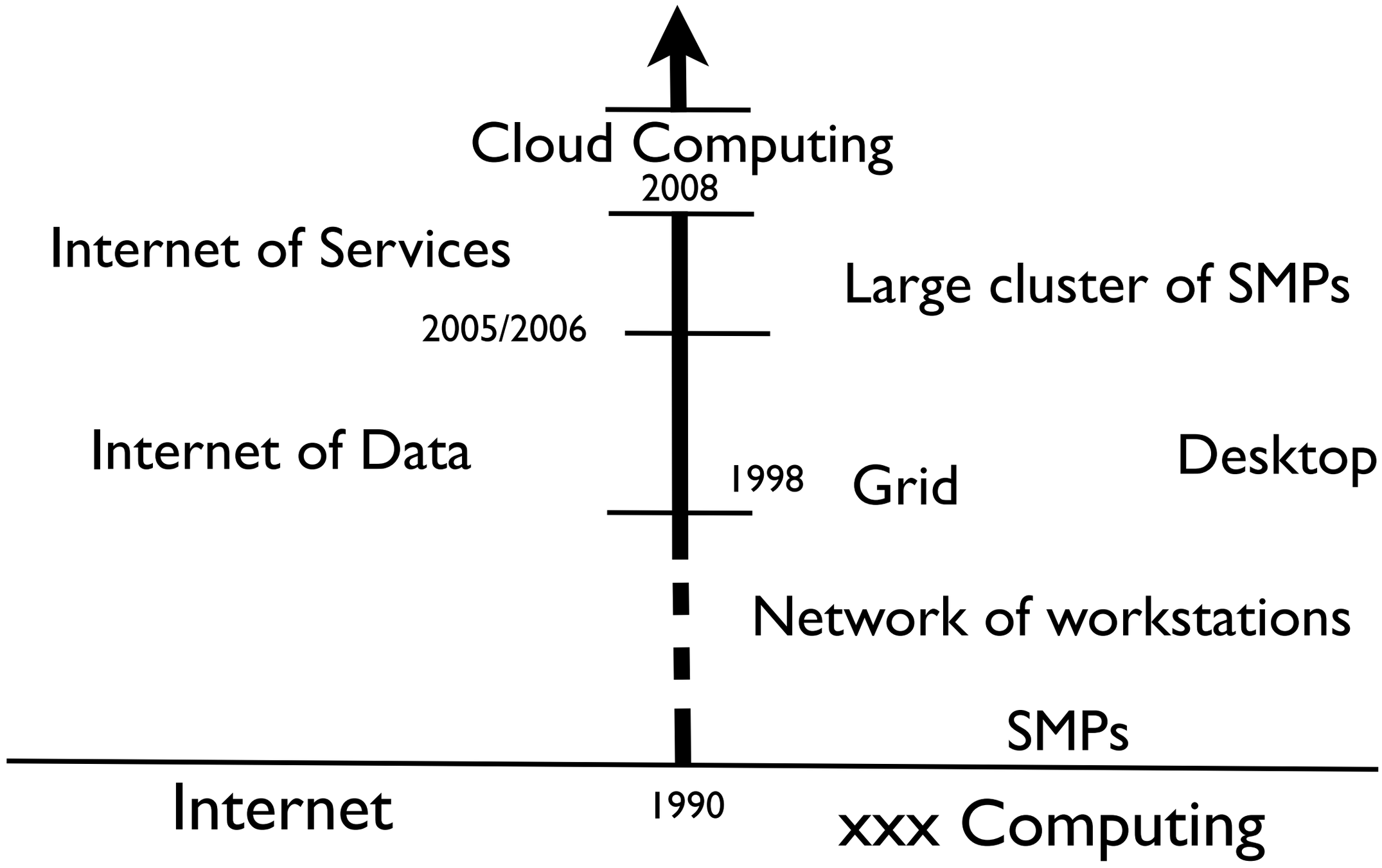
OpenStack lessons

The Cloud…just an infrastructure?

Internet + Distributed Computing ?



Cloud Computing

- A "merge" between Internet and Distributed Computing

  From Internet point of view:
  Not only data/services but raw resources

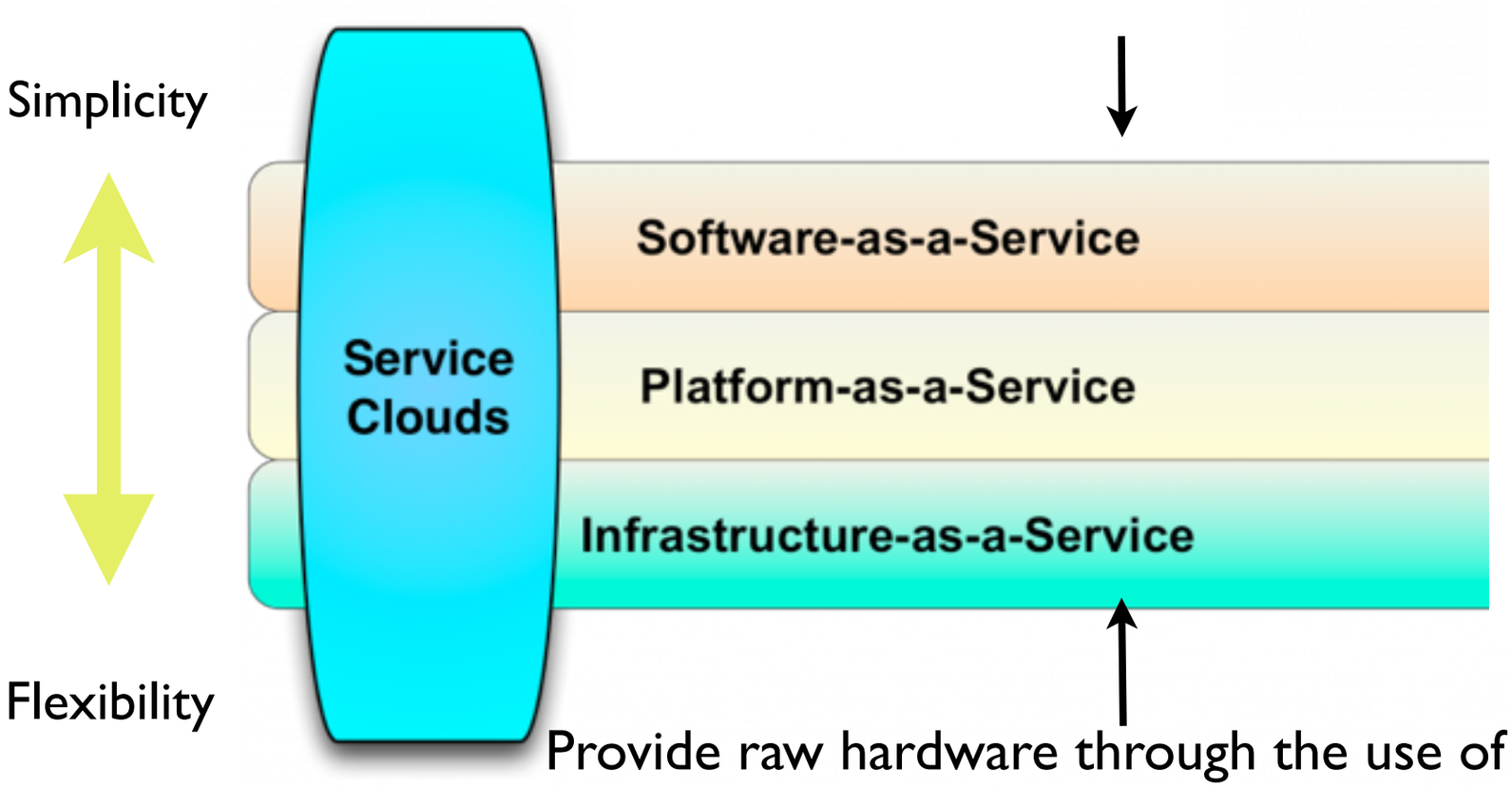
  From distributed computing point of view:
  a common objective - provide computing resources (both hardware and software) in a flexible, transparent, secure, reliable, ... way

SPI Classification

Internet of Services

free ⇒ gmail, google maps, google docs, youtube ...

pay as you go ⇒ Microsoft office, SQL server, ...



Provide a complete stack (microsoft windows azur, google PAAS, ...)

Windows Azure

Provide raw hardware through the use of virtual machines (Leader: Amazon)

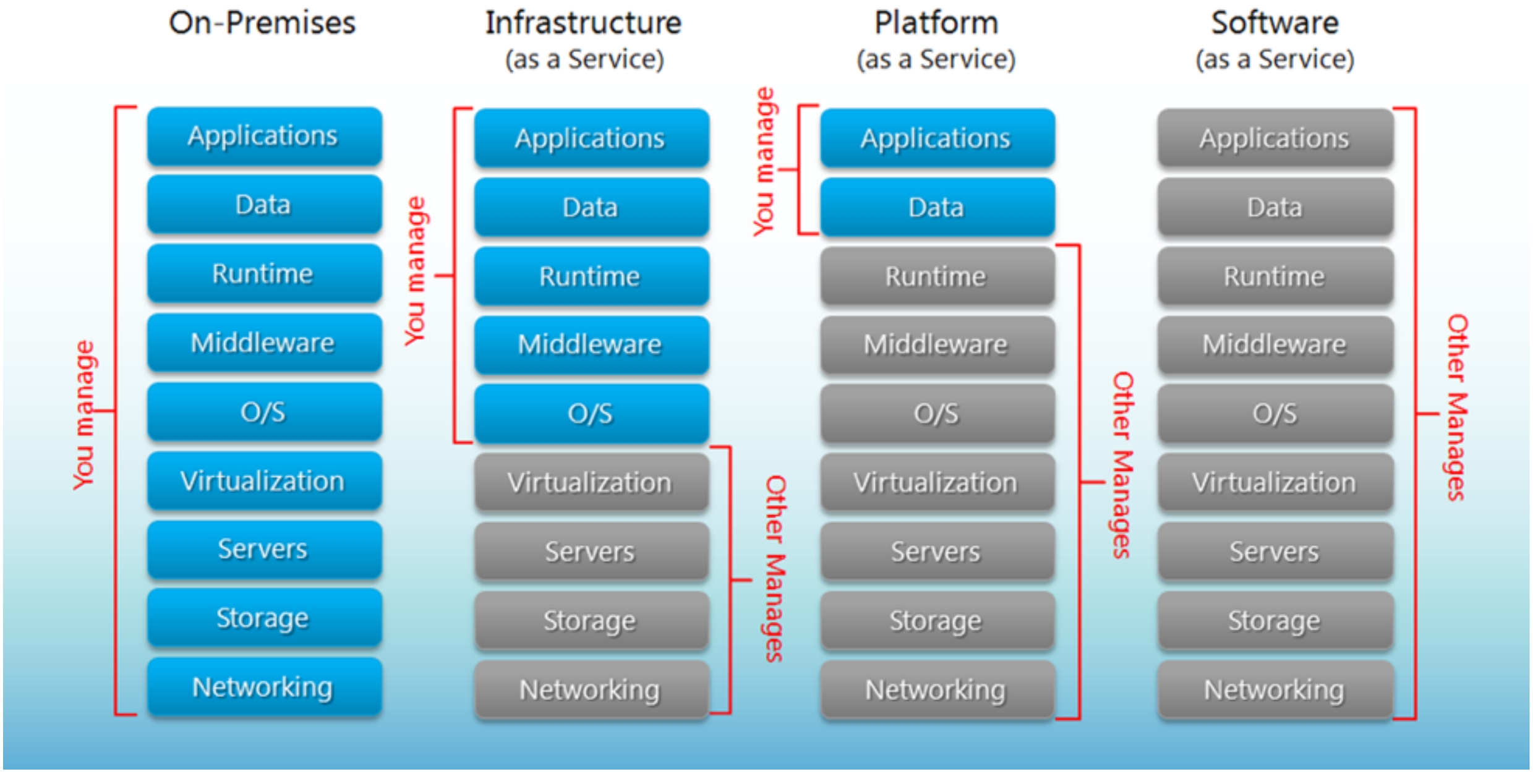
amazon.com web services

Dropbox

a SaaS hosted on Amazon for a long period before moving to their own infrastructure

Who is in charge of?

Separation of Responsibilities



The Cloud needs scalable infrastructure

- Scalability: capacity to increase throughput as the size of the infrastructure increases.
- A scalable infrastructure requires scalable software and hardware architectures:
  - More resources must imply better performance
  - No single Point of Failure (PoF)
  - Efficient resource usage
  - Ability to manage heterogeneous resources

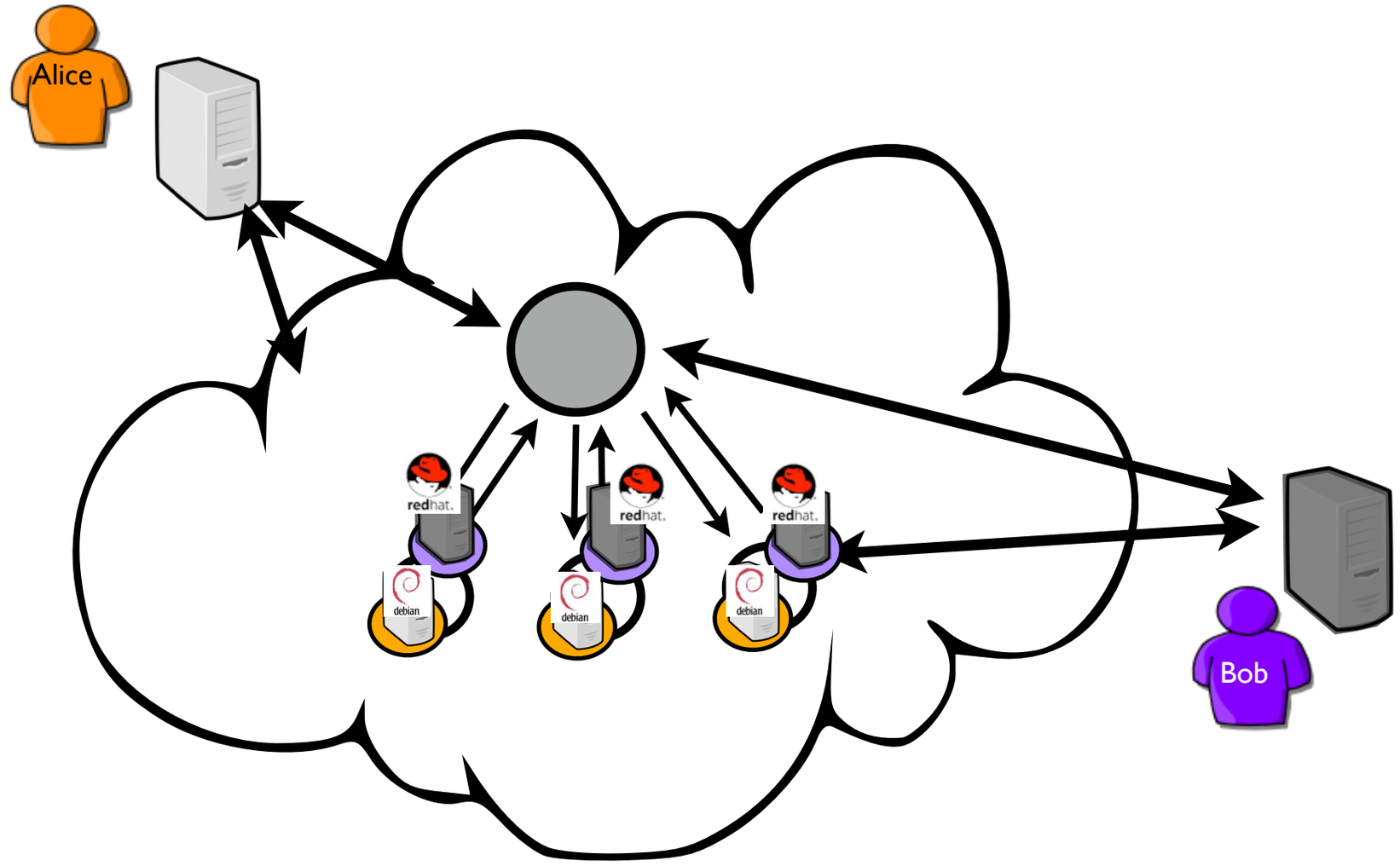
The Cloud needs scalable infrastructure

- 2 strategies to scale up an infrastructure:
  - Vertical scaling: increase the capacity of individual resources (scale up).
  - Horizontal scaling: increase the number of resources (scale out)

- The Cloud: make scale in/out cheap and easier
  - Virtually infinite resources
  - Available and charged on demand
  - no contract

Where we are?

- IaaS challenges



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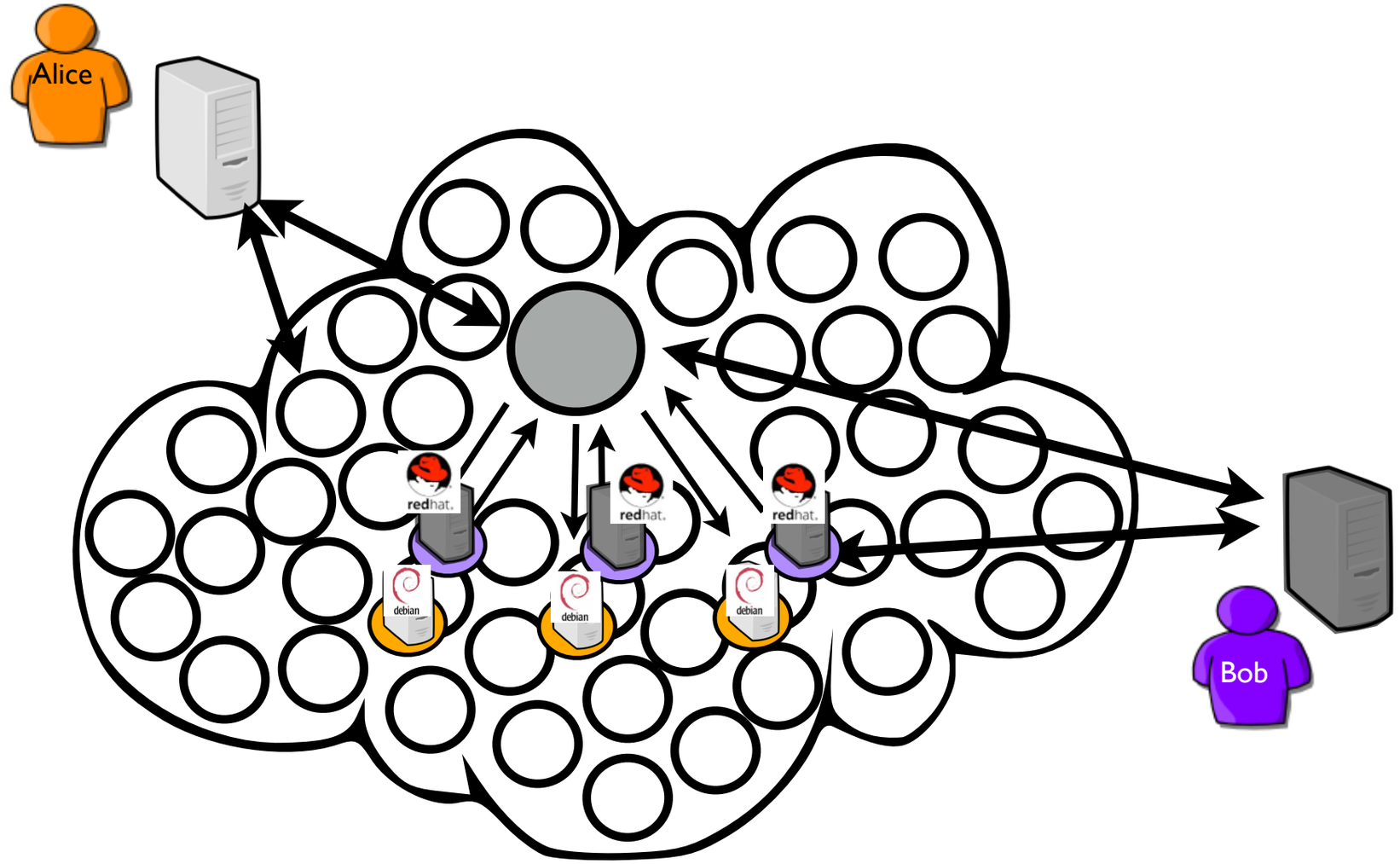

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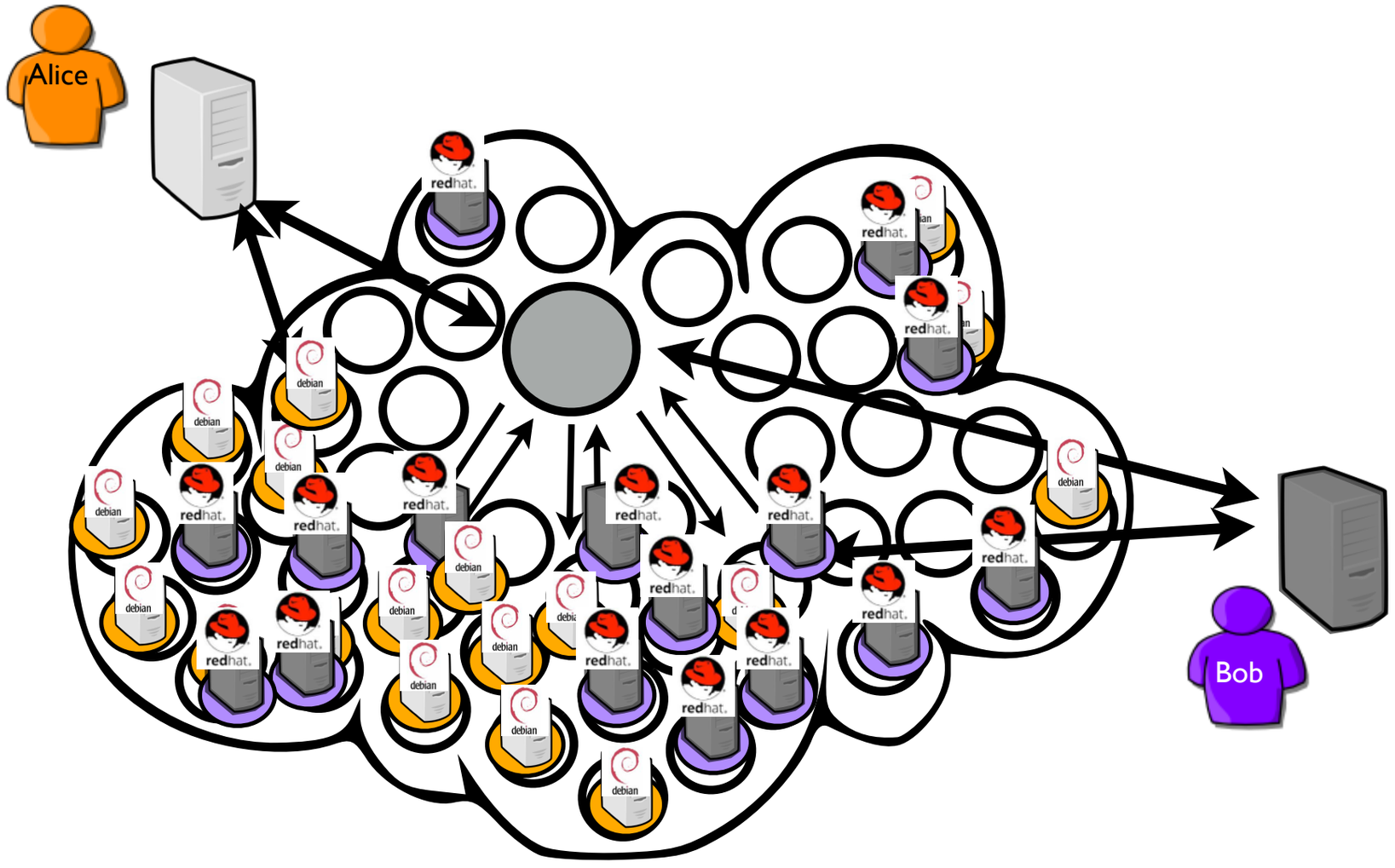
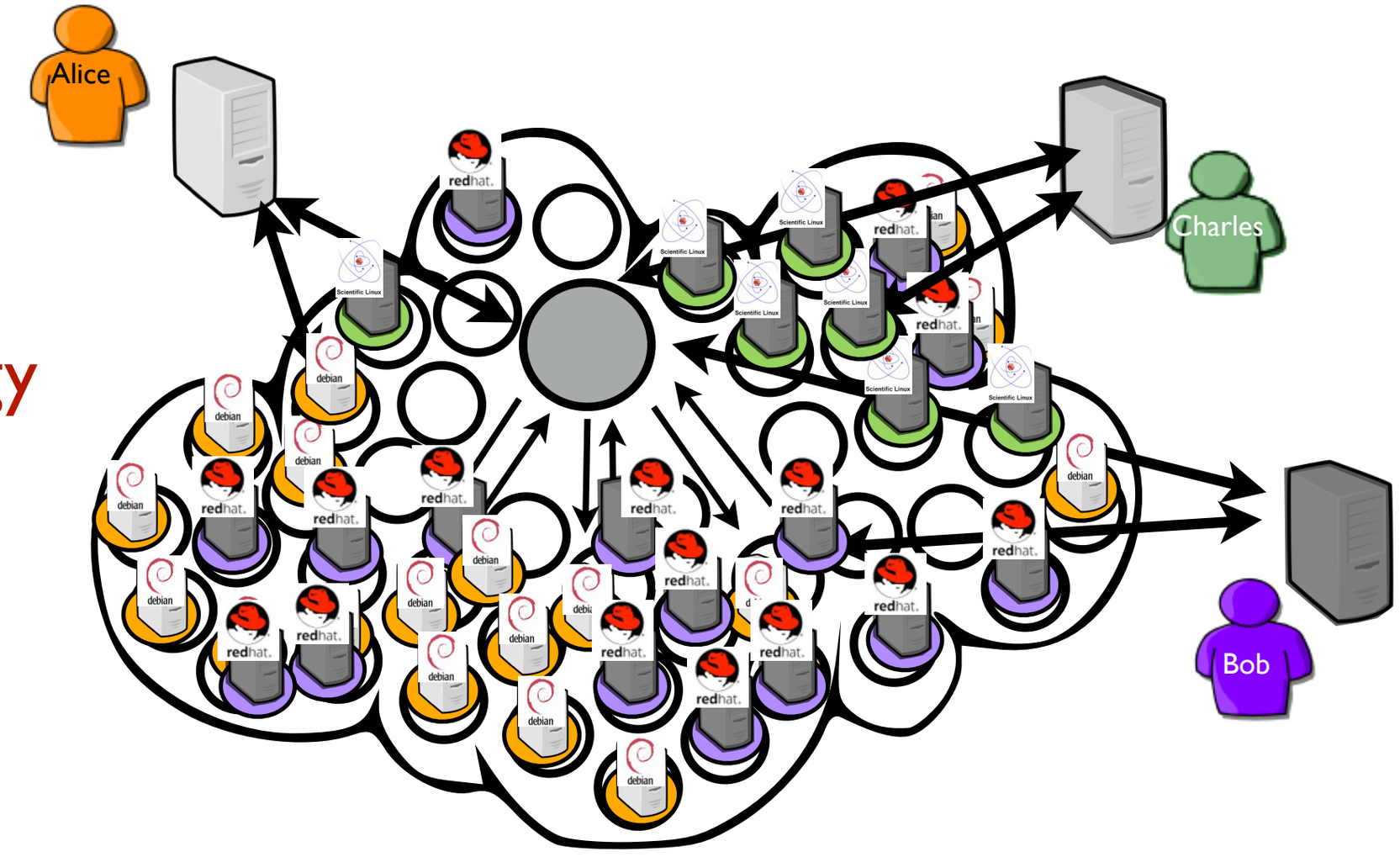


Where we are?

- IaaS challenges
  - Scalability / Energy



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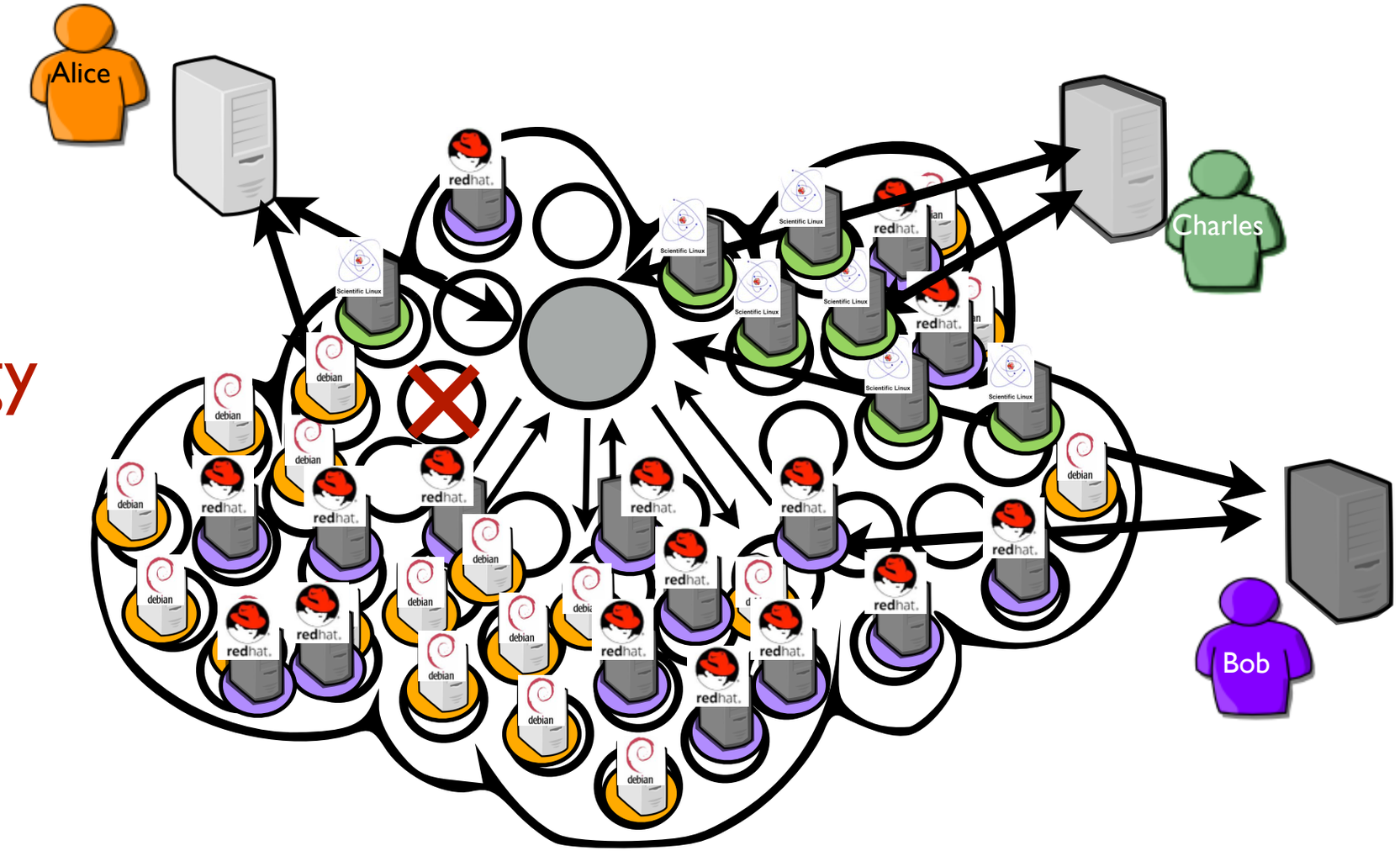

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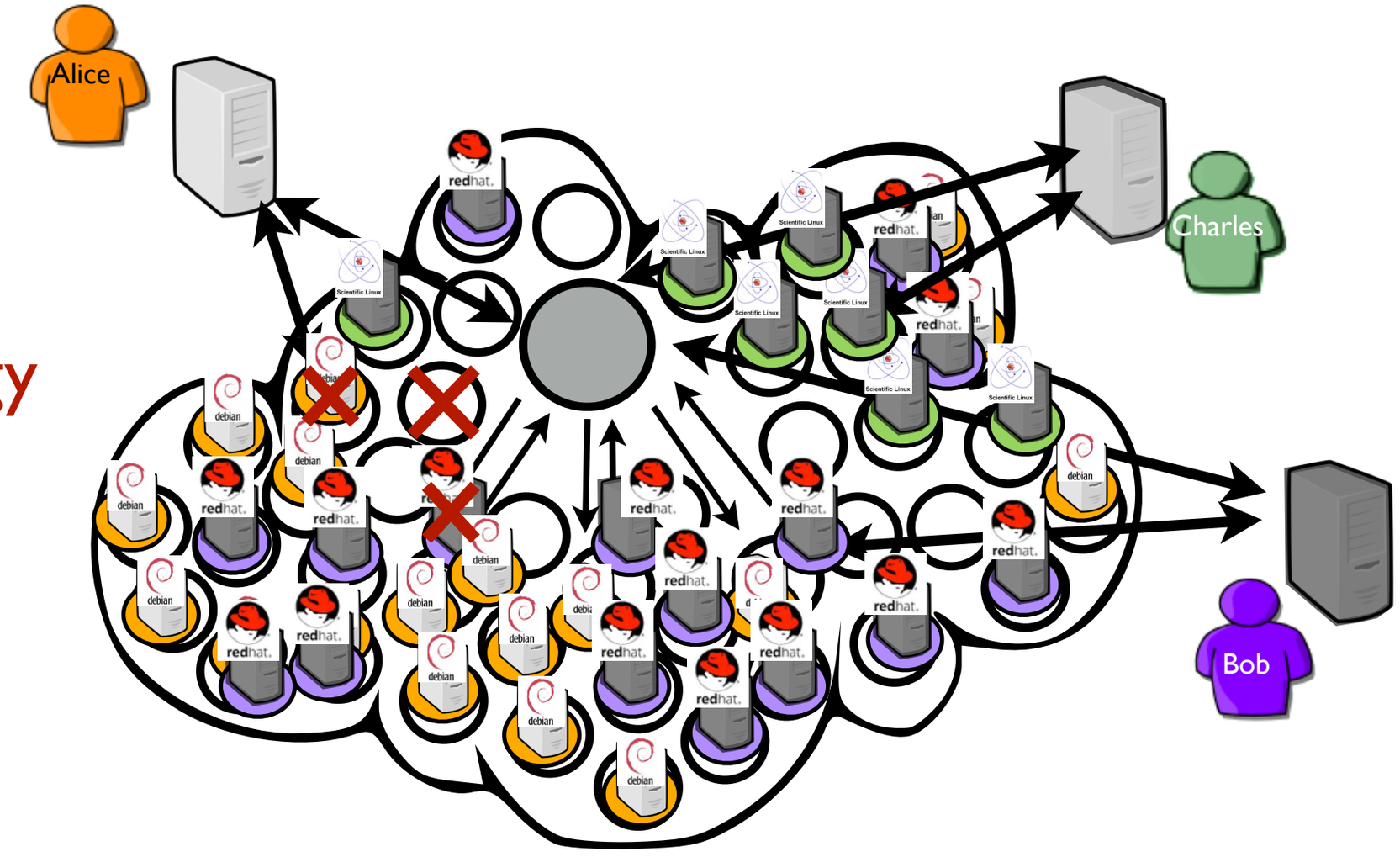
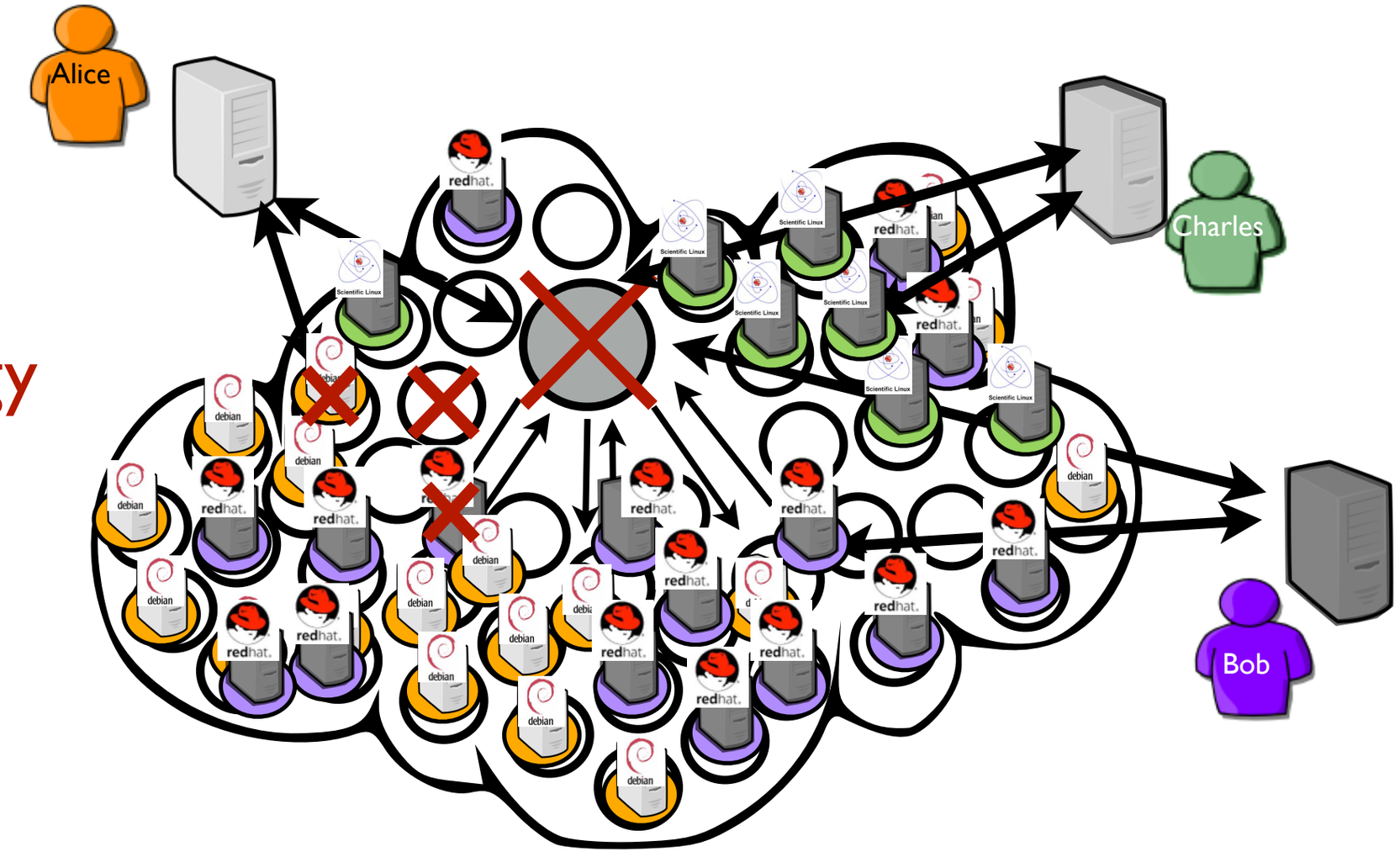


Where we are?

- IaaS challenges
  - Scalability / Energy
  - Reliability



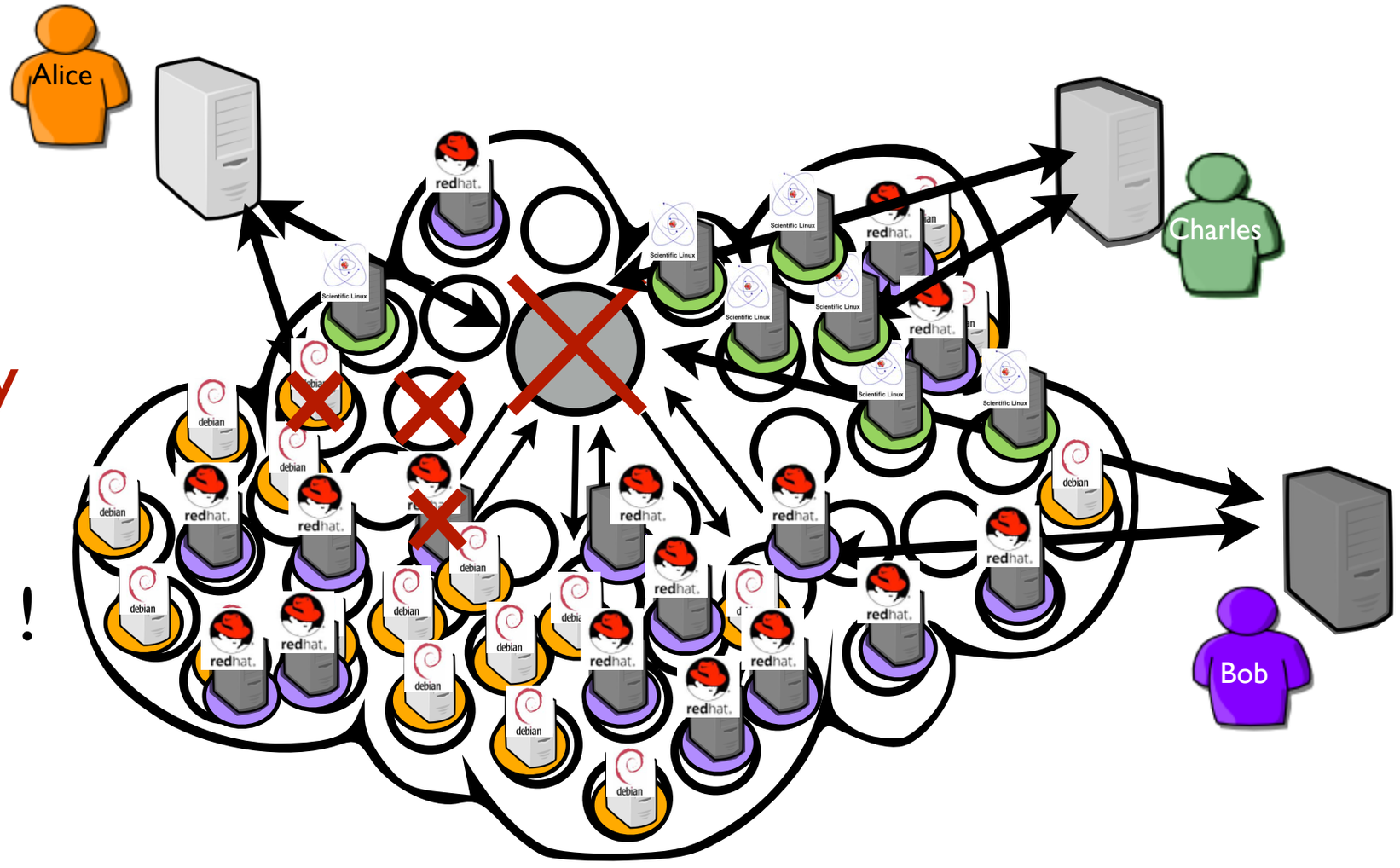
Where we are?

