University of Bologna

Dipartimento di Informatica – Scienza e Ingegneria (DISI)

Engineering Bologna Campus

Class of

Principles, Applications and Models for Distributed Systems M

Cloud computing

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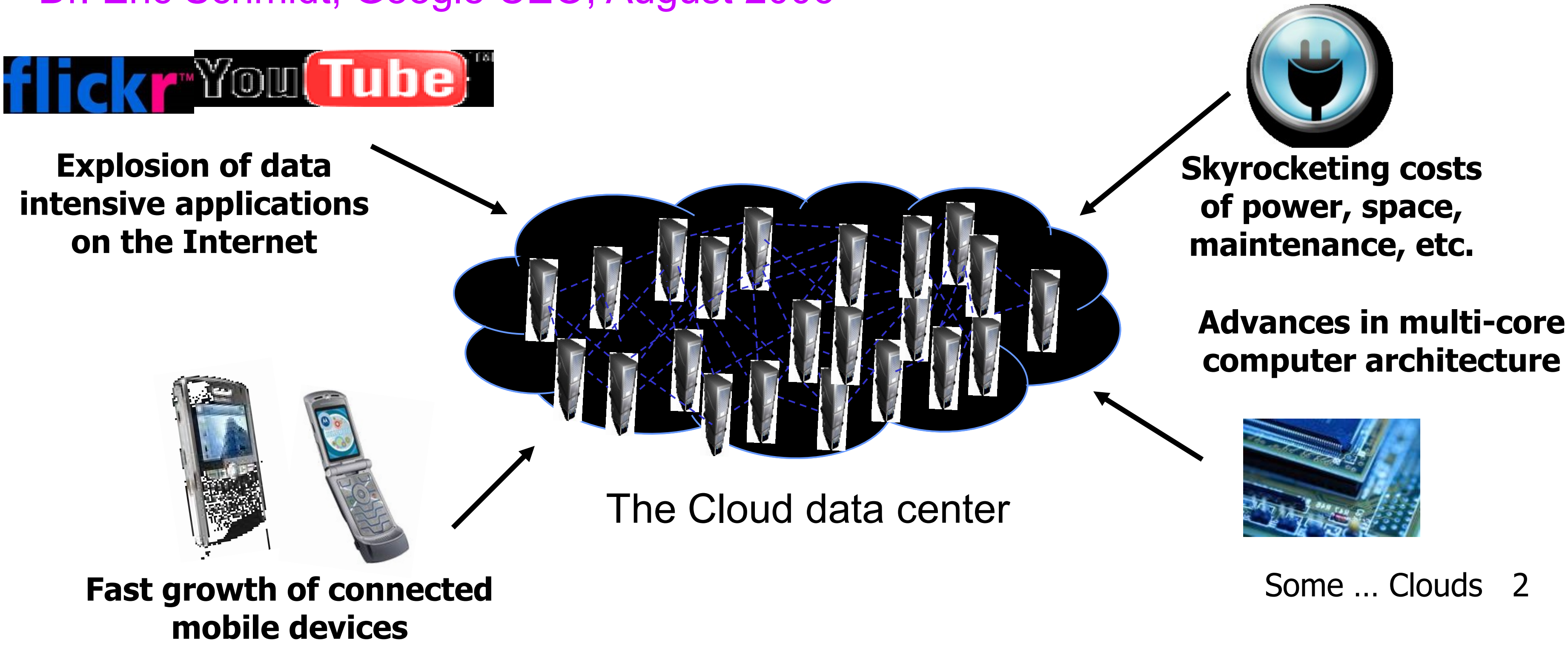
Cloud Computing Problem Space

"It starts with the premise that the **data services and architecture** should be on **servers**. We call it **cloud computing** – they should be in a 'cloud' somewhere. And that if you have the right kind of **browser** or the right kind of access, it doesn't matter whether you have a PC or a Mac or a mobile phone or a BlackBerry or what have you – or new devices still to be developed – you can get access to the cloud…"

Dr. Eric Schmidt, Google CEO, August 2006



Explosion of data intensive applications on the Internet

Skyrocketing costs of power, space, maintenance, etc.

Advances in multi-core computer architecture

Fast growth of connected mobile devices

The Cloud data center

Cloud Concepts

- IT [redacted] pricing
- Best benefits in a [redacted] context
- Pool of [redacted] computer resources
- Rapid live [redacted] while demanding
- Systems on [redacted] architecture

Cloud keywords

on demand,
reliability,
virtualization,
provisioning,
scalability

What is a Cloud

One Cloud is capable of providing IT resources 'as a service'

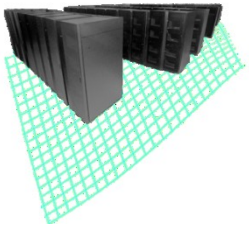
One Cloud is an **IT service** delivered to users that have:

- a **user interface** that makes the infrastructure underlying the service transparent to the user
- reduced **incremental management costs** when additional IT resources are added
- **services oriented management** architecture
- **massive scalability**

A bit of history

Grid Computing

- Solving large problems with parallel computing



Utility Computing

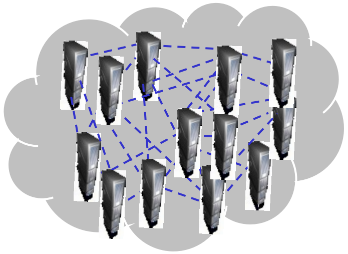
- Offering computing resources as a service

Software as a Service

- Network-based subscriptions to applications

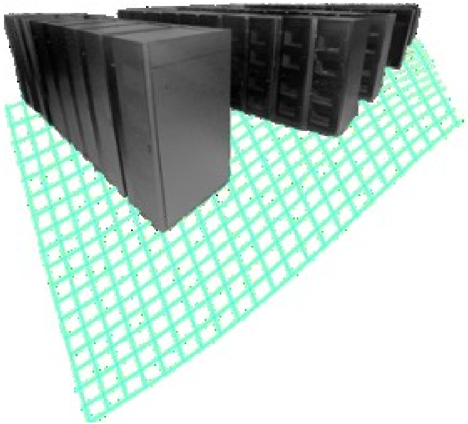
Cloud Computing

- Anytime, anywhere access to IT resources delivered dynamically as a service.



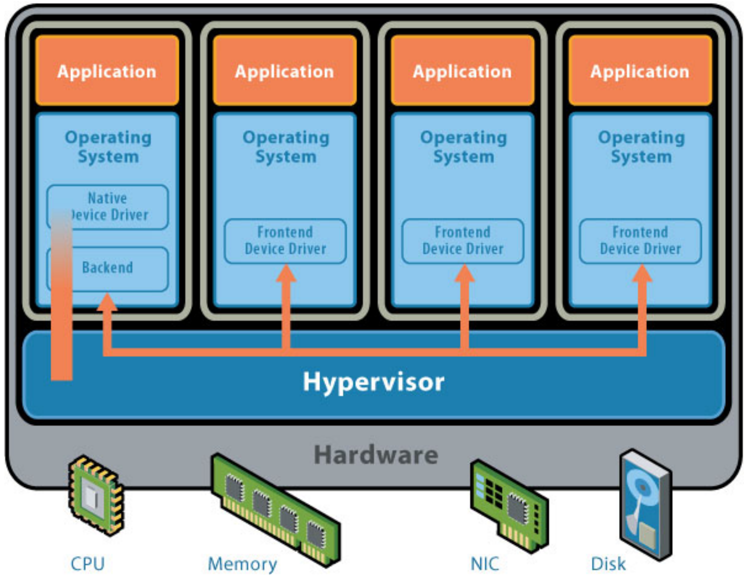
Before Cloud computing: GRID

- **Grid computing**
  - Sharing of **heterogeneous resources** (computer, software, data, memory, computational power,, …) in **highly distributed environments** with the goal of **creating a virtual organization scalable** (***by need!***)
  - Interfaces (for management), often **too fine grained, with low level of abstraction,** and **non self-contained** ☹
  - Application areas very **limited and specific** (parallel computation for scientific, engineering scenarios, …)



