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Key Research Challenges in Cloud Computing

Ignacio M. Llorente

Head of DSA Research Group
Universidad Complutense de Madrid

dsa-research.org



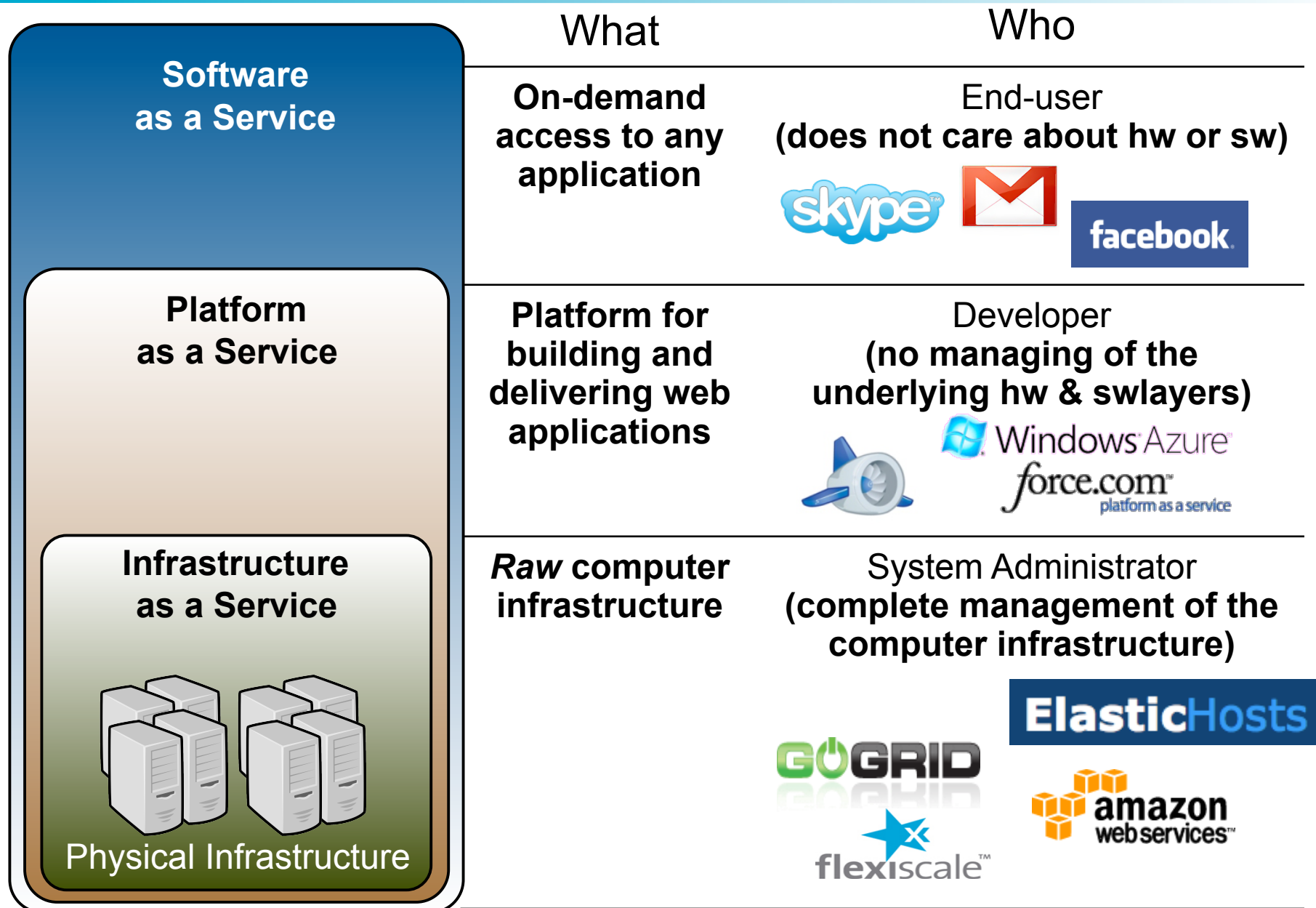
Project co-Lead and Director
OpenNebula Open-source Cloud Community

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Acknowledgments



A Model for Delivering IT Capabilities as a Service



Cloud Deployments

Public Cloud

- Simple Web Interface
- Pay-as-you-go (On-demand access)
- Elastic & “infinite” Capacity

Private Cloud

A “*Public Cloud behind the firewall*”