- IaaS challenges

  Scalability / Energy

  Reliability

  nothing really new !



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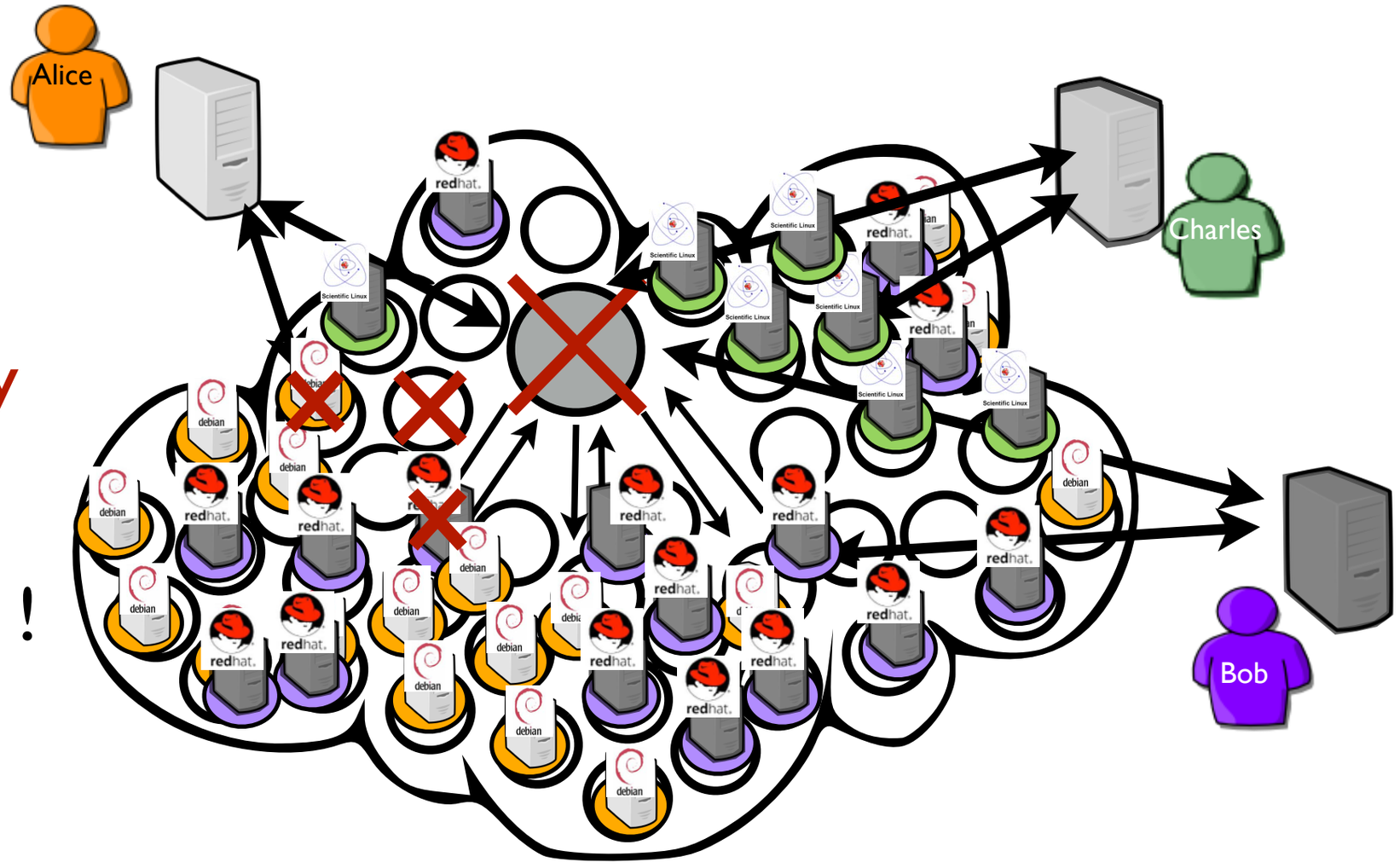
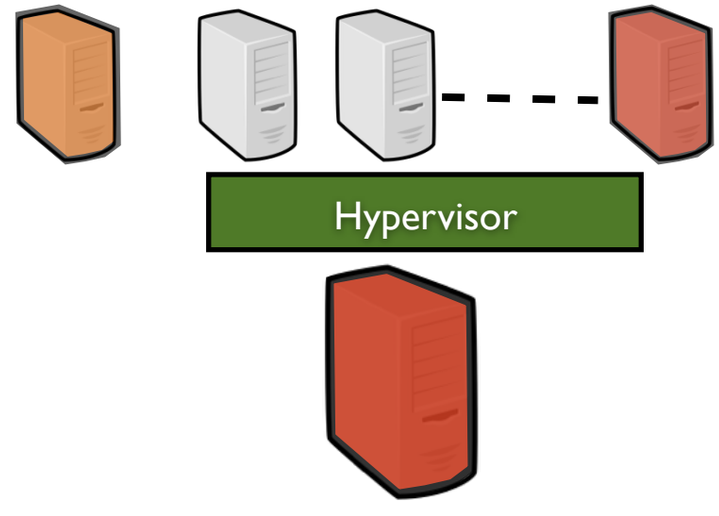


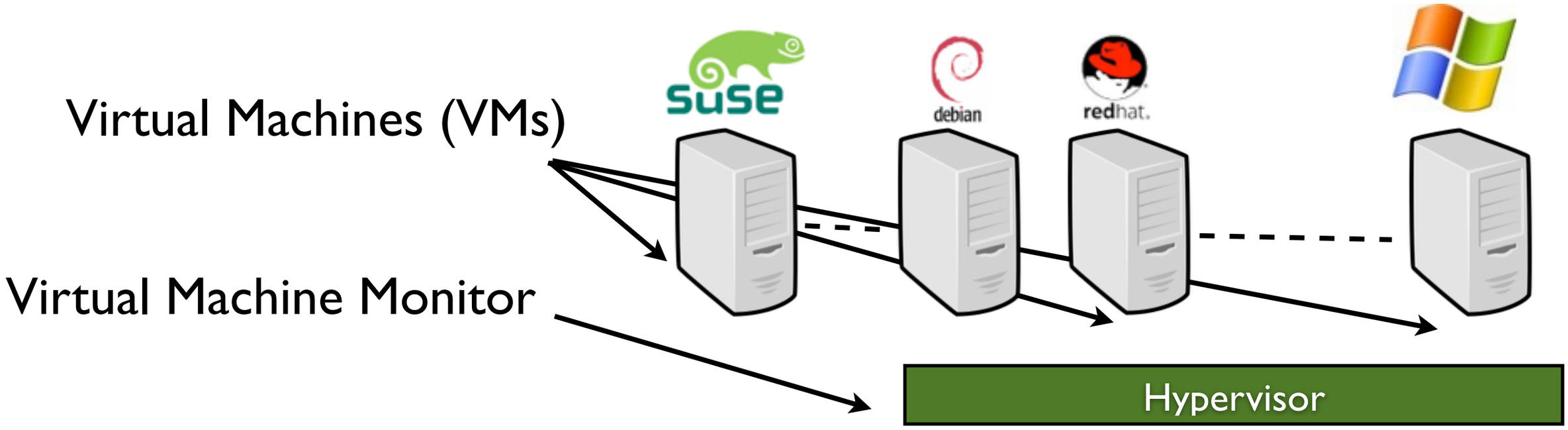
- Virtualize IT impacts performances !
  (difficulty to guarantee performances, SLAs)



Virtualisation and Performance

System Virtualisation

- System virtualization: One to multiple OSes on a physical node thanks to a hypervisor (an operating system of OSes)



"A ***virtual machine*** (VM) provides a faithful implementation of a physical processor's hardware running in a protected and isolated environment.
Virtual machines are created by a software layer called the ***virtual machine monitor*** (VMM) that runs as a privileged task on a physical processor."

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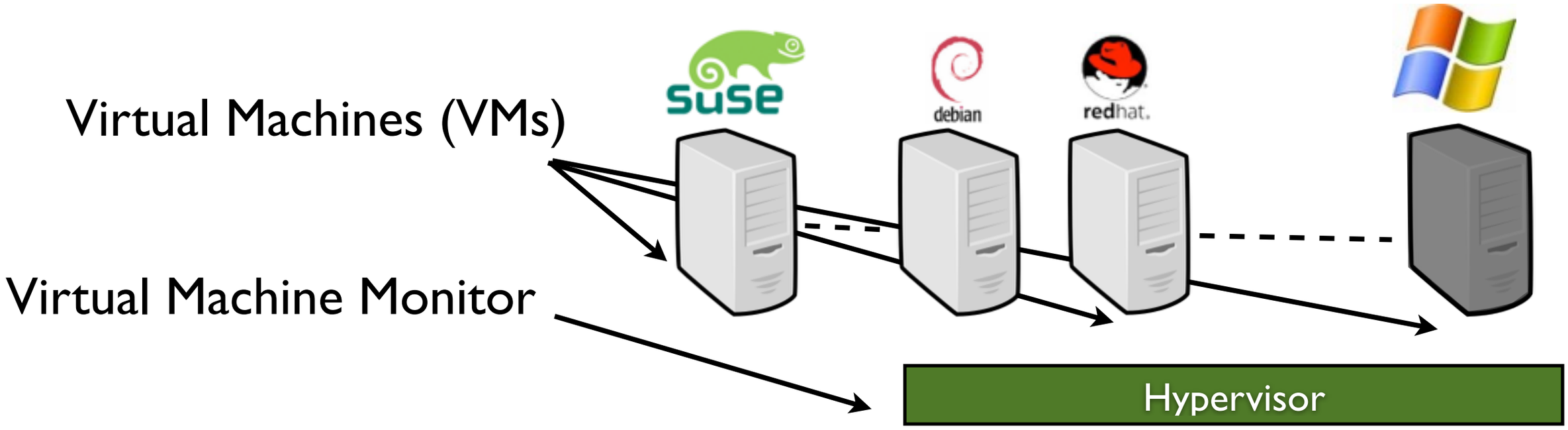

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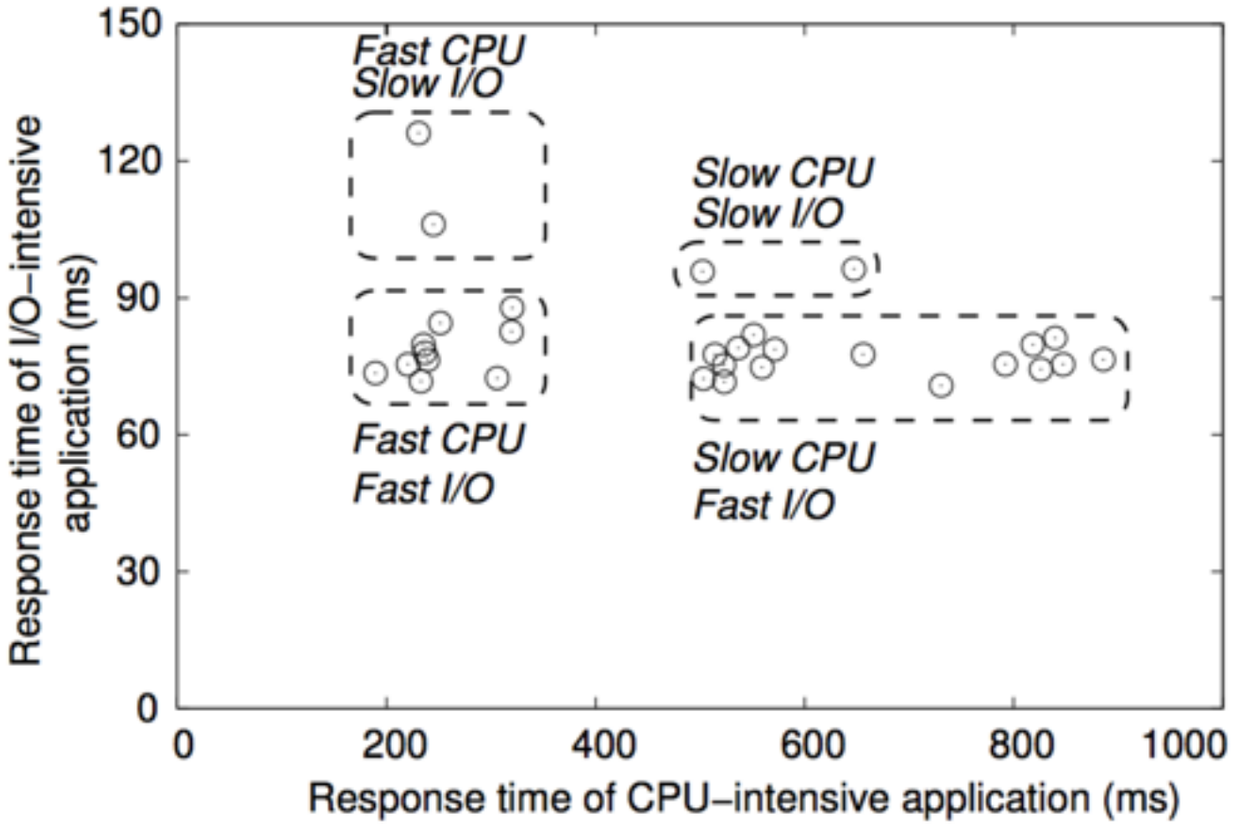
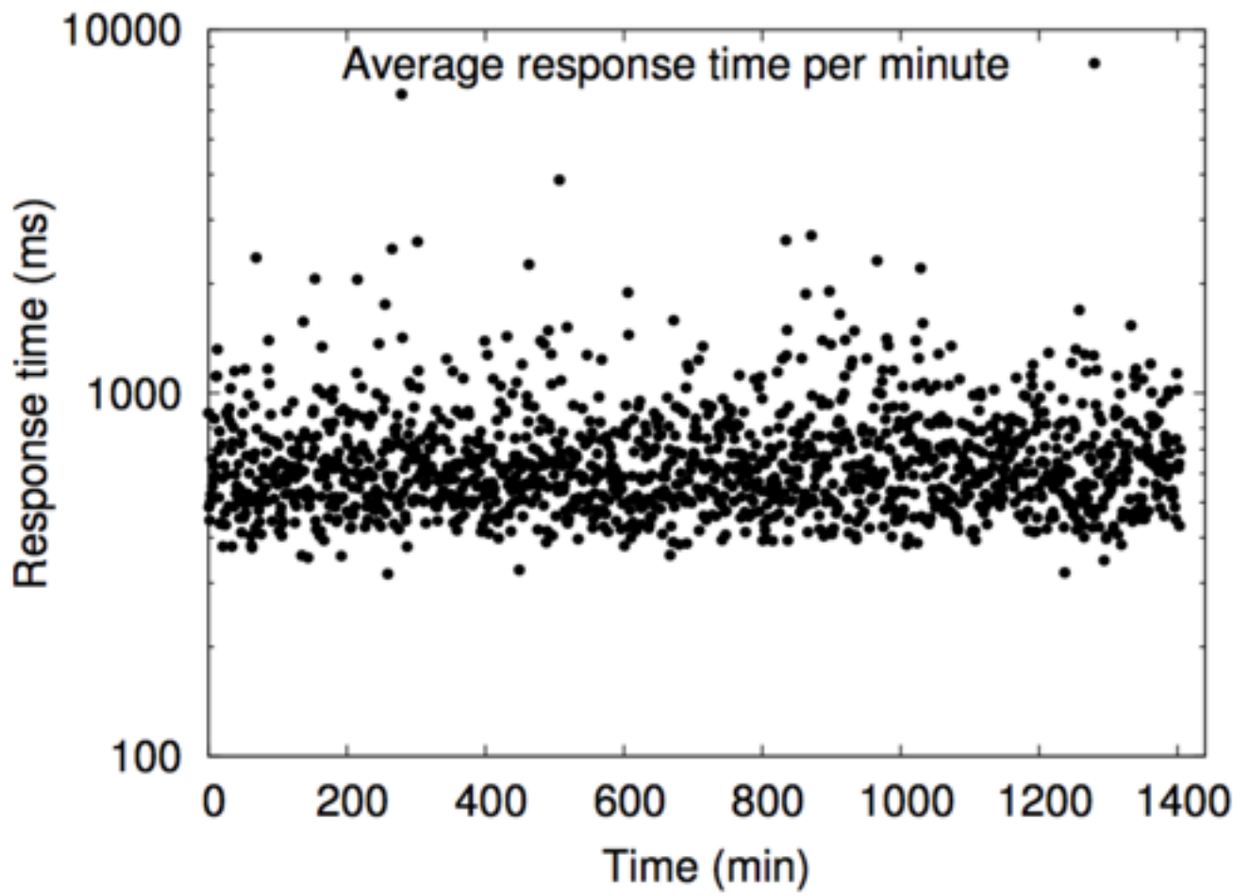
Perfomance reproducibility [Dej11]



(a) EC2 Cloud performance heterogeneity

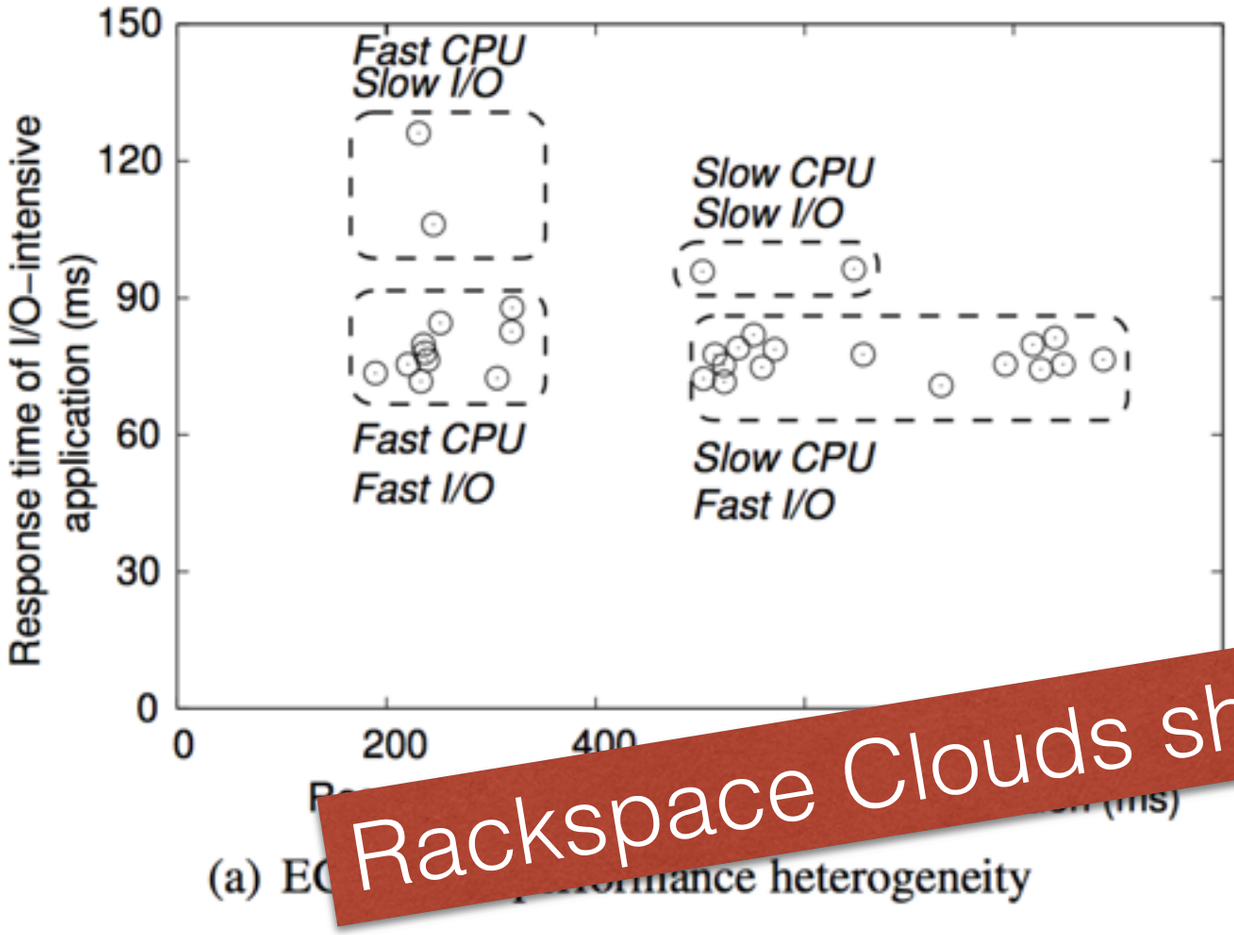
- Performance comparison of 30 'identical' EC2 instances

- Performance spikes duration: 1/3min
  Presumably caused by the launch/shutdown operations on other instances



(b) Consistent performance of individual instance over time

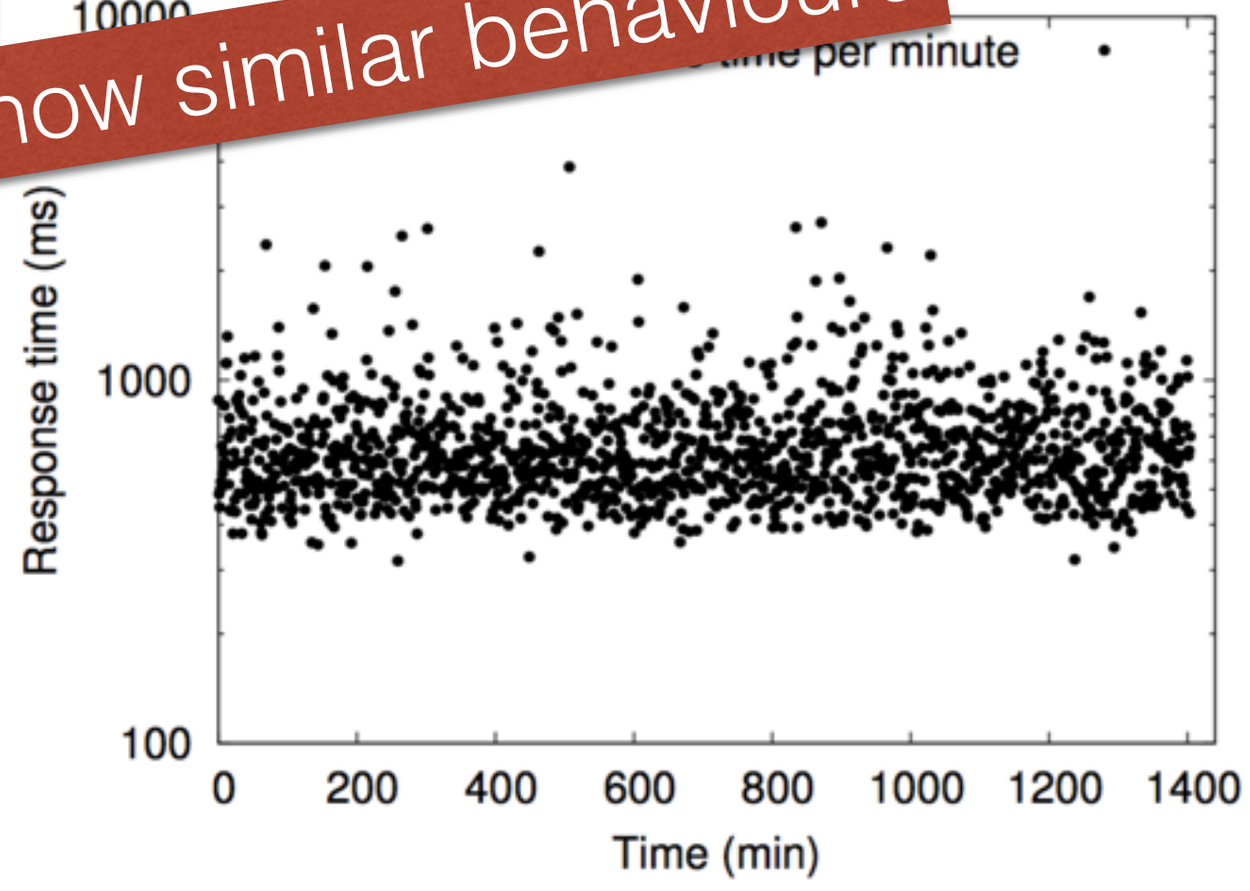
Perfomance reproducibility [Dej11]



(a) EC… performance heterogeneity

Rackspace Clouds show similar behaviours

- Performance comparison of 30 'identical' EC2 instances



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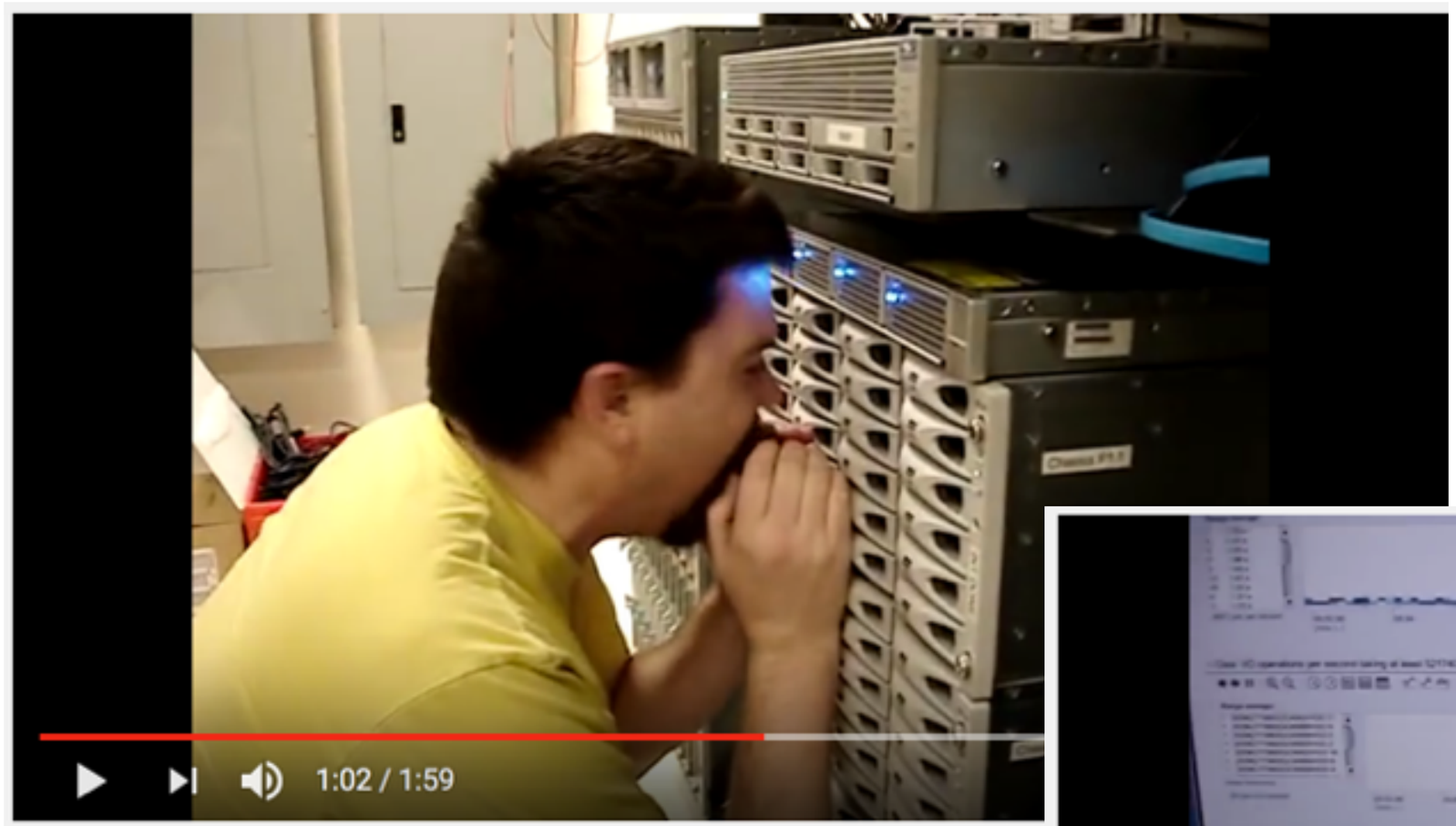
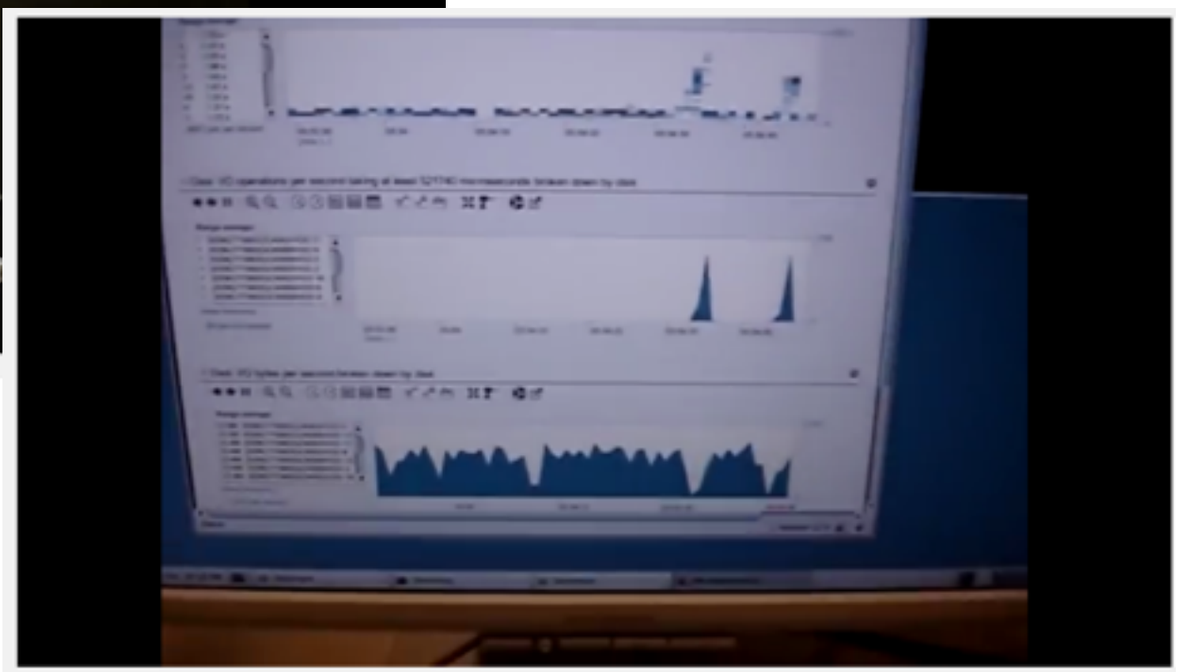
Shouting in the Datacenter

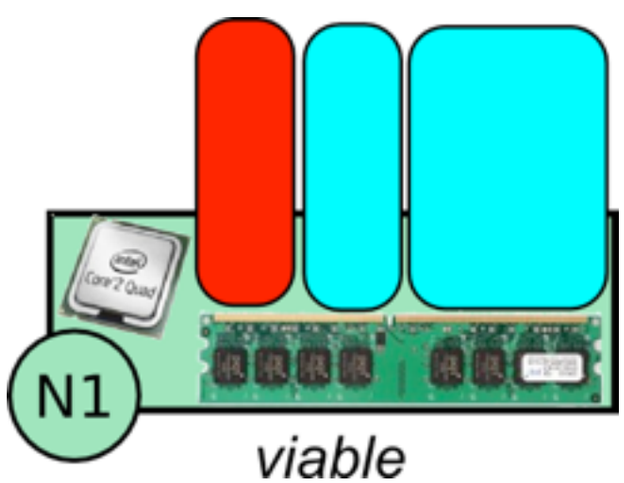




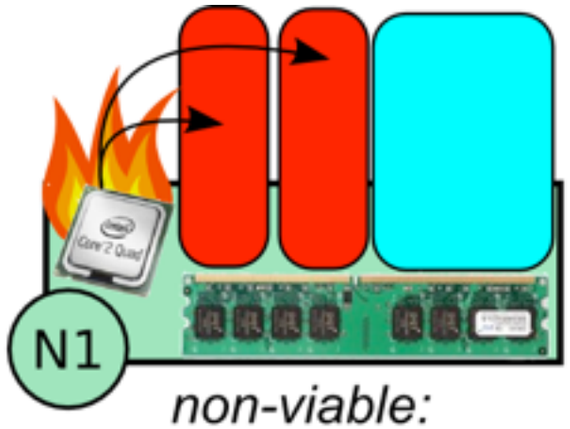
https://www.youtube.com/watch?v=tDacjrSCeq4

VM Placement and Performance

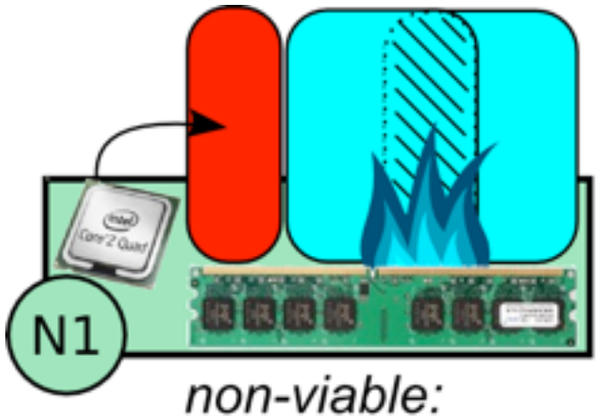
- Fine management of resources (efficiency and energy constraints)
- Find the "right" mapping between needs of VMs and resources provided by PMs



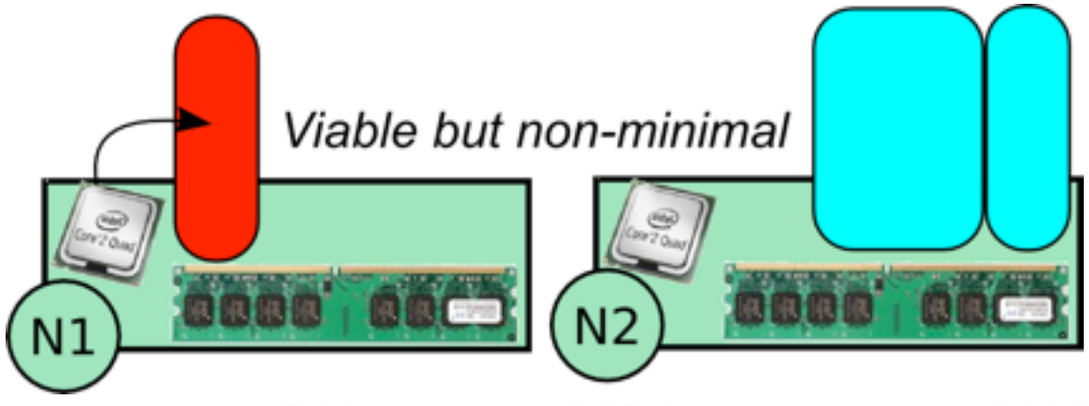
viable

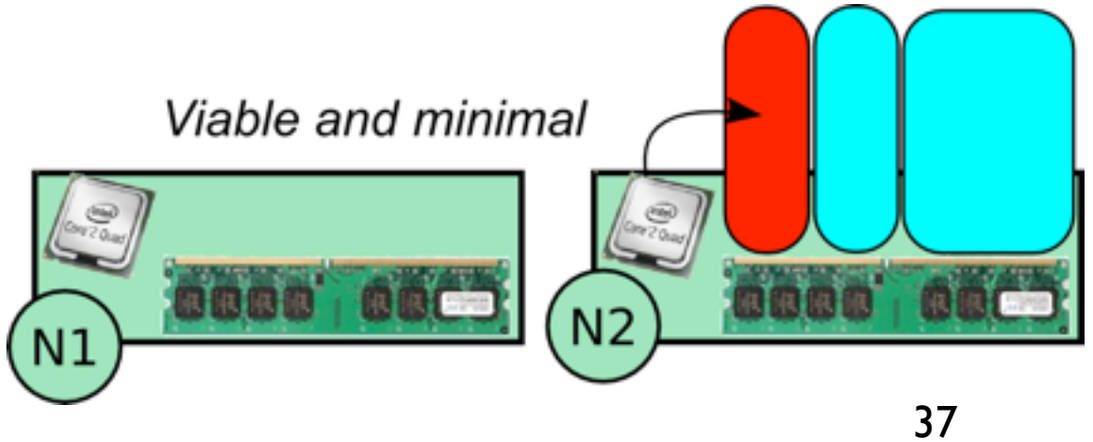


non-viable:
2 active VMs for one CPU



non-viable:
memory overcommitment





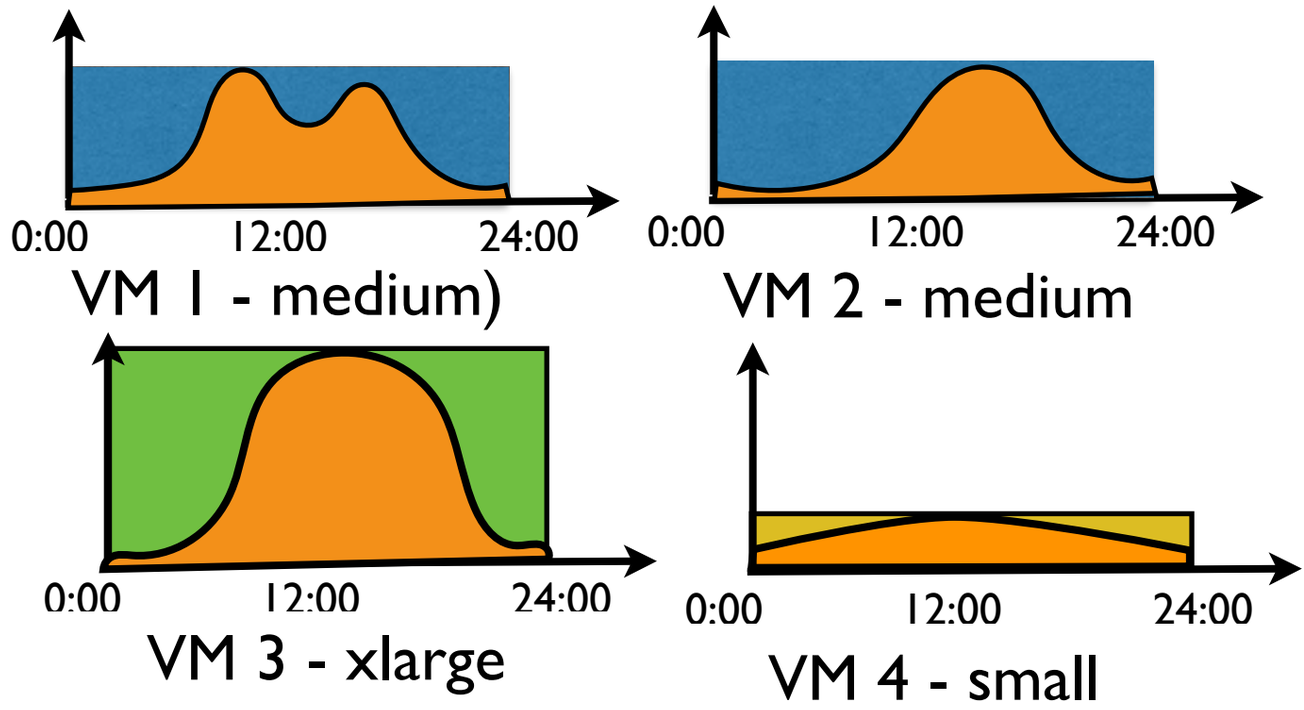
credits: F. Hermenier, OSDI poster session 2008

Fluctuations of VM Requirements

- Static placement policies (as delivered by most of the popular Cloud Computing management systems)

  "Simple" but prevent CC providers to maximize the usage of CC resources (and thus their revenue)

- Advanced dynamic placement strategies to relocate VMs according to the scheduler objectives / available resources / waiting queue / ...