Before the Cloud: Virtualization

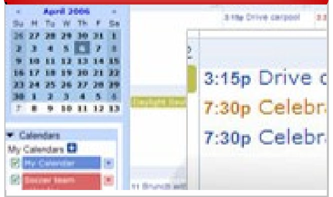
- **Virtualization**
  - Technologies for **virtualization** (either system-based or hosted), as in a server farm: Vmware, Xen, …
  - **Isolation** & **personalized infrastructure and/or SW platform** (O.S. and some additional applications)
  - Tool for the **efficient management** of computing infrastructures (IBM Tivoli suite, Xen monitoring tools, …)



Before Cloud computing: Web 2.0

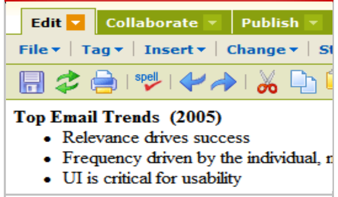
- **Web 2.0**
  - **Usage of asynchronous protocols not visible** to users to ask only **really required info** and not the **whole web pages: Asynchronous Javascript And XML (AJAX)**
  - New ways of **using Web services coupled with new applications easier to use, collaboration based** and **openly available, without requiring any installation** by interested users: new business model, **very, very cooperative** (**S**oftware **as a S**ervice ☺)

Office



https://www.google.com/hosted
http://smallbusiness.yahoo.com/email/
www.zimbra.com
many others…

Word

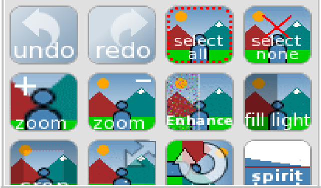


Top Email Trends (2005)

- Relevance drives success
- Frequency driven by the individual, r
- UI is critical for usability

www.writely.com
www.writeboard.com
www.inetword.com
many others…

Graphics



www.pxn8.com
www.pixoh.com
many others…

Database

Configure Field NAME Status

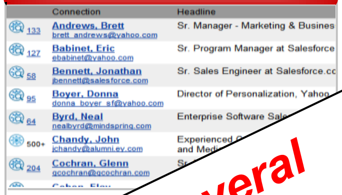
TYPE OF VALUE
○ ABC Text
○ 123 Number
○ $£€ Money
○ Date/Time
● XYZ Choice

CHOICE
□ Allow at any
□ Allow

Options
Unpaid
Paid
Overdue

www.dabbledb.com
www.Lazybase.com
www.quickbase.com
many others…

Contacts



	Connection	Headline
133	Andrews, Brett brett_andrews@yahoo.com	Sr. Manager - Marketing & Busines
127	Babinet, Eric ebabinet@yahoo.com	Sr. Program Manager at Salesforce
58	Bennett, Jonathan jbennett@salesforce.com	Sr. Sales Engineer at Salesforce.cc
95	Boyer, Donna donna_boyer_sf@yahoo.com	Director of Personalization, Yahoo
64	Byrd, Neal nealbyrd@mindspring.com	Enterprise Software Sale
500+	Chandy, John jchandy@alumni.ey.com	Experienced and Medi
204	Cochran, Glenn gcochran@gcochran.com	Sr.

…s…

And several others…

Before Cloud computing: Utility computing

- Huge computational and storage capabilities available from **utilities**, the same as for energy and electricity, and on pay-per-use base.
- “**Computing may someday be organized as a public utility**” - John McCarthy, MIT Centennial in 1961
- **Metered billing** (pay for what you use)
- **Simple to use interface** to access the capability (e.g., plugging into an outlet)

Software as a Service (SaaS)

Traditional Software

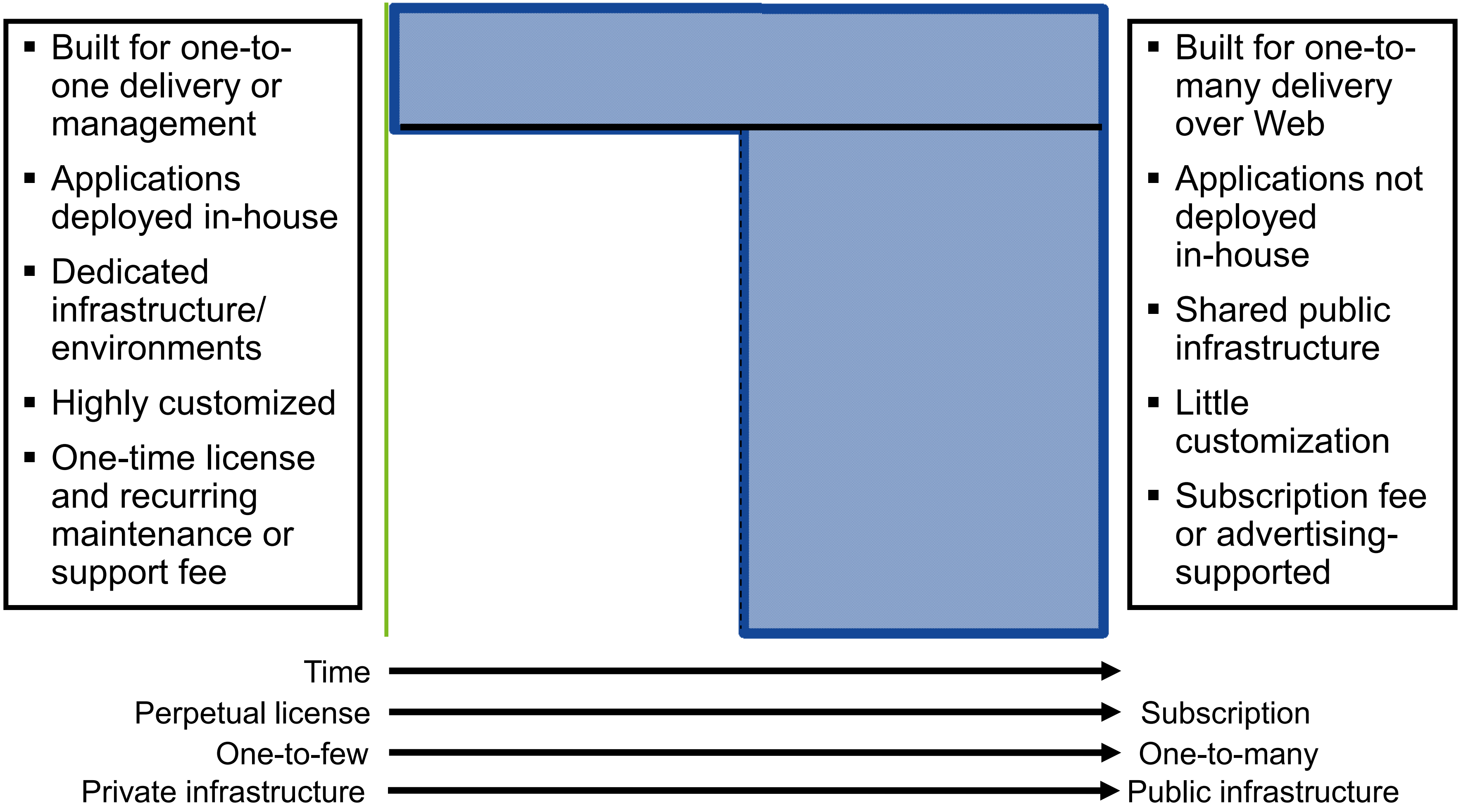
Build Your Own

On-Demand Utility

Plug In, Subscribe

Pay-per-Use

Software as a Service (SaaS)



- Built for one-to-one delivery or management
- Applications deployed in-house
- Dedicated infrastructure/ environments
- Highly customized
- One-time license and recurring maintenance or support fee

- Built for one-to-many delivery over Web
- Applications not deployed in-house
- Shared public infrastructure
- Little customization
- Subscription fee or advertising-supported