- Simplify internal operations
- Dynamic allocation of resources
- Higher utilization & operational savings
- Security concerns

Hybrid Cloud

- Supplement the capacity of the Private Cloud
- **Utility Computing dream made a reality!**

Cloud Computing as an Enabler for the Internet of Services

SaaS

- Software applications are available as a service in the Internet

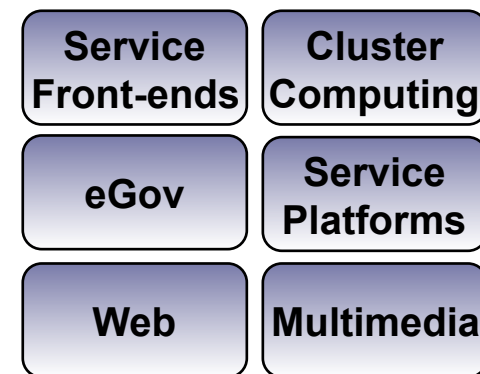
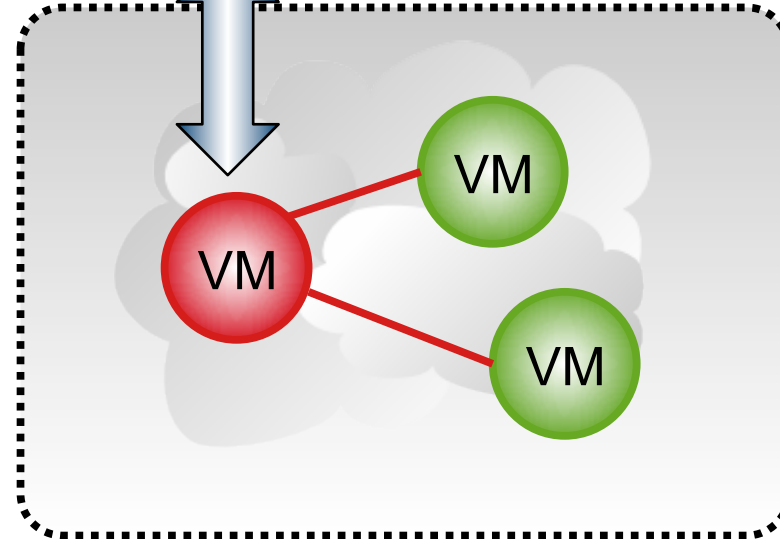
PaaS and IaaS

- The tools to develop applications and the infrastructure are available as a service

Service User



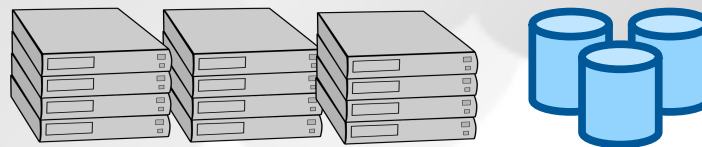
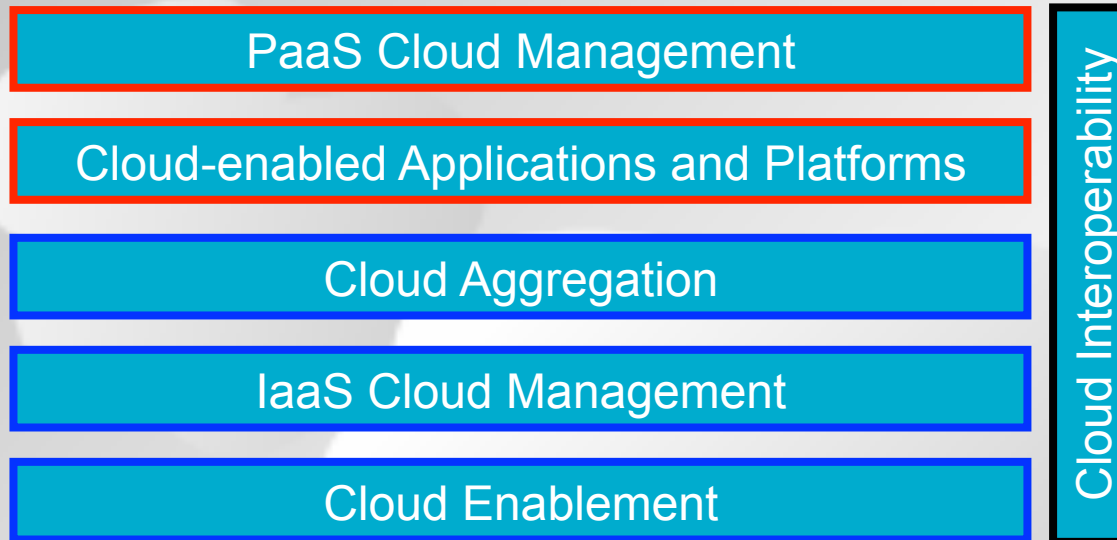
Service Provider