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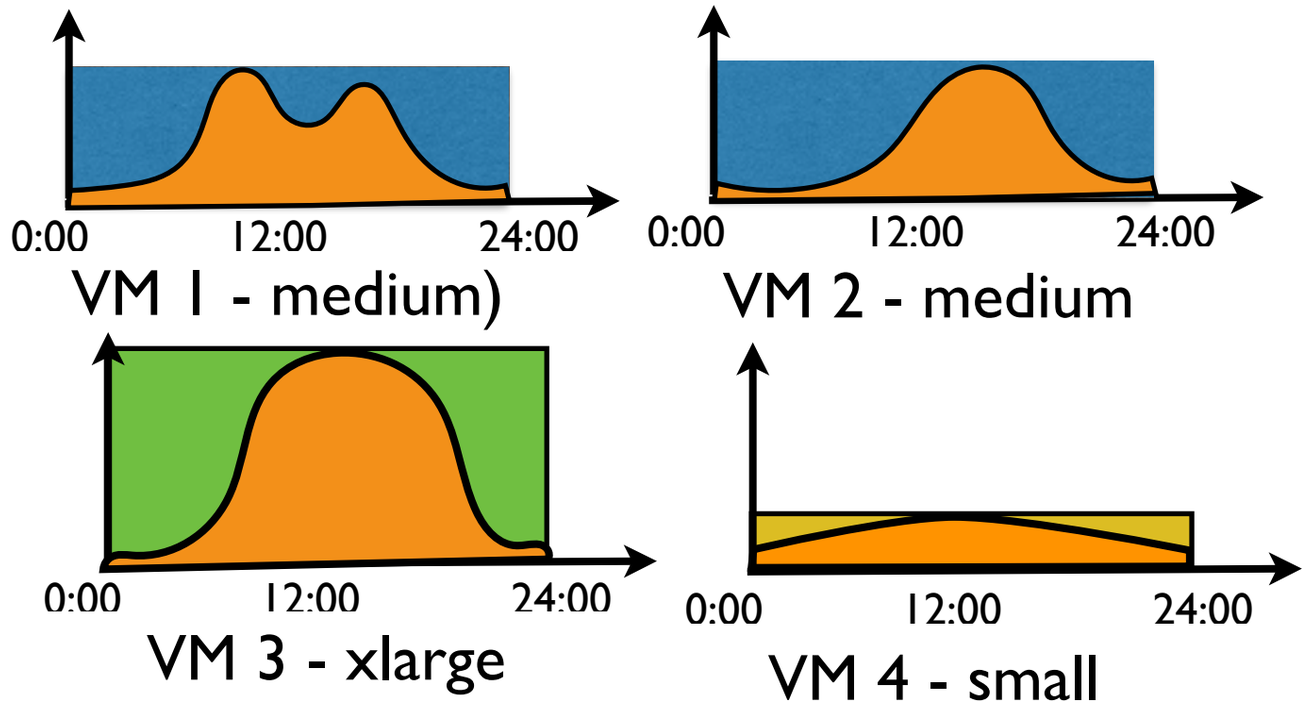

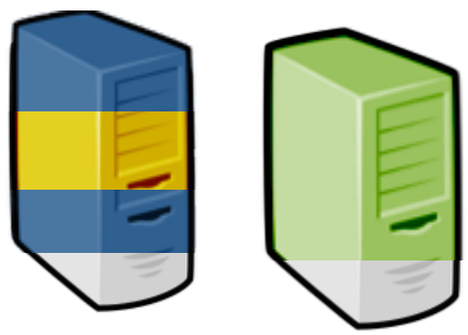

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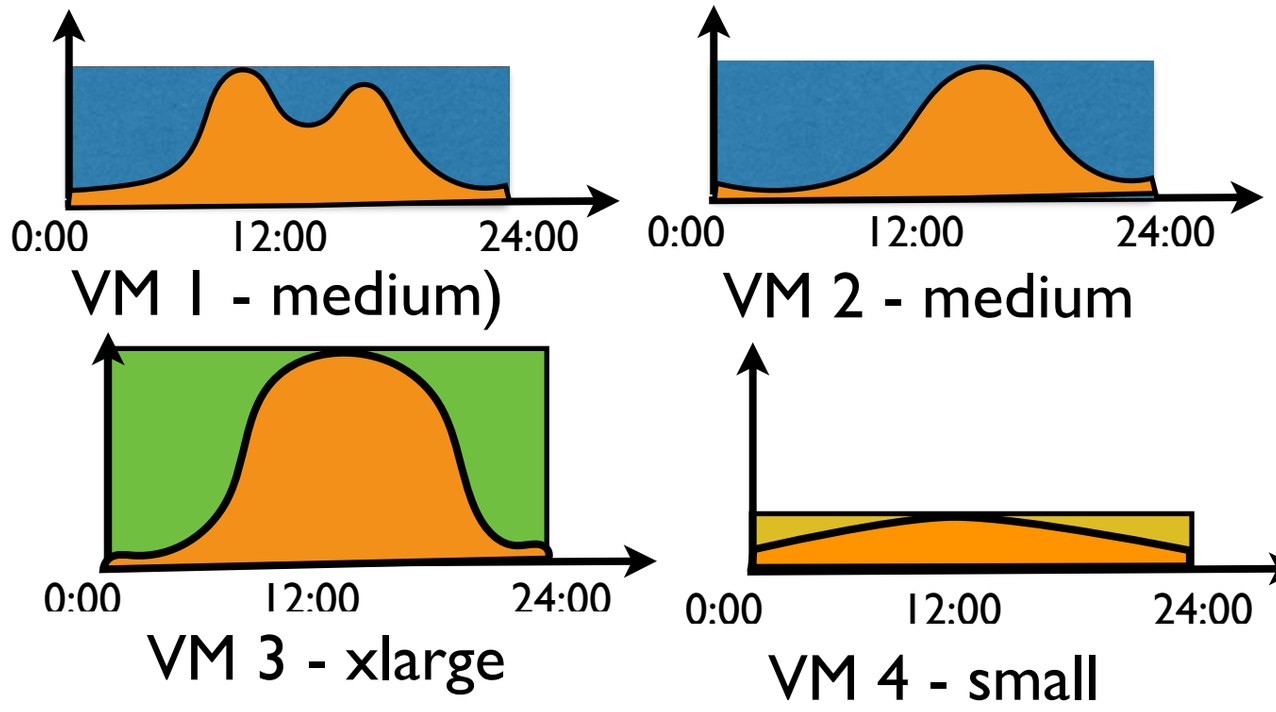

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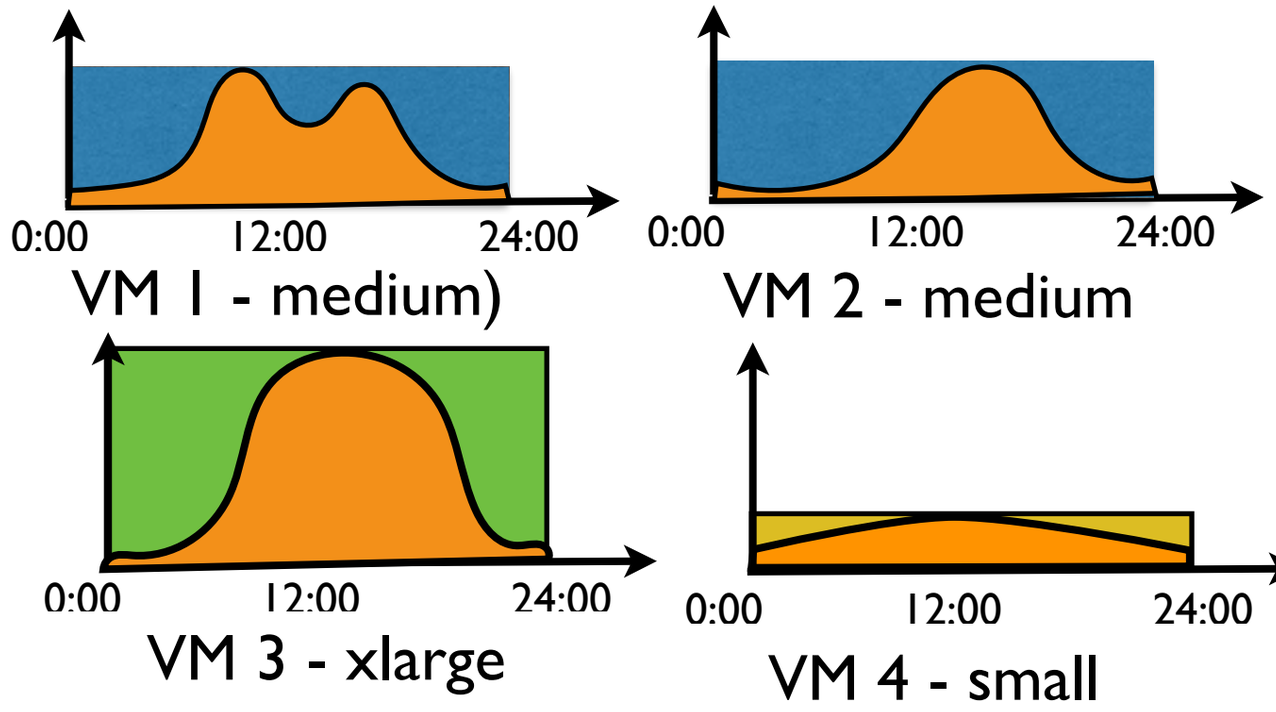

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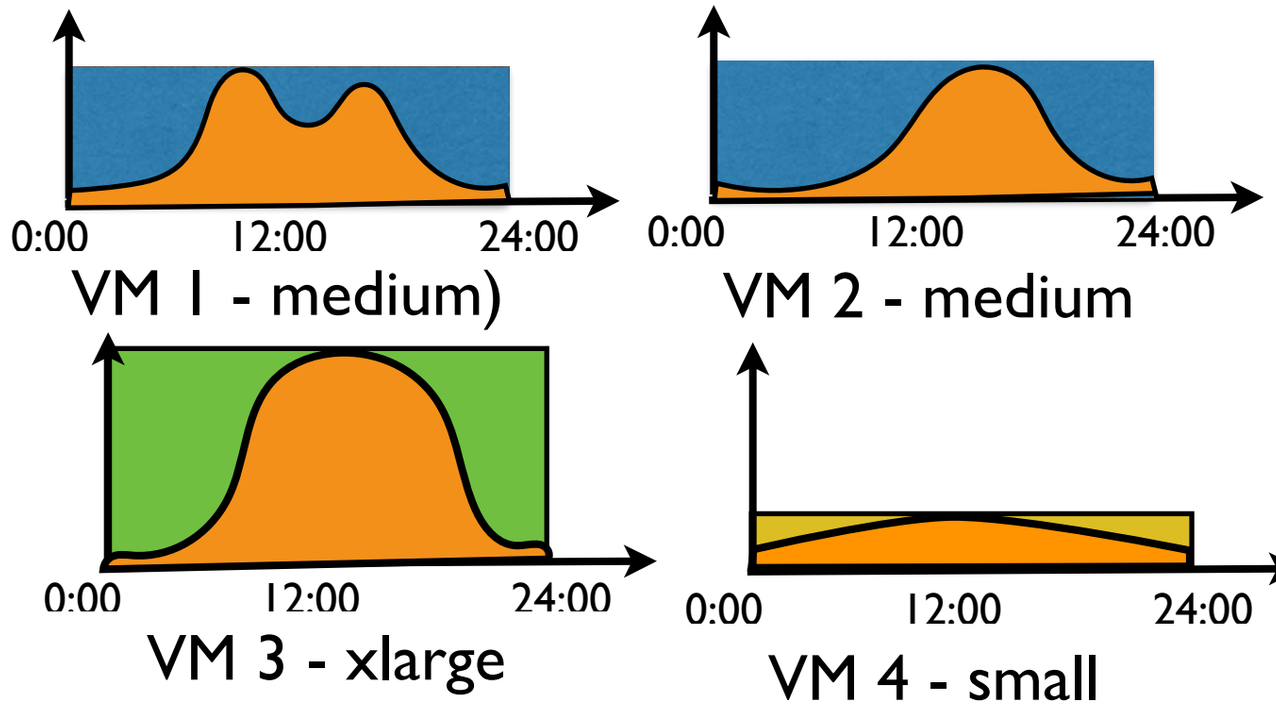
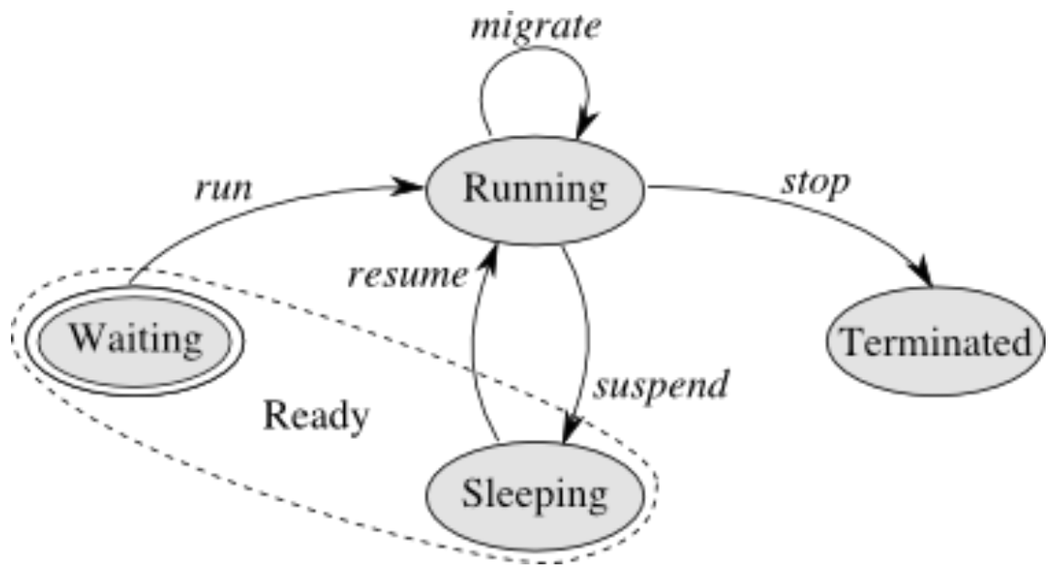


Dynamic placement

Dynamic VM Placement Policies

- Generale idea: leverage VM capabilities to manipulate VEs in a similar way of usual processes on a laptop (a VE is a users' working environment, possibly composed of several interconnected VMs)



- Each VE is in a particular state

- Perform VE context switches (a set of VM context switches) to reschedule/rebalance the LUC infrastructure [Her10]

Zoom on Live Migration

- Transfer VM's states to destination without stopping the guest OS (pre-copy algorithm)

1. Transfer all memory pages of the VM.
   (But, keep in mind the VM is still running at source.)

2. Transfer updated memory pages during the previous step

3. Iterate this step until the rest of memory pages becomes sufficiently small to meet an acceptable downtime (30ms in KVM).

4. Stop the VM. Transfer the rest of of memory pages and states

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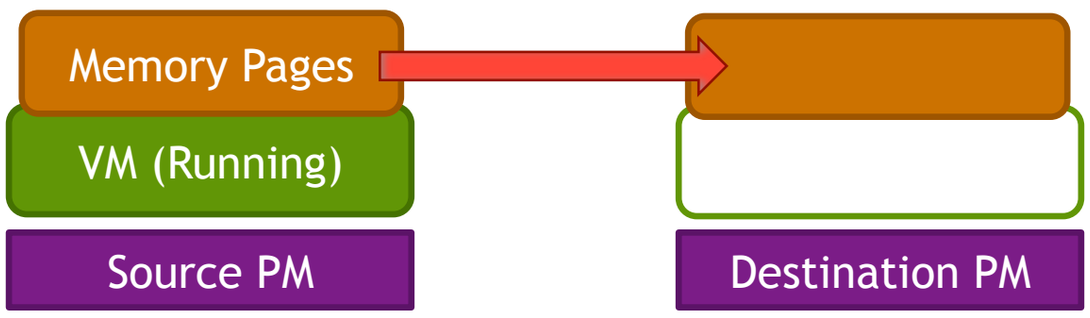

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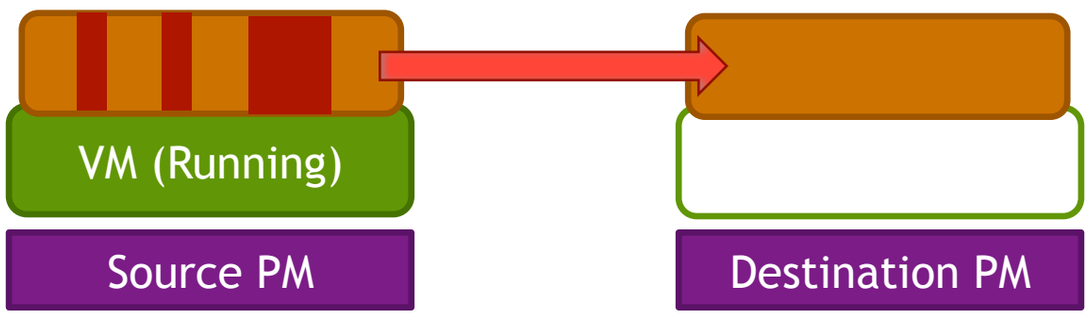

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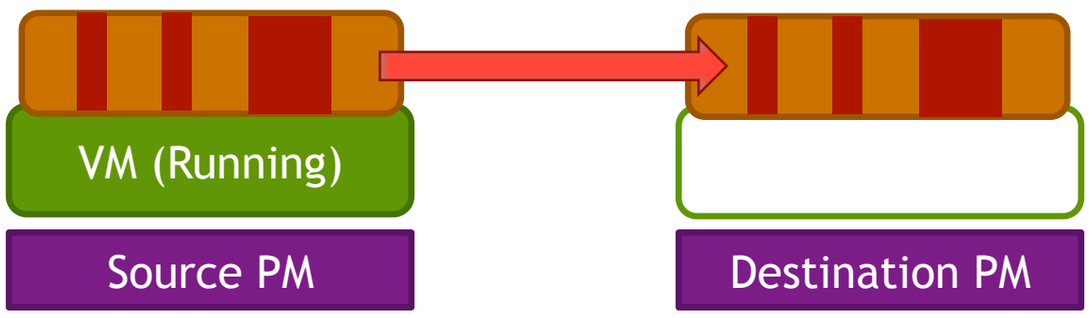

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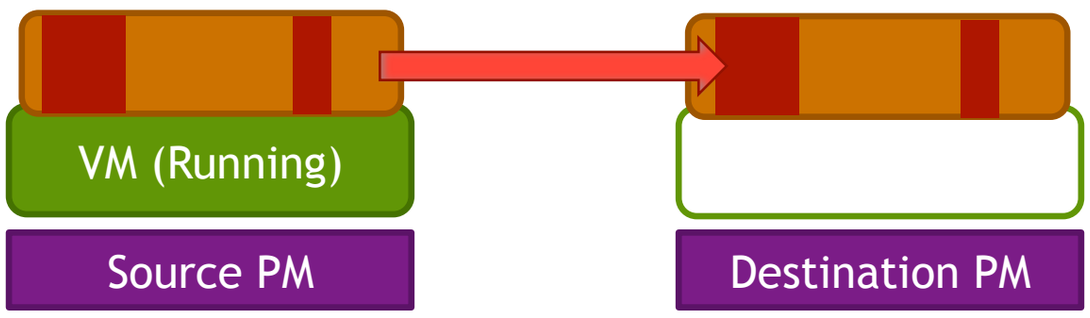

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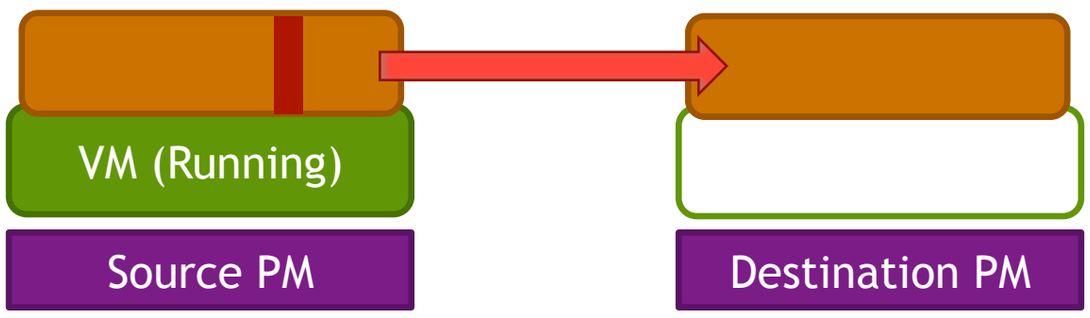

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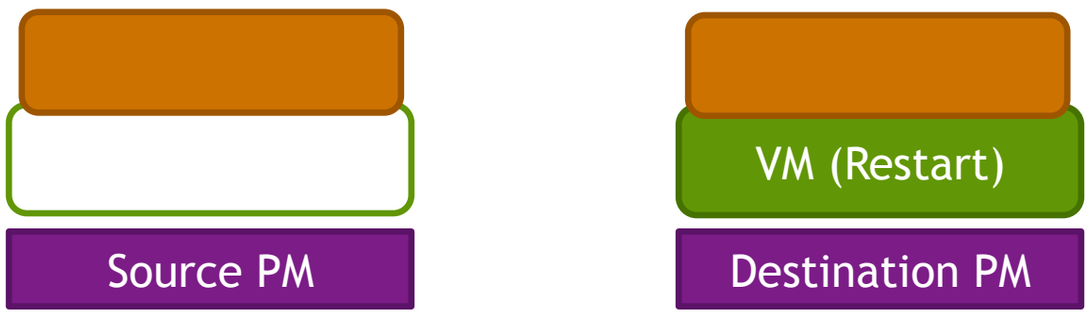
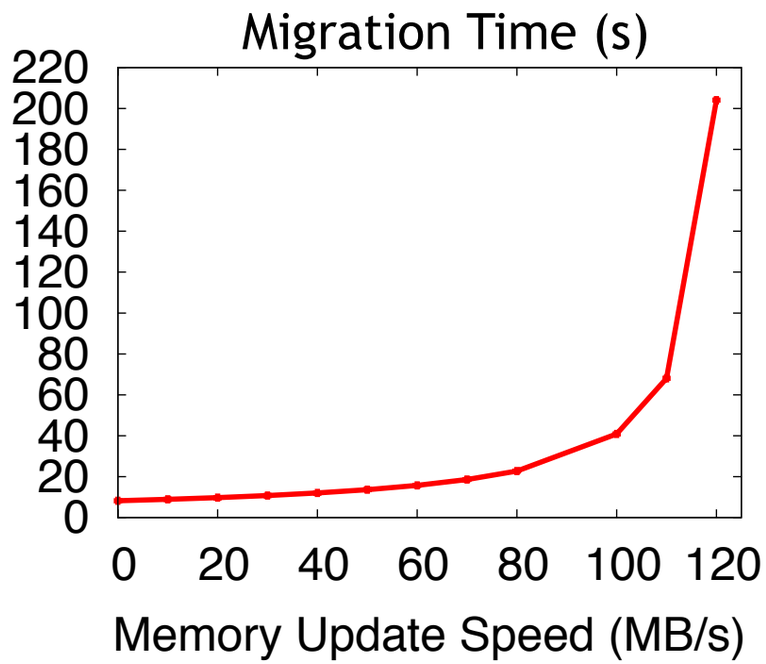
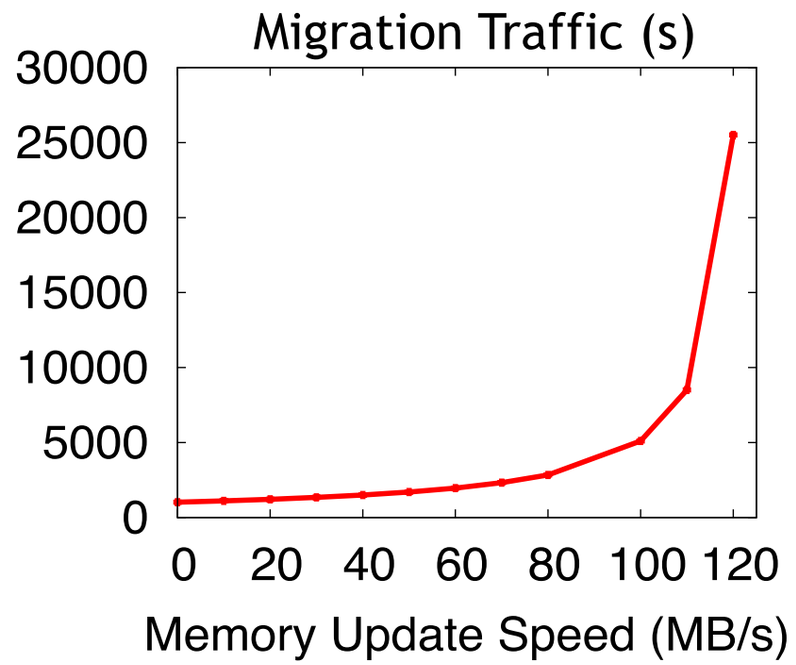
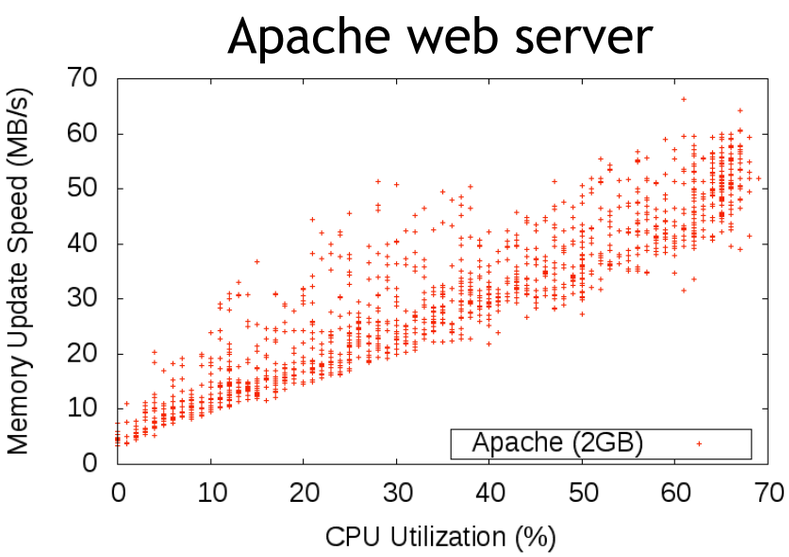


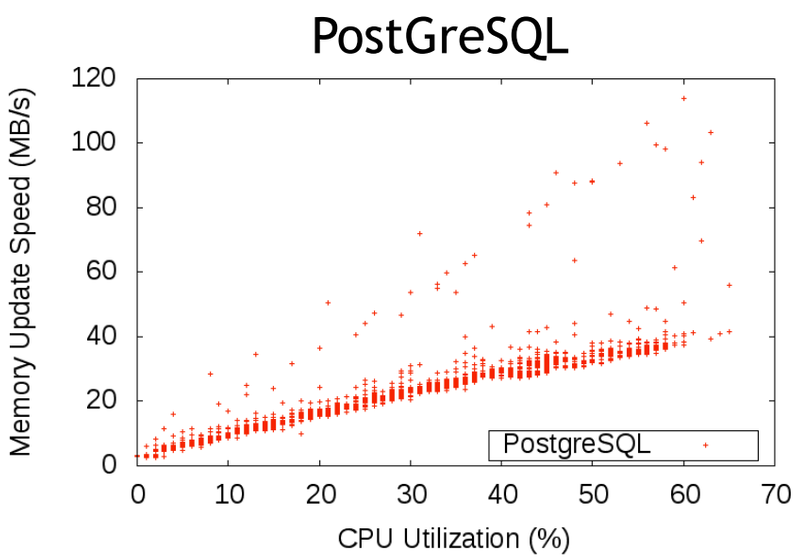
Zoom on the live migration operation

- The more your VM is memory intensive, the longer the migration will be [Hiro13]









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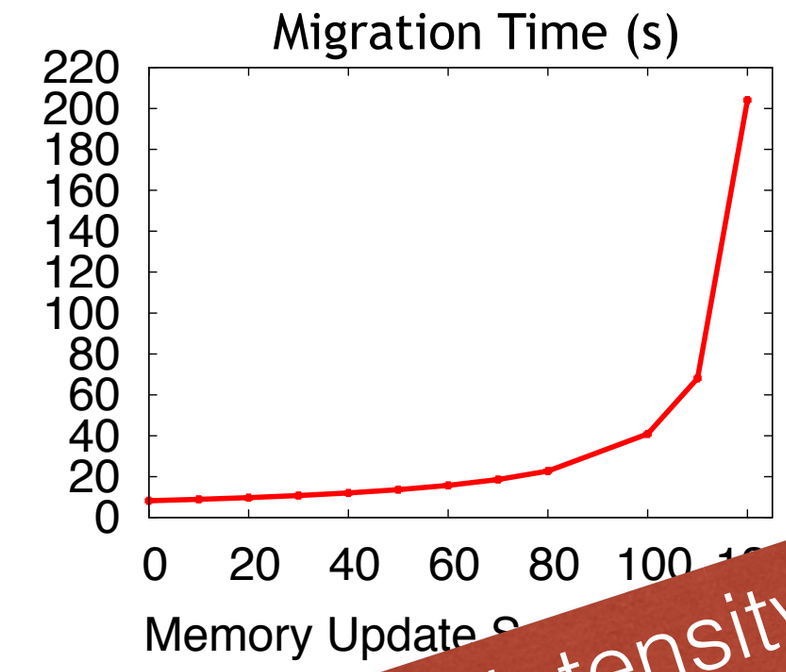
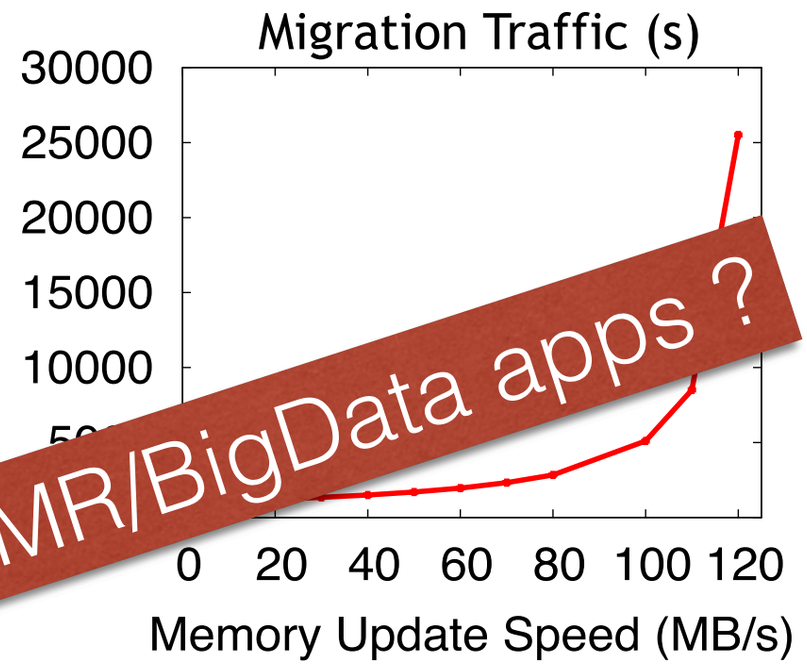
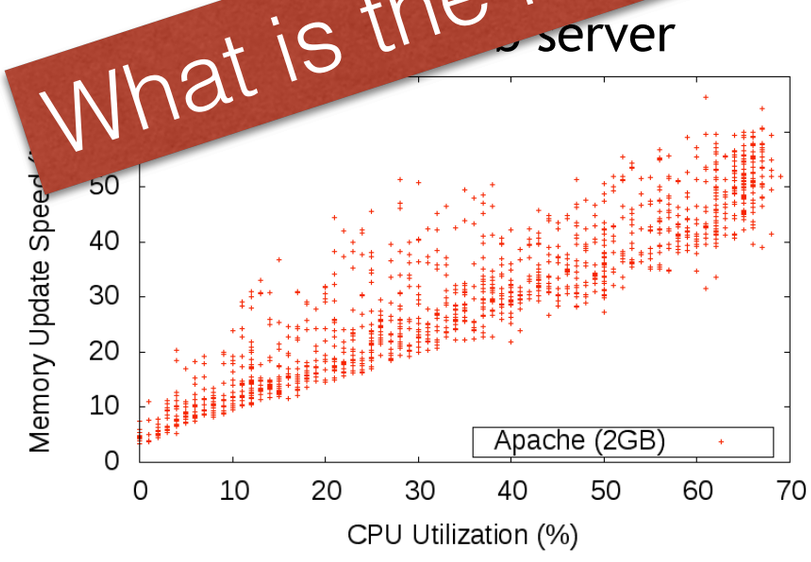
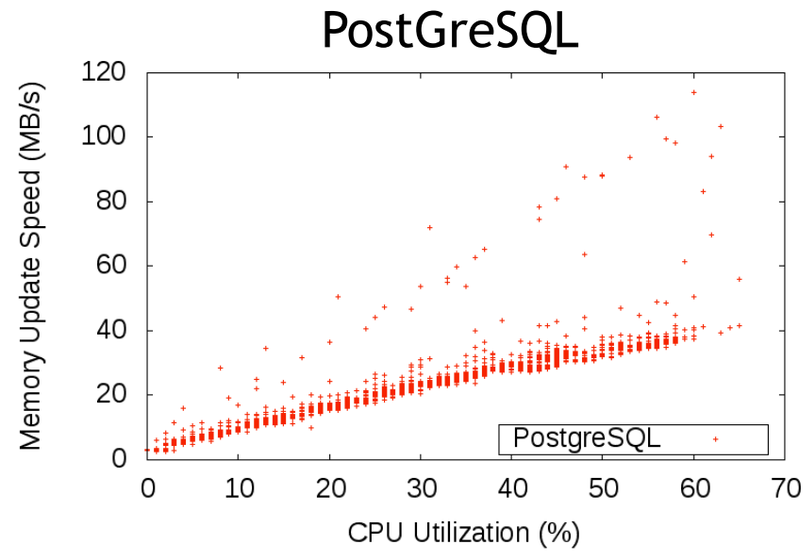


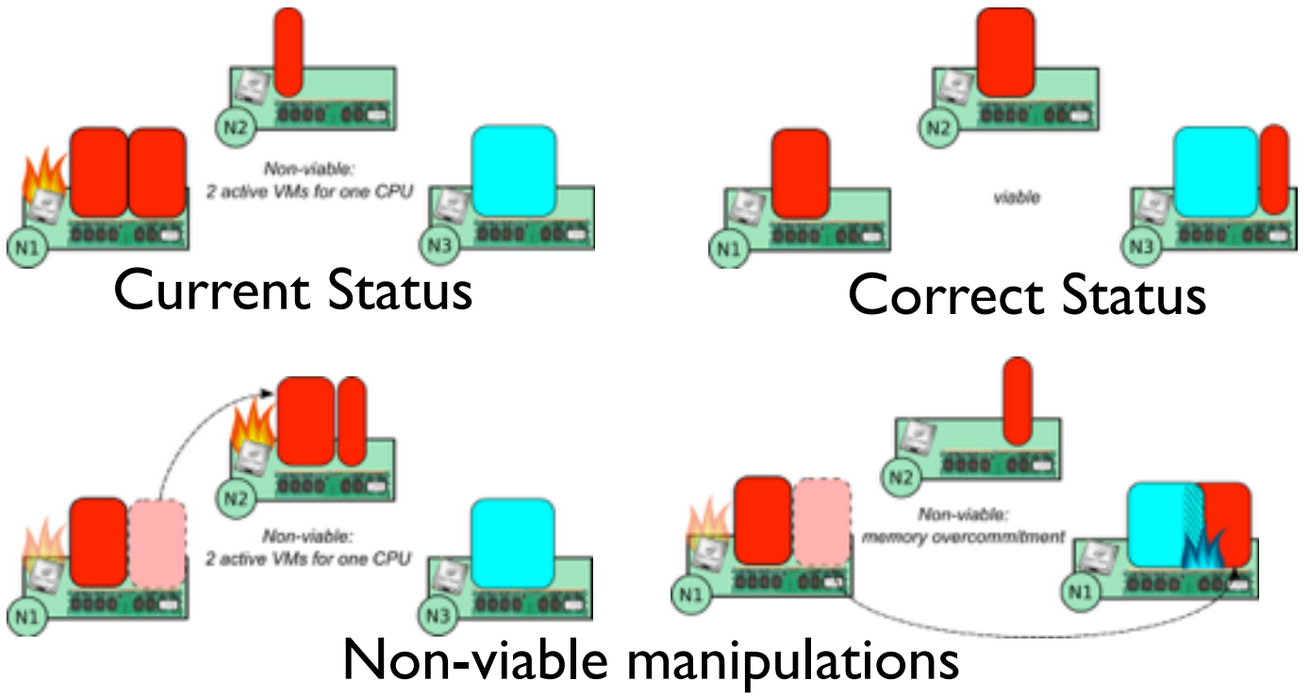


What is the intensity of a MR/BigData apps ?