Time →

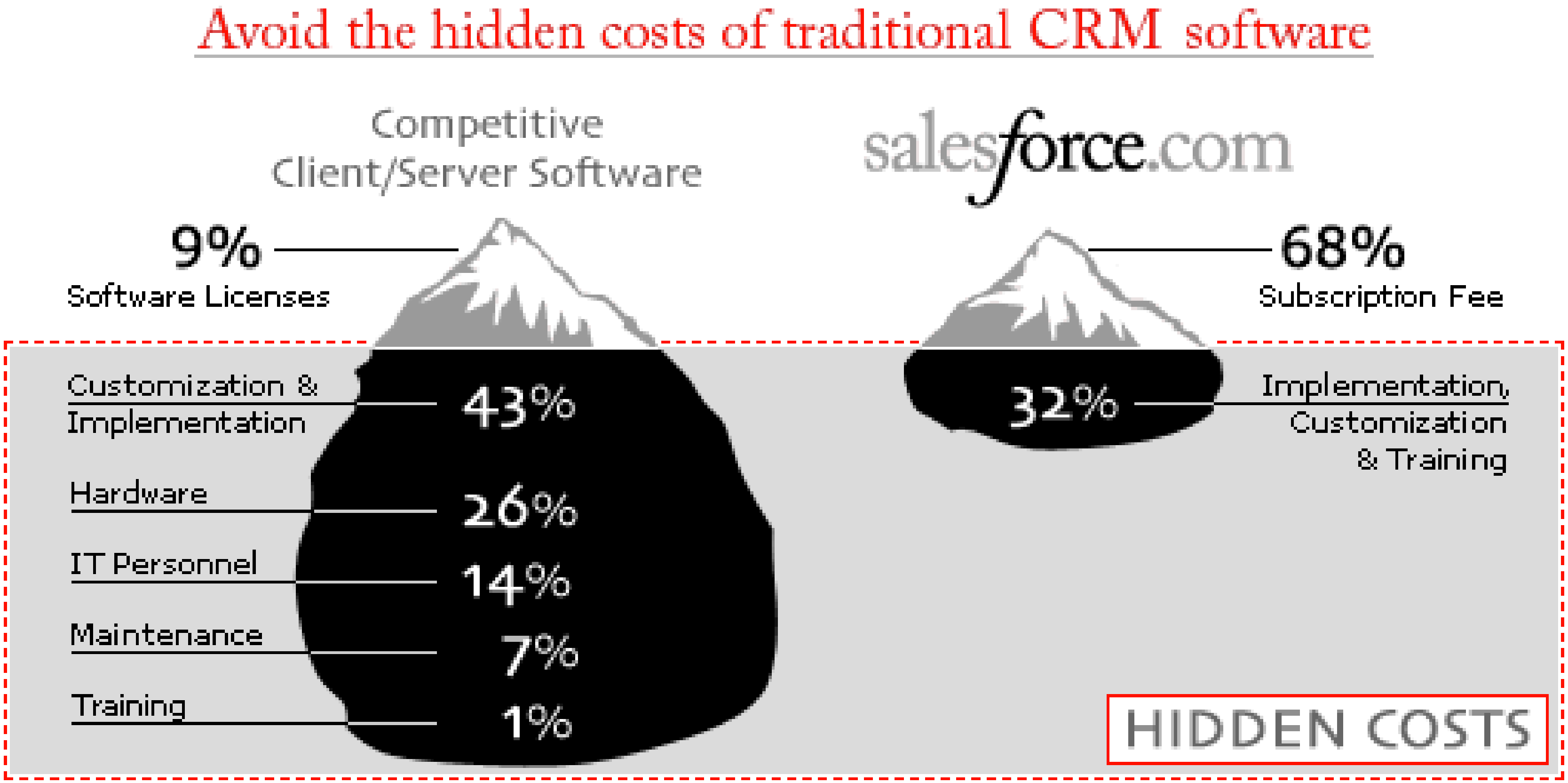
Perpetual license → Subscription

One-to-few → One-to-many

Private infrastructure → Public infrastructure

Source: IDC, 2006

Hidden Cost of IT



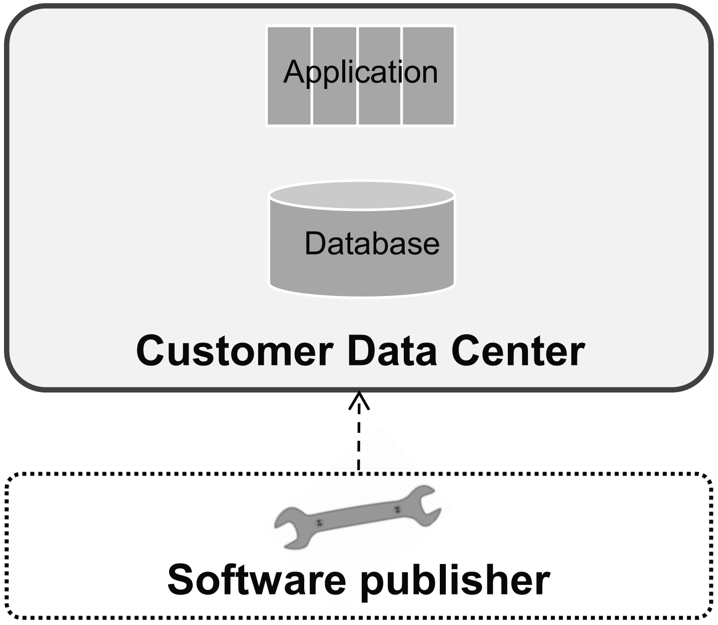
SaaS - Software as a Service

- **Software ownership costs pushed to vendor** - hardware, software, system security, disaster recovery, maintenance, monitoring
- **Return to core competency** - organizations shift resources to core competencies, vendors focus on managing their SaaS
- **More efficient deployment** - instant evaluation, more collaboration between vendor and IT organization, much faster deployments
- **Eliminate shelfware & maintenance** - pay for what you use
- **Always on current version** - version-free software means the latest for the customer
- **Modern, Web 2.0 interface** - drive technician usage and better customer interaction with IT
- **SaaS homogeneity costs less** - one version for the vendor to support means lower costs for everybody

Application areas suitable for SaaS

- **ERP vertical business** applications, both specialized and very specific
- **General-purpose** applications without any adaptation (potentially sharable)
  - self-service provisioning and ad-hoc personalization
  - applications available to several different users
- **Business B2B** applications **domain specific**
  - no need of third party hosting and involvement
- **Customer/Supplier** applications
  - applications where most of users and access is externally to the organization and where ubiquitous access via Web is critical and intrinsic
- **Business** applications **even critical**, but not the **core business ones**

Traditional on-premise Deployment at the client site



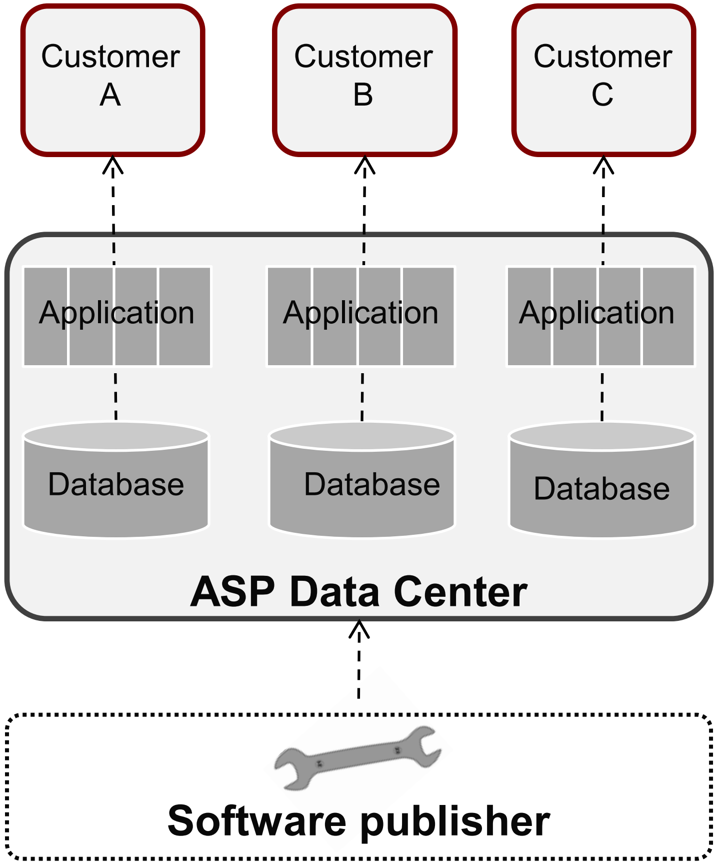
Details

- Full ownership
- Significant implementation
- Customizable
- Difficult to upgrade / maintain