Cloud Computing as an Enabler

- Reduce infrastructure management complexity
- Automatic scalability
- Cloudbursting
- Reduce infrastructure costs
- Pay-per-use (utility) models
- Reduce development time
- Speed-up time-to-market of services

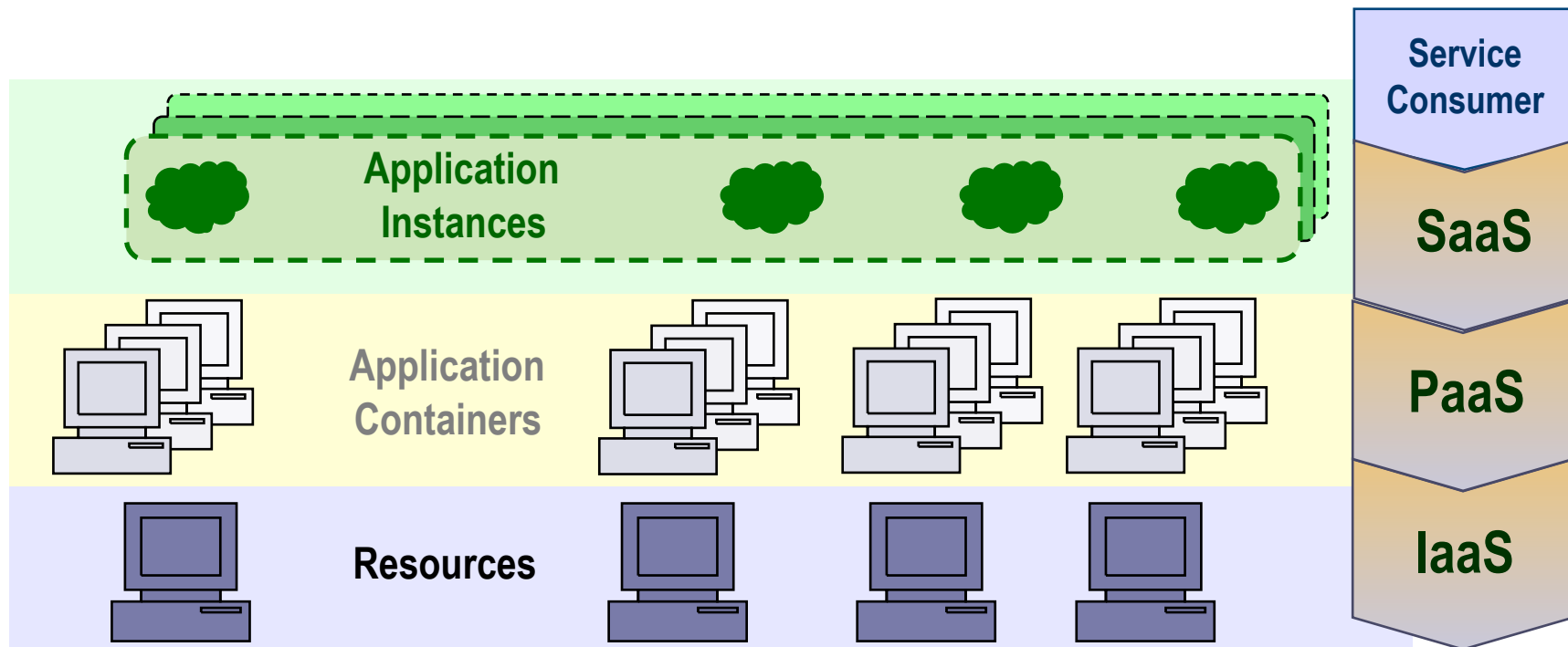
Open Research Issues



Platform Management

Challenges in **delivering middleware capabilities** for building, deploying, integrating and managing applications in a multi-tenant, elastic and scalable environment