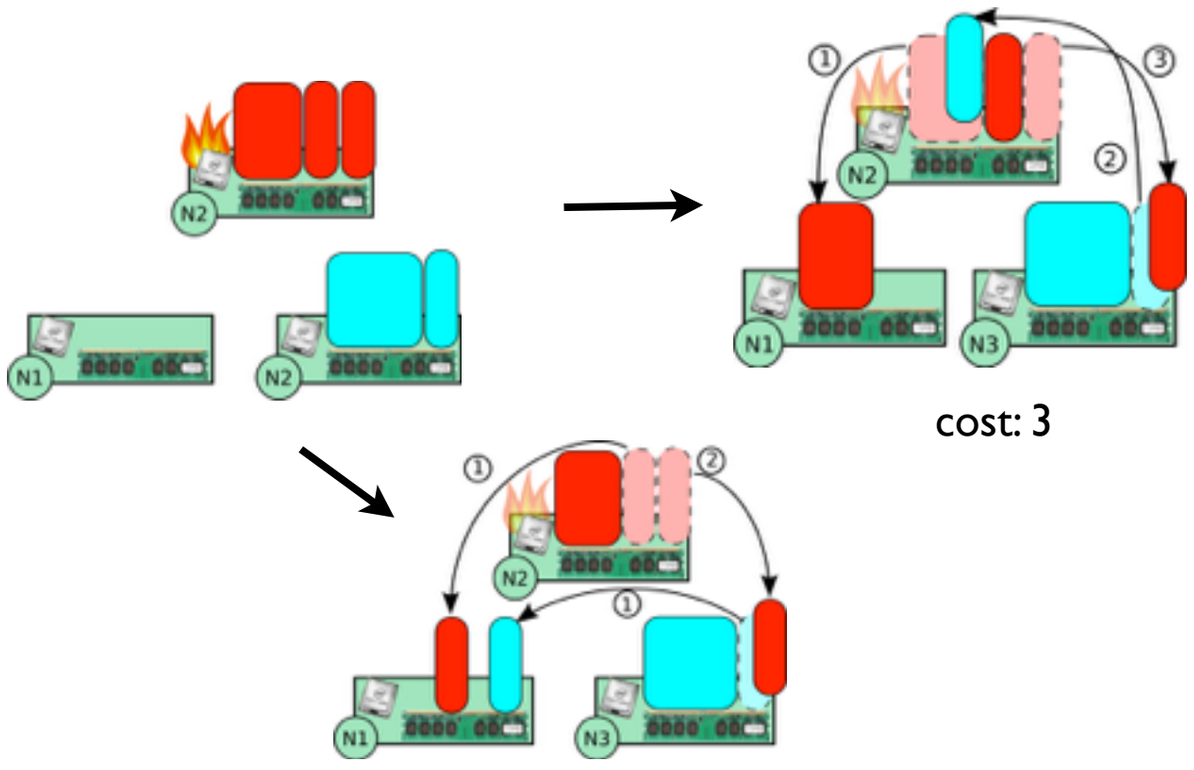


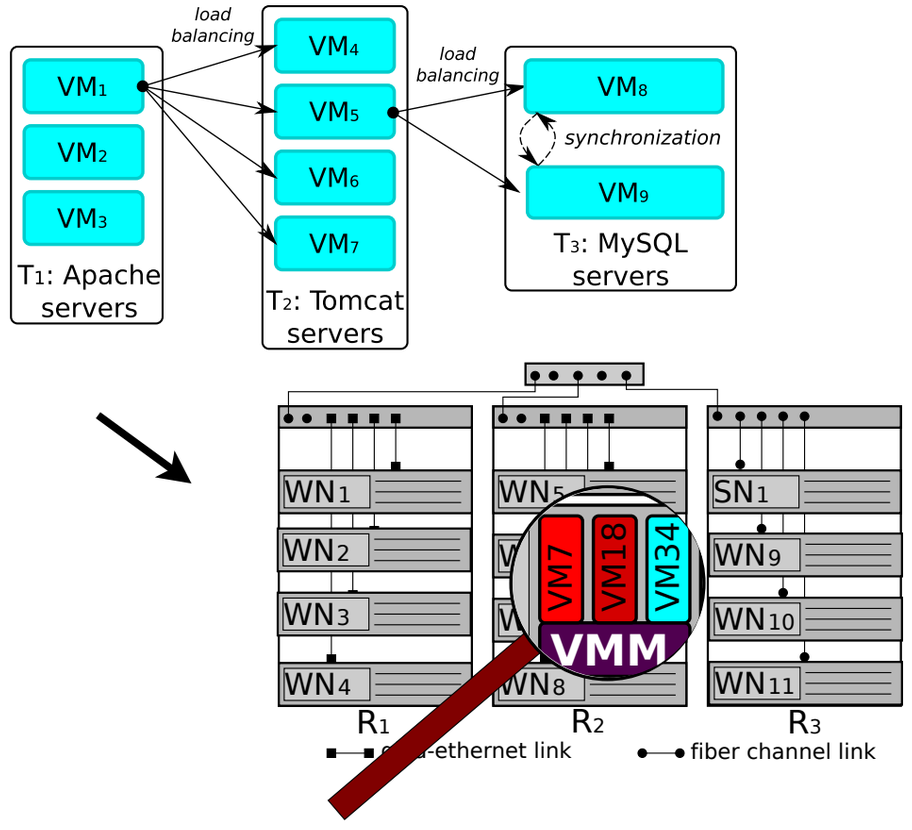


Placement constraints (btrPlace)



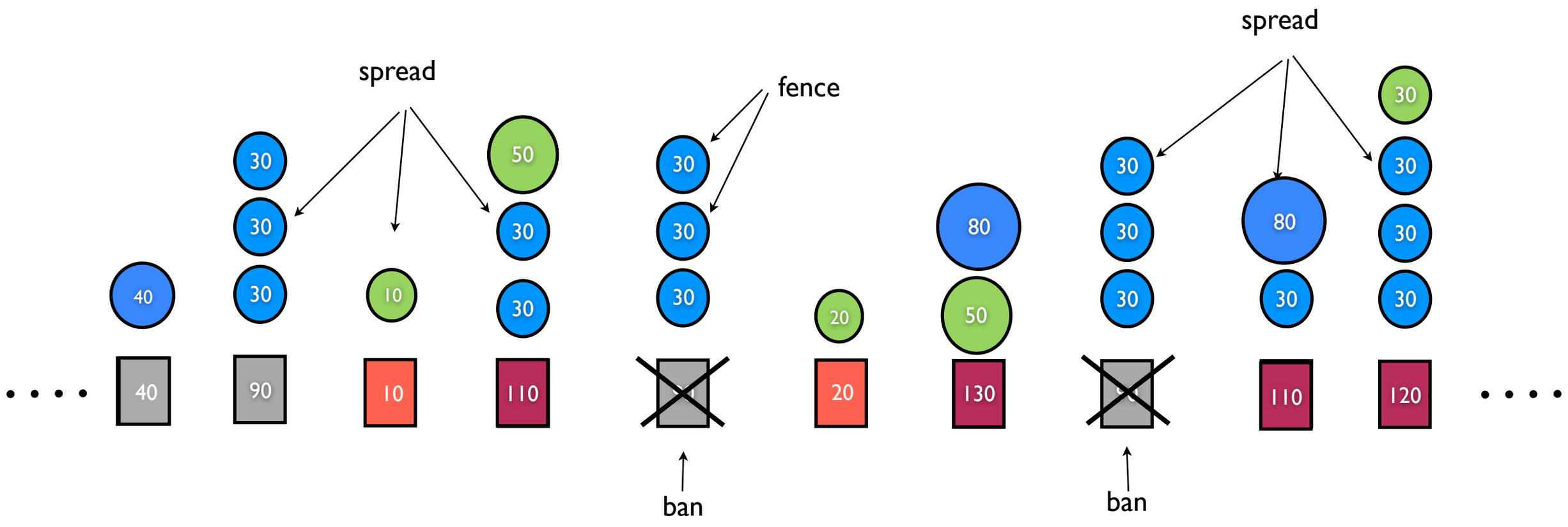
- Find the "right" mapping between needs of VMs, their constraints and resources provided by PMs [Her13]





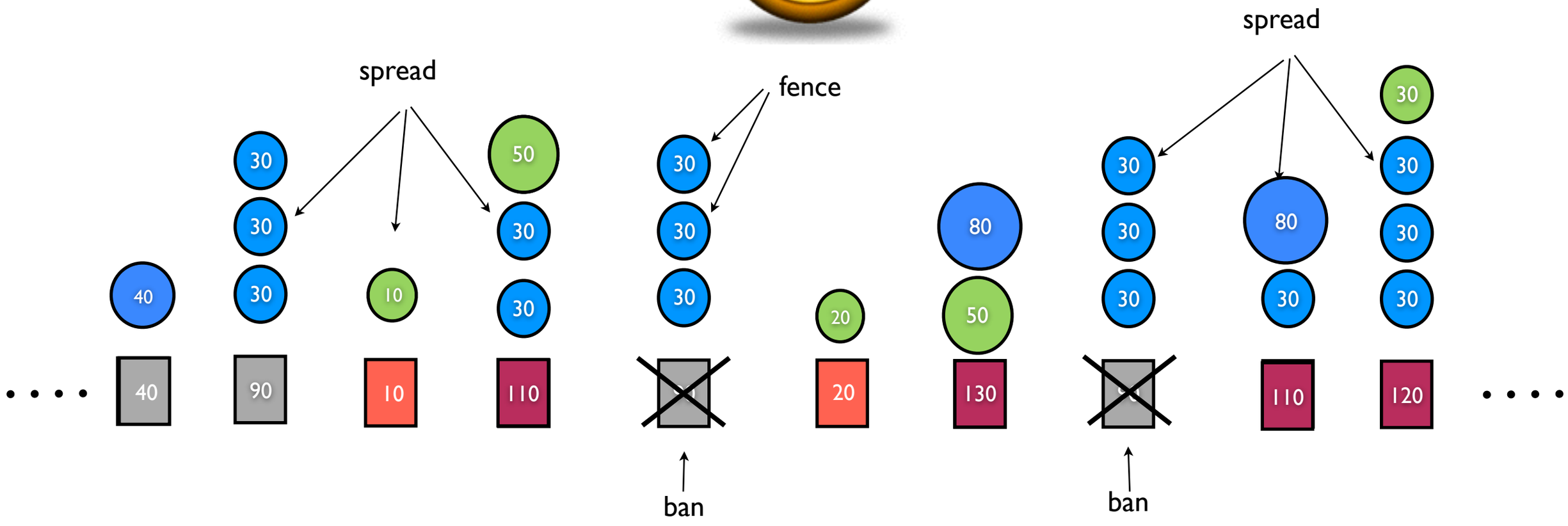
credits: F. Hermenier, Sophia Antipolis University, www.btrplace.org

a Small Example



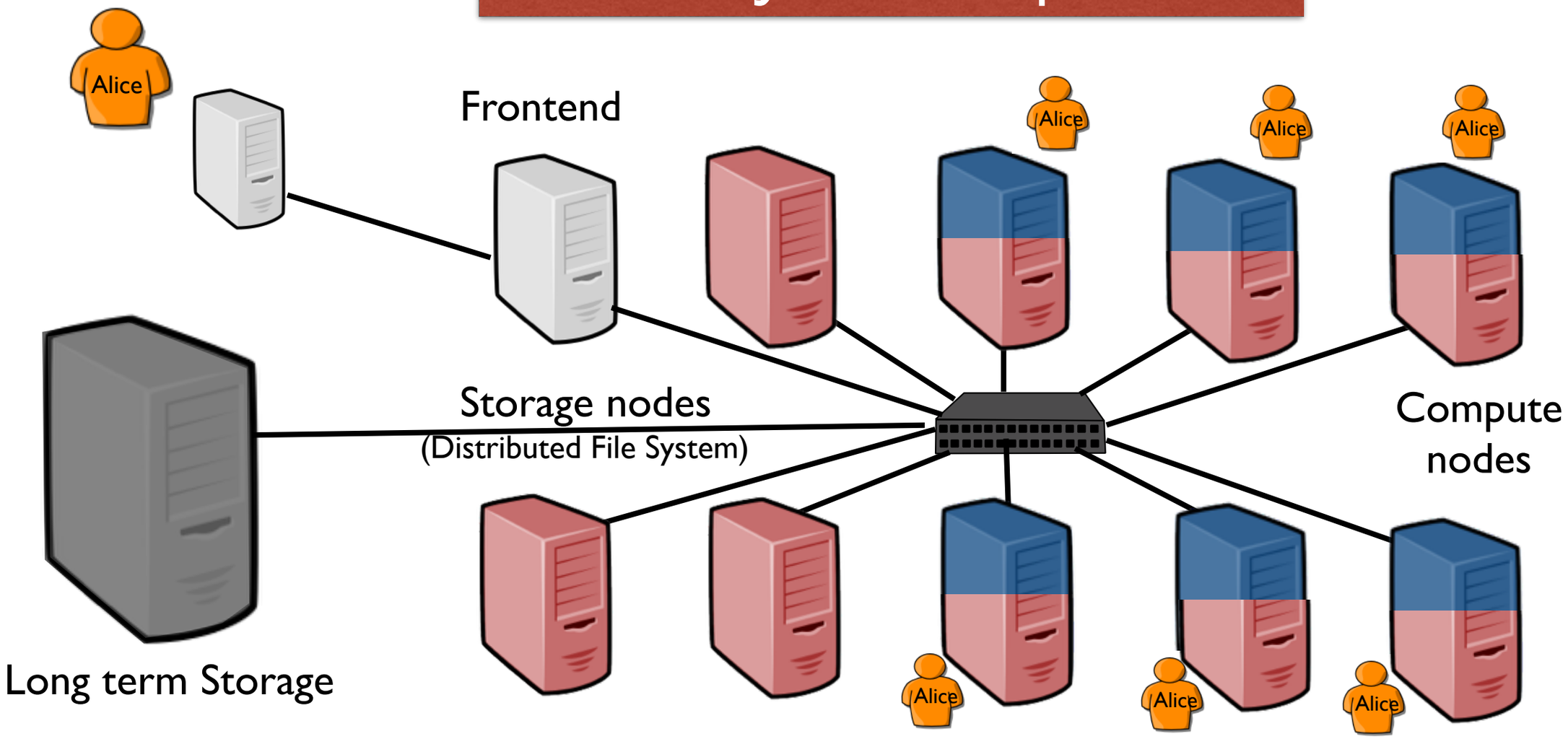
a Small Example

Only CPU is considered in this simple example



Another with Map/Reduce

What you expect !



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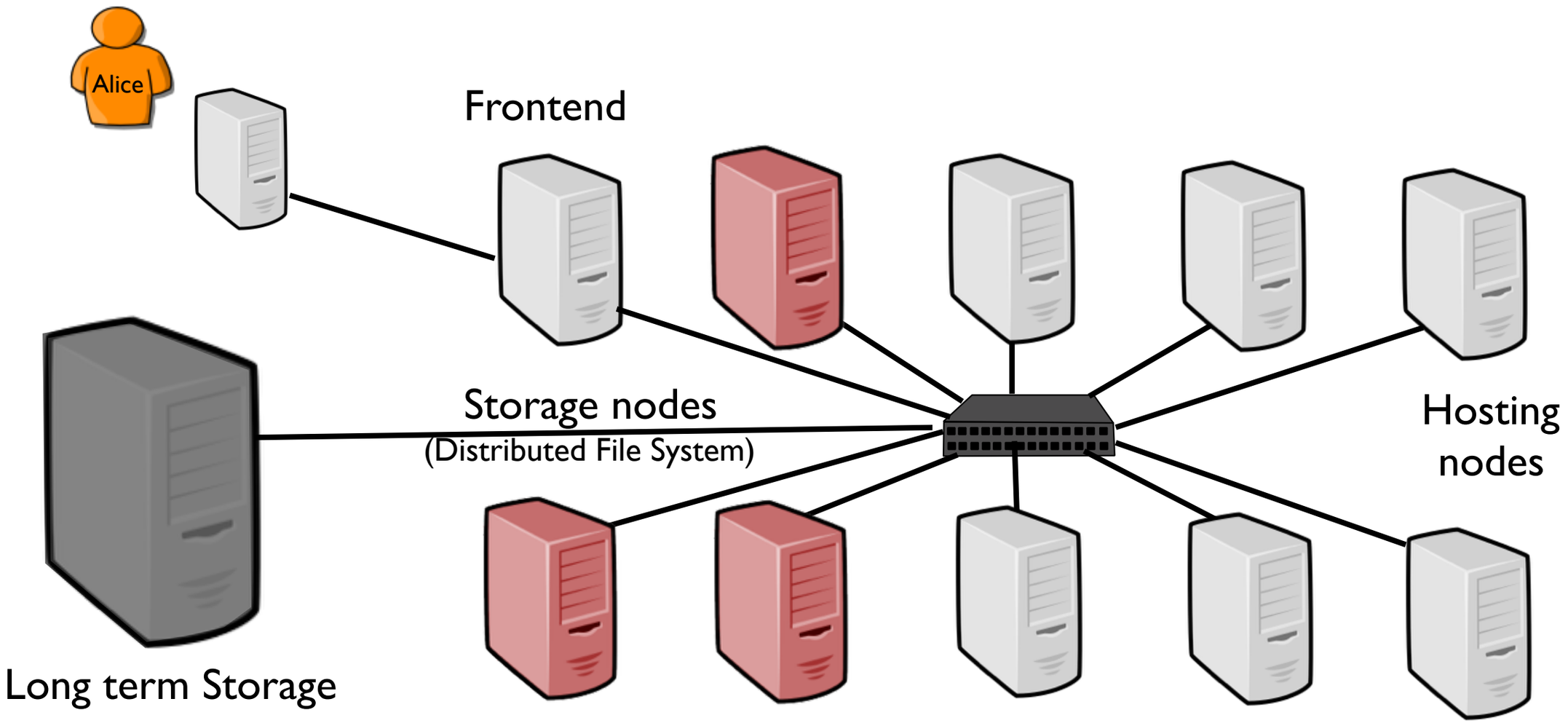
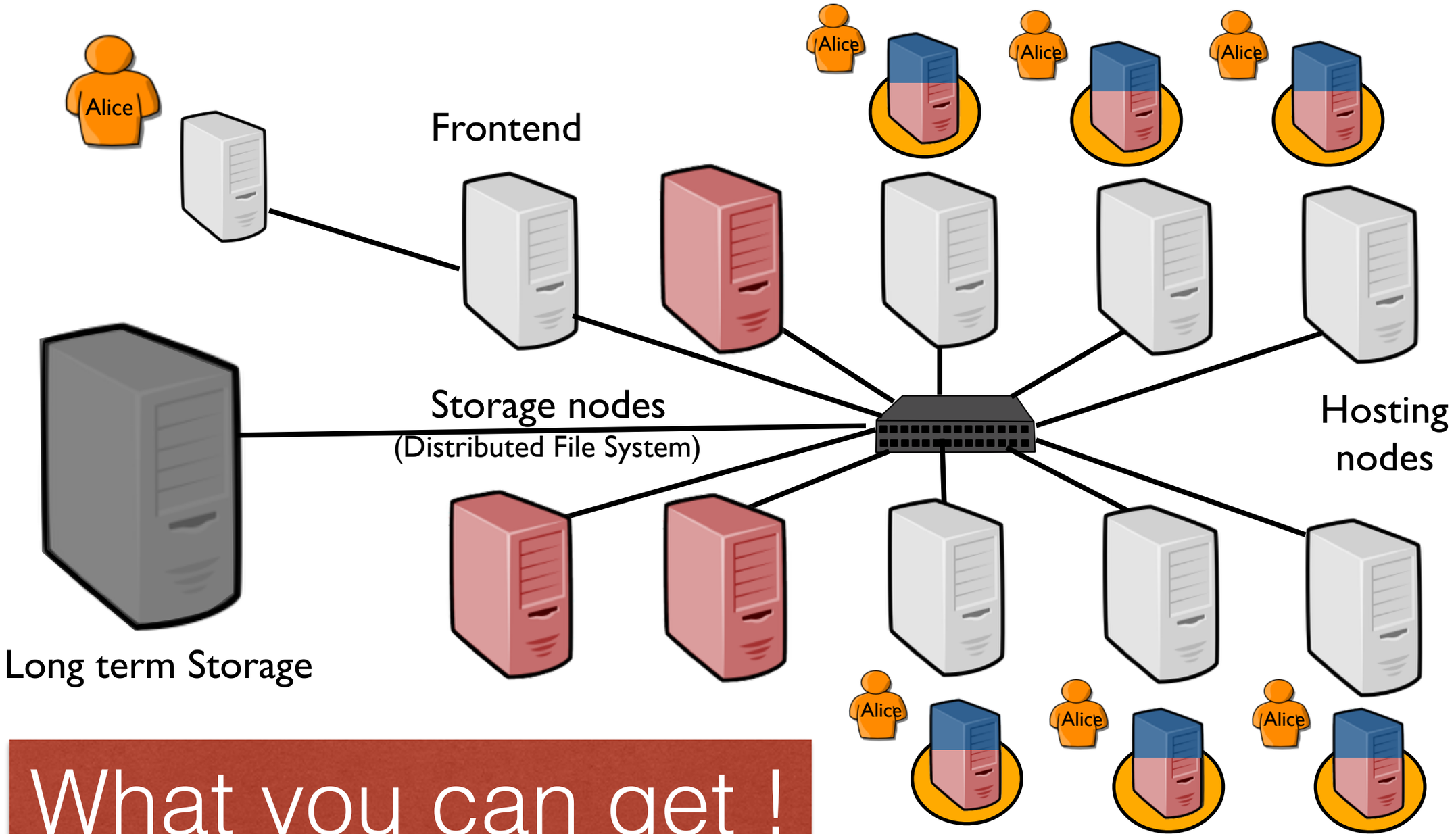


What you can get !

Another with Map/Reduce



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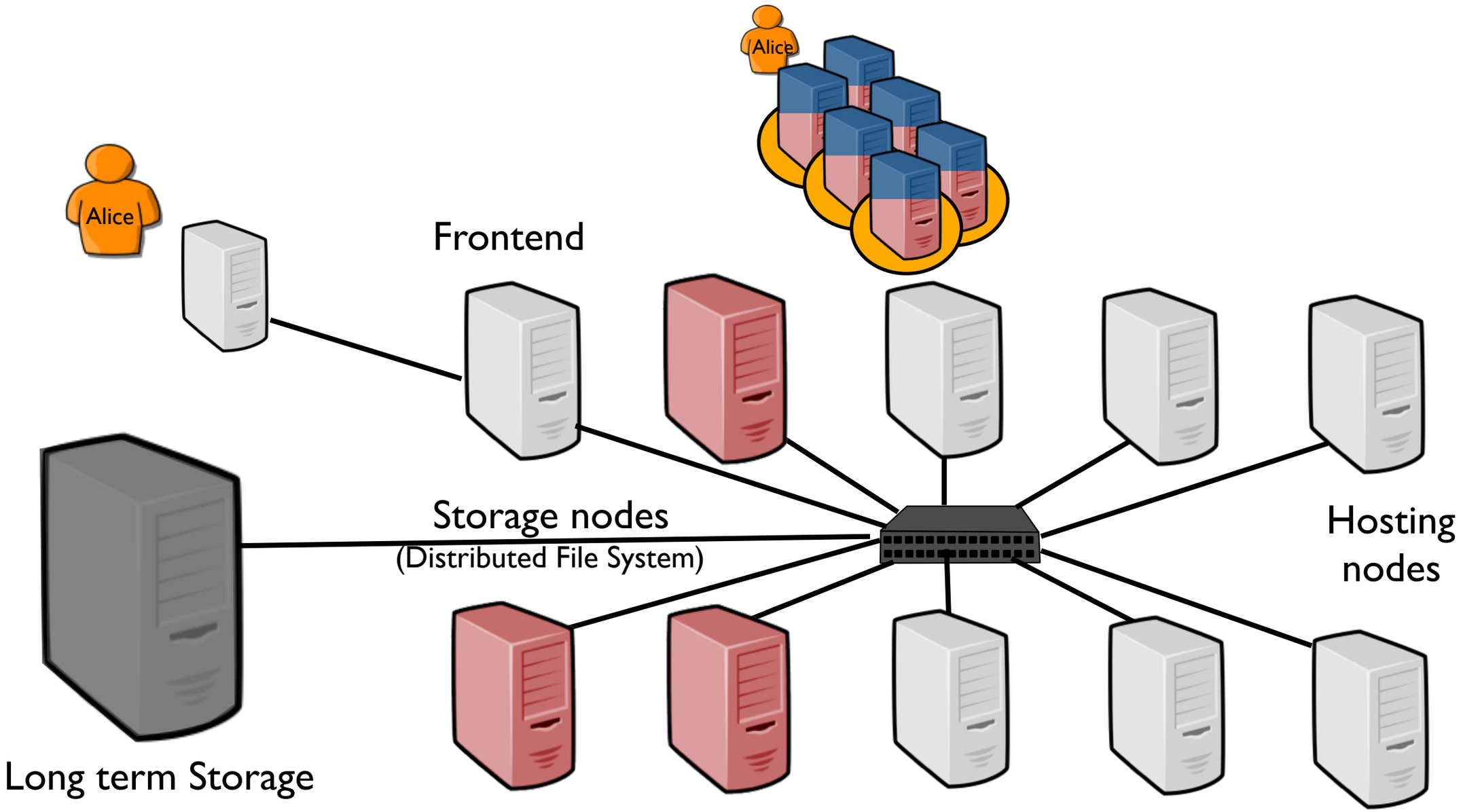

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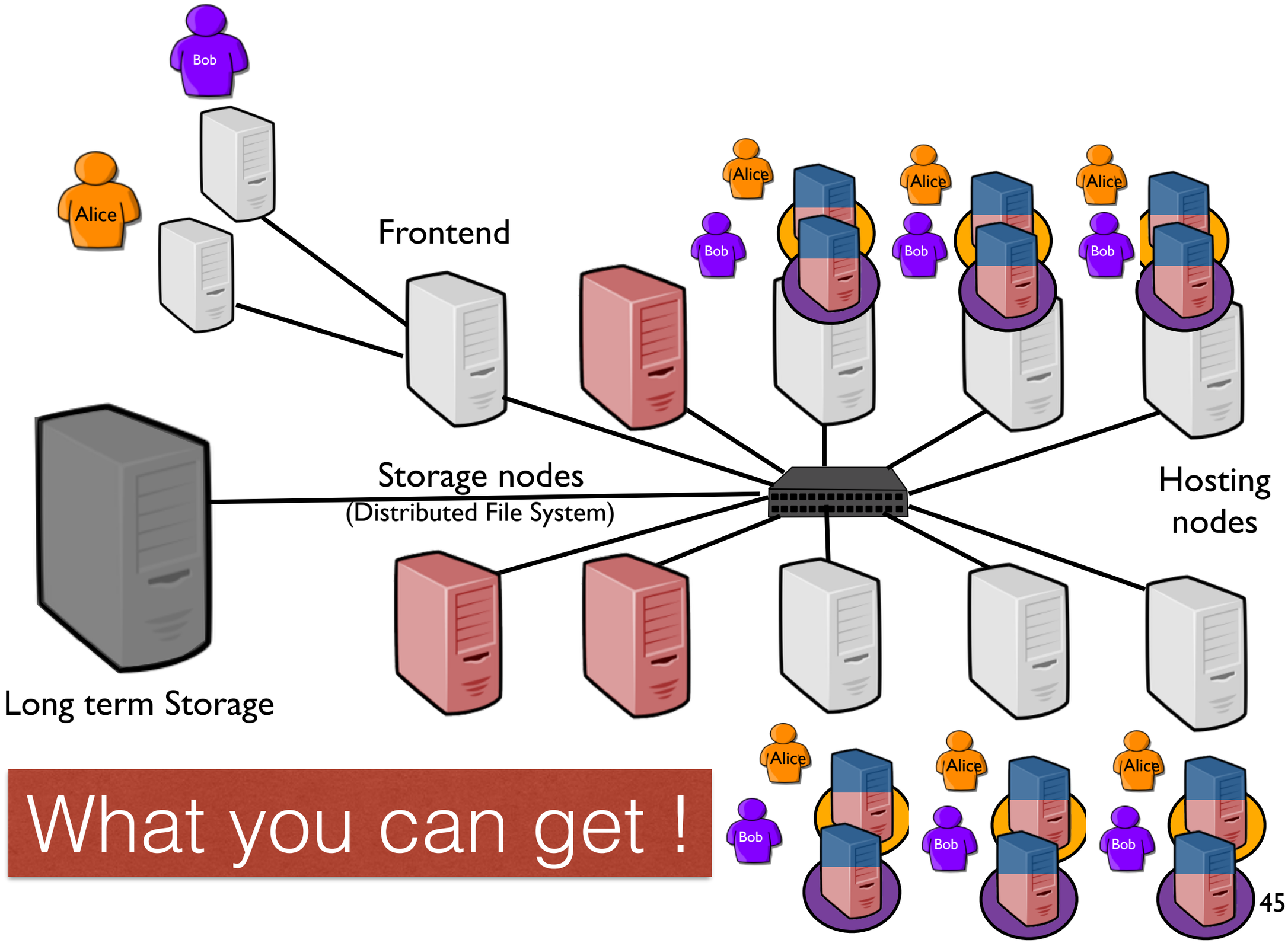


What you can get !

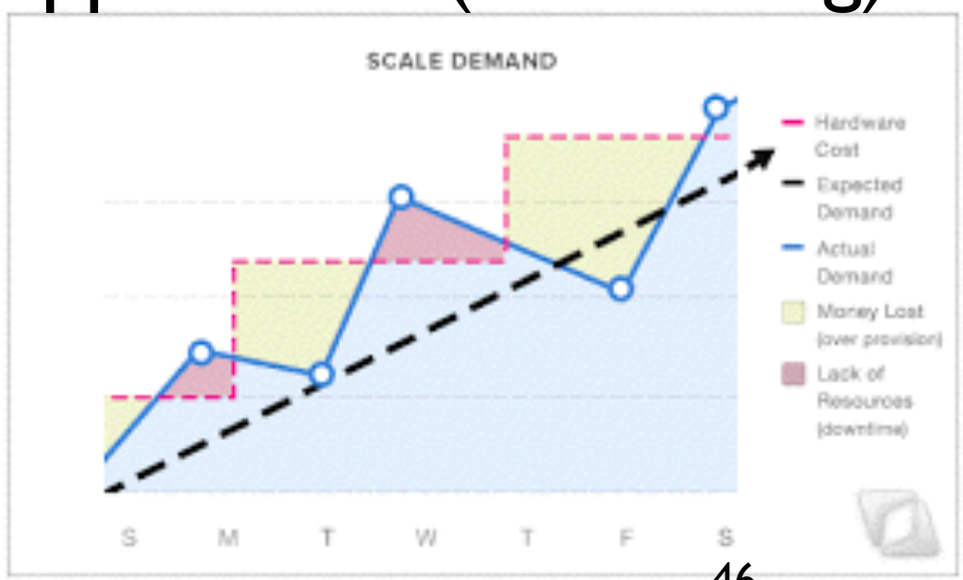
Virtualization and Performance

- Virtualization
  Contextualization / portability / security "isolation"
  Hard to guarantee (reproductible) performance

- Scheduling:
  Mainly static ⇒ lead to energy/resource wastes
  Dynamic scheduling strategies ⇒ Good achievements but still "food" for researchers (SLAs, migration overheads, ….)

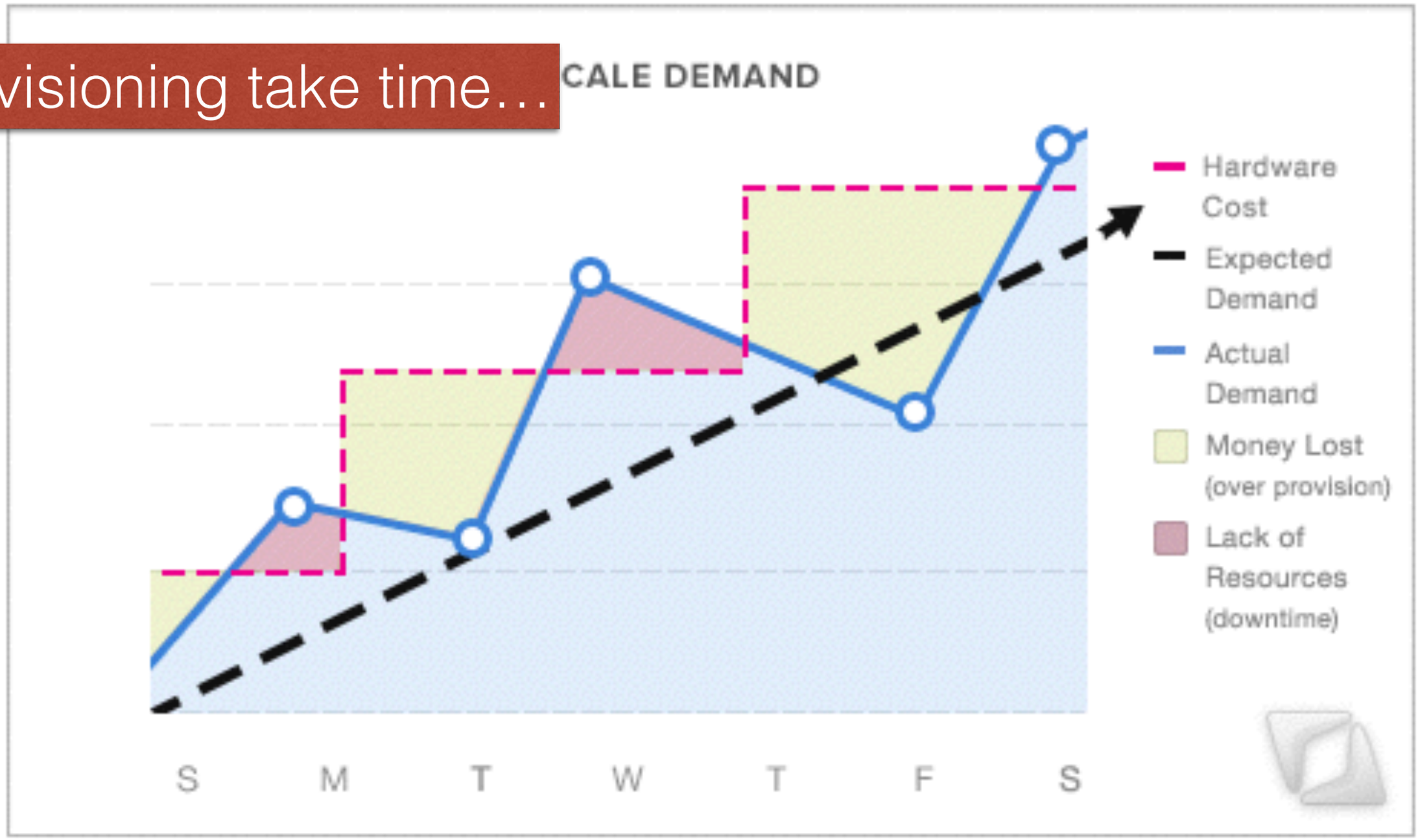
- Mitigate/Control performance issues :
  Nested virtualisation / Containers / Applications (autoscaling)

- I/O isolation/consolidation
  An important challenge



Autoscaling Mechanisms (few words)

Provisioning take time…

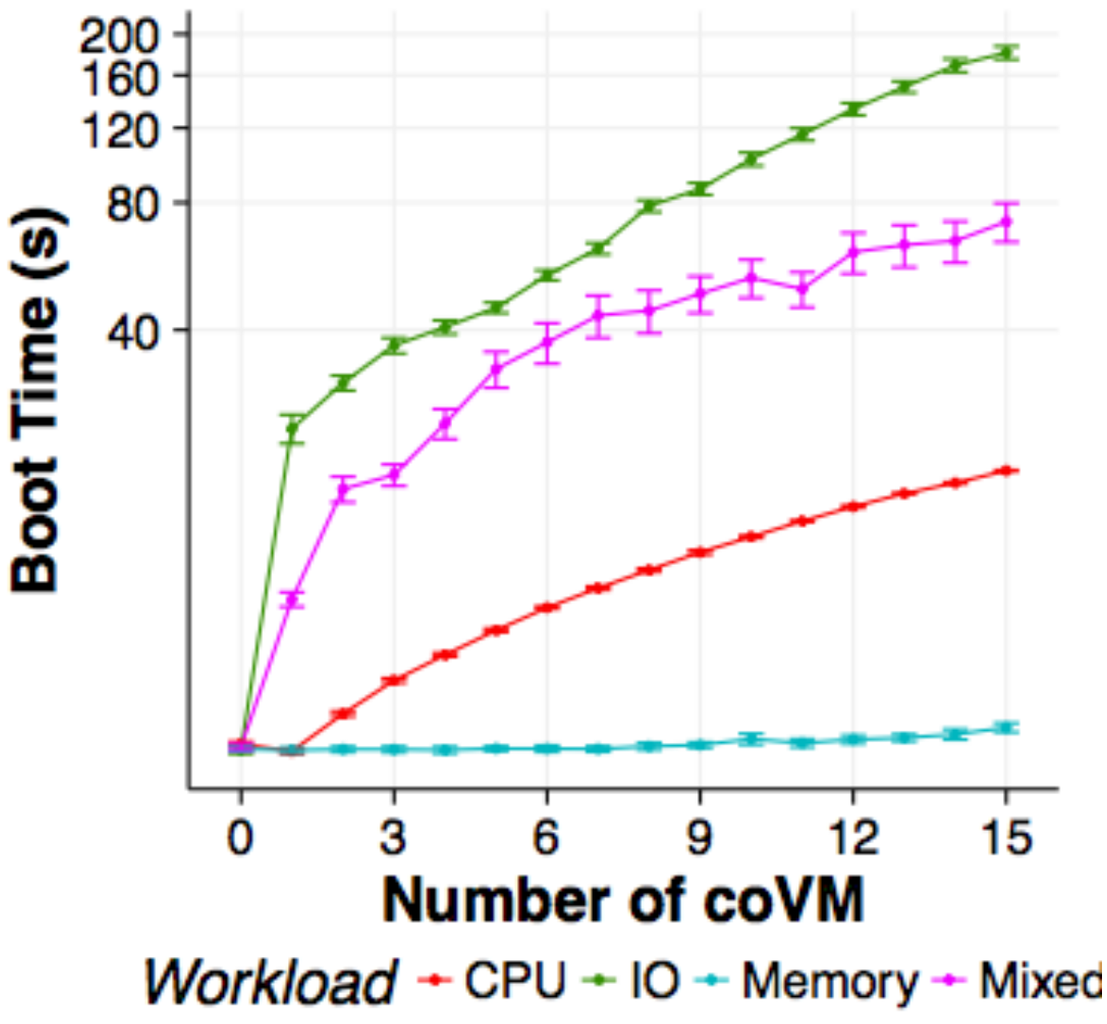


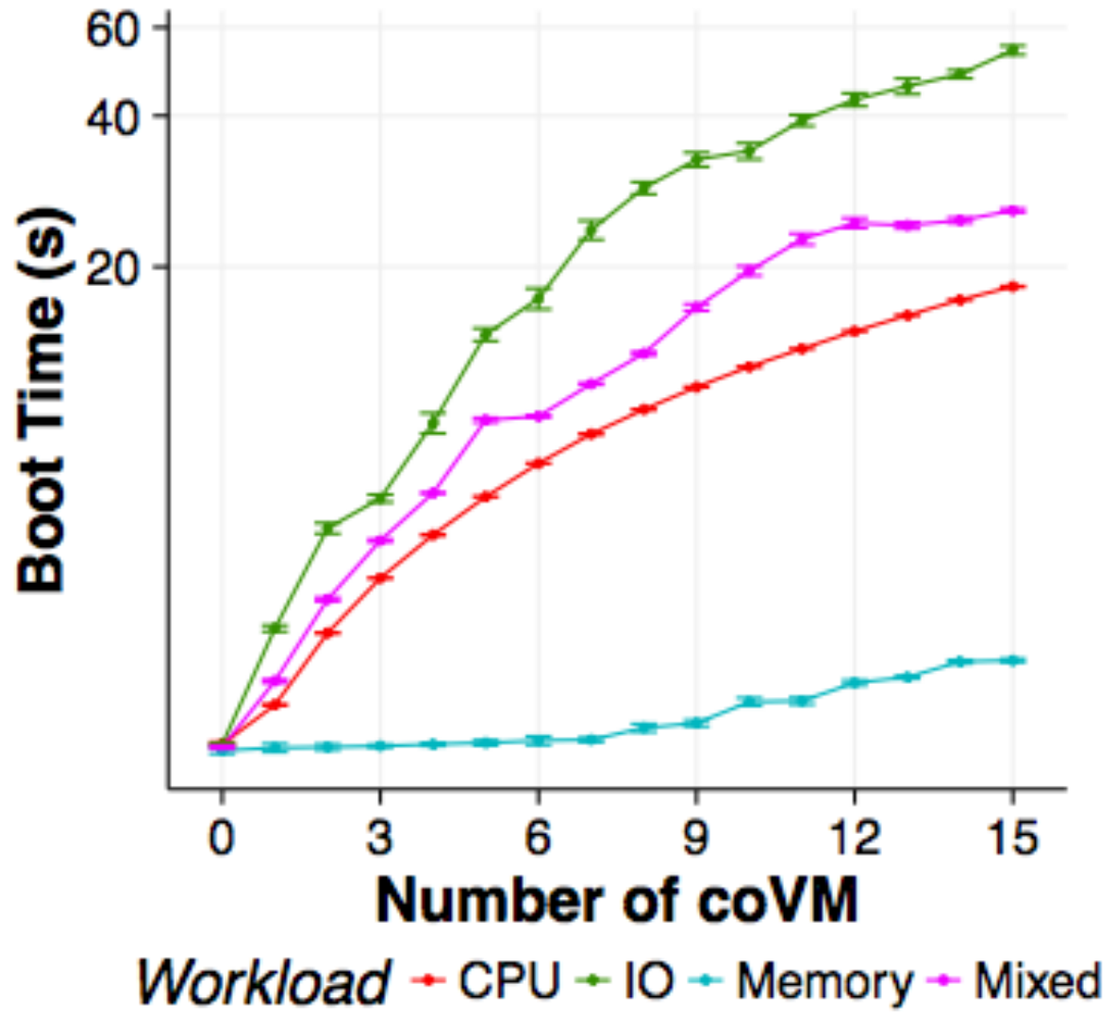
…especially if you are provision DB/Storage tiers.

Autoscaling Mechanisms (few words)

Provisioning take time…

- [NGuyen17]





…especially if you are provision DB/Storage tiers.

Containers ?