Examples

- HP Service Manager
- BMC Remedy
- CA Service Desk
- EMC Infra

Application Service Provider (ASP)



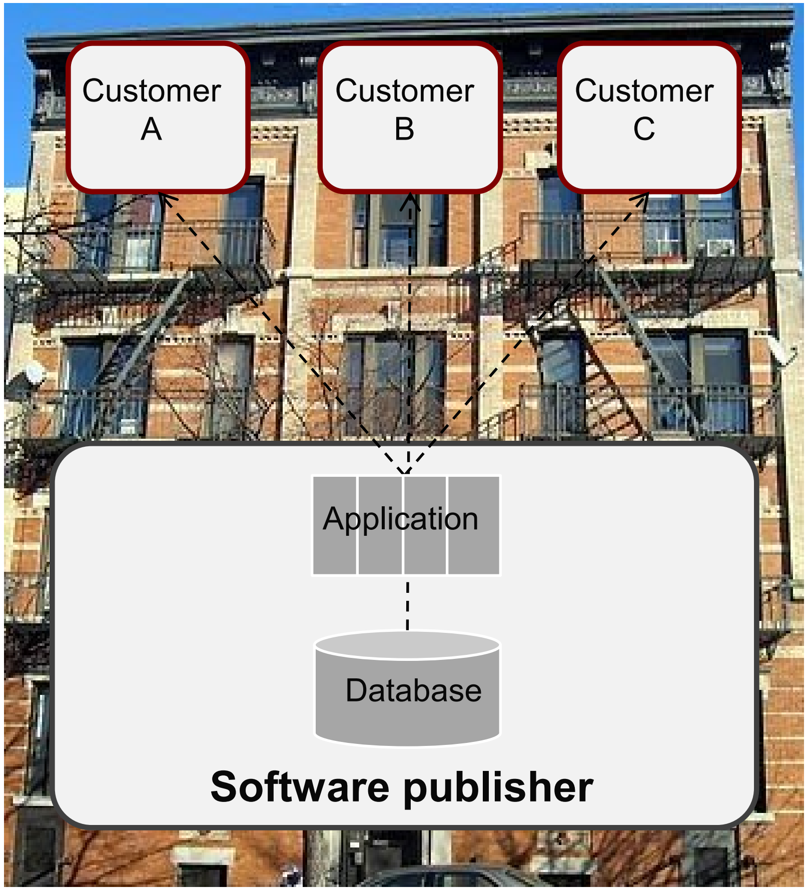
Details

- Procures app and resells service
- Broker between customer and publisher
- Focus on ‘out-of-box’

Examples

- IBM GS
- HP Services
- BMC AAS
- CSC

SaaS multi-tenant



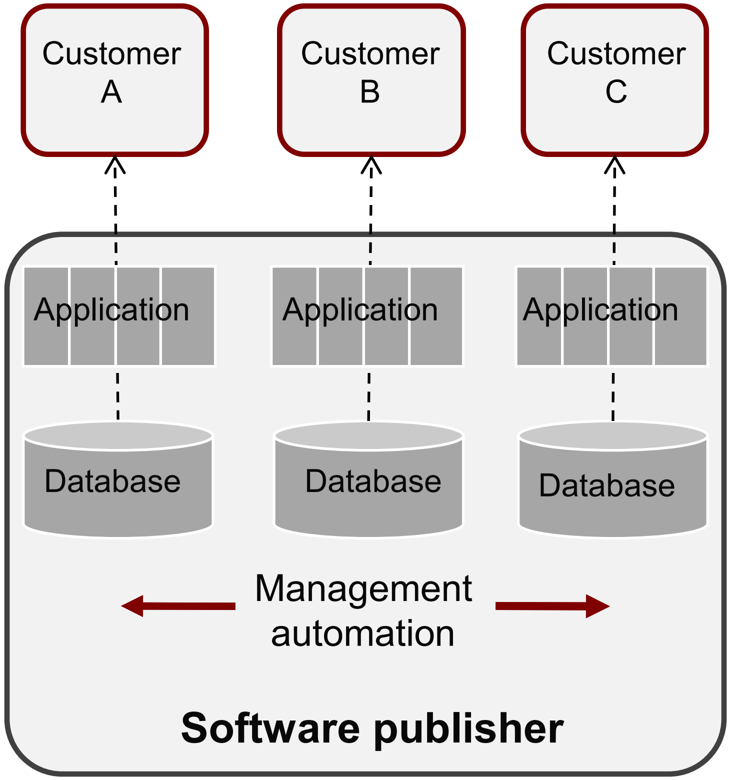
Details

- Hosted by software publisher
- Many customers to one application set
- Thought to be inflexible

Examples

- Salesforce.com
- Workday
- Innotas

SaaS single-tenant



Details

- Hosted by software publisher
- Customers receive their own app and database
- Auto-upgrades
- Extensive customization

Examples

- Service-now.com
- InteQ
- Eloqua

SaaS Models

Some increasing resources models for providing some resources as a service, X**aaS**

SaaS **S**oftware **as a S**ervice

- Resources are simple **applications available** via remote Web access

PaaS **P**latform **as a S**ervice

- Resources are **whole software platforms available** for remote execution, i.e., several programs capable of interacting with each other

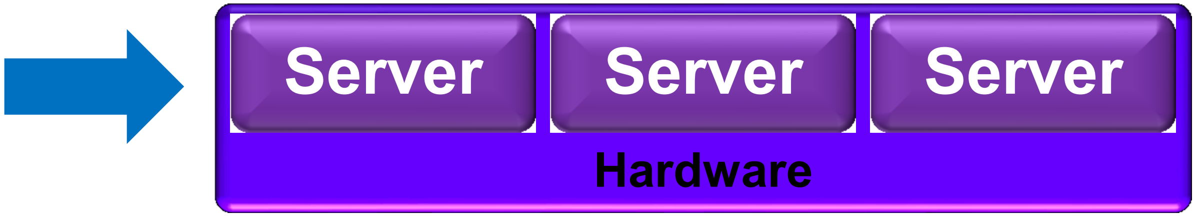
Iaas **I**nfrastructure **as a S**ervice

- Resources are intended **in a wider and complete way,** from **hardware platforms**, to **operating systems,** to **support** to final **applications**: usually via virtualization