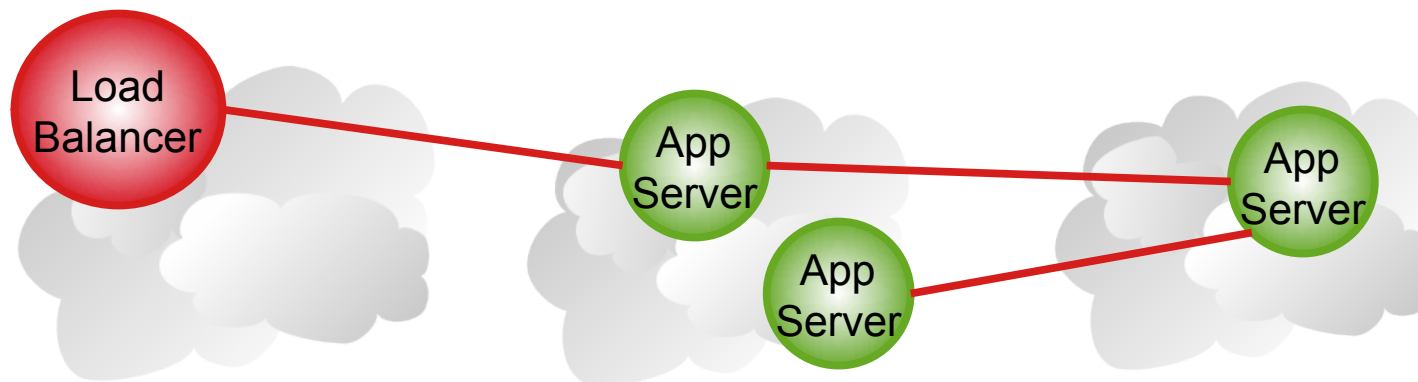
- **Scalability** and **multi-tenancy** of application containers
- **Placement optimization algorithms** of containers in resources



Cloud-enabled Applications and Platforms

Challenges in **building cloud-enabled applications and platforms** to take advantage of the scalability, agility and reliability of the cloud

- **Elastic** and **scalable** applications and frameworks on very large-scale environments
- **Self-scaling, self-awareness, self-knowledge, and self-management** capabilities of services
- **Novel applications** of cloud computing
- **Power-efficient** applications and platforms



Cloud Aggregation

Research challenges in the **aggregation of resources from diverse cloud providers** adding additional layers of service management

- **Novel architectural models** for aggregation of cloud providers
- **Brokering algorithms** for high availability, performance, proximity, legal domains, price, or energy efficiency
- **Sharing of resources** between cloud providers
- **Networking in the deployment of services** across multiple cloud providers
- **SLA negotiation and management** between cloud providers
- **Additional privacy, security and trust management** layers atop providers
- Support of **context-aware applications**
- Automatic management of **service elasticity**