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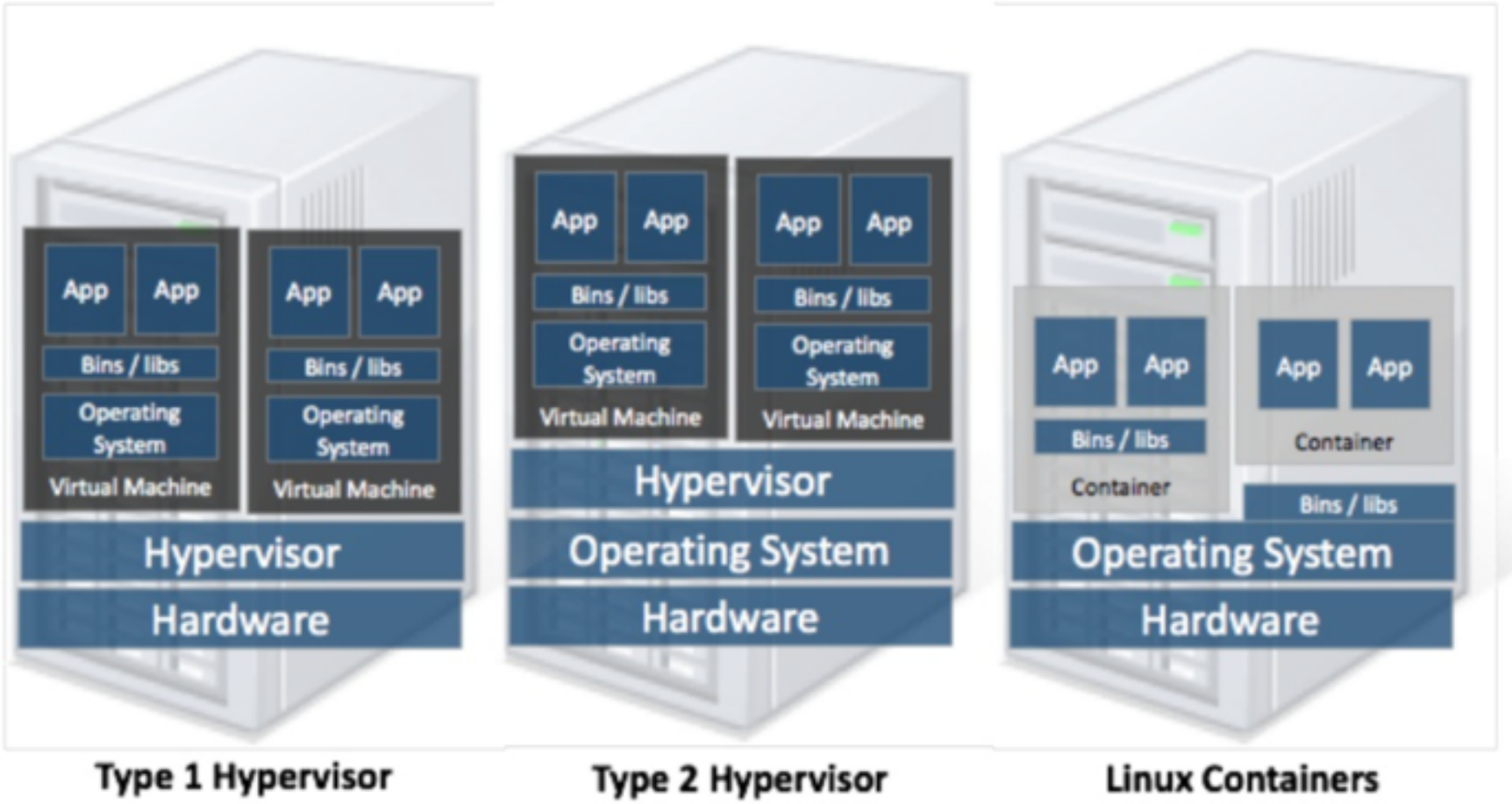

Linux Container Brief for IEEE WG P2302, Boden Russell

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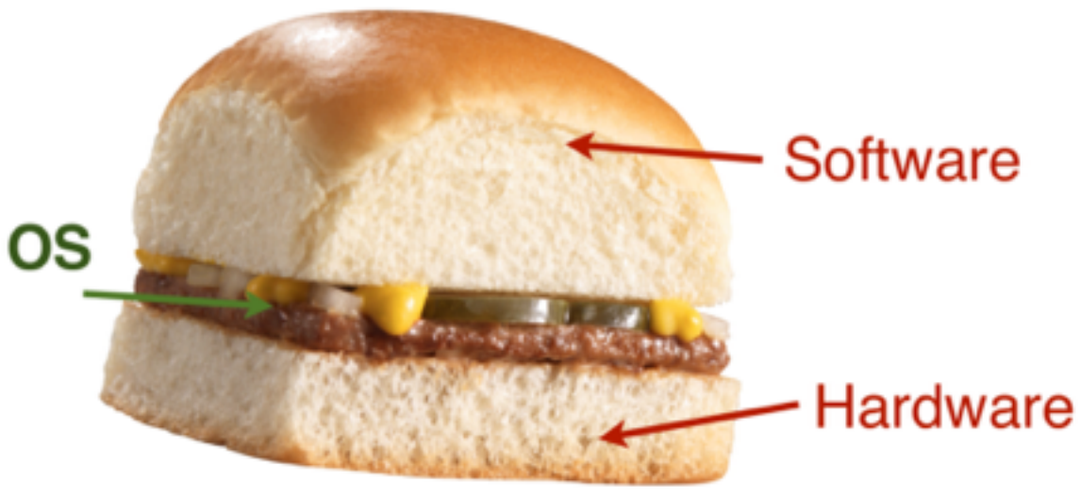

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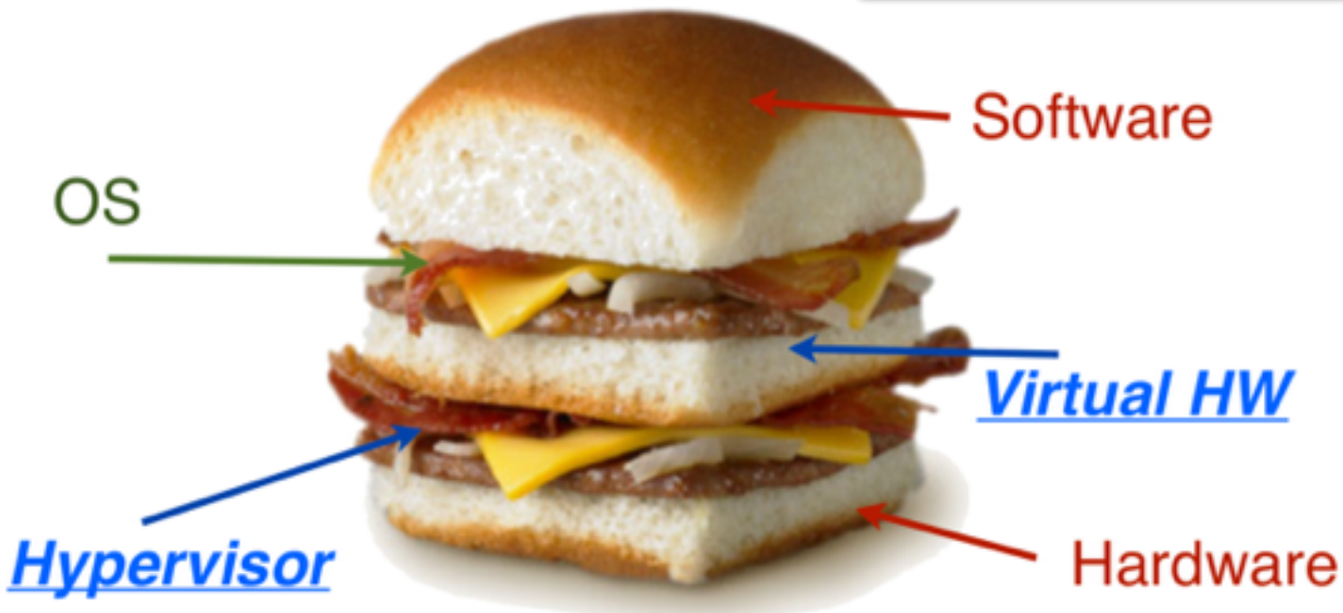
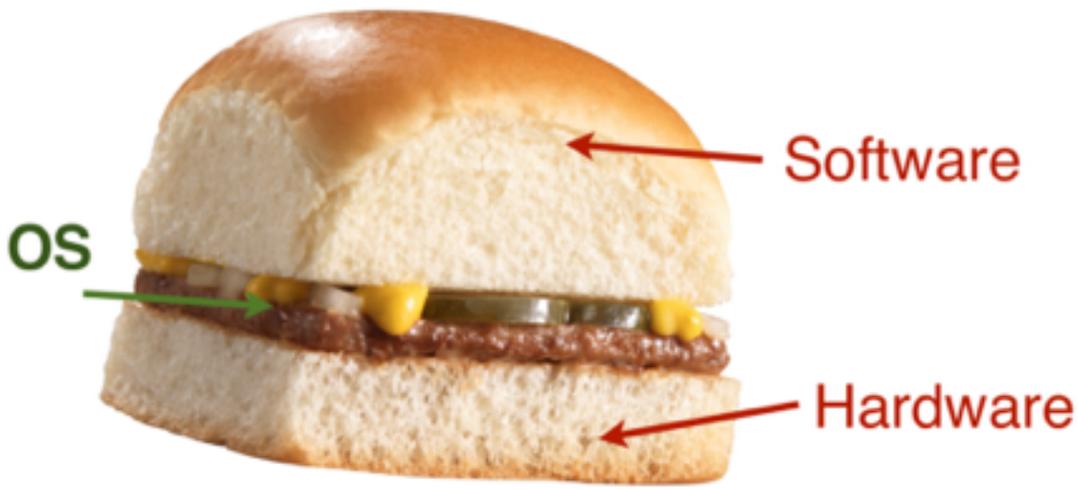
Lesson : R-A. Cherrueau





VMs make the control of performance harder,
Containers can tackle this issue..

Are Clouds just perfect?

Efficient data management

- IP over Avian Carriers

Request for commons 1149,
Optimisation described in 2549 and 6214
(packet loss ratio, latency, …)

Efficient data management

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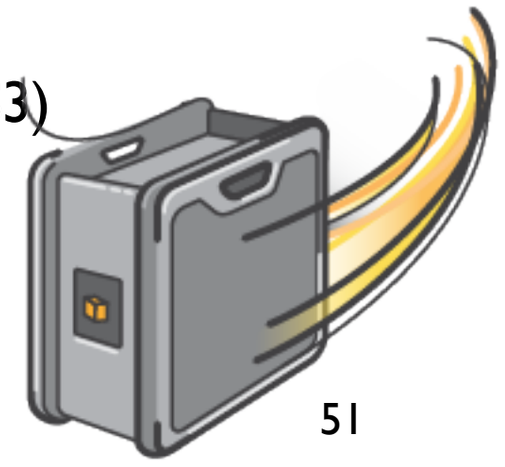
- But FedEx is still the most efficient way to share data

"sneakernet: transfer of electronic information, especially computer files, by physically moving removable media… from one computer to another, usually in lieu of transmitting the information over a computer network"

Google has used a sneakernet to transport large datasets, such as the 120 TB of data from of data from the Hubble Space Telescope.
Users of Google Cloud can import their data into Google Cloud Storage through sneakernet

Amazon introduced in 2015 the snowball
(Up to 50TBytes from your company to an AWS infrastructure and to S3)
https://aws.amazon.com/importexport/



Ok but is there something more critical….

The Current Trend: Large off shore DCs

- To cope with the increasing UC demand while handling energy concerns but…

credits: datacentertalk.com - Microsoft DC, Quincy, WA state

The Current Trend: Large off shore DCs

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credits: google map - Quincy

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credits: coloandcloud.com

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Inherent limitations of current solutions

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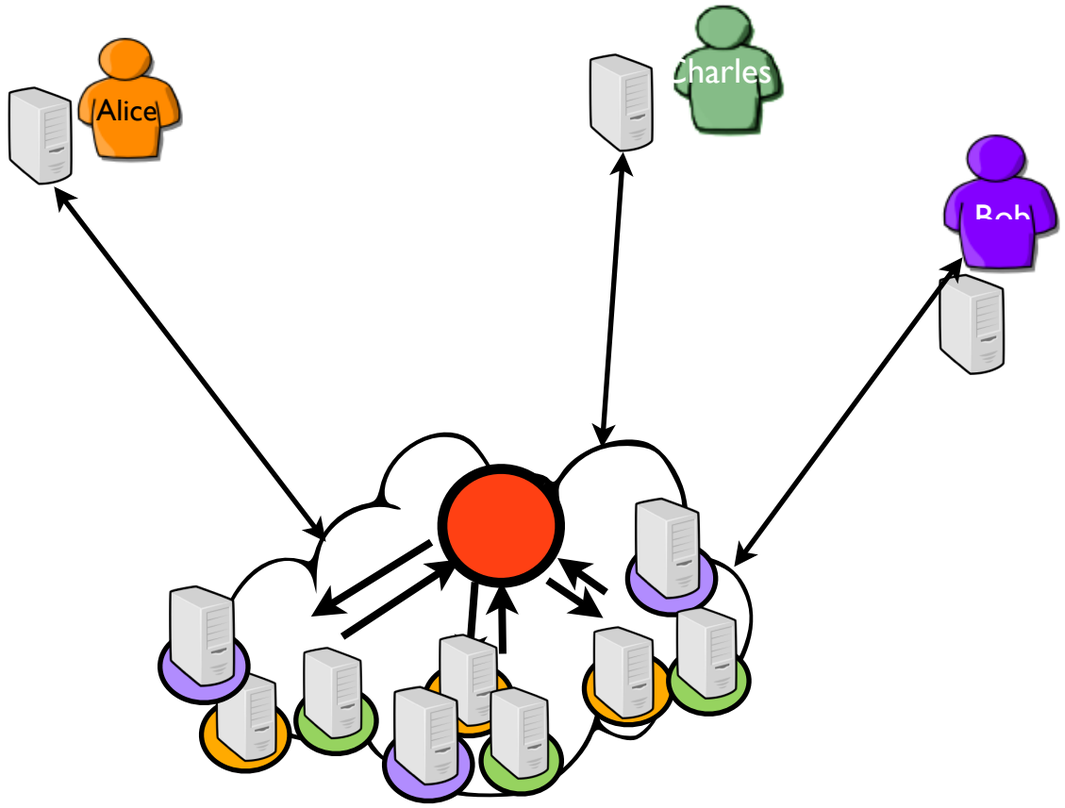

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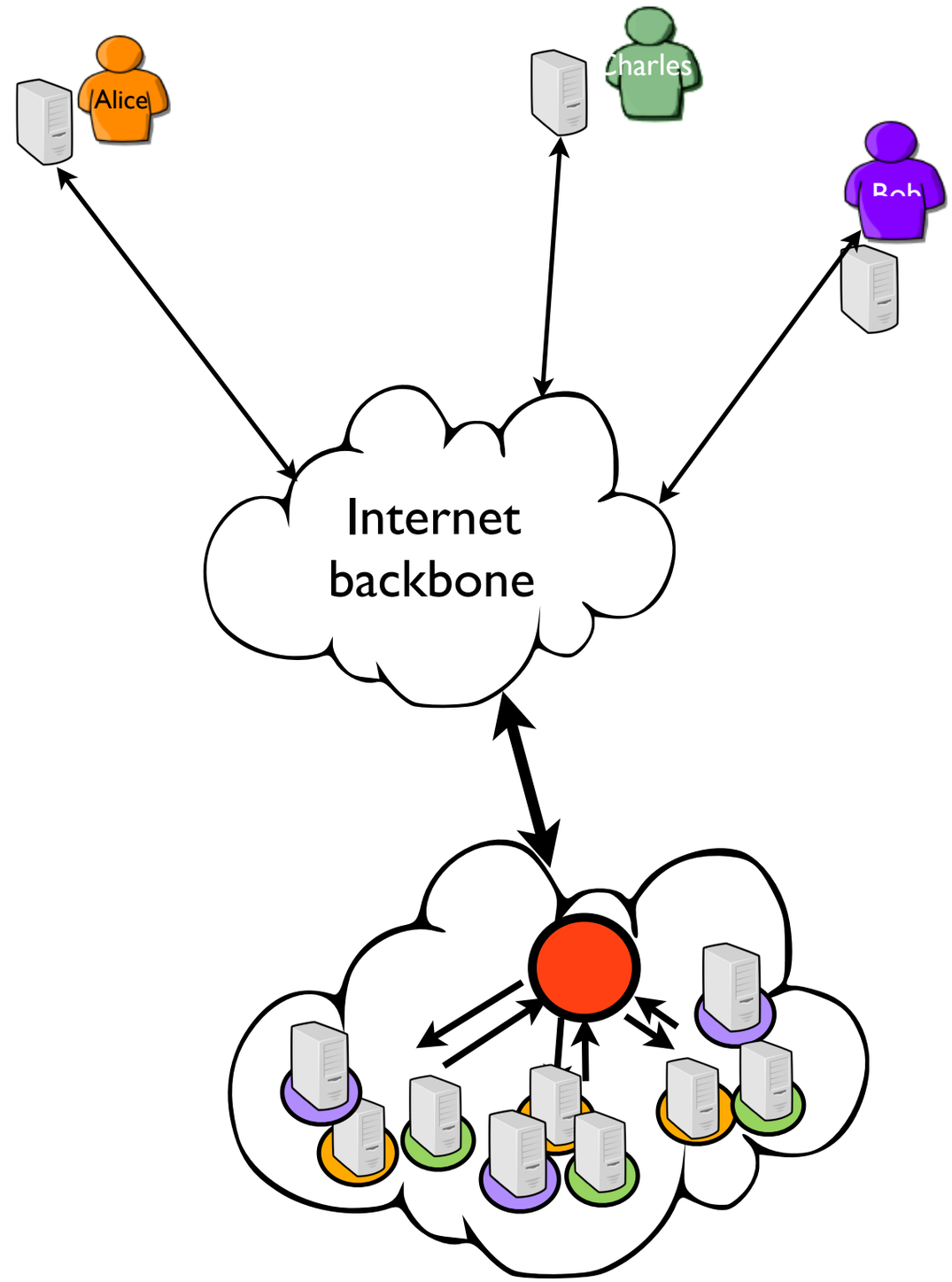

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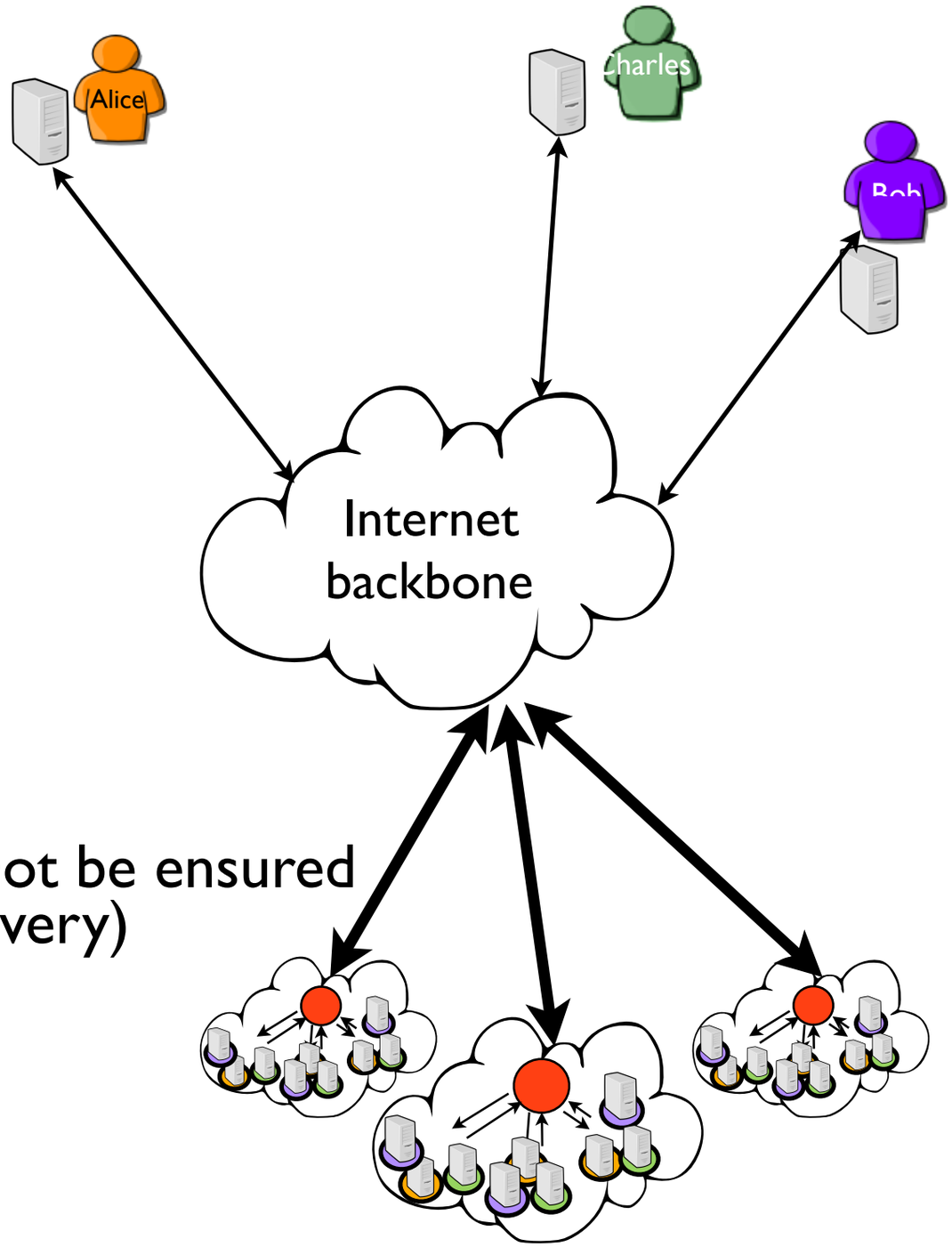

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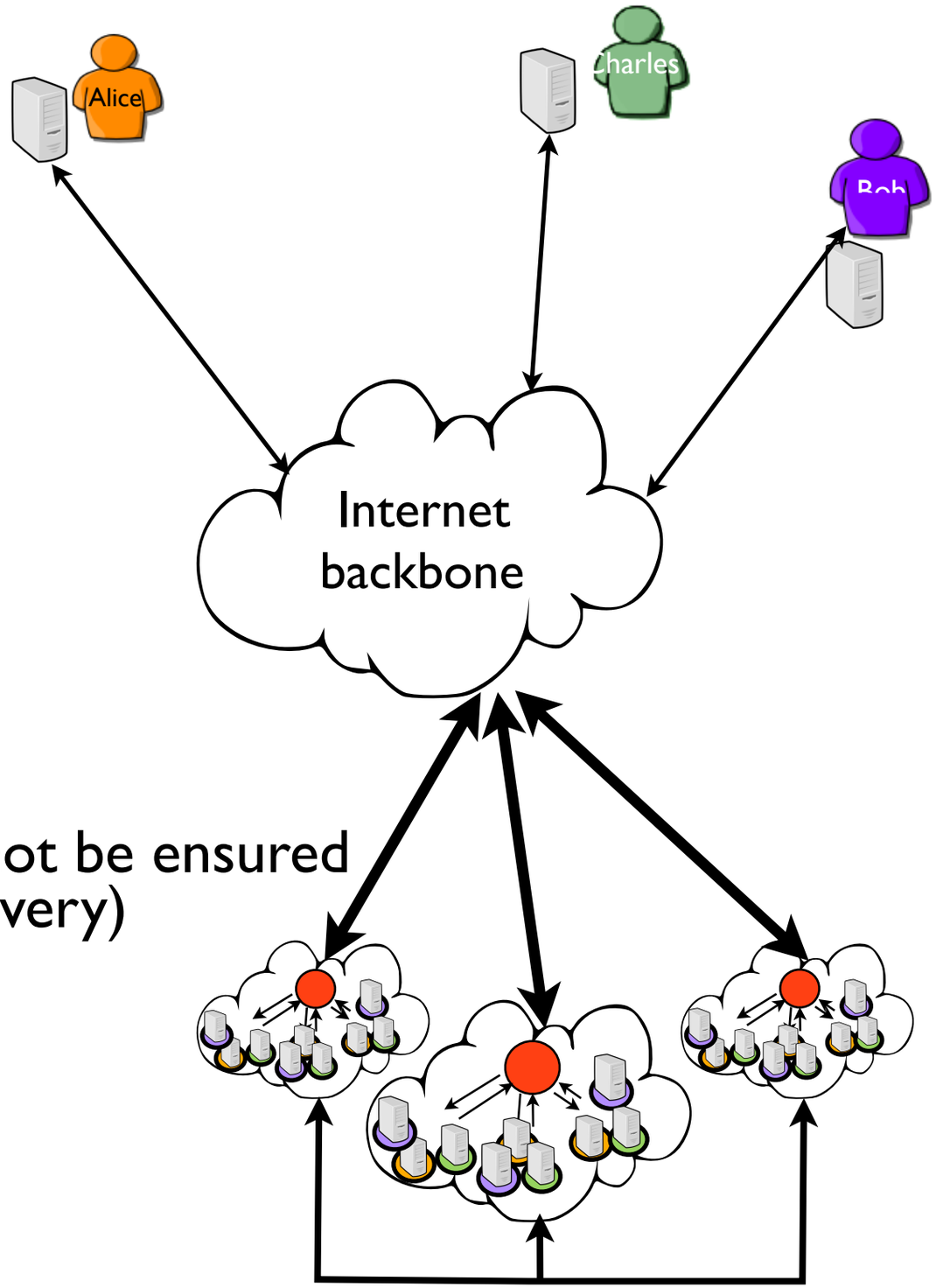

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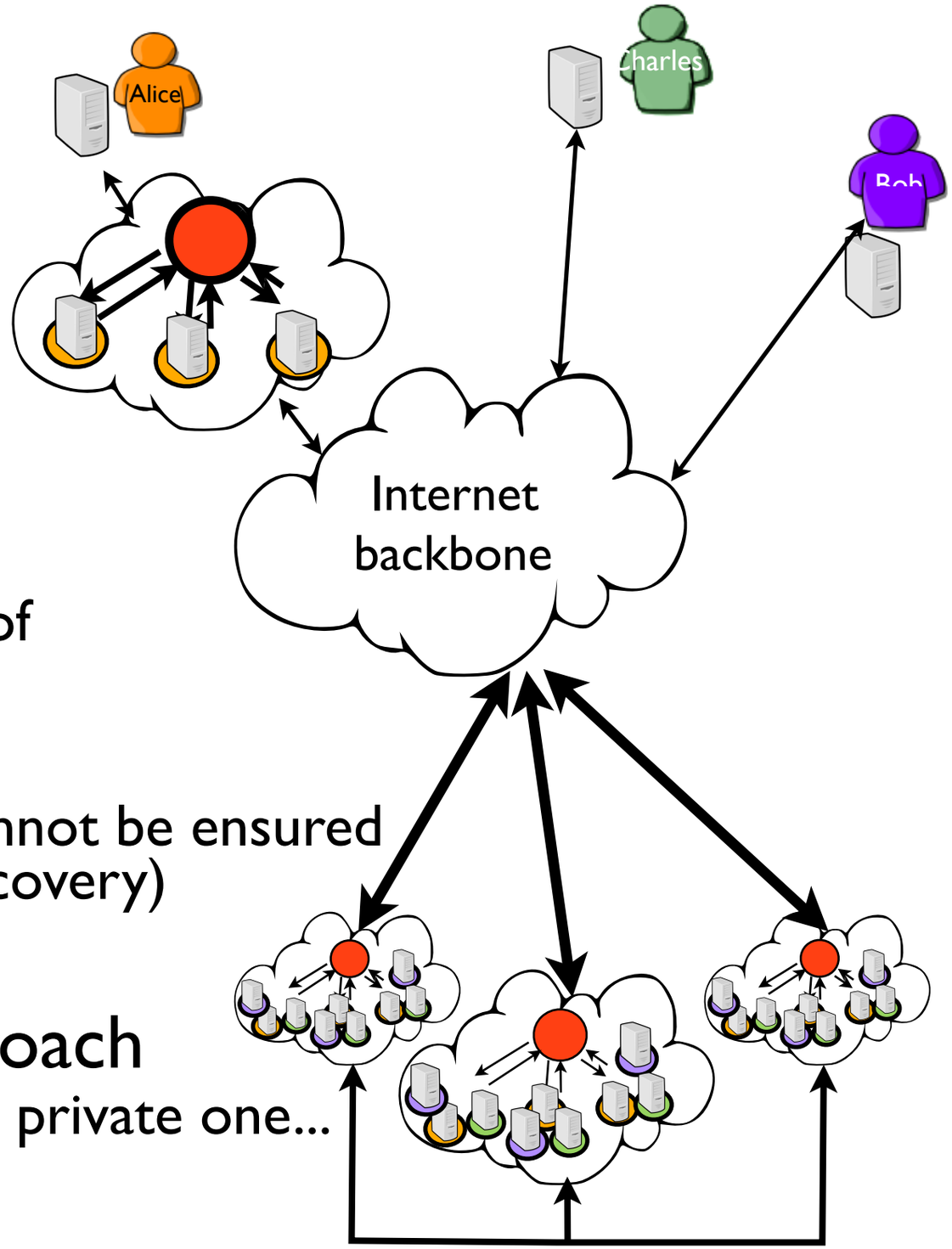

- Hybrid platforms: a promising approach

  It depends how you are going to extend the private one...

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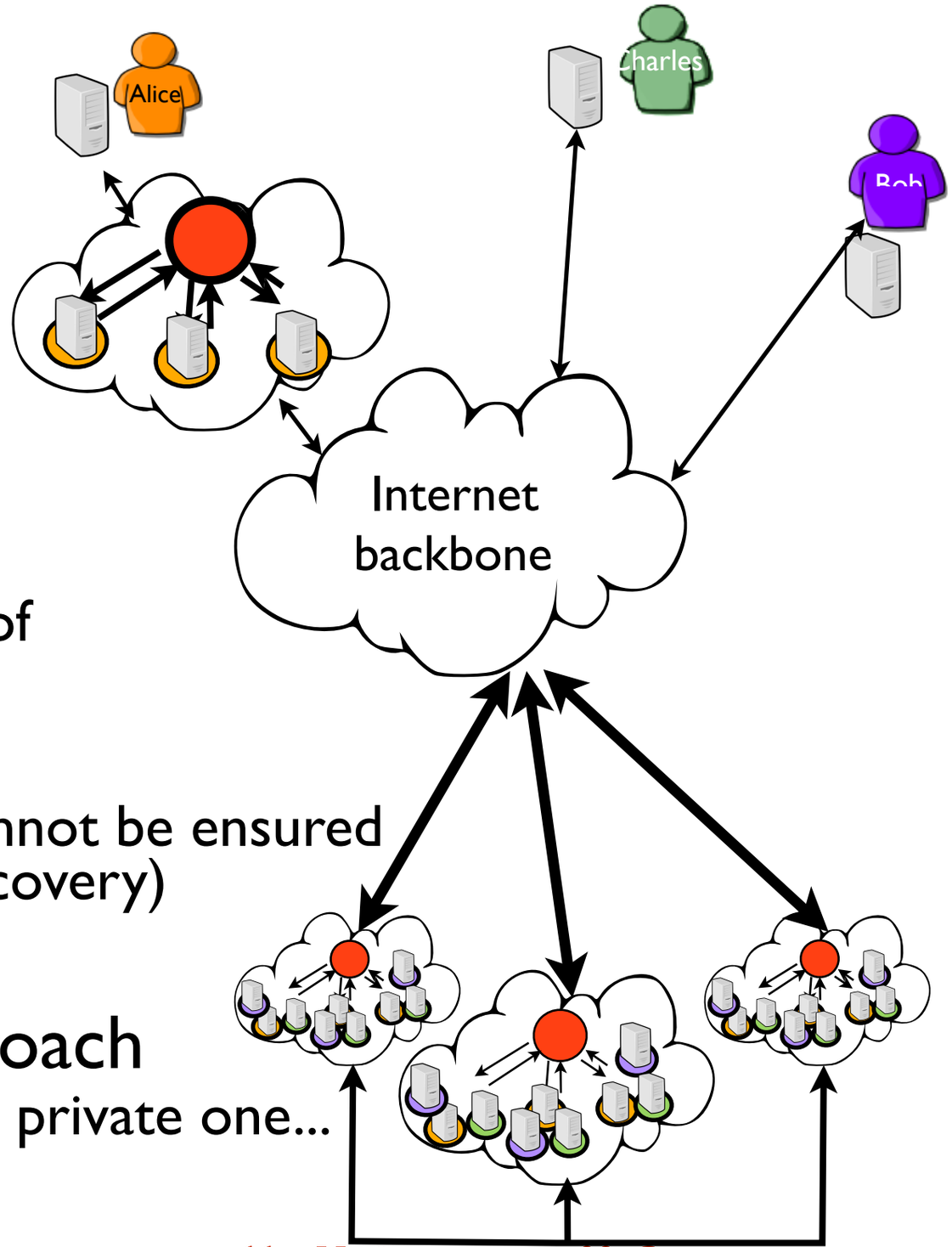


- Hybrid platforms: a promising approach
  It depends how you are going to extend the private one...

Is there a way to address these concerns "all in one" ?

Micro/Nano DCs

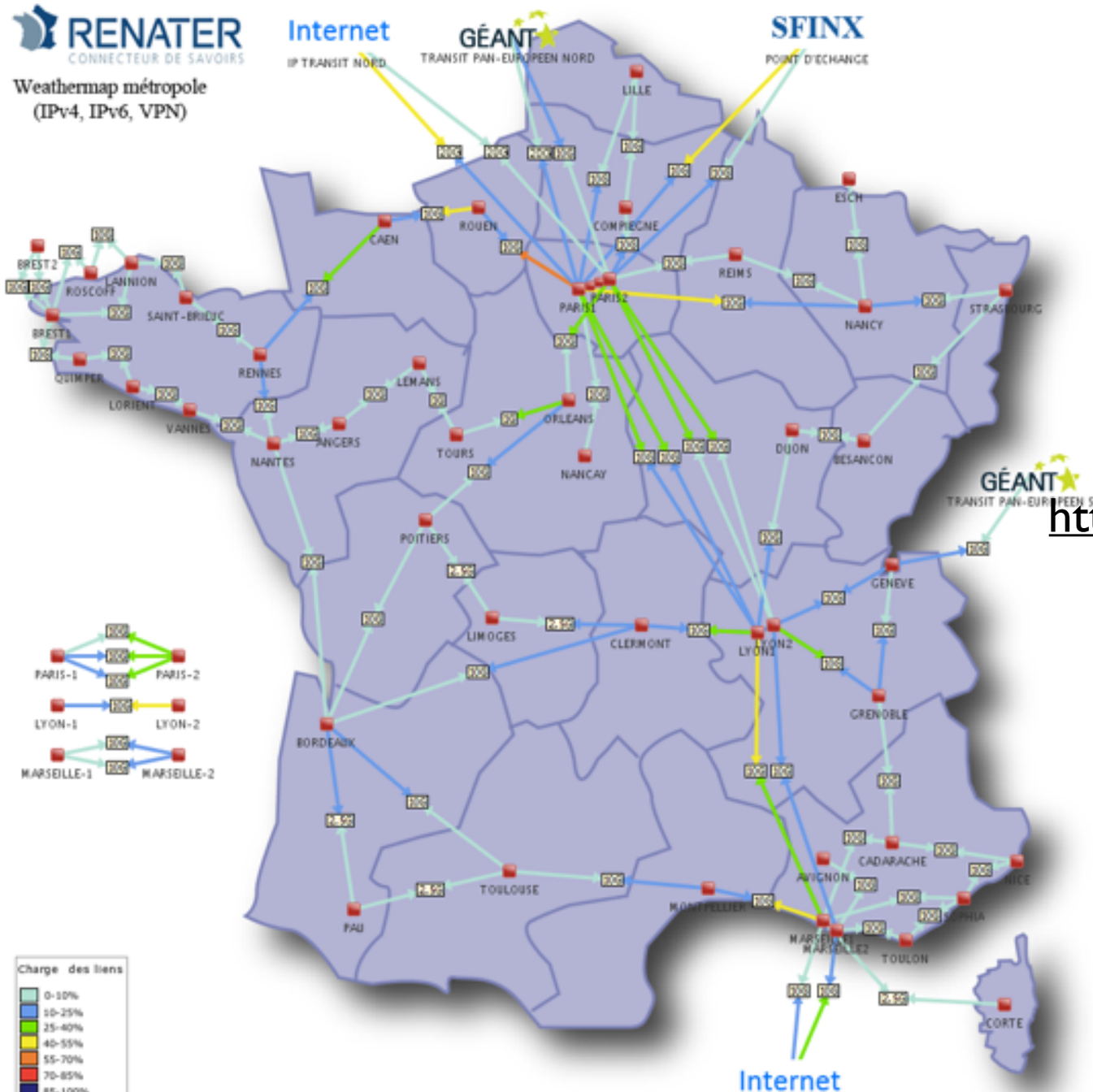
μDC at the edge !

How and where the μDC concept can be deployed ?

Beyond the Clouds…

- Locality-based UC infrastructures (aka. Fog/Edge)

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



http://www.renater.fr/raccourci?lang=fr

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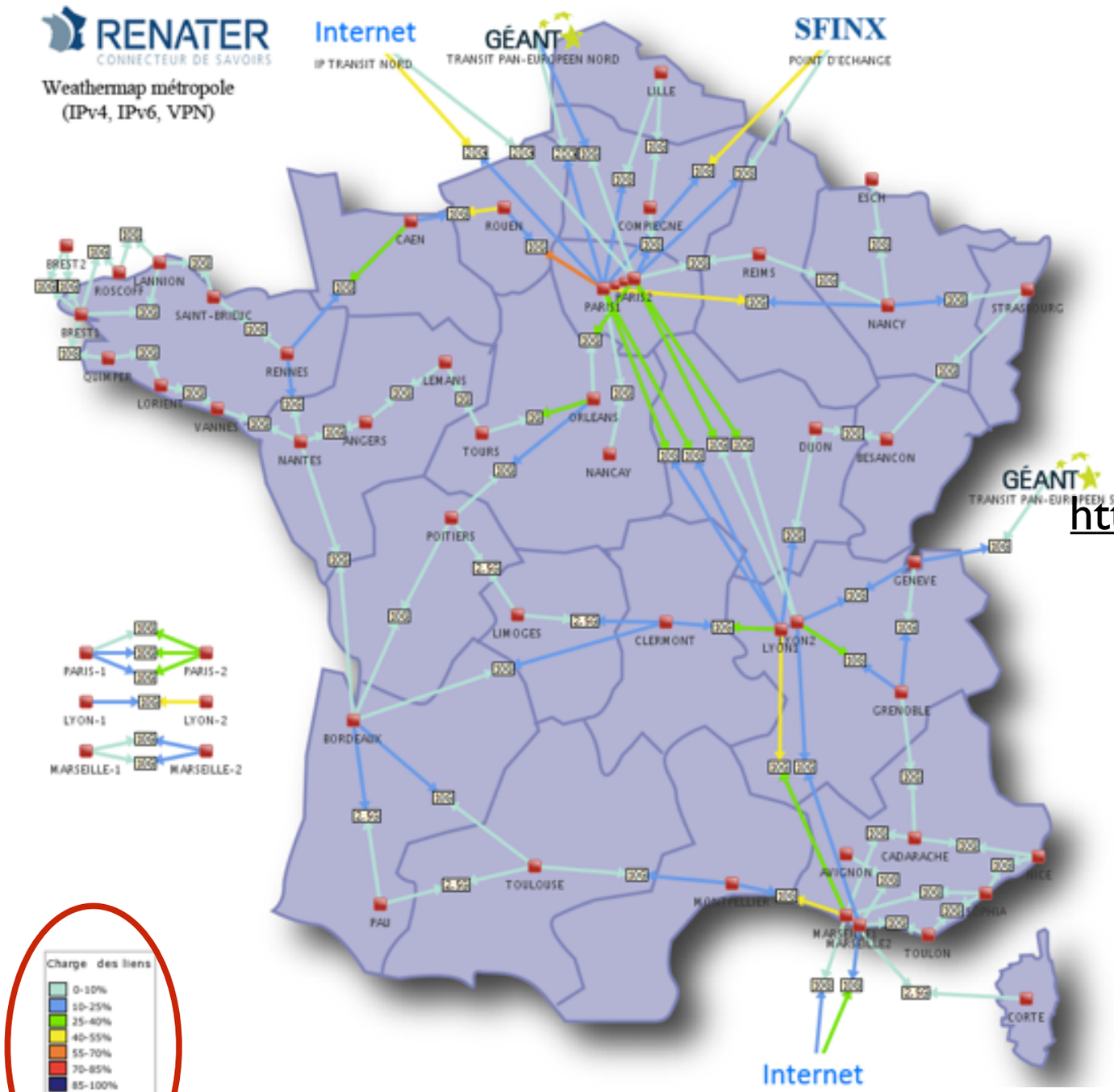

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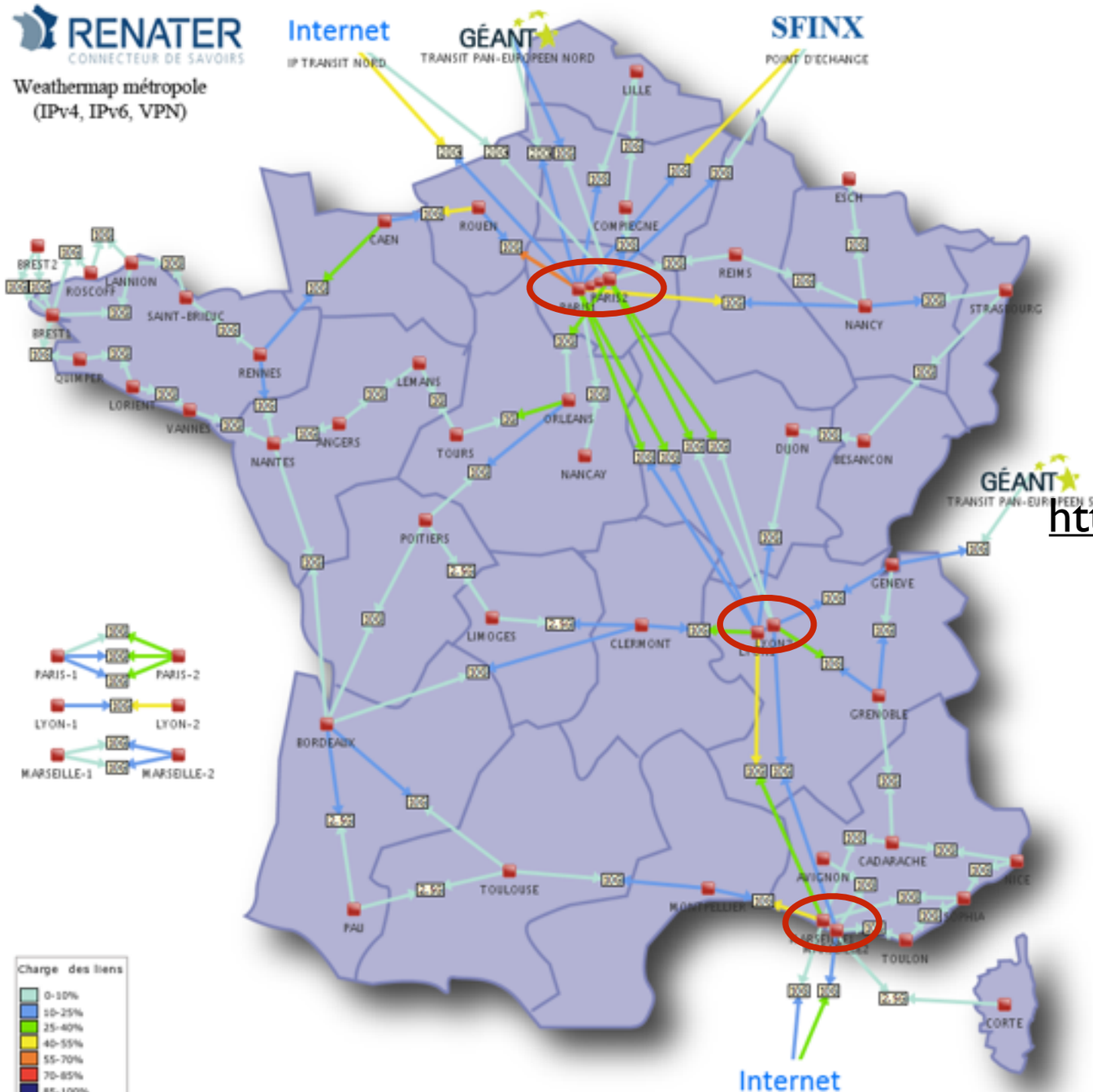