  up to **Cloud Computing**

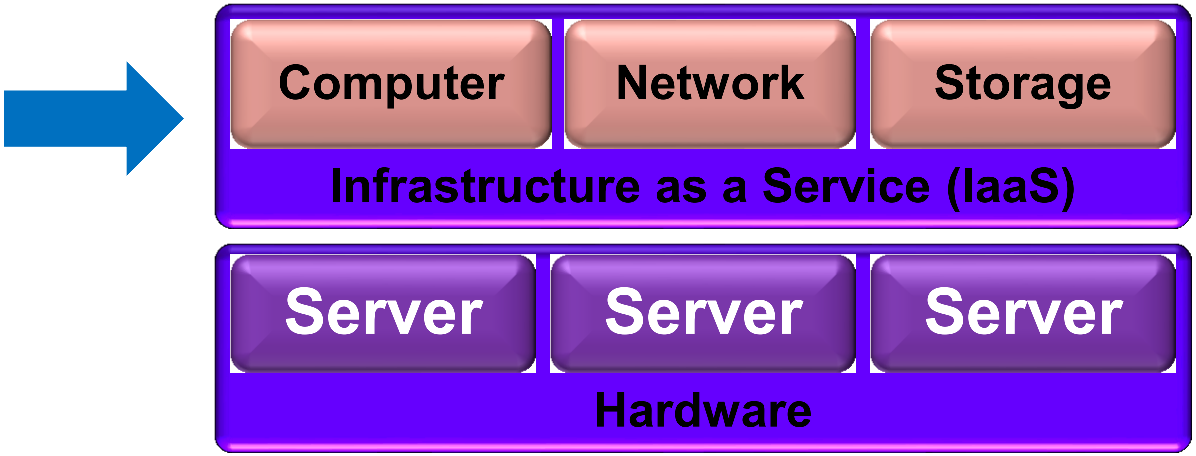
Layered Architecture: IaaS, PaaS & SaaS

- Below the real architecture: **hardware** components & software products



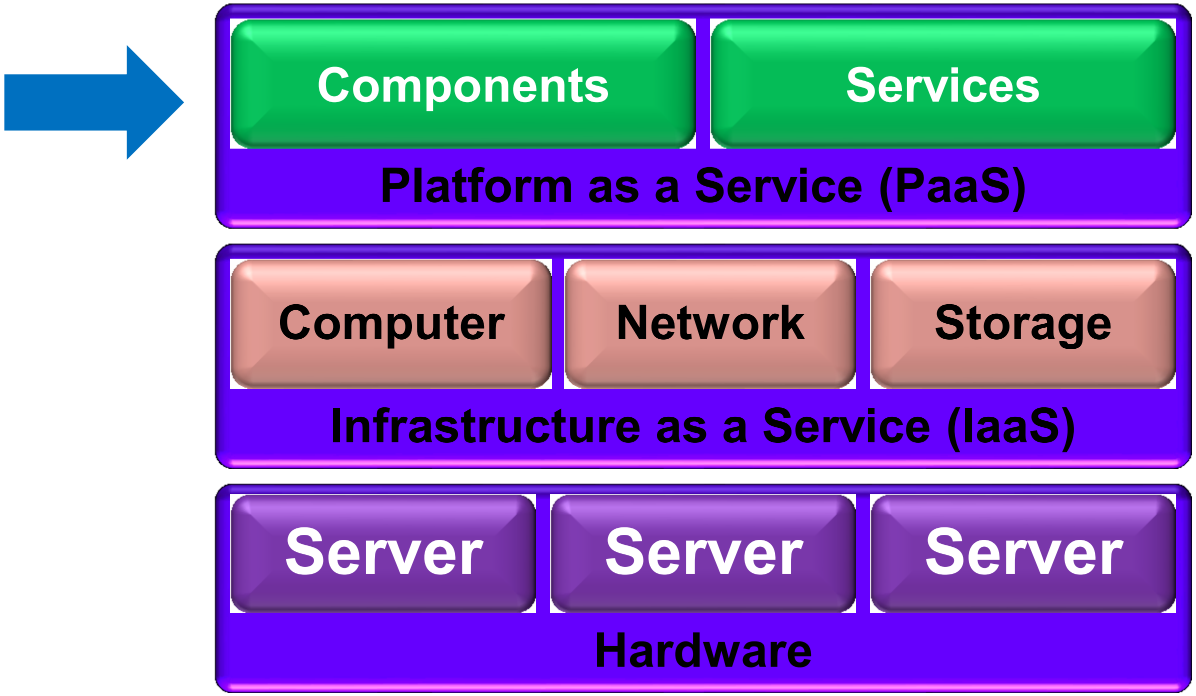
Layered Architecture: IaaS, PaaS & SaaS

- **Infrastructure**: layer to enable the distribution of Cloud services, typically realized by a virtualization platform



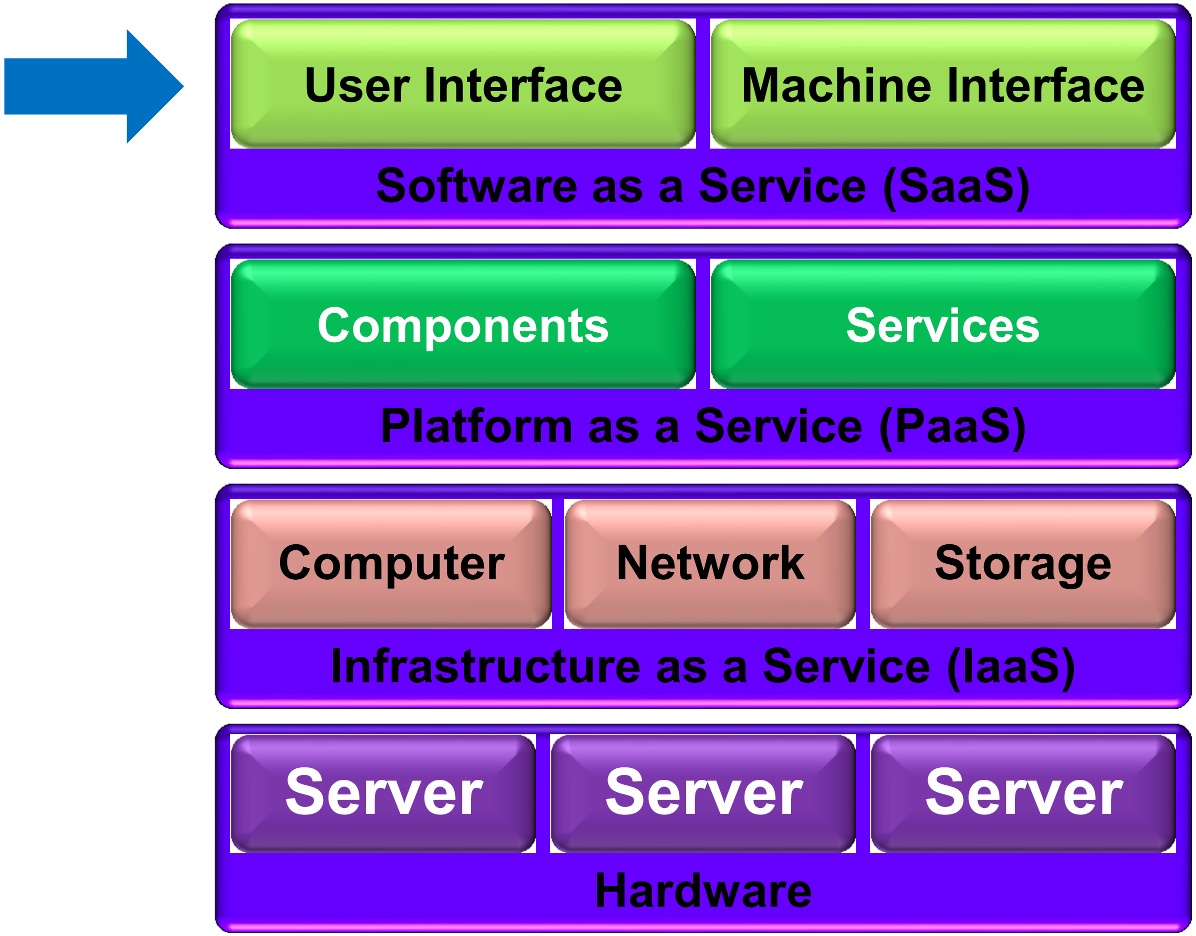
Layered Architecture: IaaS, PaaS & SaaS

- **Platform:** layer to provide to upper layers a set of services and components remotely available



Layered Architecture: IaaS, PaaS & SaaS

- **Application**: layer to install applications, to be available via Web and Internet via Cloud



User Interface

Machine Interface

Software as a Service (SaaS)

Components

Services

Platform as a Service (PaaS)

Computer

Network

Storage

Infrastructure as a Service (IaaS)