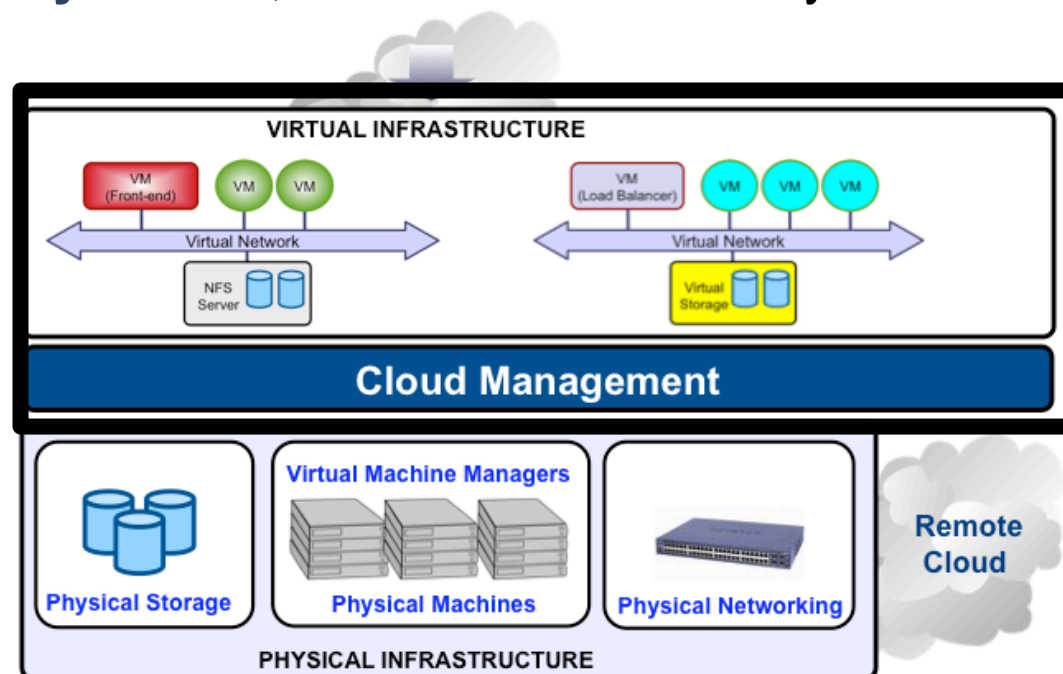
Cloud Aggregation



Cloud Management

Research challenges in **delivering infrastructure resources** on-demand in a multi-tenant, secure, elastic and scalable environment

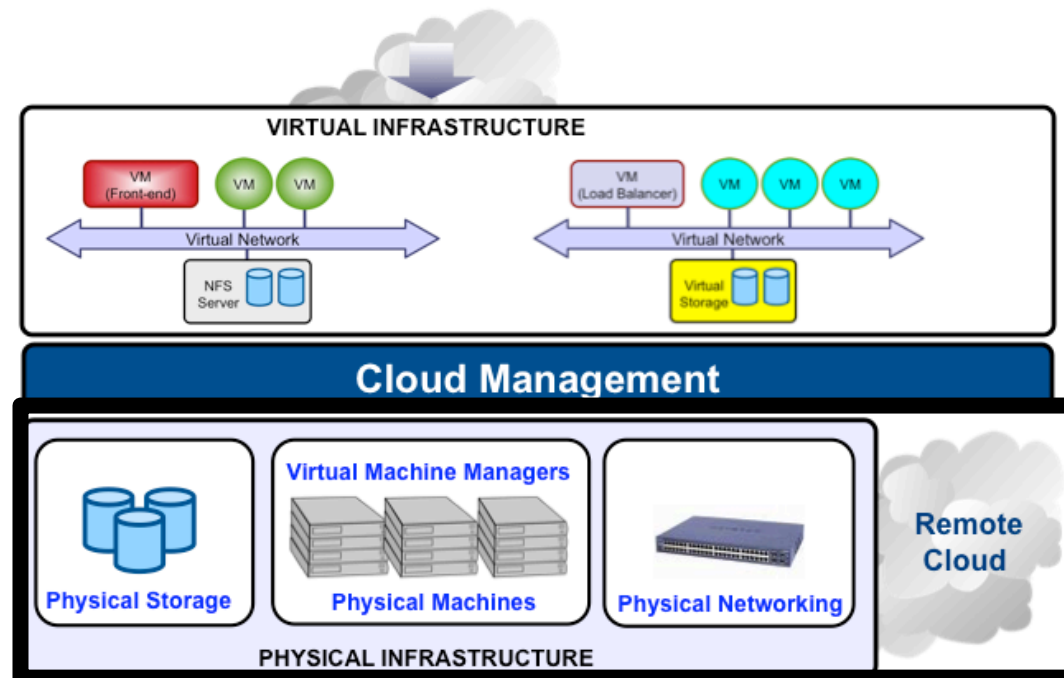
- **Scalable management** of network, computing and storage capacity
- **Scalable orchestration** of virtualized resources and data
- **Placement optimization algorithms** for energy efficiency, load balancing, high availability and QoS
- **Accounting, billing, monitoring** and **pricing** models
- **Security, privacy** and **trust** issues in the cloud
- **Energy efficiency** models, metrics and tools at system and datacenter levels



Cloud Enablement

Research challenges in enhancing platform infrastructure to support cloud management requirements