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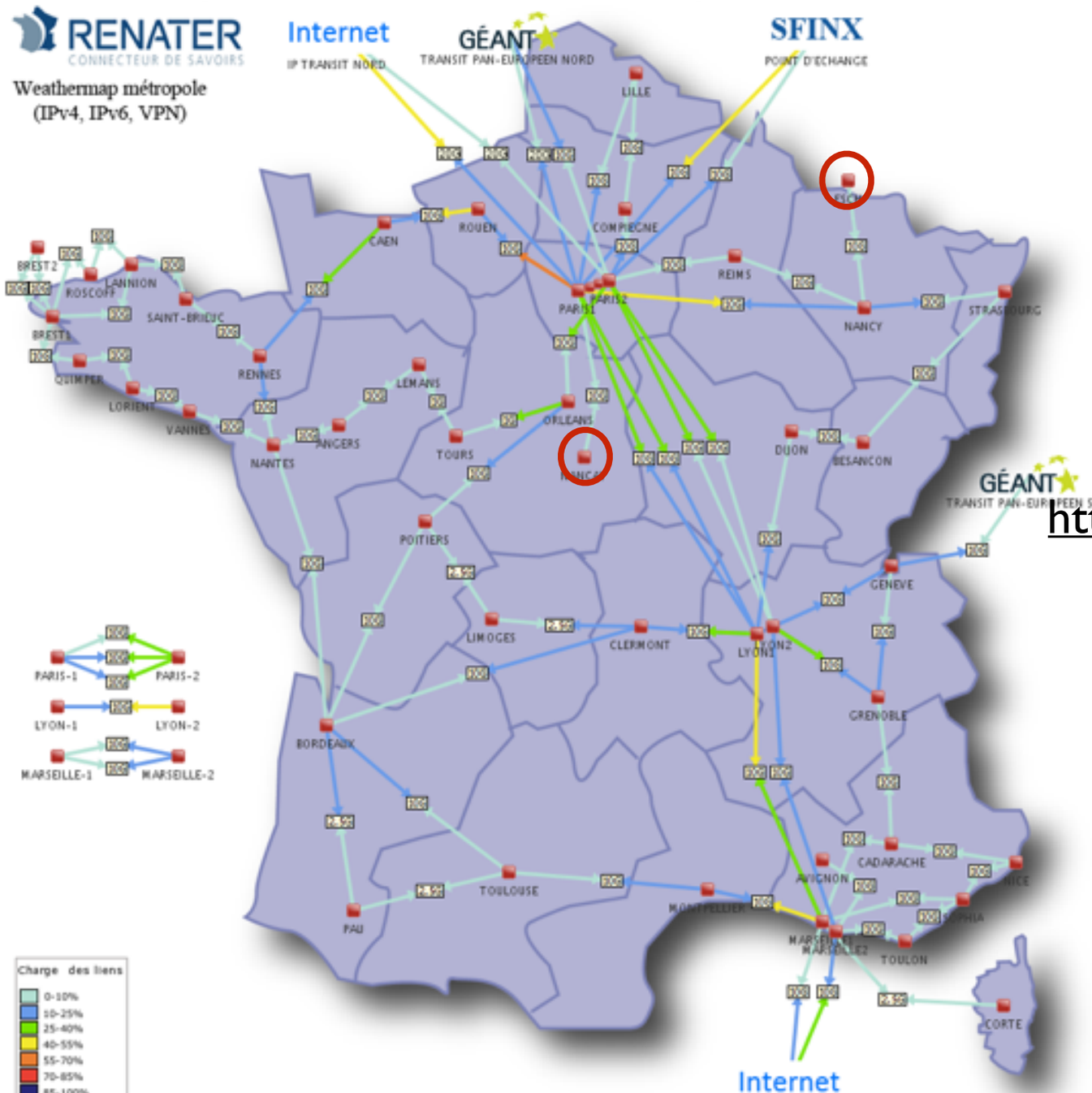

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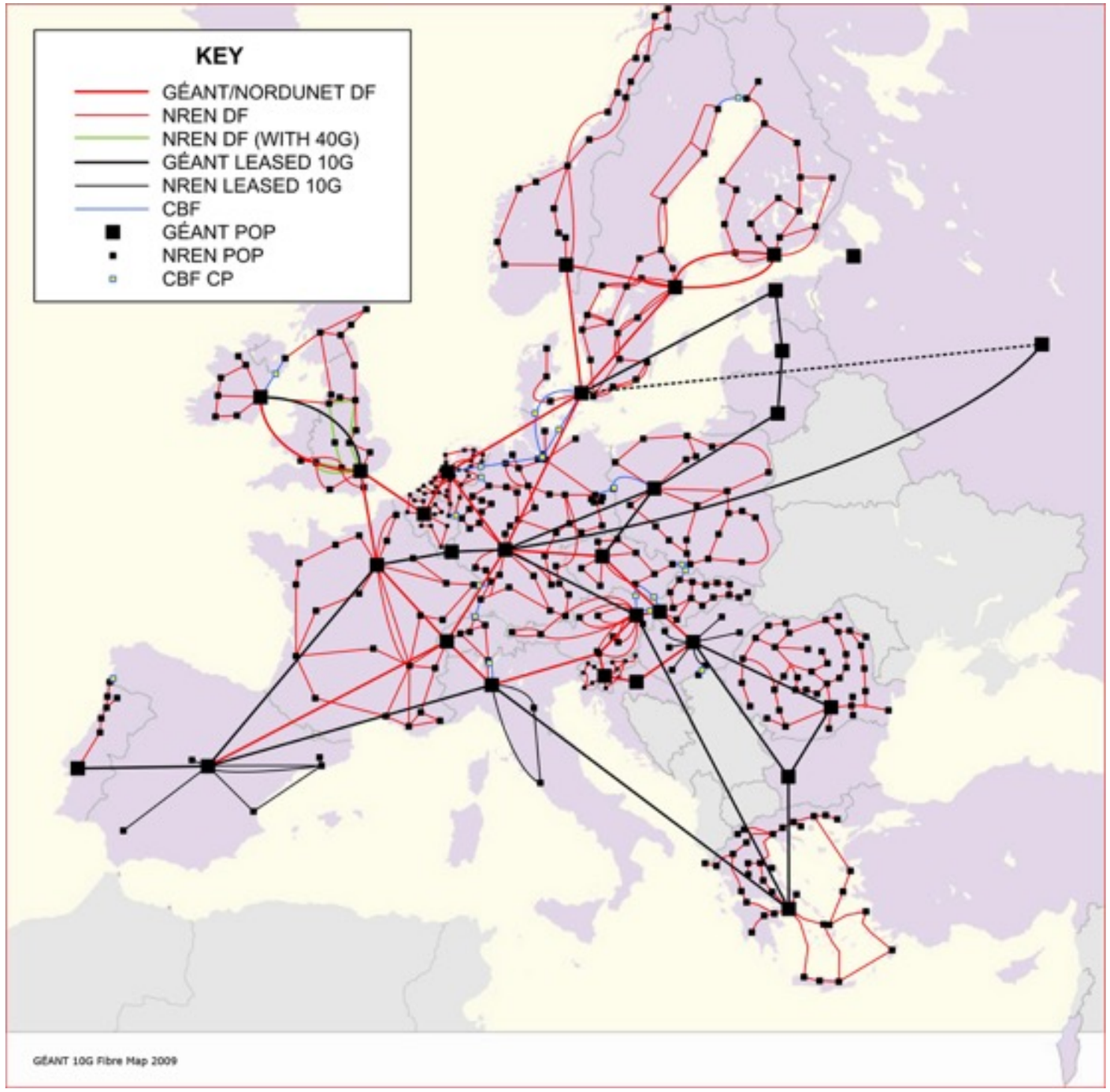
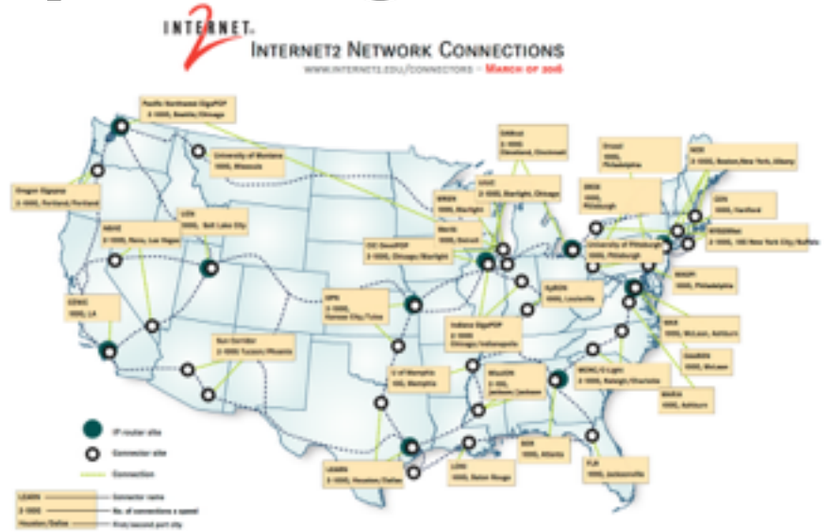


….The Fog/Edge Computing

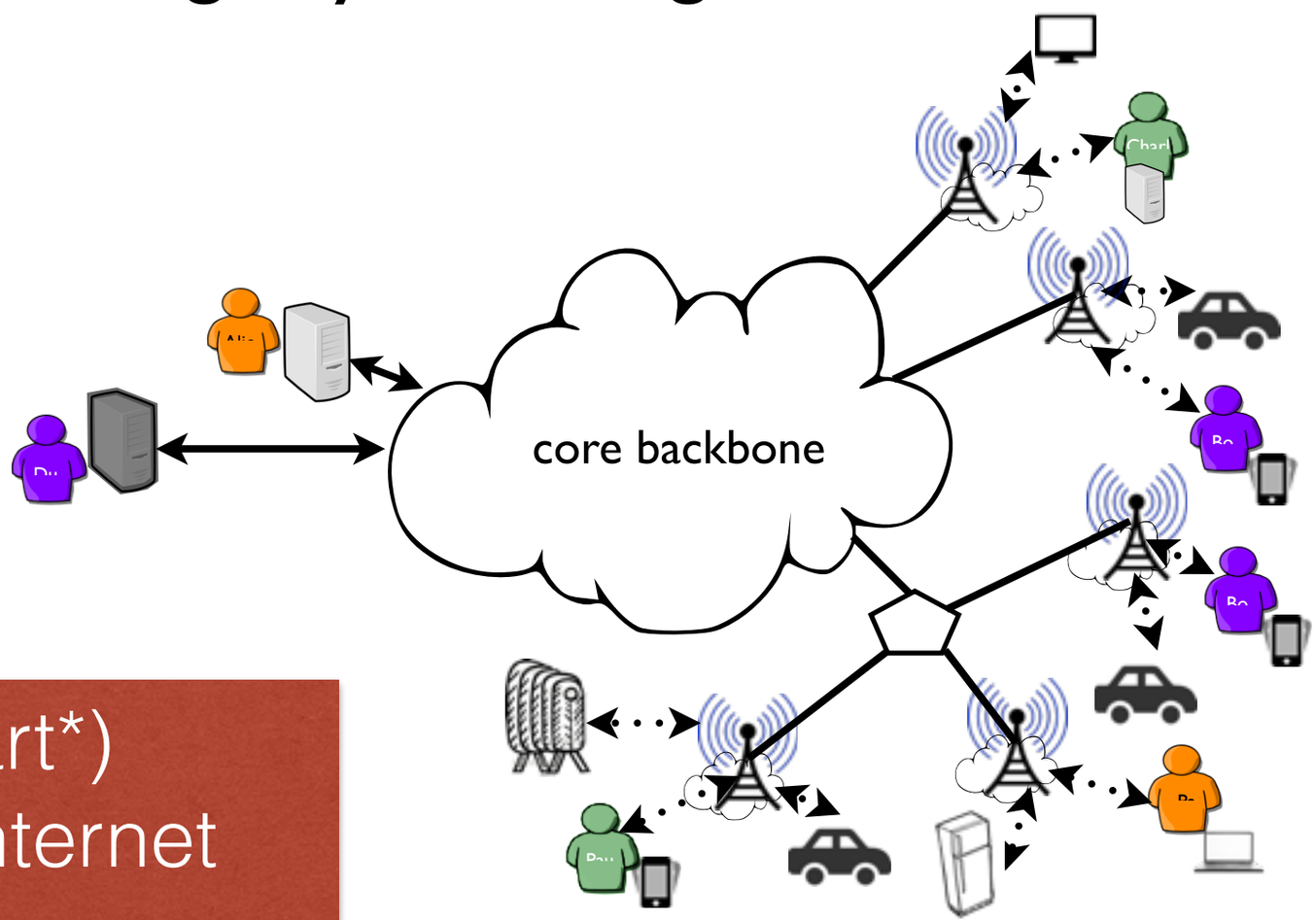
- Leverage network backbones

  Extend any point of presence of network backbones (aka PoP) with servers (from network hubs up to major DSLAMs that are operated by telecom companies, network institutions…).

- Extend to the edge by including wireless backbones



USA NREN



IoT (smart*)
Industrial Internet
NFV

Virtual Customer Premises Equipment

Classical Network Appliance Approach

Message Router

CDN

Session Border Controller

WAN Acceleration

DPI

Firewall

Carrier Grade NAT

Tester/QoE monitor

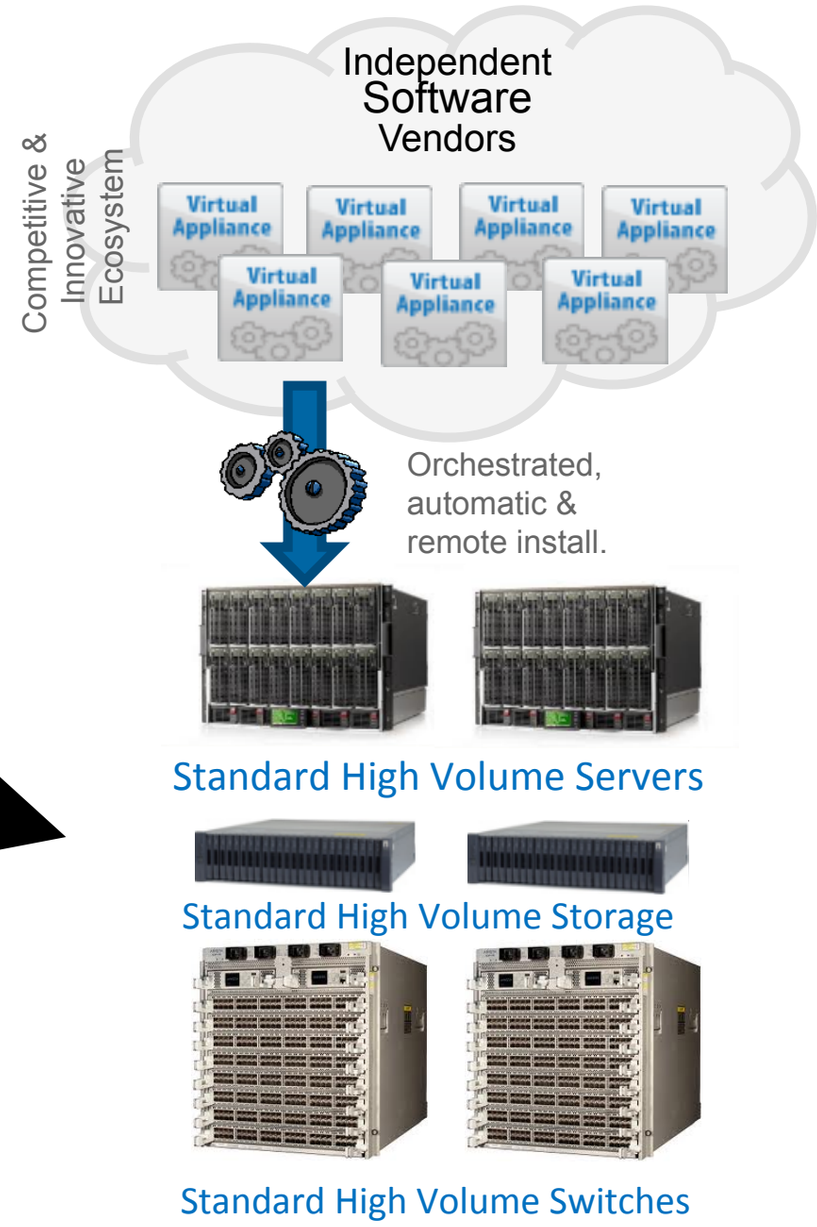
SGSN/GGSN

CE Router

Media Gateway

Radio Network Controller

Fragmented non-commodity hardware.
Physical install per appliance per site.
Hardware development large barrier to entry for new vendors constraining innovation & competition.



Network *functions* Virtualisation Approach

credits: P.Willis, BT, July 2016, Discovery Plenary meeting

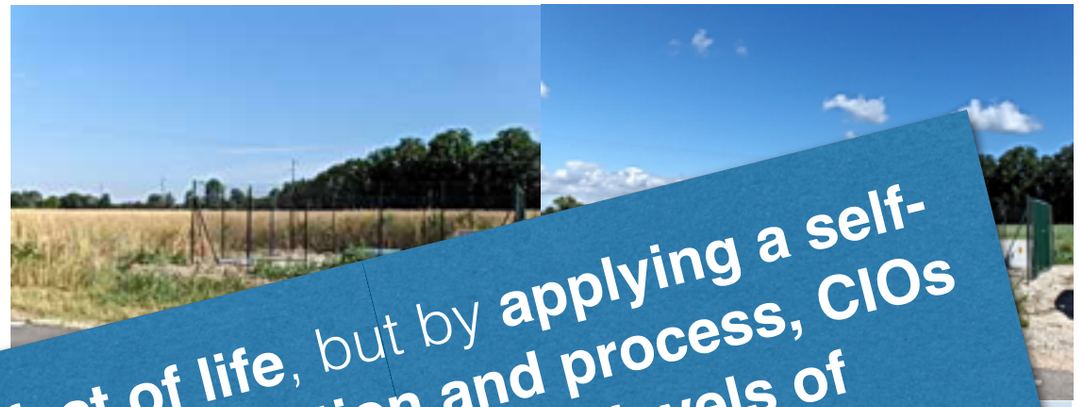
Micro/Nano DCs

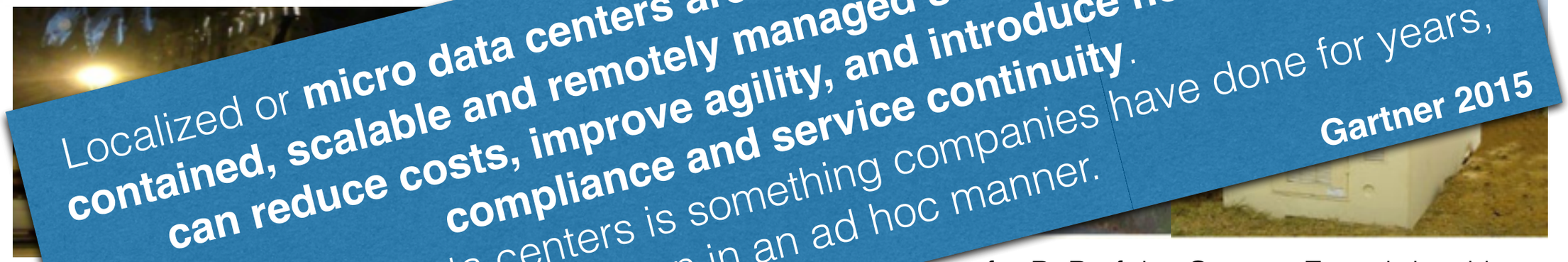
Sagrada Familia microDC
(Barcelona, Spain)

Deployment of a PoP of the Orange French backbone

MDC Industry - Brazil

Micro/Nano DCs





Localized or **micro data centers are a fact of life**, but by **applying a self-contained, scalable and remotely managed solution and process, CIOs can reduce costs, improve agility, and introduce new levels of compliance and service continuity**.

Creating micro data centers is something companies have done for years, but often in an ad hoc manner.

Gartner 2015

ployment of a PoP of the Orange French backbone

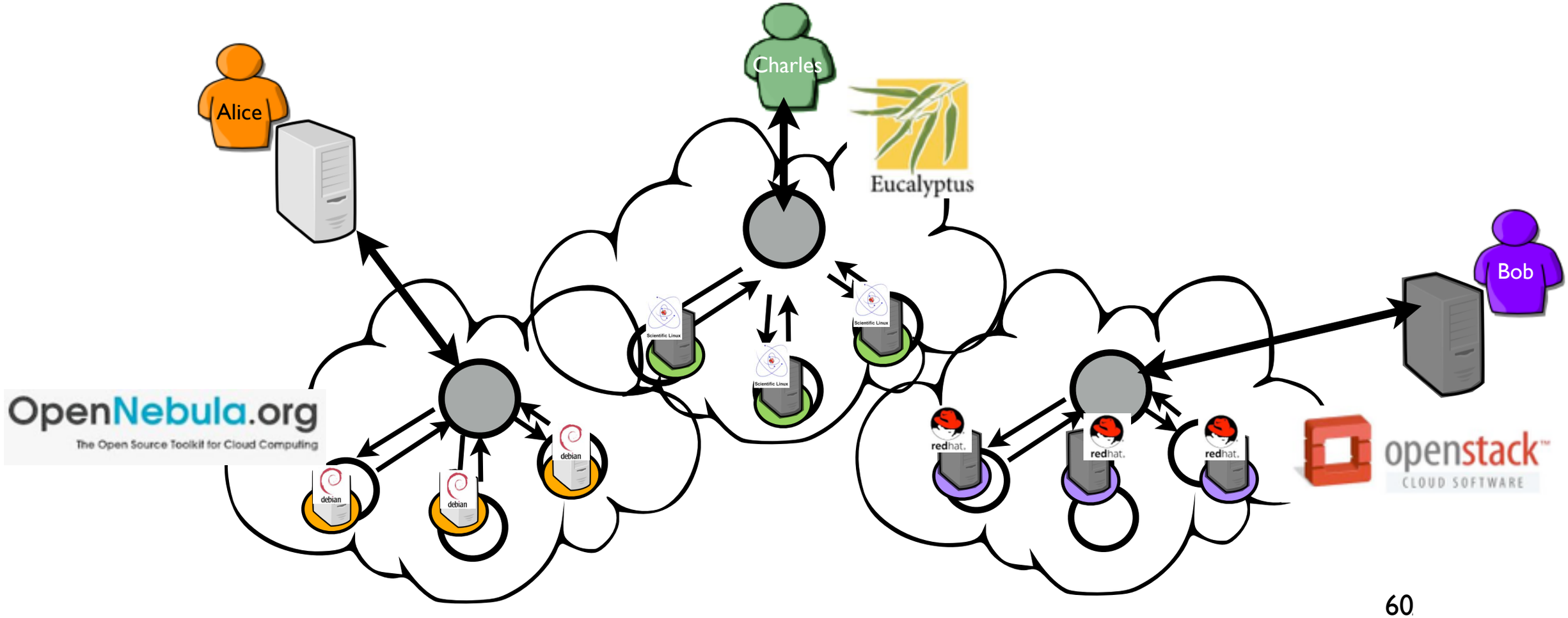
Sagrada Familia microDC
(Barcelona, Spain)

MDC Industry - Brazil

A broker ?

- “federation of clouds” (sky computing,)

  Sporadic (hybrid computing/cloud bursting) almost ready for production
  While standards are coming (OCCI, OVF, ….), current brokers are rather limited



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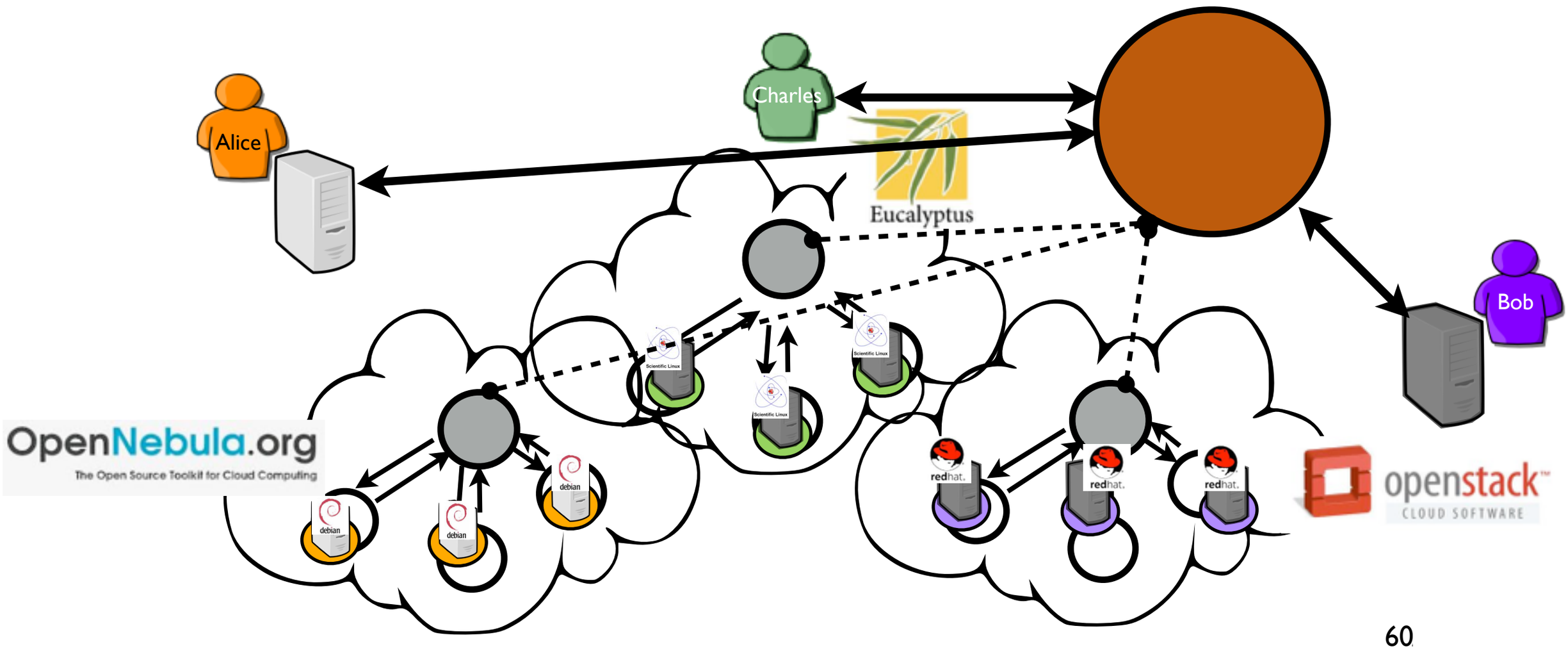

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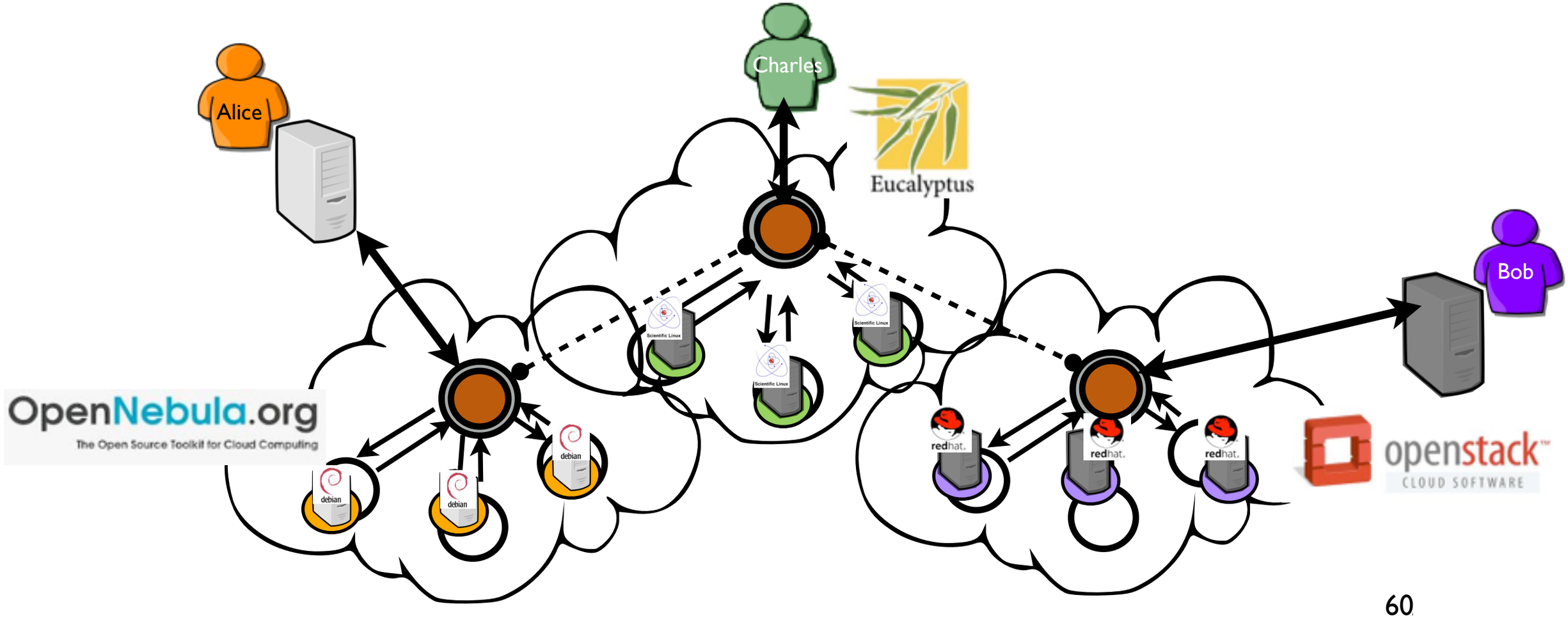

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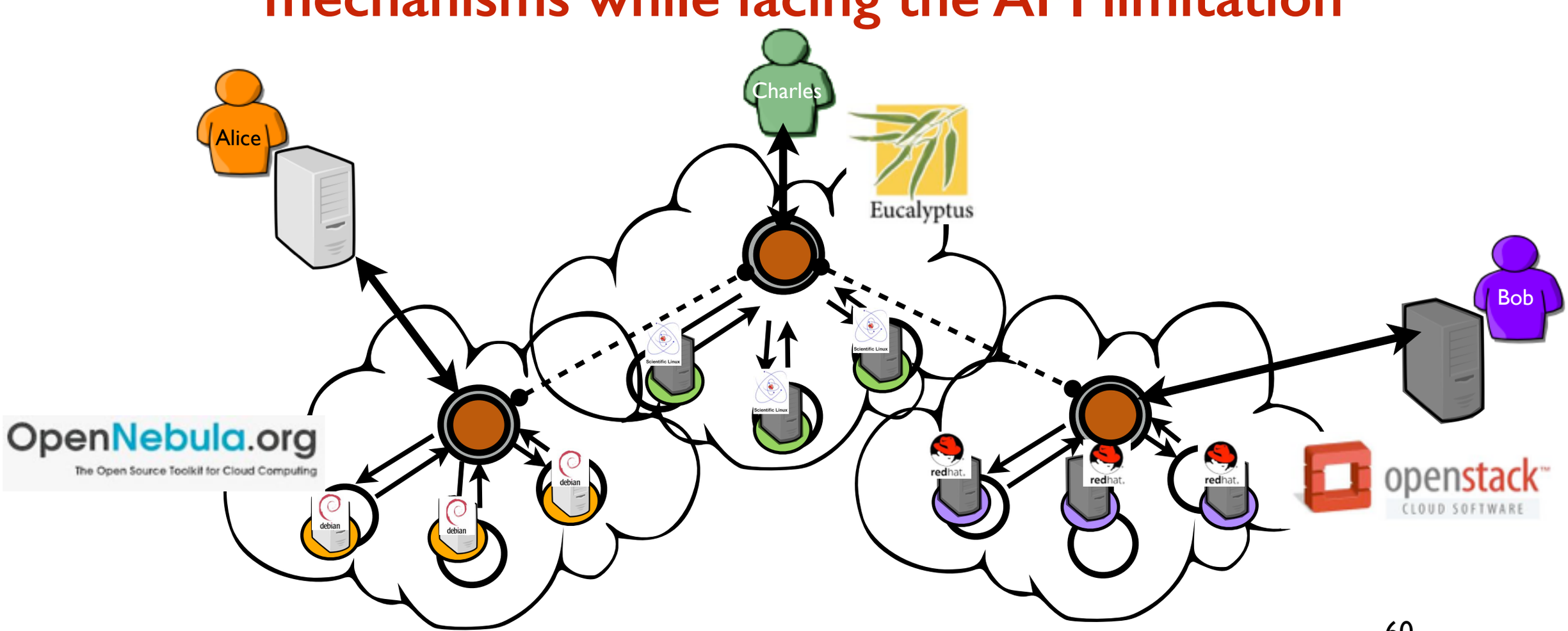
Advanced brokers must reimplement standard IaaS mechanisms while facing the API limitation



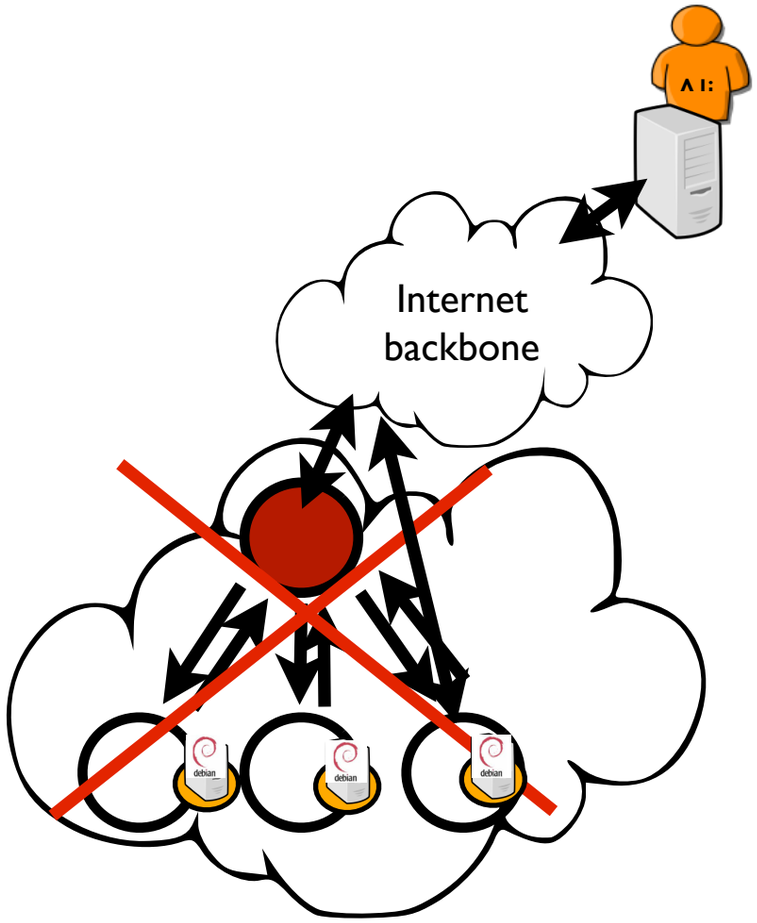
The DISCOVERY Proposal

- DIStributed and COoperative framework to manage Virtual EnviRonments autonomously

orange™ Orange Labs

Inria
INVENTORS FOR THE DIGITAL WORLD

Do you Want more ! Visit
http://beyondtheclouds.github.io



The DISCOVERY Proposal

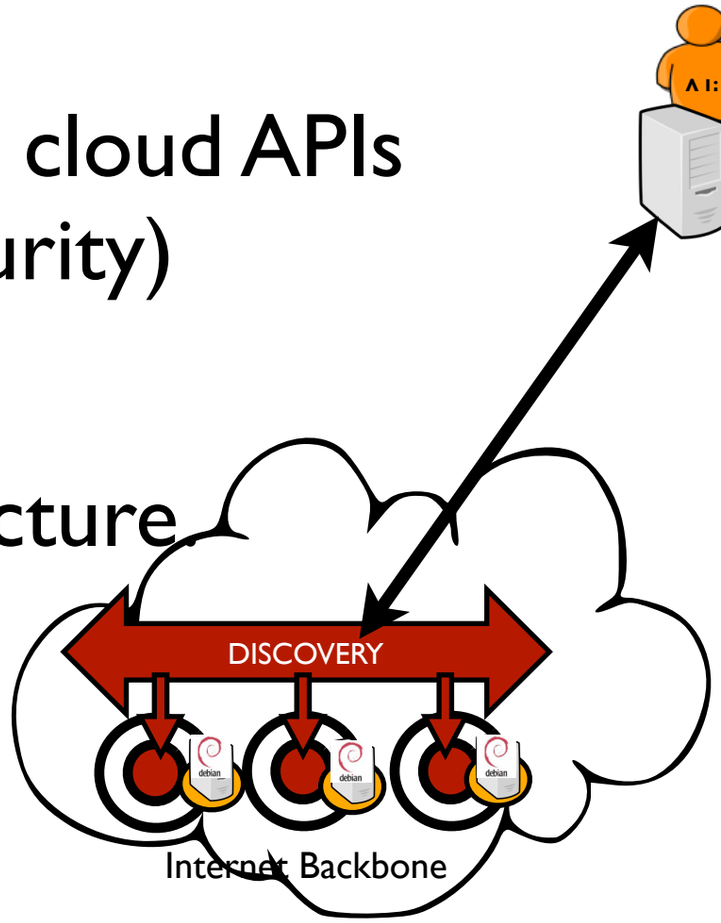
- DIStributed and COoperative framework to manage Virtual EnviRonments autonomously

- A fully distributed IaaS system and not a distributed system of IaaS systemS

We want to/must go further than high level cloud APIs (cross-cutting concerns such as energy/security)

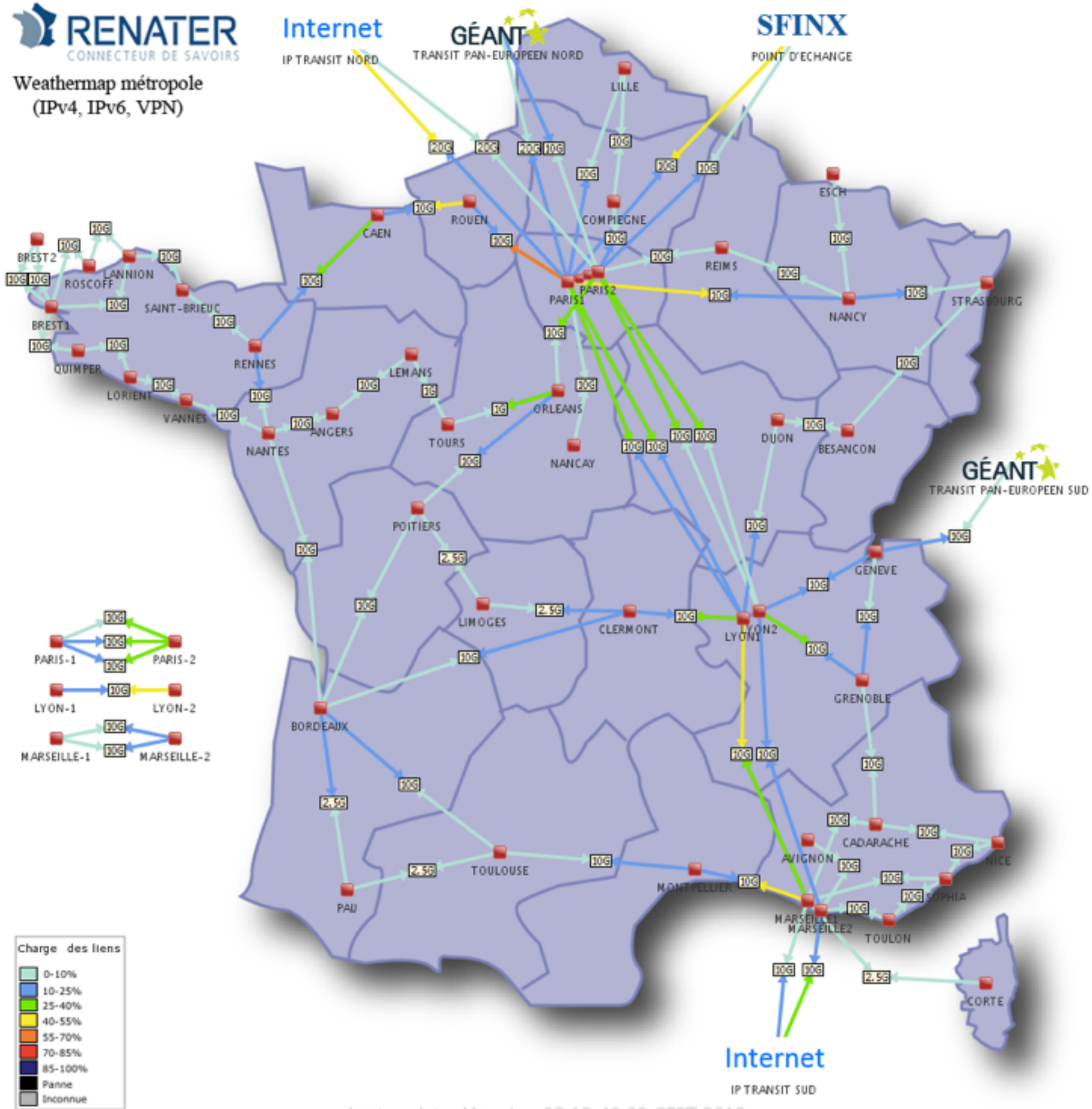
- Leverage P2P algorithms and self-* approaches to operate a LUC infrastructure.