Server

Server

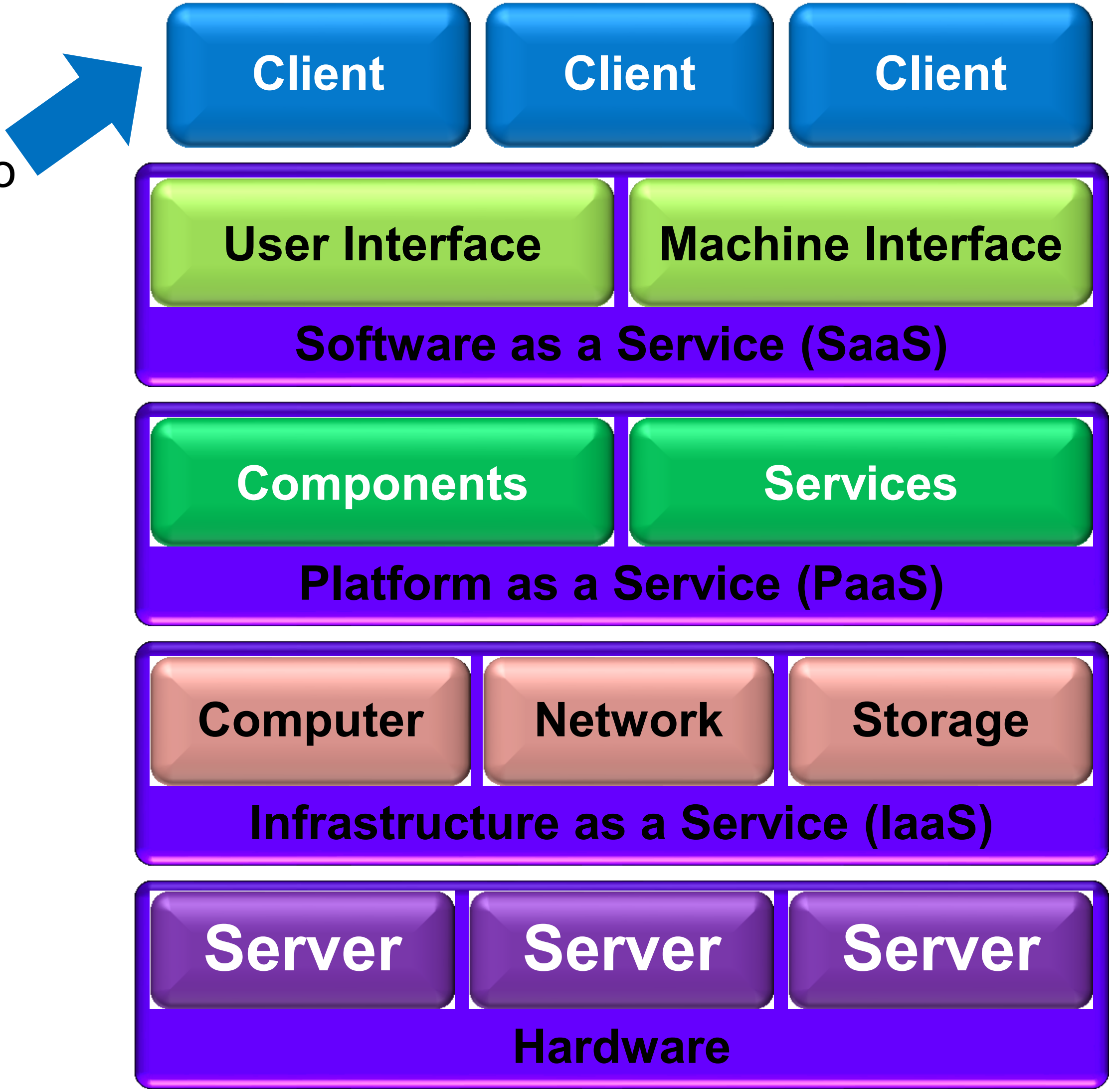
Server

Hardware

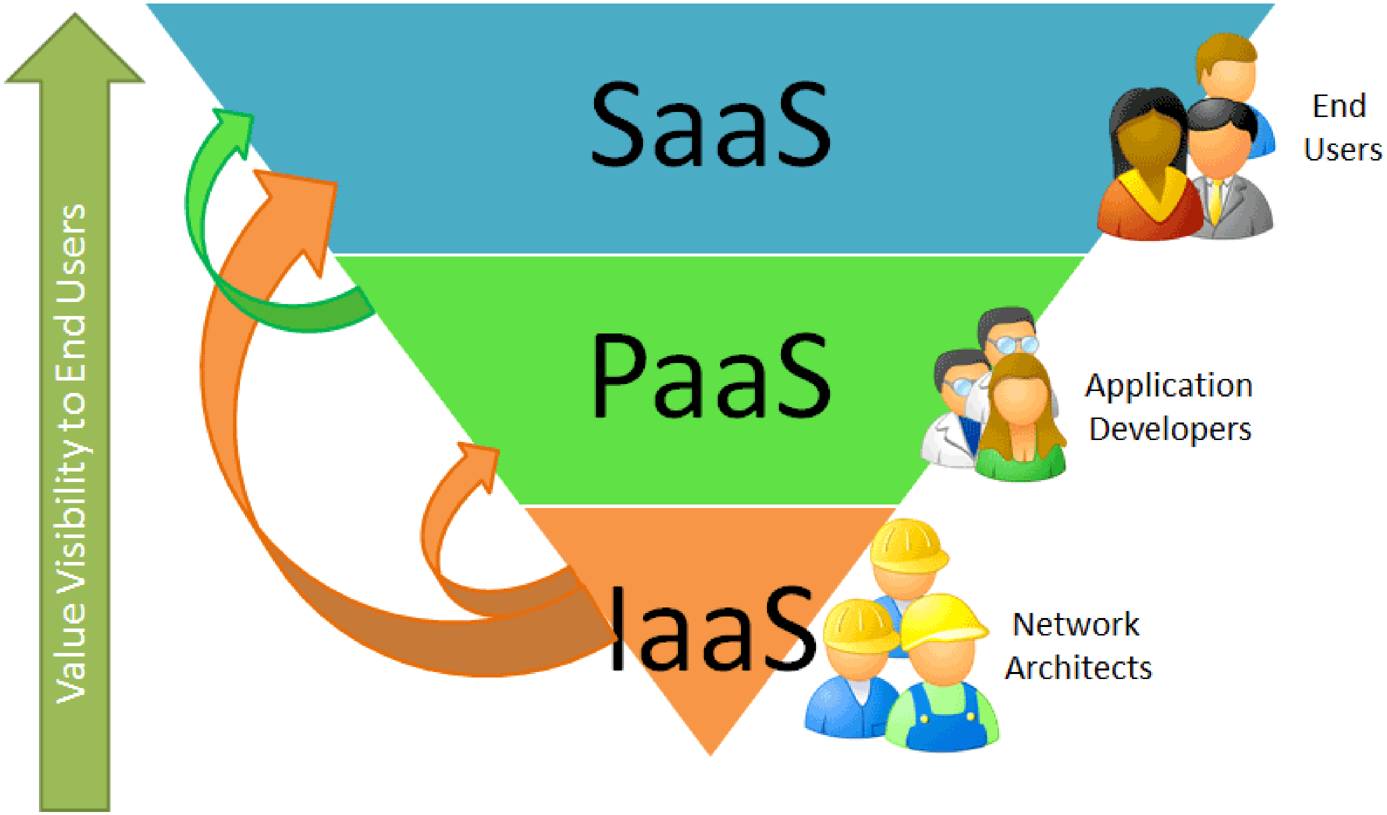
Layered Architecture: IaaS, PaaS & SaaS

- **Client** software to get access to the system.
  Those applications execute on the **client physical platforms** (remote computers) owned by the final remote user

  they can communicate with the Cloud via the **available interfaces**



Layered Architecture: Actors



Some SaaS and *-aaS examples

SaaS

From desktop applications: **Google Apps** (Gmail, Google calendar & docs), **Microsoft Window live** (Hotmail, Messenger, …) to search engines, Google, Yahoo, Several **social networks** **(**Facebook, LinkedIn, Twitter, …)

PaaS typically accessed via Web service

Services available internally to and interacting with other applications, as **Google Maps**