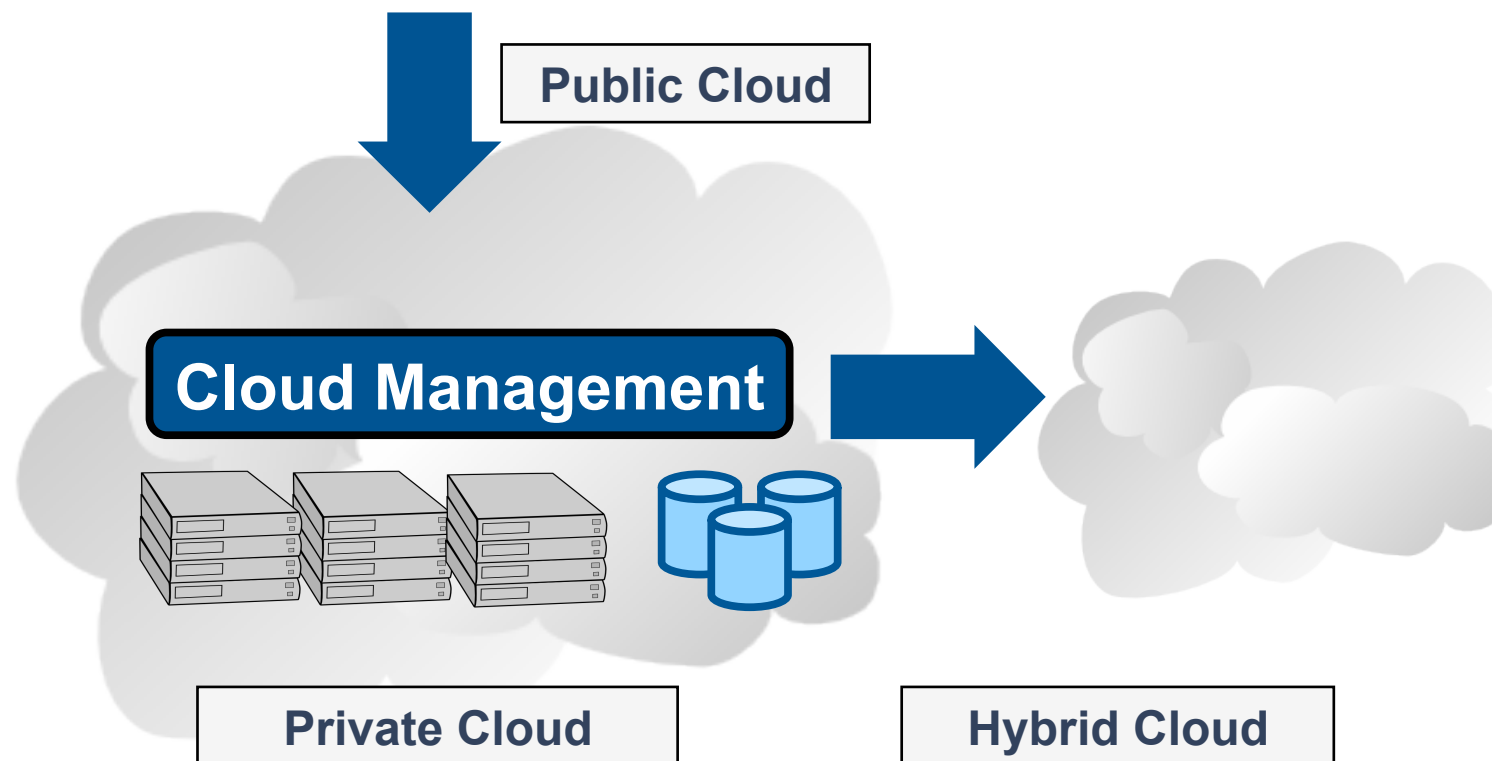
- **Technologies for virtualization** of infrastructure resources
- **Virtualization of high performance** infrastructure components
- **Autonomic and intelligent management** of resources
- Implications of Cloud paradigm on **networking and storage systems**
- Support for **vertical elasticity**
- **Provision of service related metrics**