Do you Want more ! Visit http://beyondtheclouds.github.io



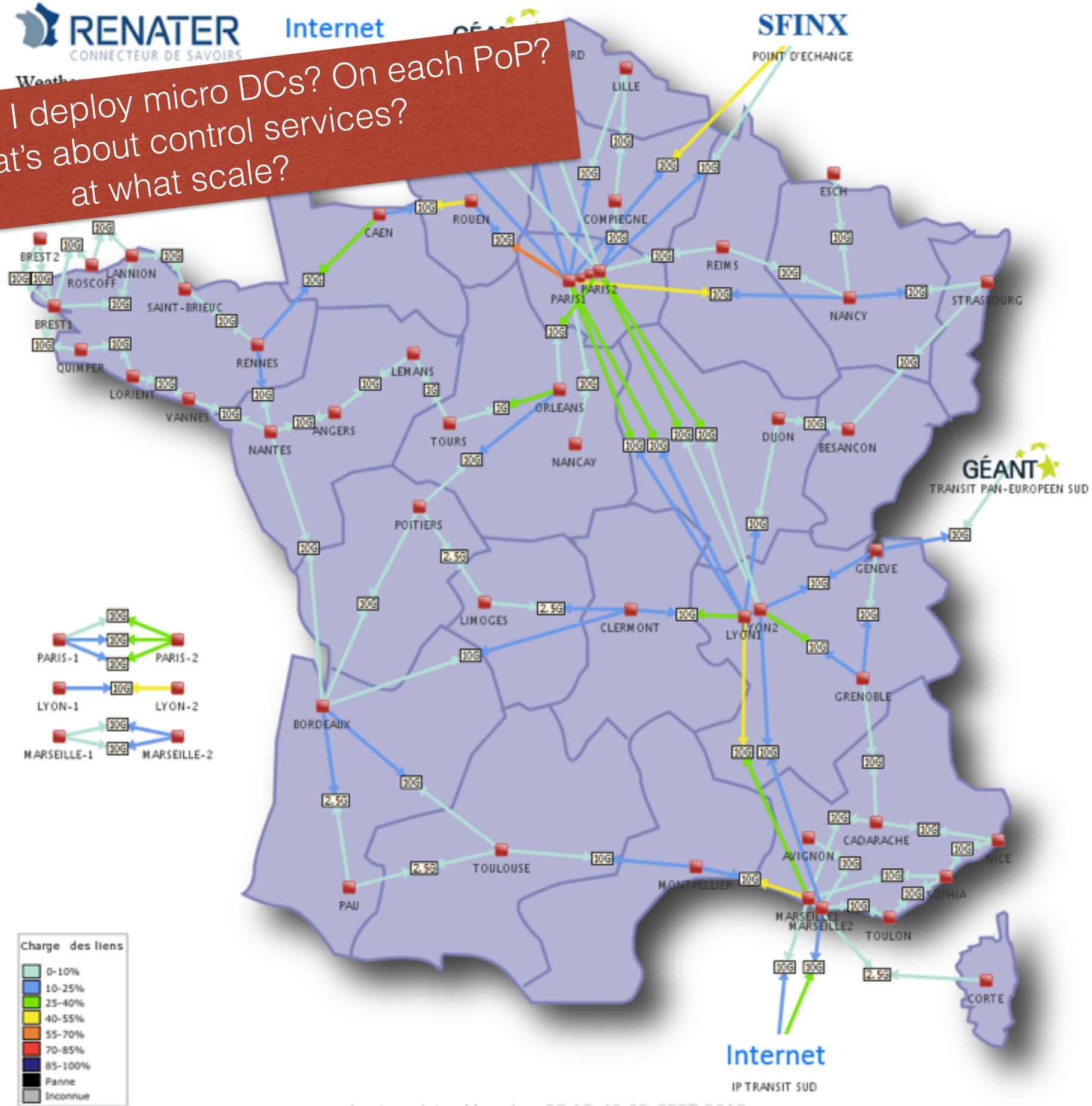
RENATER
CONNECTEUR DE SAVOIRS

Weathermap métropole (IPv4, IPv6, VPN)



Last update: Mon Apr 08 13:49:02 CEST 2013

Where should I deploy micro DCs? On each PoP?
What's about control services?
at what scale?



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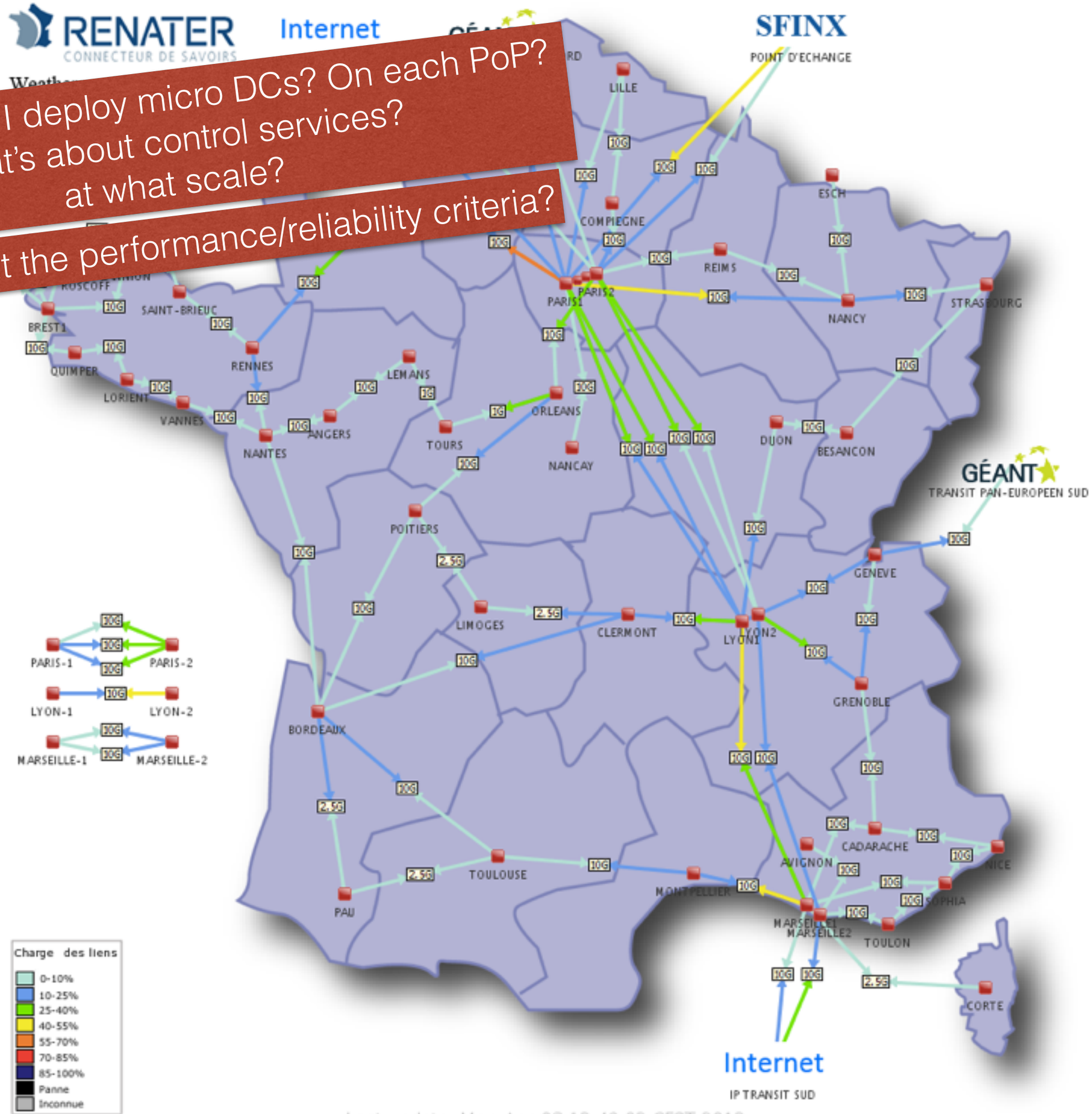

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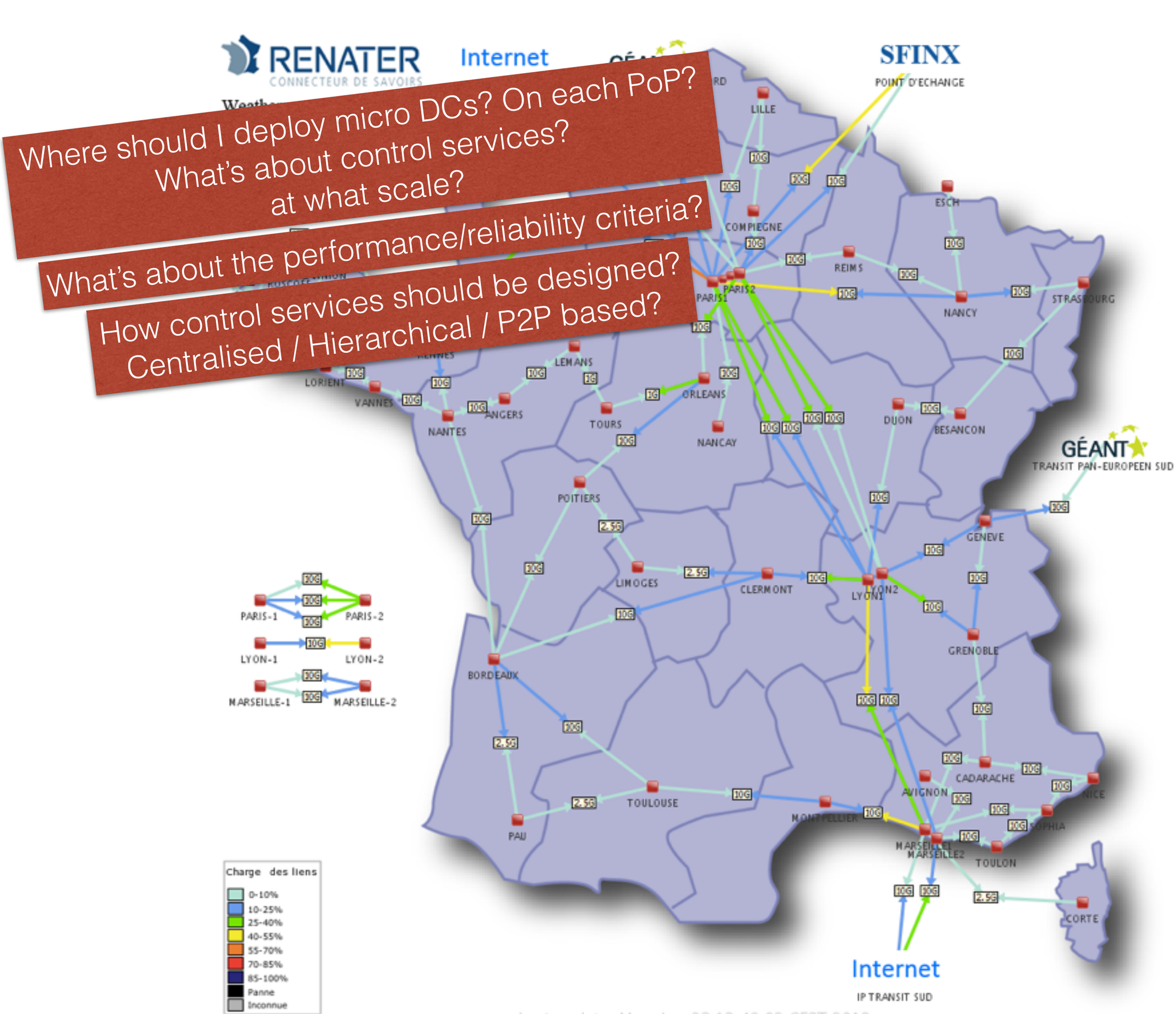

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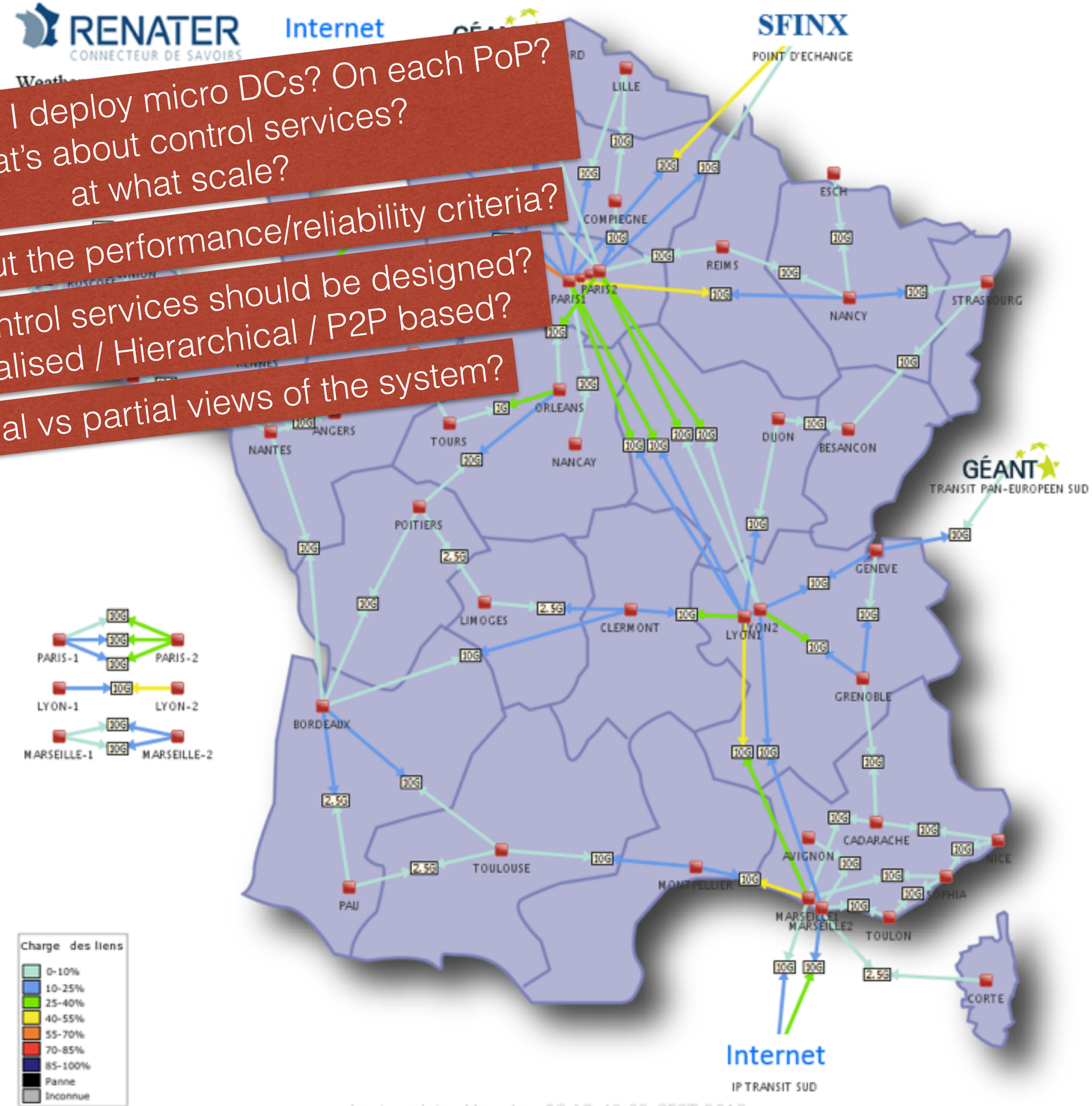

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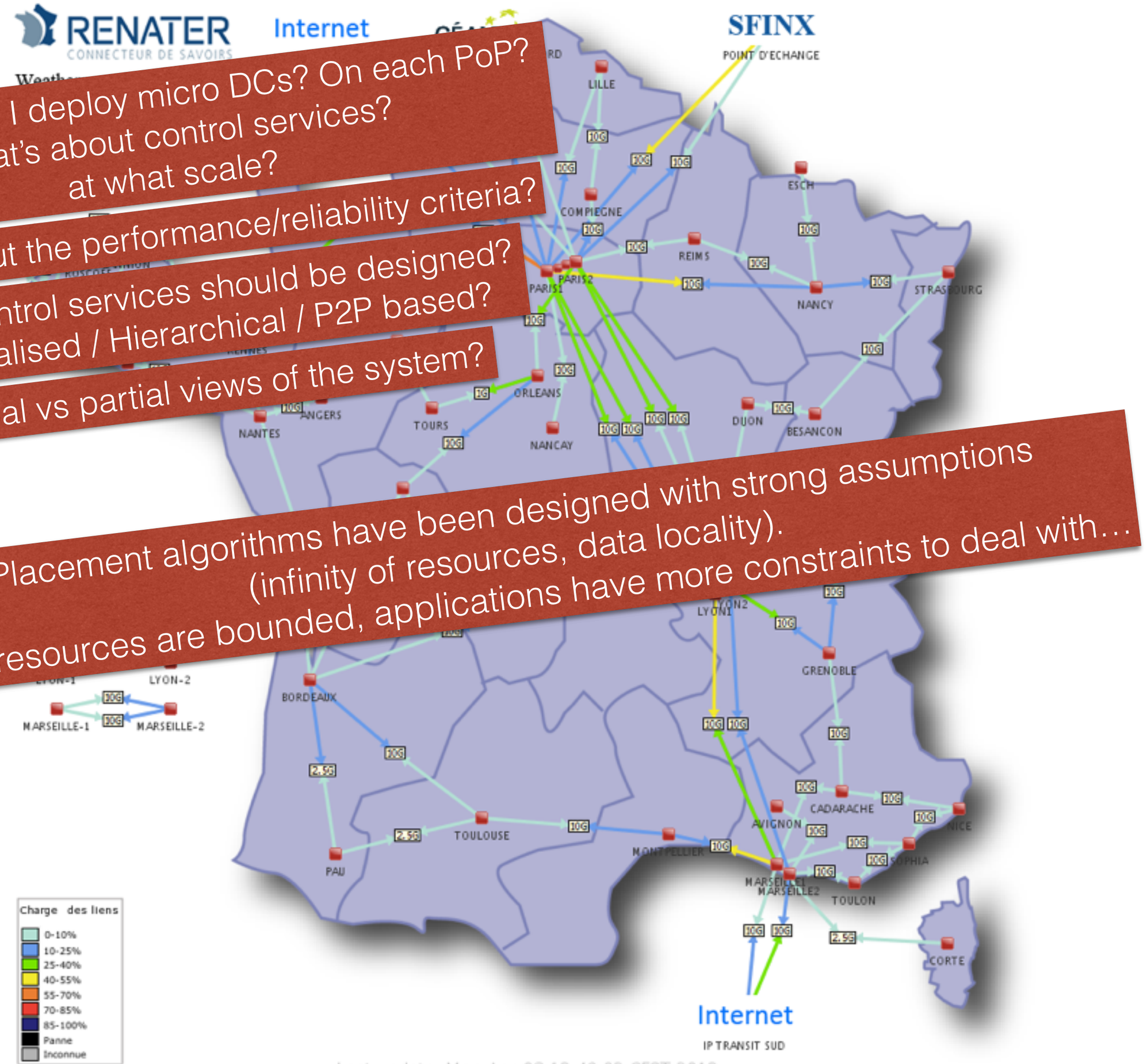

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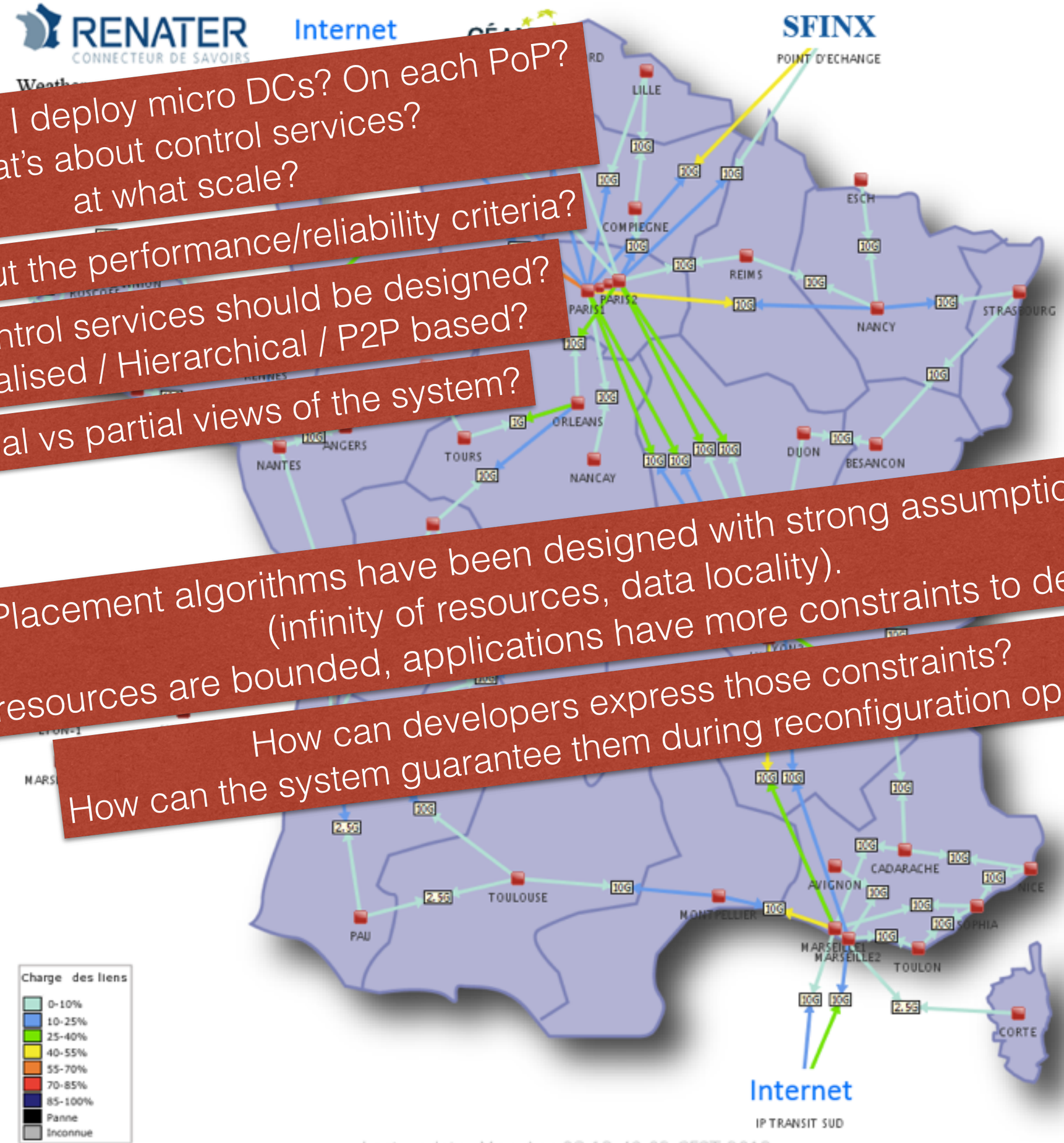

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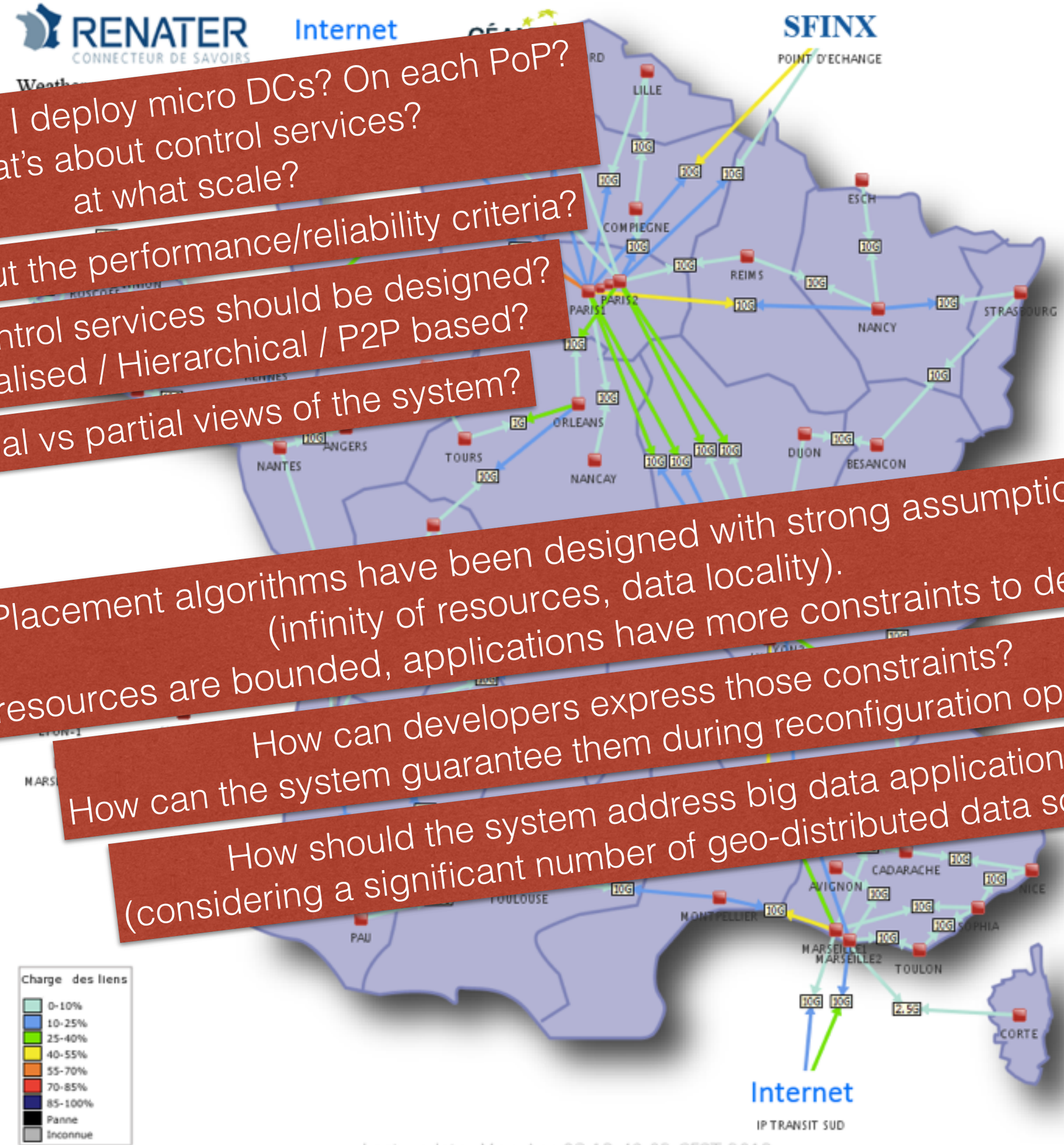

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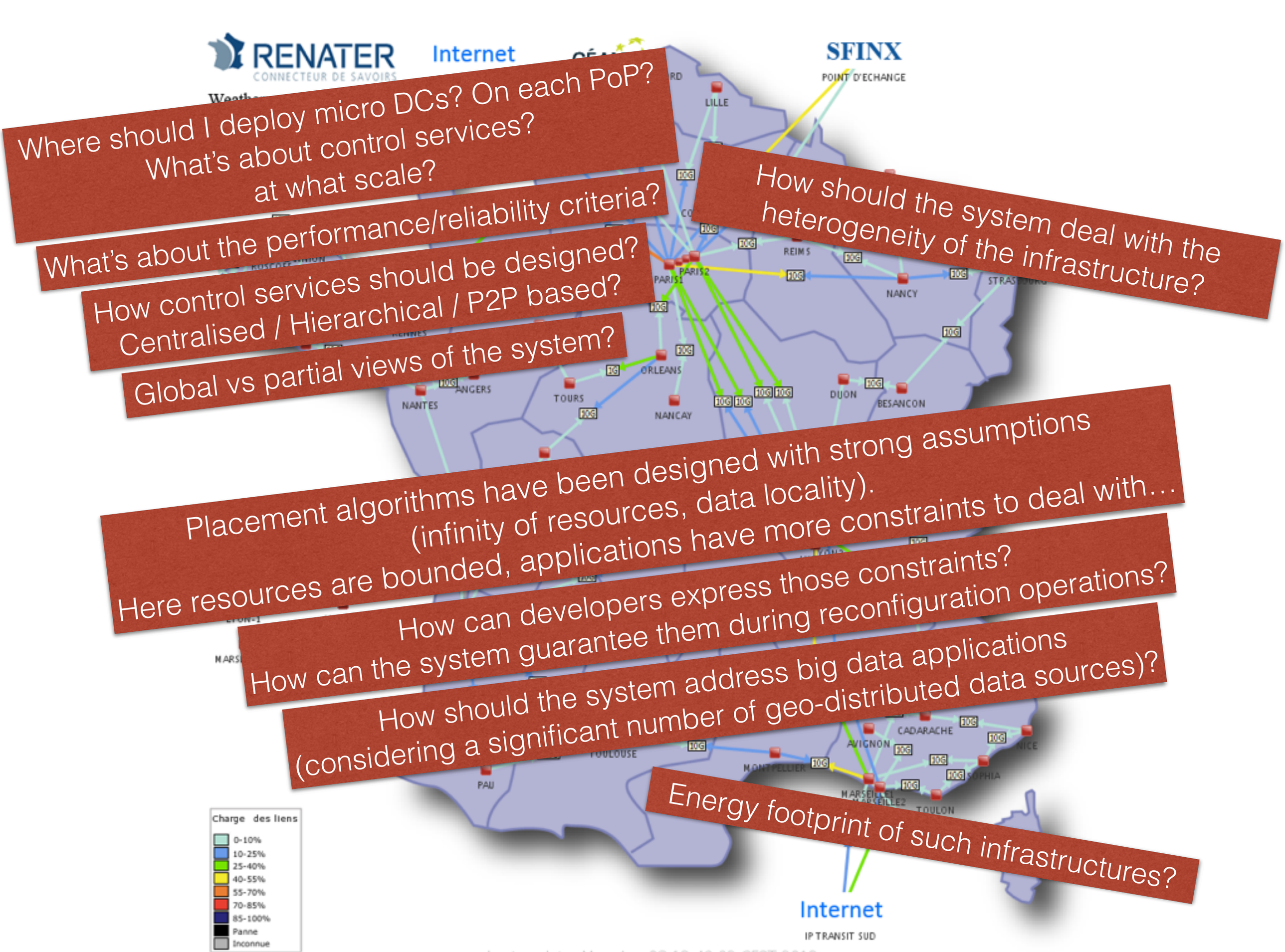

Where should I deploy micro DCs? On each PoP?
What's about control services?
at what scale?

What's about the performance/reliability criteria?

How control services should be designed?
Centralised / Hierarchical / P2P based?

Global vs partial views of the system?

How should the system deal with the heterogeneity of the infrastructure?

Placement algorithms have been designed with strong assumptions
(infinity of resources, data locality).
Here resources are bounded, applications have more constraints to deal with…

How can developers express those constraints?
How can the system guarantee them during reconfiguration operations?

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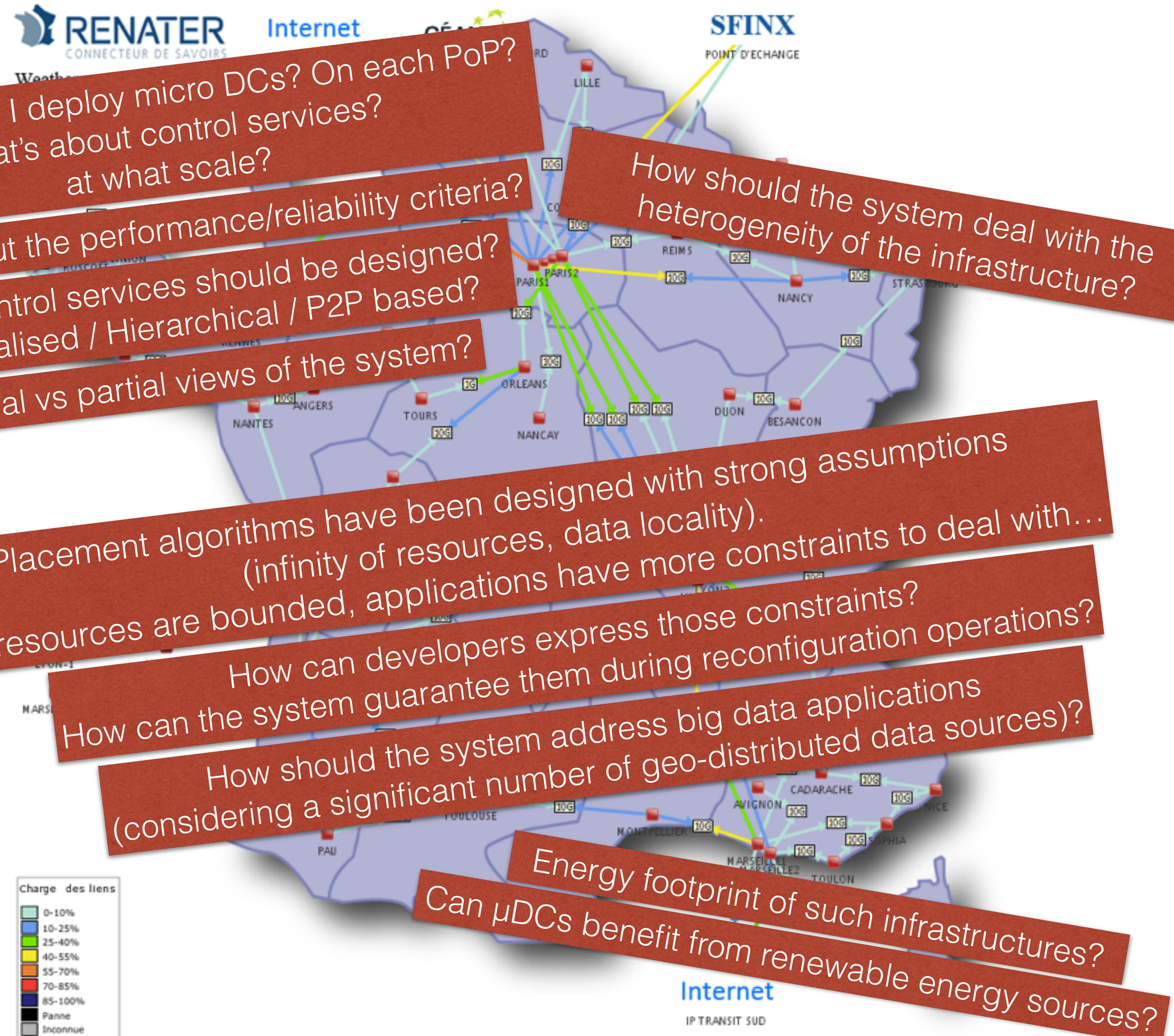
Can µDCs benefit from renewable energy sources?