Iaas   some experimental infrastructures

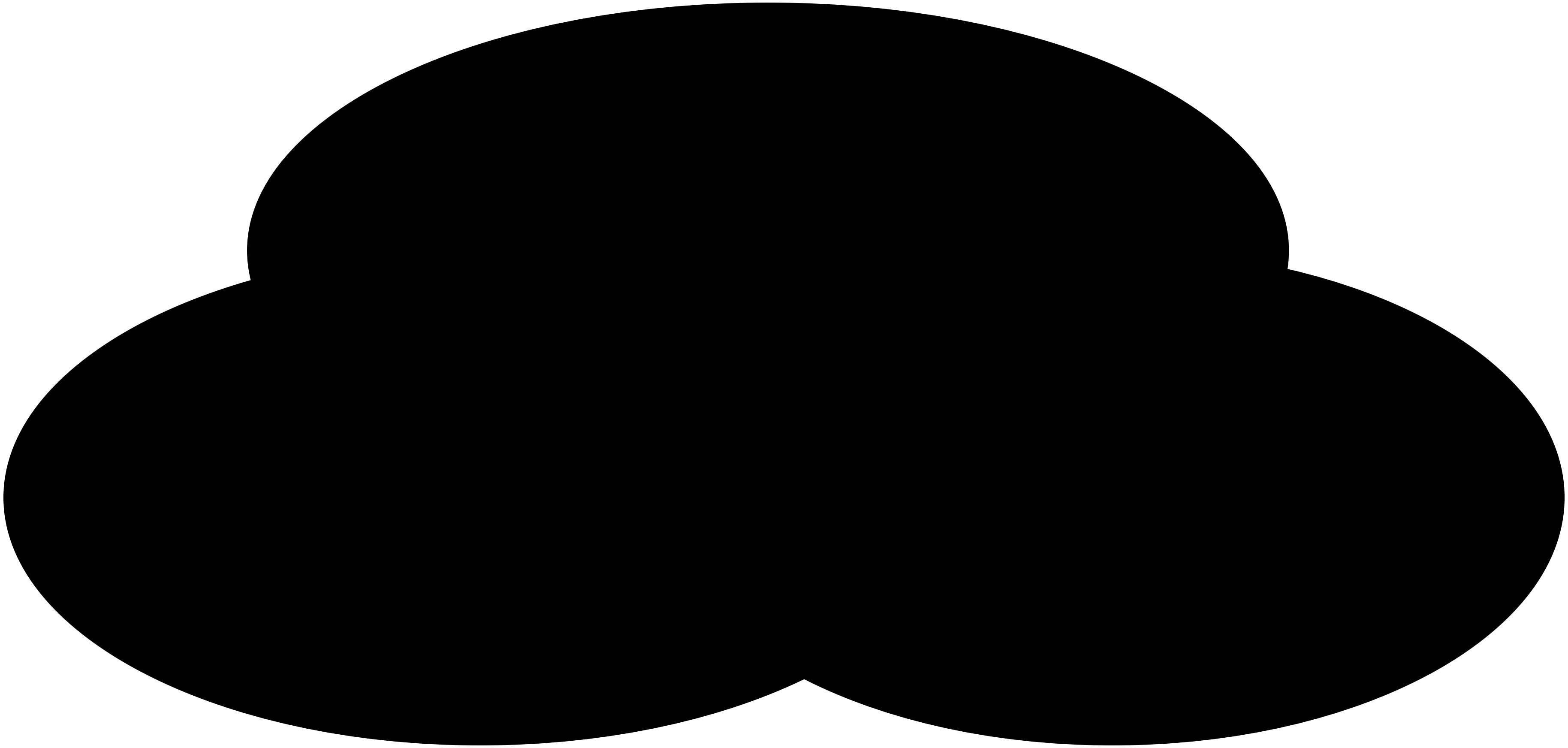
Several examples, with virtualization services, **Amazon Web Services** (S3), **Elastic Computing Cloud** (EC2), to several management and monitoring desktops to control execution (Sun global desktop, Zimdesk, …)

Cloud different from …

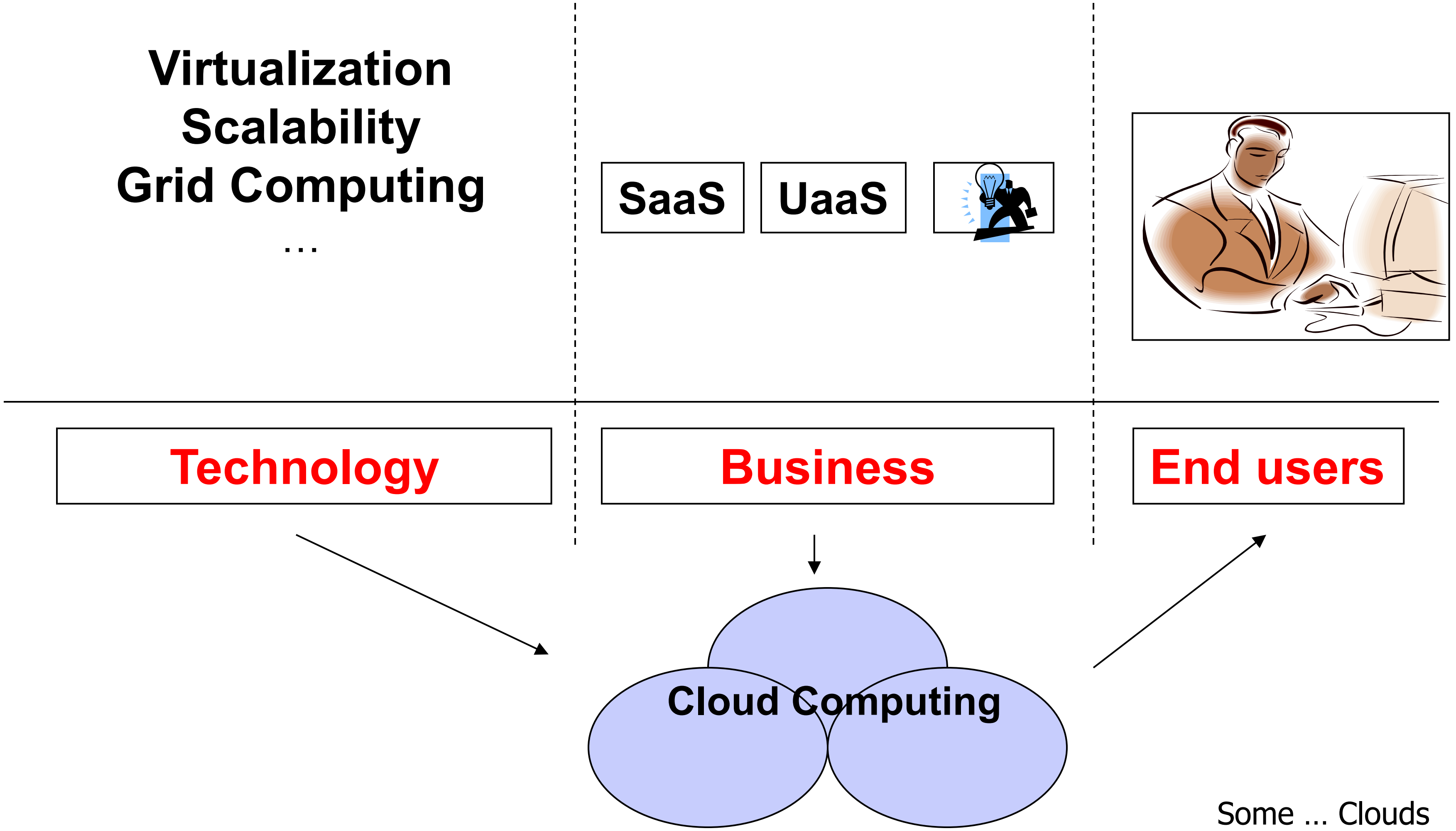
- **Grid Computing**
  - A cloud is more than a **collection of computer resources** because a cloud provides a mechanism to manage those resources