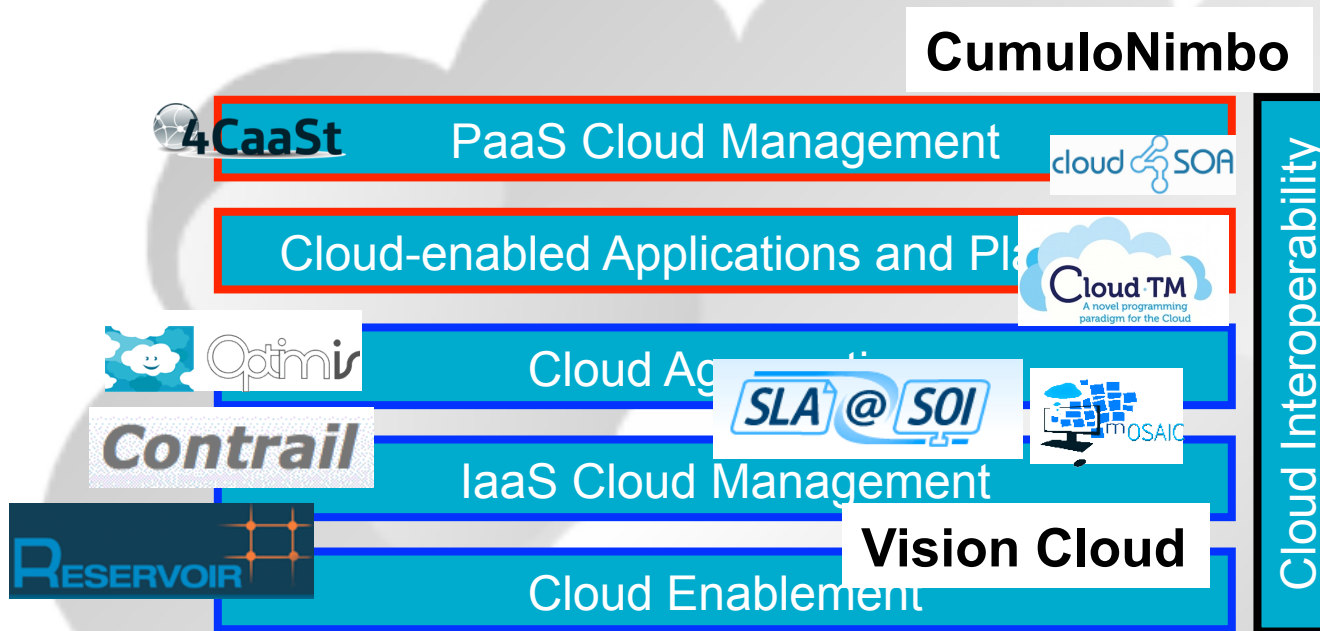
Cloud Interoperability

Challenges to ensure that the available cloud services can work together and interoperate successfully.

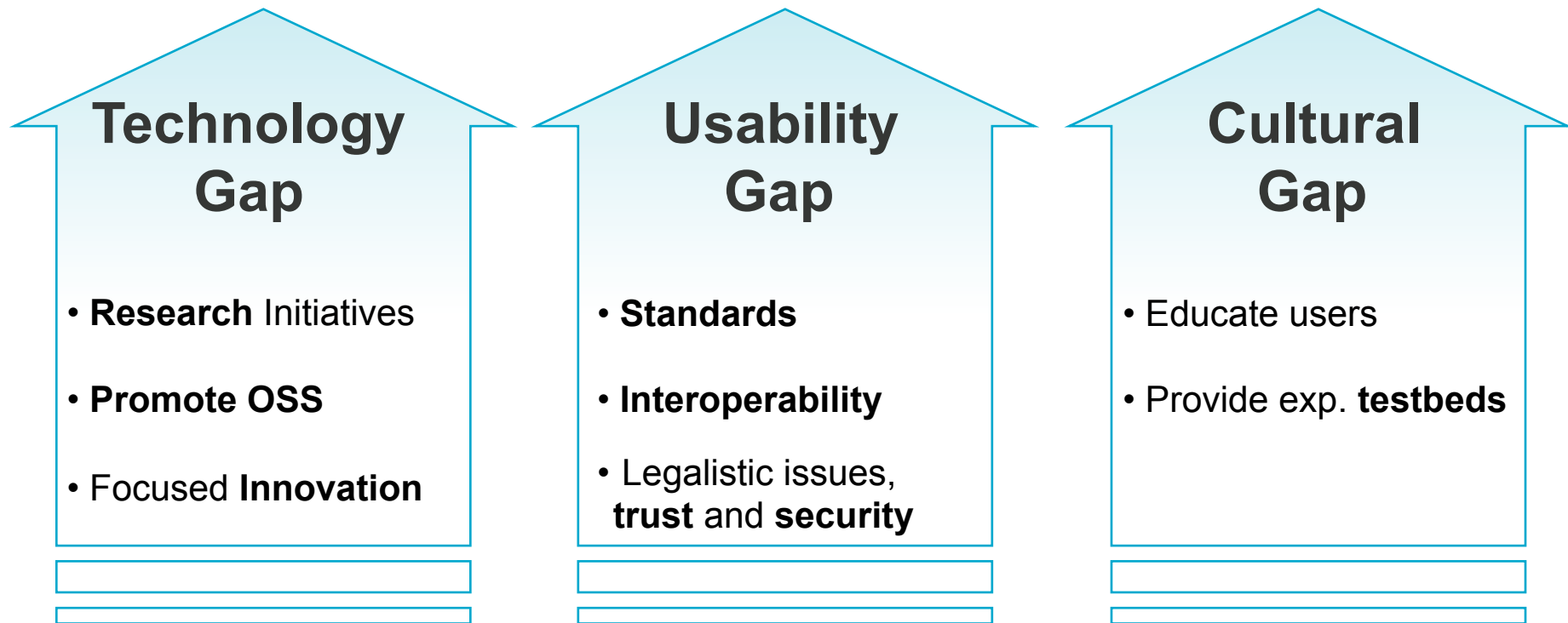
- **Common and standard interfaces** for cloud computing
- **Portability of virtual appliances** across diverse clouds providers