STACK Proposal

- Designing a tightly-coupled software stack to operate and use massively geo-distributed ICT infrastructures.
- Delivering appropriate system abstractions, from low (system) to high-levels (applications), and by addressing cross cutting dimensions such as energy or security, to operate massively geo-distributed infrastructures

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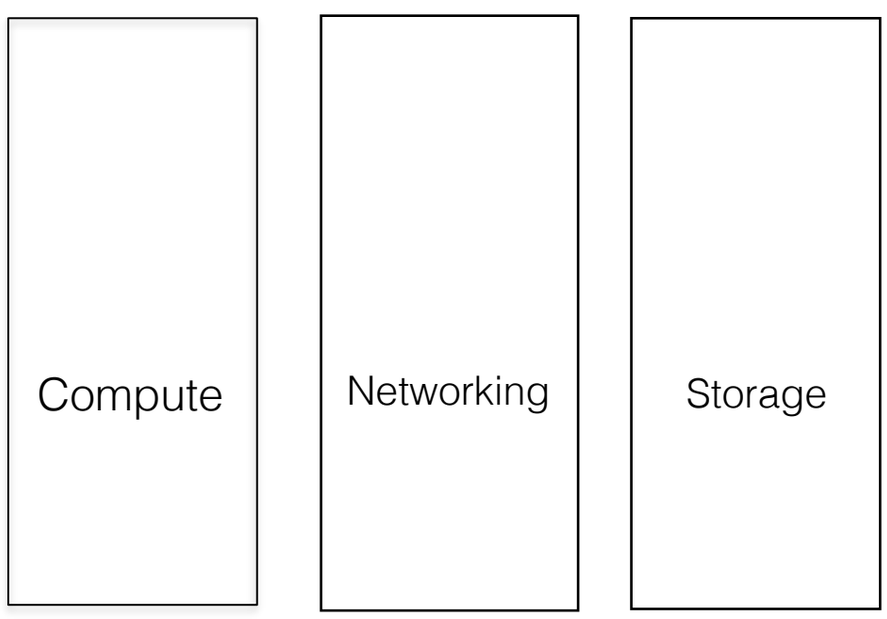

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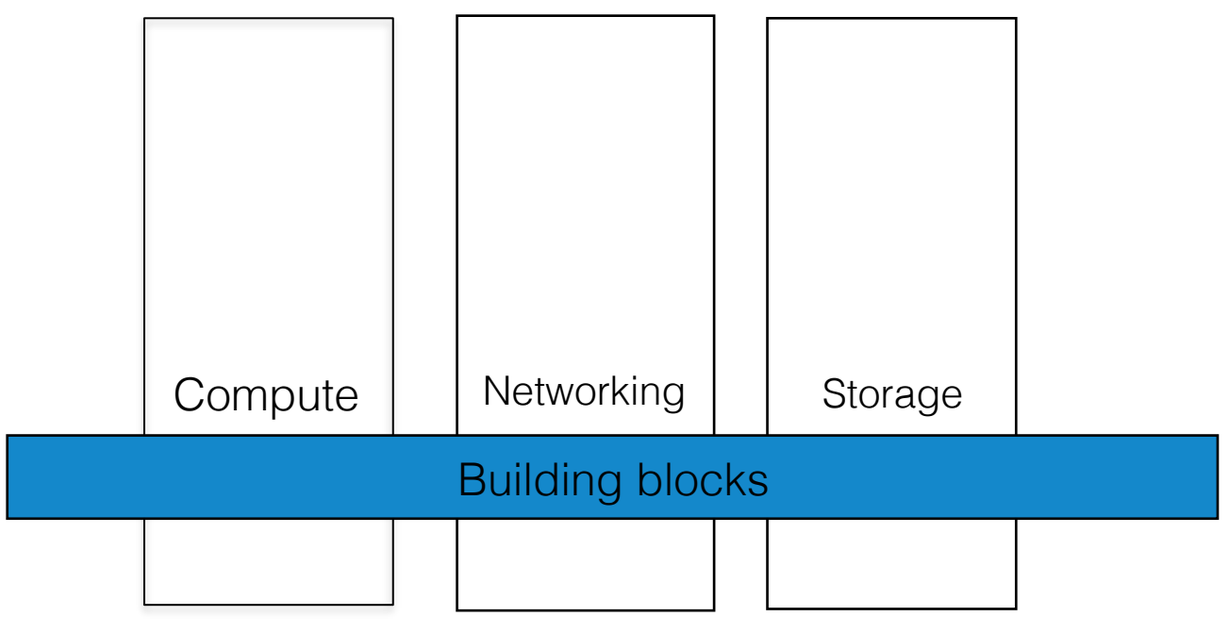

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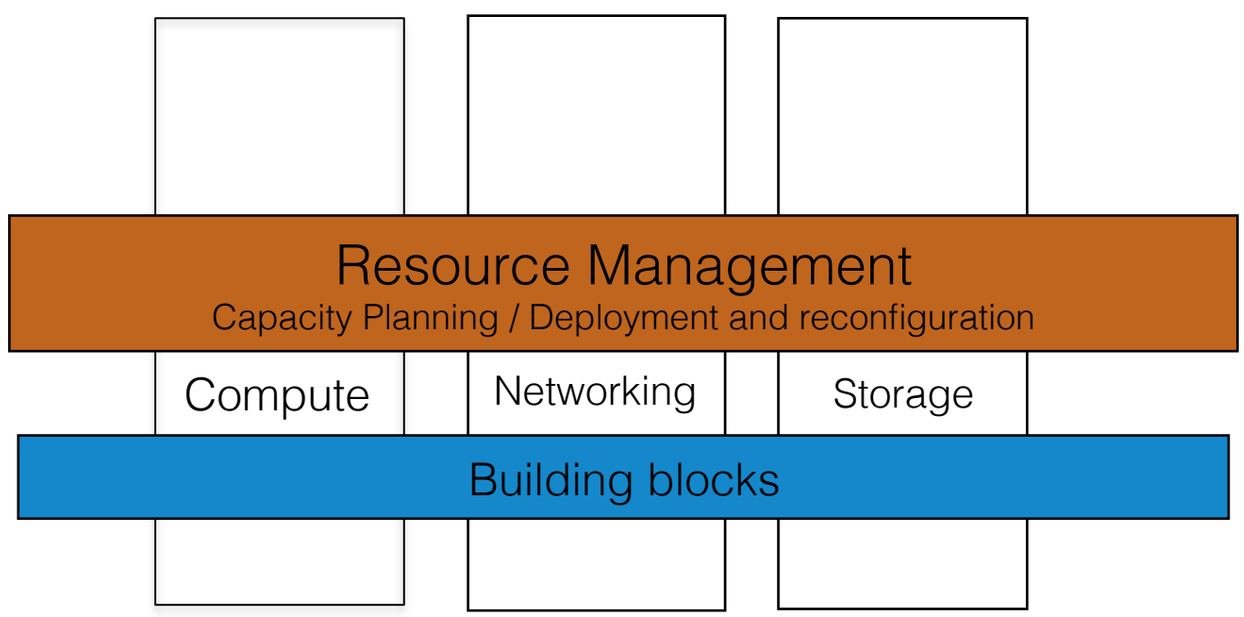

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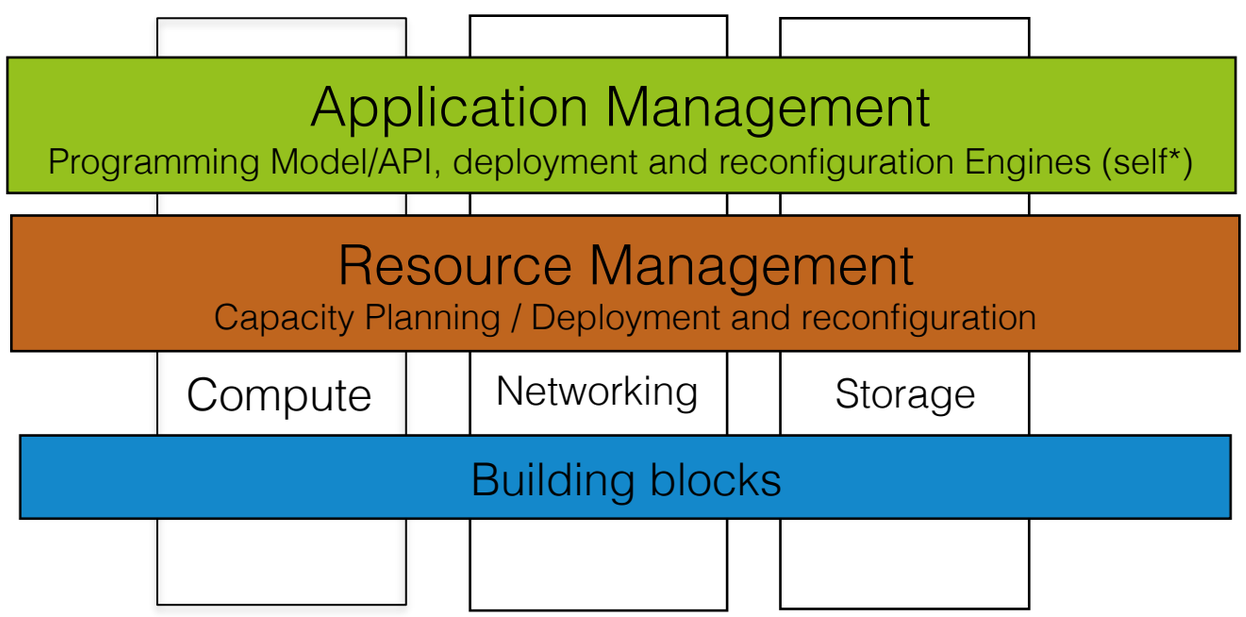

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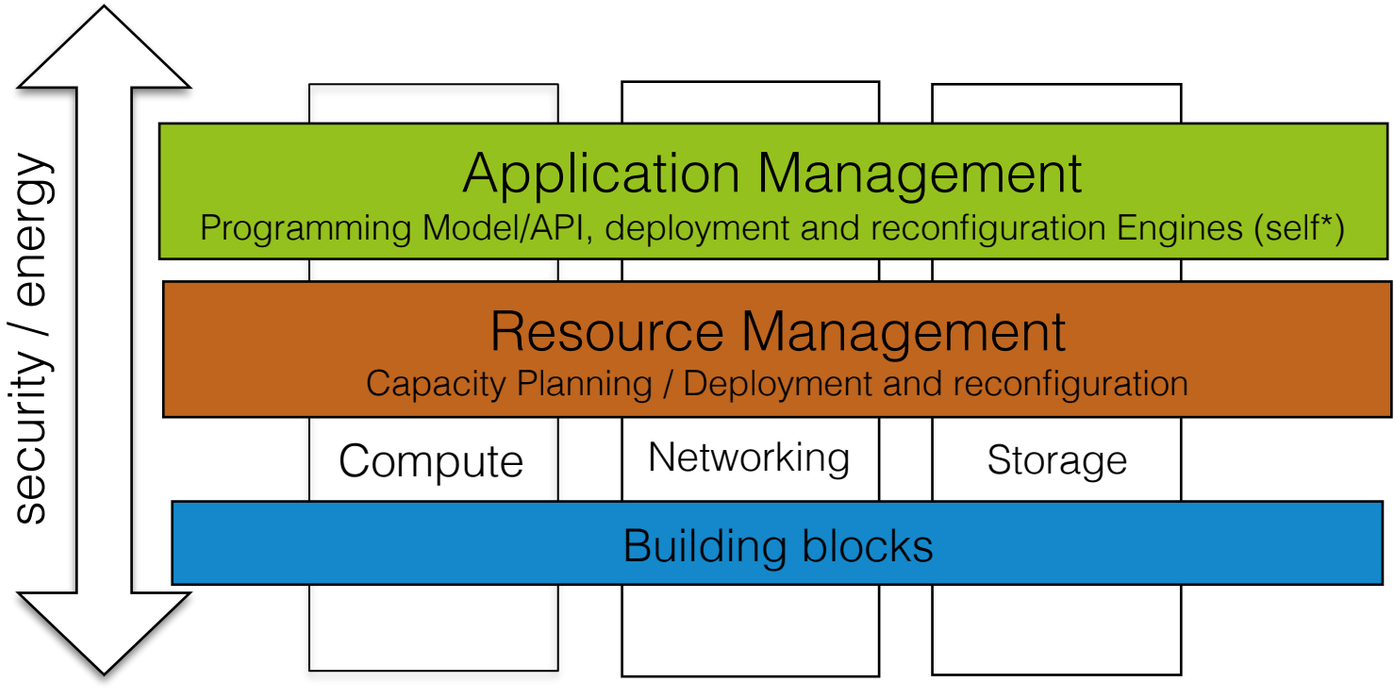

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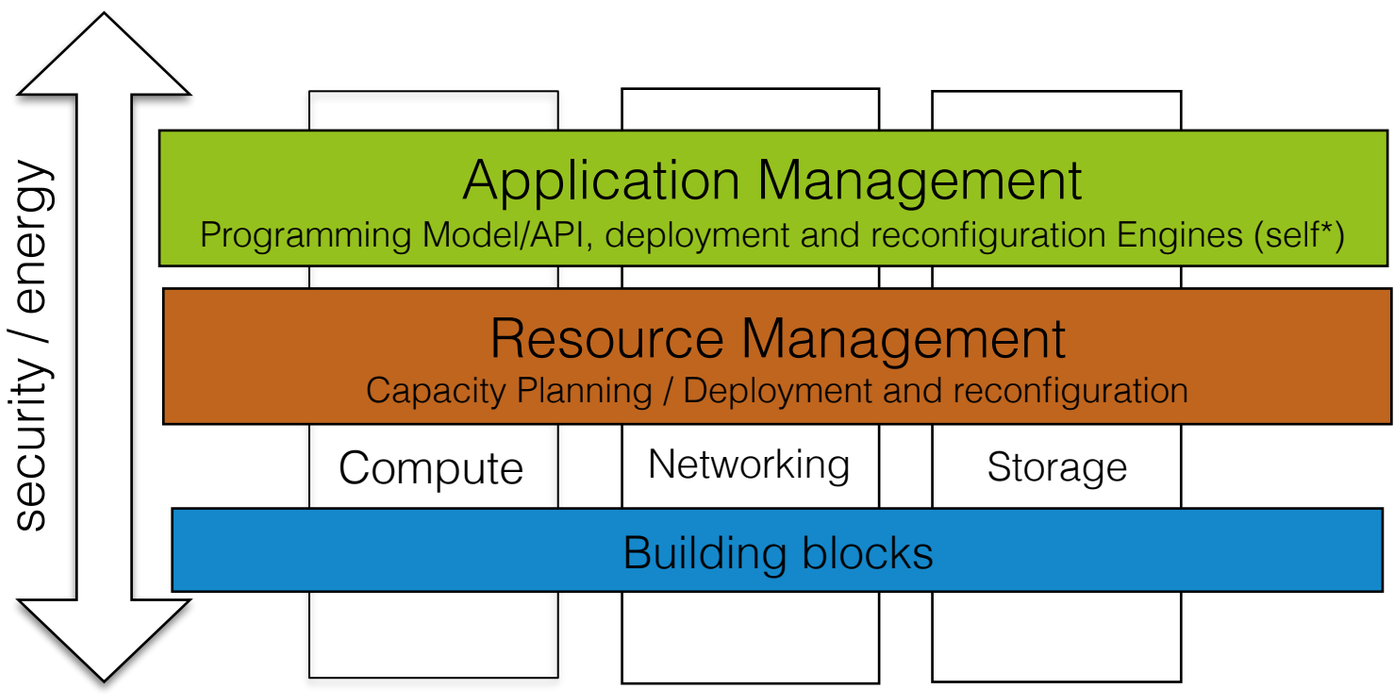


General: Revising such a stack to deal

Challenges & Foundations

- Challenges

  Identify and revise core mechanisms/algorithms to address fog/edge specifics (scalability, heterogeneity) across the whole stack

  Extend API and software programming abstractions (high level) and identify missing mechanisms (low-level) to benefit from geo-distribution opportunities.

  Infrastructure/Application life cycle management

  Tightly coupled : synergy between all mechanisms composing the system, taking into account crosscutting aspects.

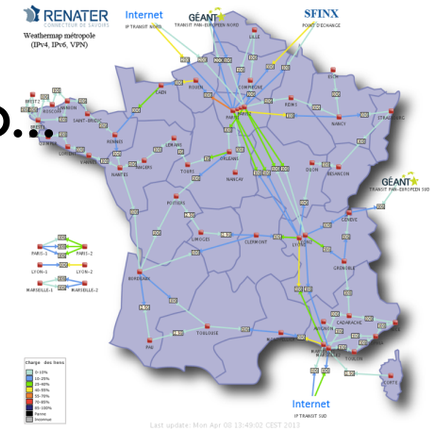
- Foundations

  (Distributed) systems
  Software programming (Component-based model, DSL, composition)
  Self-* mechanisms (Control theory, MAPE-K loop)
  Performance evaluations (experiment driven research)

Beyond IT !

- From sustainable data centers to a new source of energy

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



- Leverage "green" energy (solar, wind turbines...)

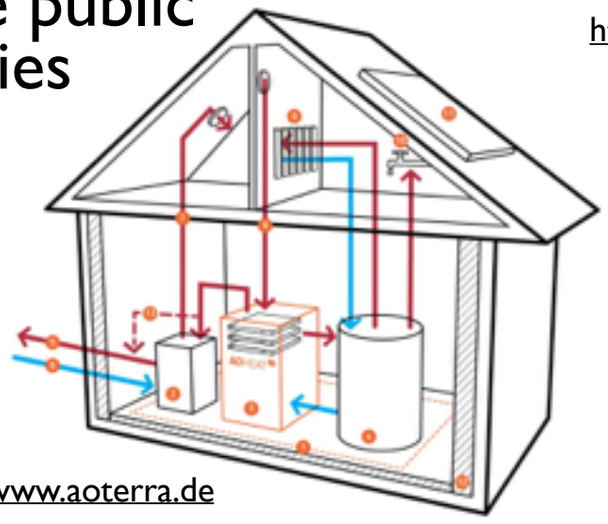
  Transfer the green micro/nano DCs concept to the network PoP

  Take the advantage of the geographical distribution

http://parasol.cs.rutgers.edu

- Leveraging the data furnaces concept

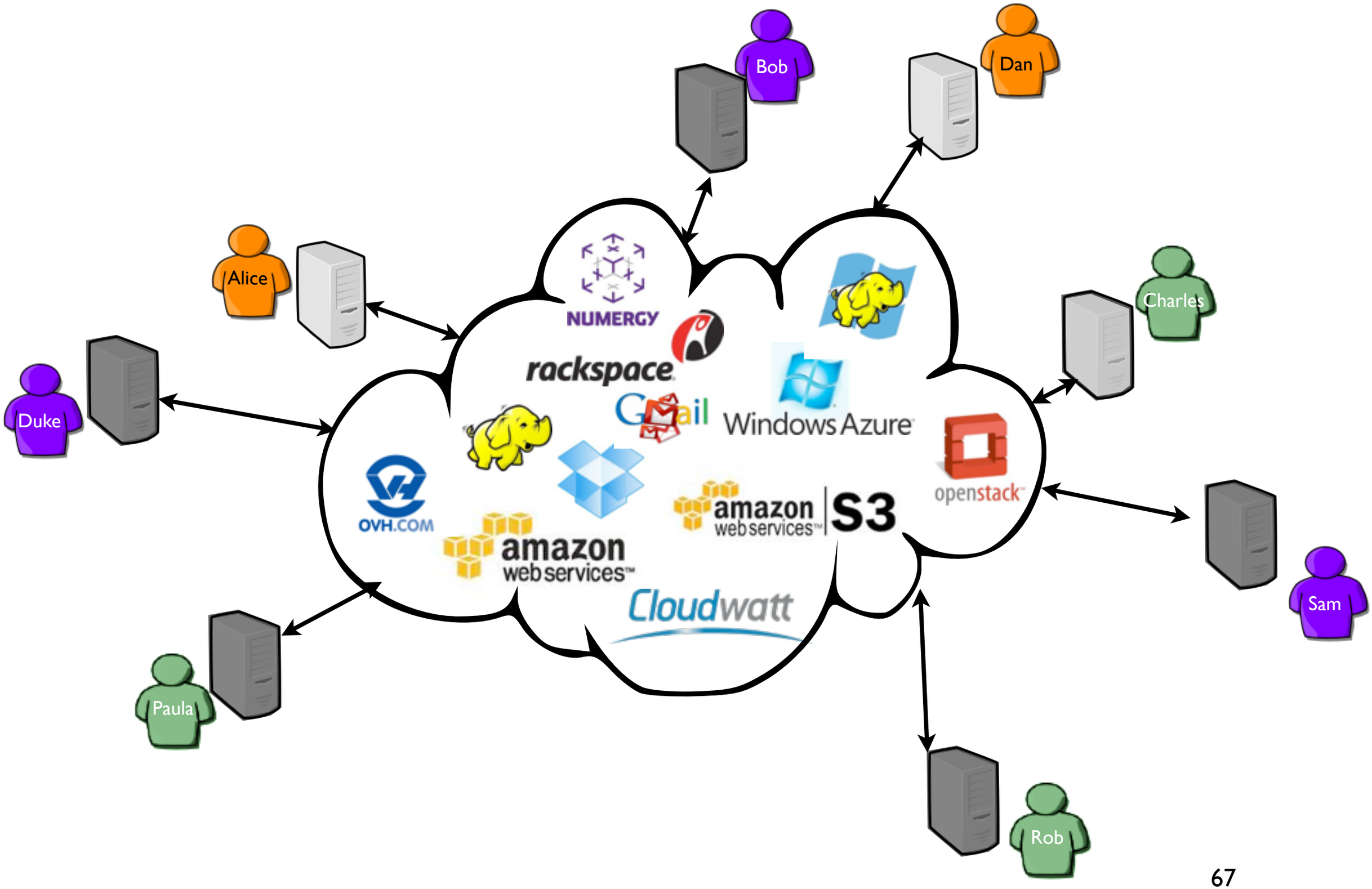
  Deploy UC servers in medium and large institutions and use them as sources of heat inside public buildings such as hospitals or universities



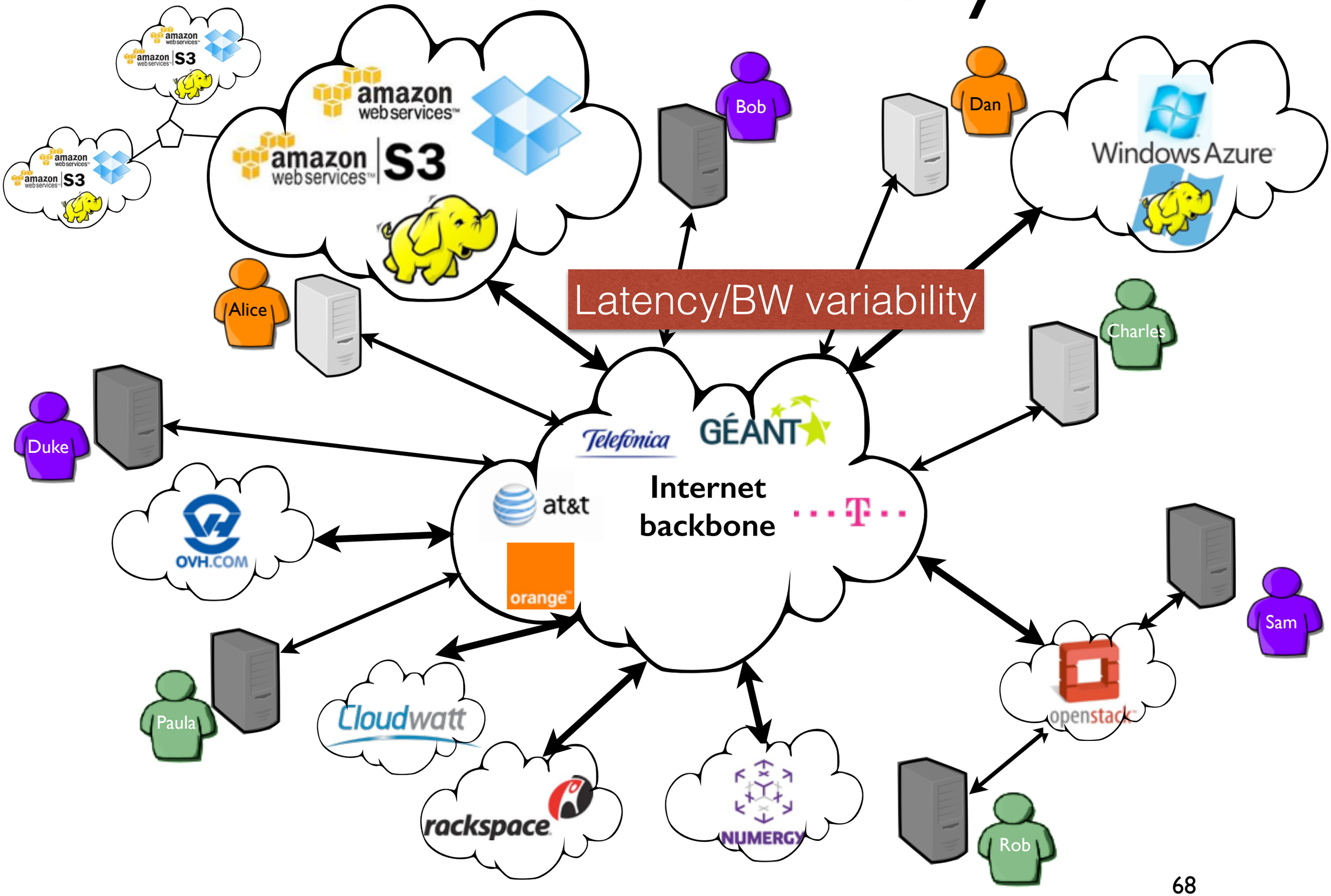
https://www.aoterra.de

Takeaway Message

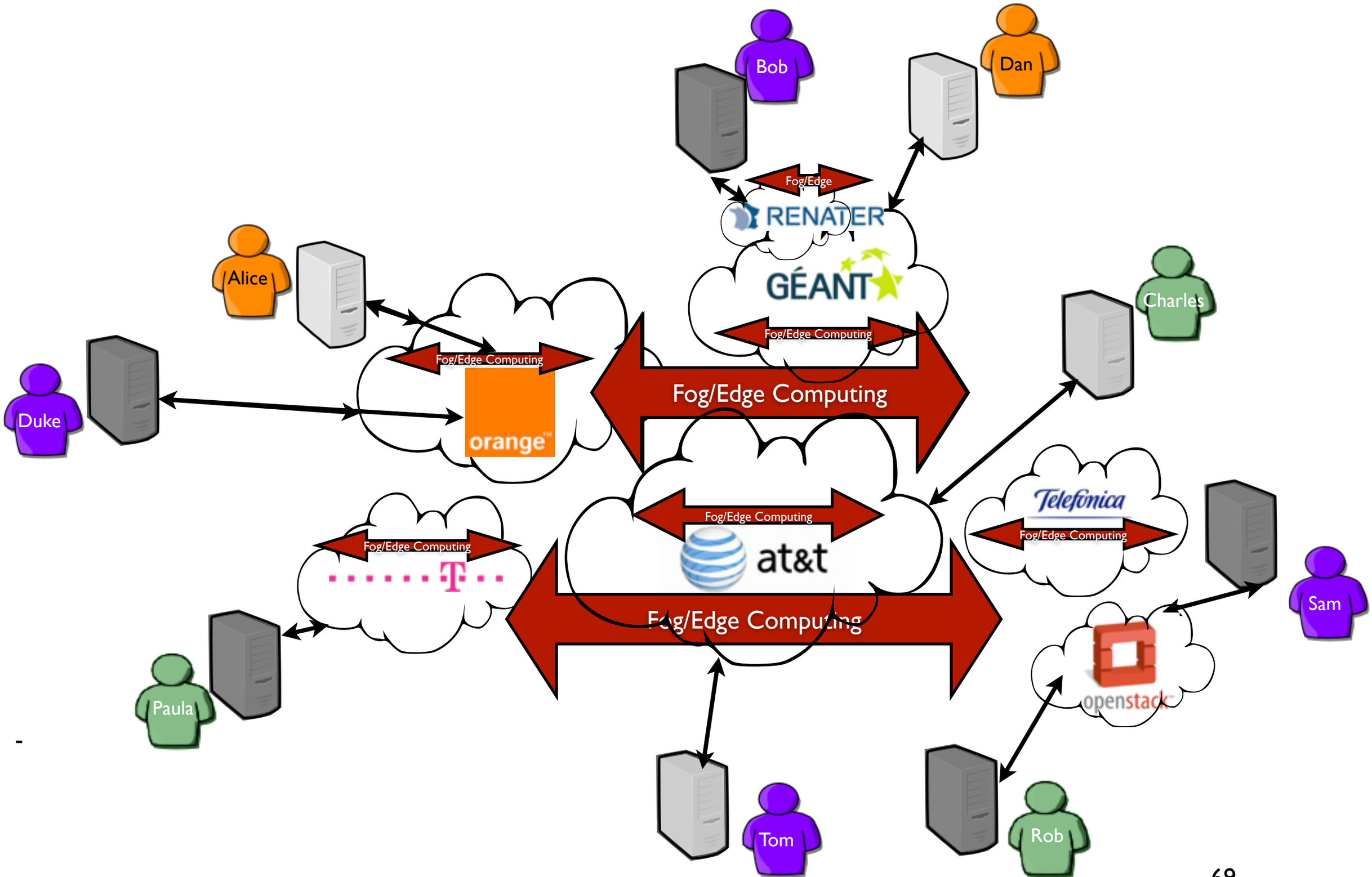
The cloud from end-users



The cloud in reality



Distributed Clouds (Fog/Edge)



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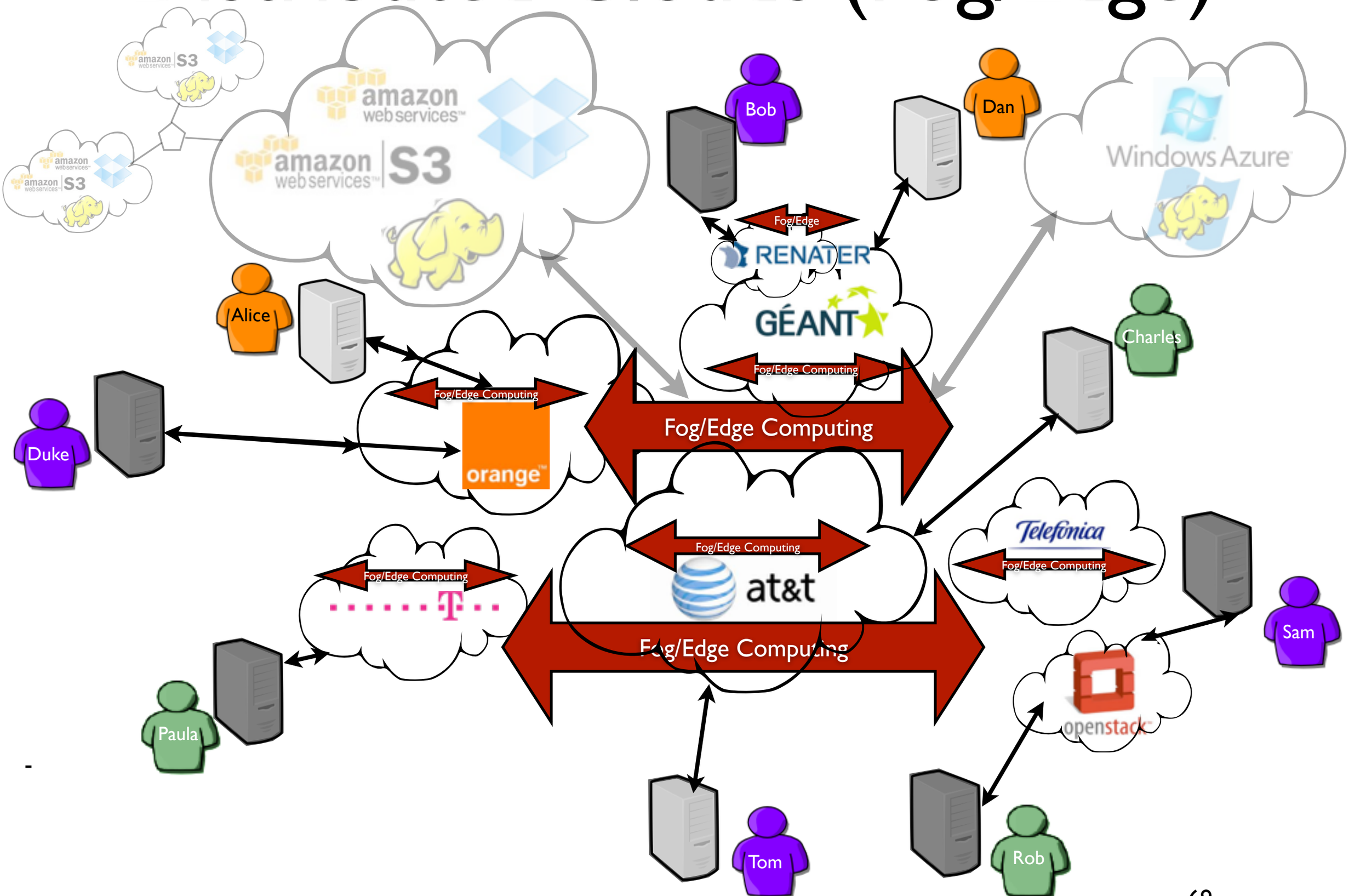

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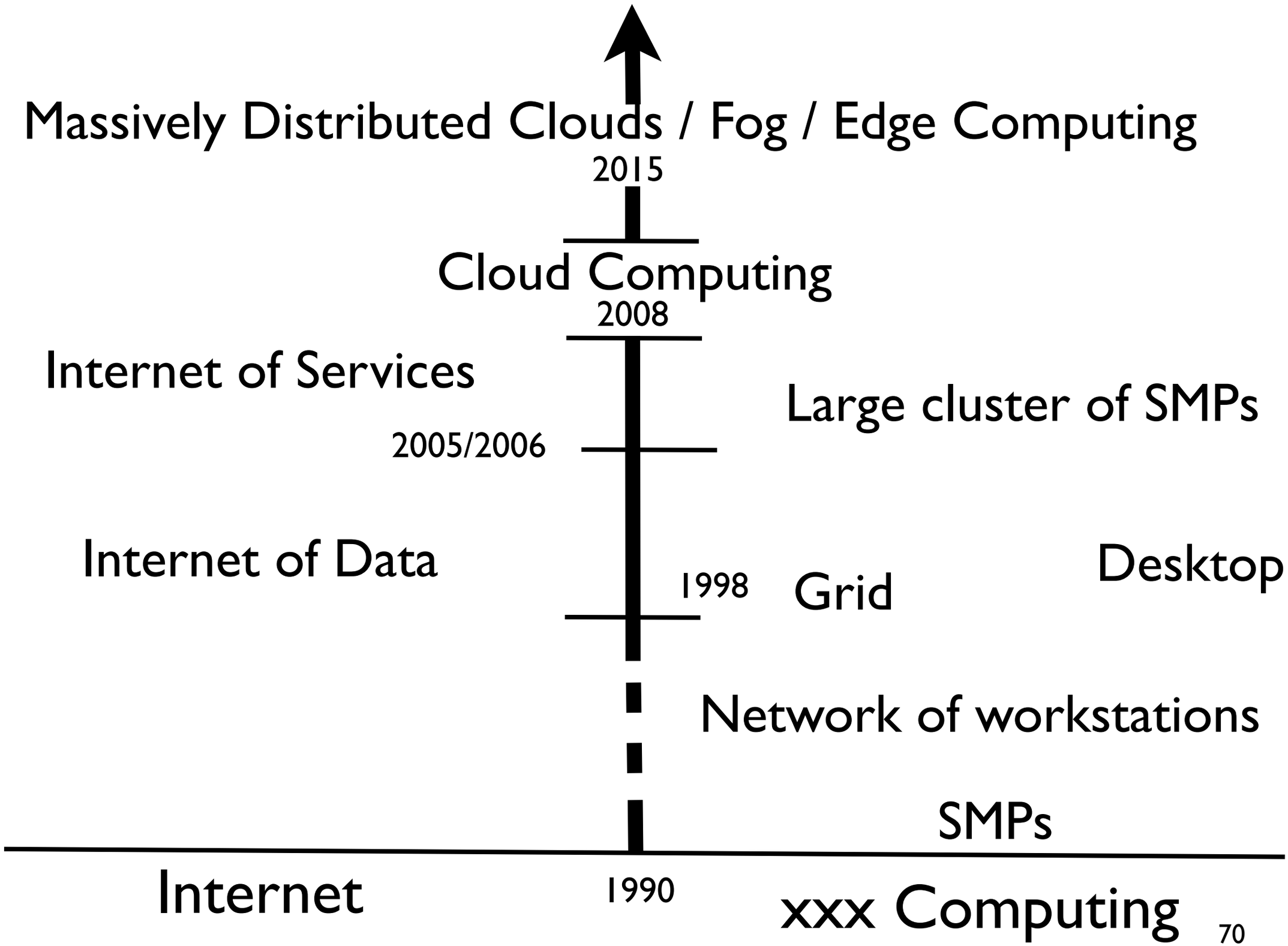
Clouds hide the infrastructure…
….by adding more layers !

and someone else's network

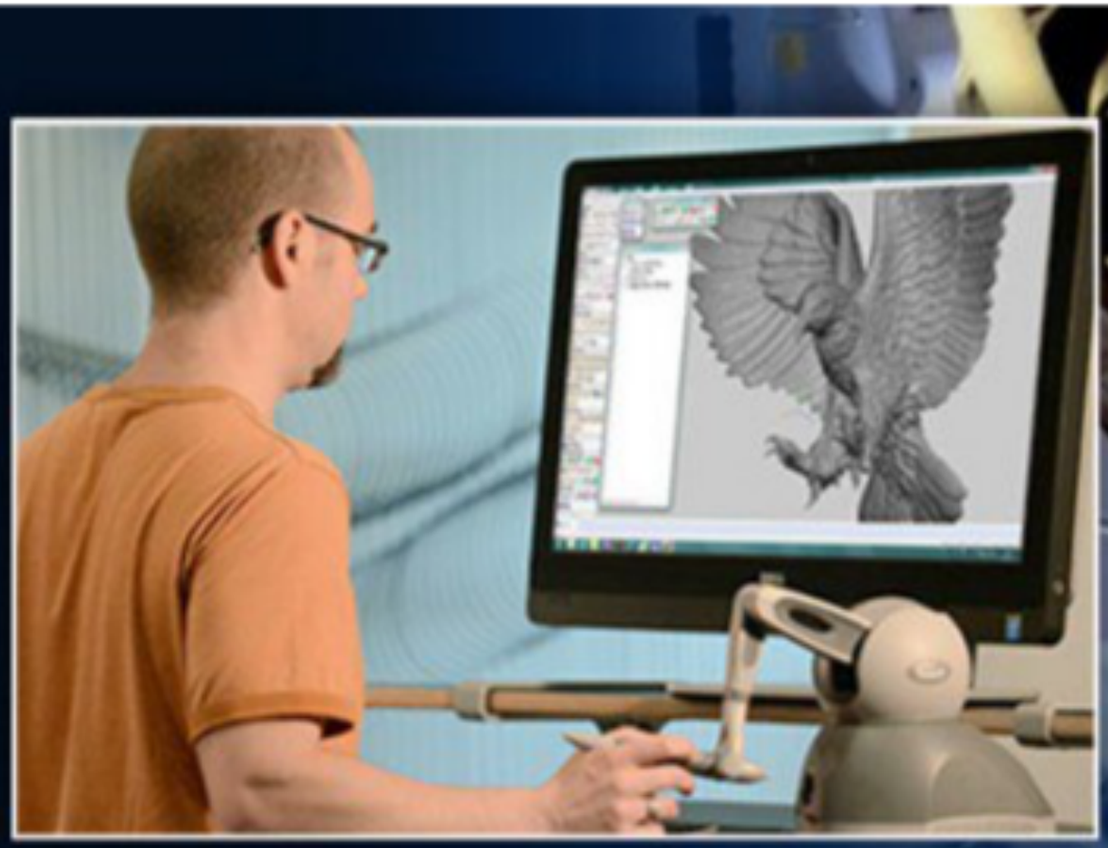
Clouds hide the infrastructure…
….by adding more layers !

What's next?

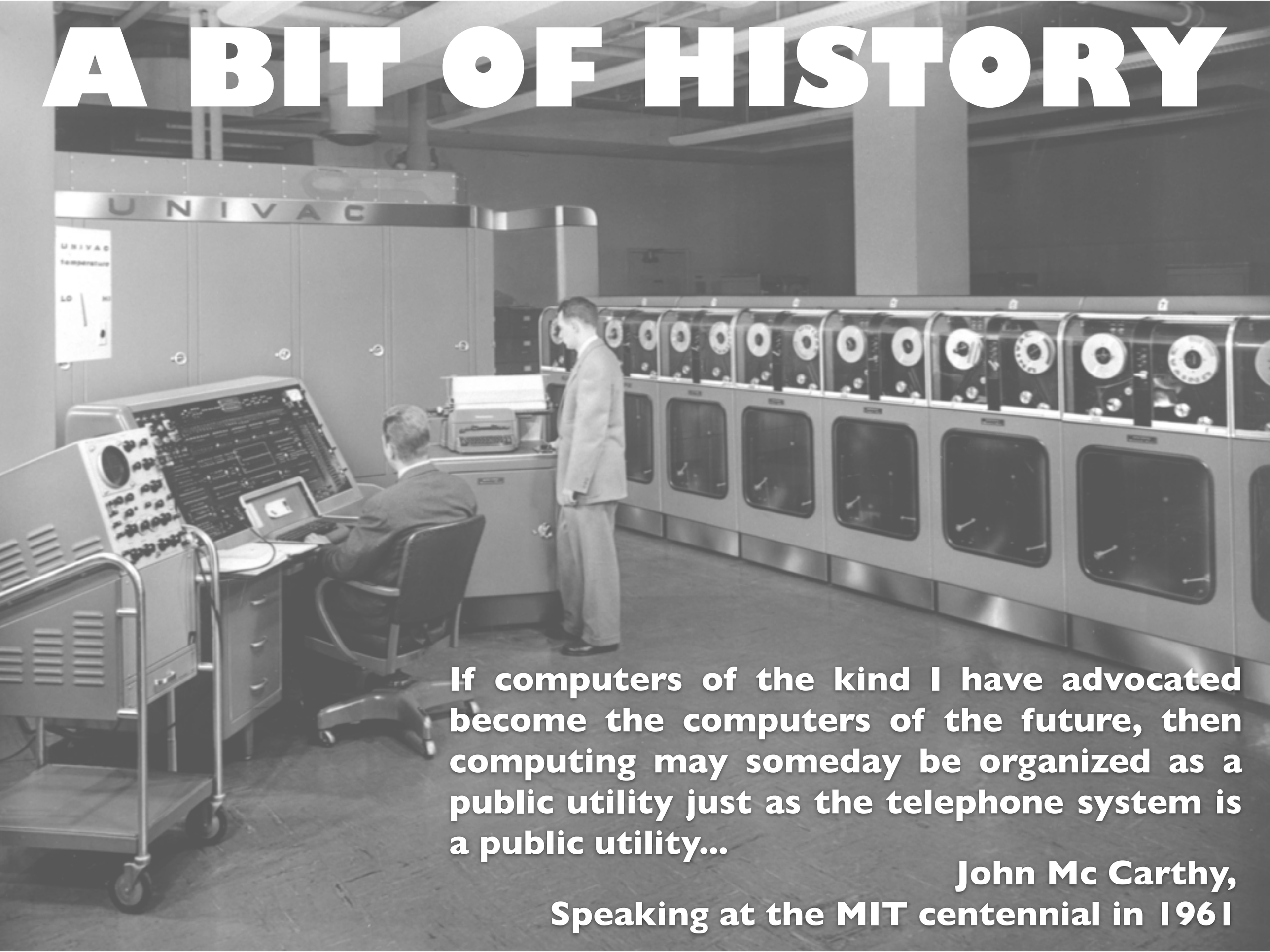

Massively Distributed Clouds / Fog / Edge Computing
2015
Cloud Computing
2008
Internet of Services
Large cluster of SMPs
2005/2006
Internet of Data
Desktop
1998
Grid
Network of workstations
SMPs
Internet
1990
xxx Computing

Internet of Skills/Tactile Internet

- ability to deliver physical experiences remotely



A BIT OF HISTORY



If computers of the kind I have advocated become the computers of the future, then computing may someday be organized as a public utility just as the telephone system is a public utility...

John Mc Carthy,
Speaking at the MIT centennial in 1961

Thanks

Utility

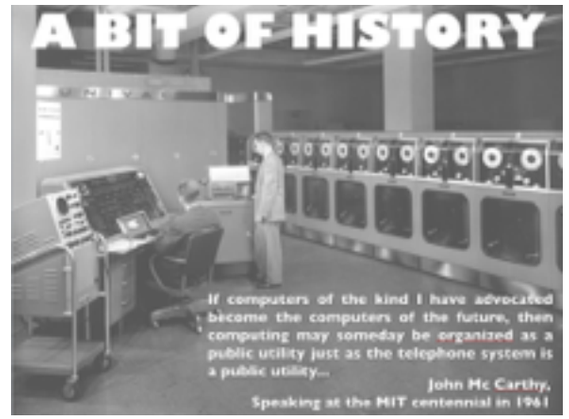
Cloud Computing technology is changing every day

How developers should develop new applications to benefit from geographically distributed infrastructures.

How to locate hardware/software components?

…

Do not hesitate to push the boundaries



http://beyondtheclouds.github.io/

adrien.lebre@inria.fr

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