Ongoing Research Projects



Boost Adoption of Cloud Technologies



Main Areas for EU-Japan Collaboration

Openness

- Open architectures
- Open interfaces
- Open code

Adaptability

- Modular architectures

Key Principles to Maximize Value

Standardization

- Use standards
- Implement standards

Re-use

- Re-use existing open-source components
- Contribute to existing communities

The OpenNebula Case



Flagship International Project in Cloud Computing

Result of many years of research and development in efficient and scalable management of virtual machines on large-scale distributed infrastructures.



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Open-source Toolkit

Open platform for innovation to research the challenges that arise in cloud management, and production-ready tool in both academia and industry

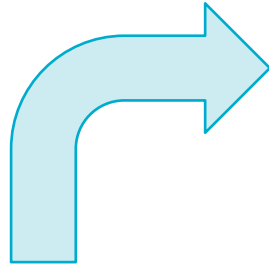
- **Started in 2005, first release in march 2008**
- **Open-source** released under Apache v2.0, packaged for main Linux distributions
- Mailing lists for **best-effort support** and **open development framework**
- Development and roadmap definition **driven by the community and projects**
- Active and engaged **open community and ecosystem**
- **> 3,000 downloads/month** (not including code repository and Ubuntu)

Reference Open Source Stack for Cloud Computing

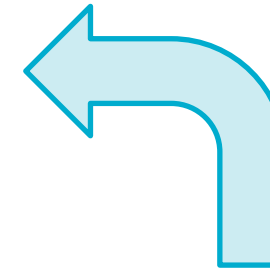
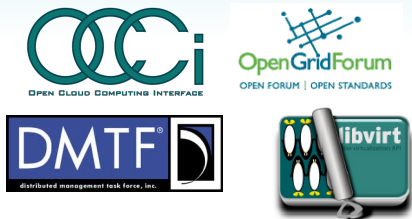
Open Source Community

- Open architecture and interfaces
- Open code
- Open community and ecosystem
- Very liberal license

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Adopt Standards



Avoid Software Fragmentation Re-use sw Components



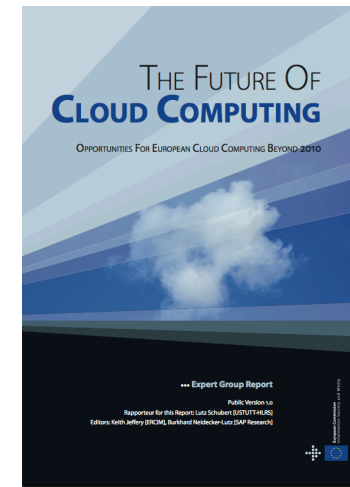
Wide Adoption

- Tool for innovation
- Build a commercial service
- Build a commercial product

References, Questions and Comments

Reports

- **The Future of Cloud Computing. Opportunities for European Cloud Computing Beyond 2010**, Expert Group Report (<http://cordis.europa.eu/fp7/ict/ssai/docs/cloud-report-final.pdf>)



Research References

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- B. Sotomayor, R. S. Montero, I. M. Llorente and I. Foster, “*Virtual Infrastructure Management in Private and Hybrid Clouds*”, **IEEE Internet Computing**, September/October 2009 (vol. 13 no. 5)
- Rafael Moreno-Vozmediano, Ruben S. Montero, Ignacio M. Llorente, “*Multi-Cloud Deployment of Computing Clusters for Loosely-Coupled MTC Applications*”, **IEEE Transactions on Parallel and Distributed Systems**, in press