    Provisioning, change requests, workload balancing, monitoring
  - Cloud computing is an infrastructure that sits on top of a data centre for efficiency
- **Utility Computing**
  - Service that allows users to **deploy, manage, and scale** online services using the provider's resources and pay for resources they consume
  - Users want to be in control of what runs on each server
  - **Cloud users** want to avoid infrastructure. The provider is in complete control.
- **SaaS**
  - Software that is **owned, delivered, and managed remotely** by one or more providers
  - Software that allows a sharing of application processing and storage resources in a one-to-many environment on a pay-for-use basis, or as a subscription

Evolution of Cloud Computing



Technology & Business



Virtualization
Scalability
Grid Computing
…

SaaS

UaaS

Technology

Business

End users

Cloud Computing

Cloud computing: reality check

- **Amazon Elastic Computing – EC2**: virtualized images (DB+Software and middleware+OS), Xen, simple SLA console
- **Google App Engine** (Software as a Service, web applications, Google App Engine, sandbox for management and security)
- **IBM Blue Cloud**: virtualized images (DB+Software and middleware+OS), Xen, Tivoli (monitoring and management), simple SLA console
- **HP/Yahoo/Intel Test Bed**: virtualized images, Xen, simple SLA console
- **Microsoft Azure**: recently launched by Microsoft
- **Openstack**: standard effort with large diffusion
- **Research initiatives** (***RESERVOIR EU FP7 project***, previous projects on grid computing such as EEGE, …)

Others ongoing projects: **Eucalyptus**, **3Tera**, …

Cloud Key Goals
Infrastructure Perspective

- How can we provide flexible compute resources quickly to promote **rapid prototyping**?
- How do we deploy applications that **scale up** to meet increasing demands over time?

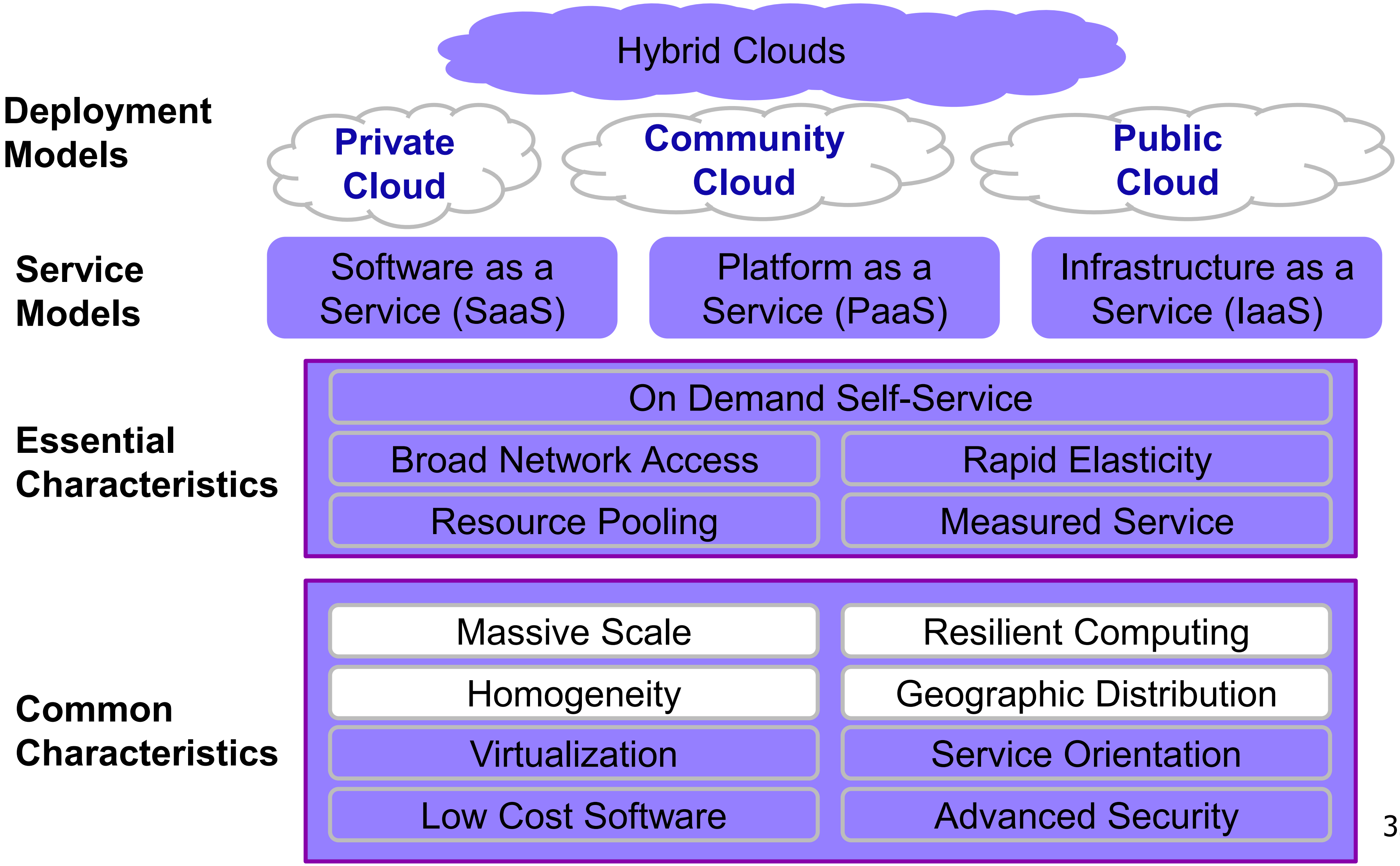
- How do we manage 100,000's of machines with **minimal human intervention**?
- How can we make the most **efficient** use of all the compute resources in a data center?

Cloud Deployment Models

Typically three models

- **Private cloud**
  - enterprise owned or leased
- **Community cloud**
  - shared infrastructure for specific community
- **Public cloud**
  - sold to the public, mega-scale infrastructure
- Hybrid cloud
  - composition of two or more clouds

The NIST Cloud Definition Framework



Hybrid Clouds

Deployment Models

Private Cloud

Community Cloud

Public Cloud

Service Models

Software as a Service (SaaS)

Platform as a Service (PaaS)

Infrastructure as a Service (IaaS)

Essential Characteristics

On Demand Self-Service

Broad Network Access

Rapid Elasticity

Resource Pooling

Measured Service

Common Characteristics

Massive Scale

Resilient Computing

Homogeneity

Geographic Distribution

Virtualization

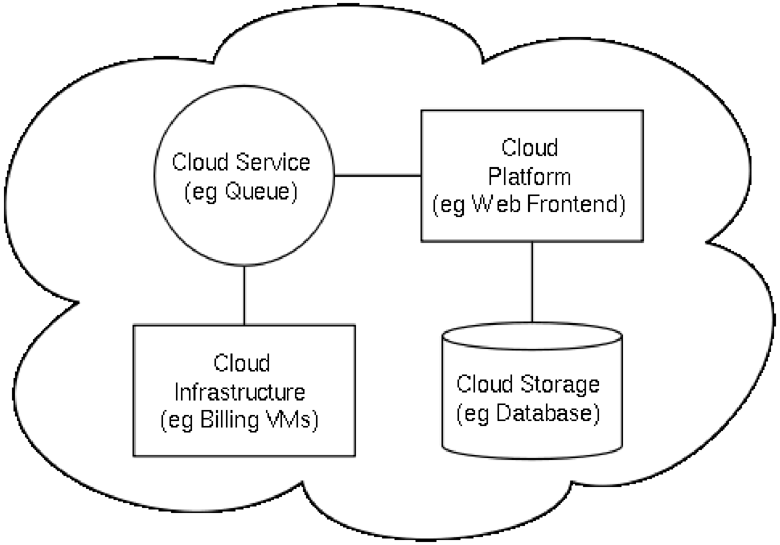
Service Orientation

Low Cost Software

Advanced Security

Cloud components

Cloud Computing software systems have a typical **structure based on components** that can communicate with each other via well defined **interfaces** (often Web Services)

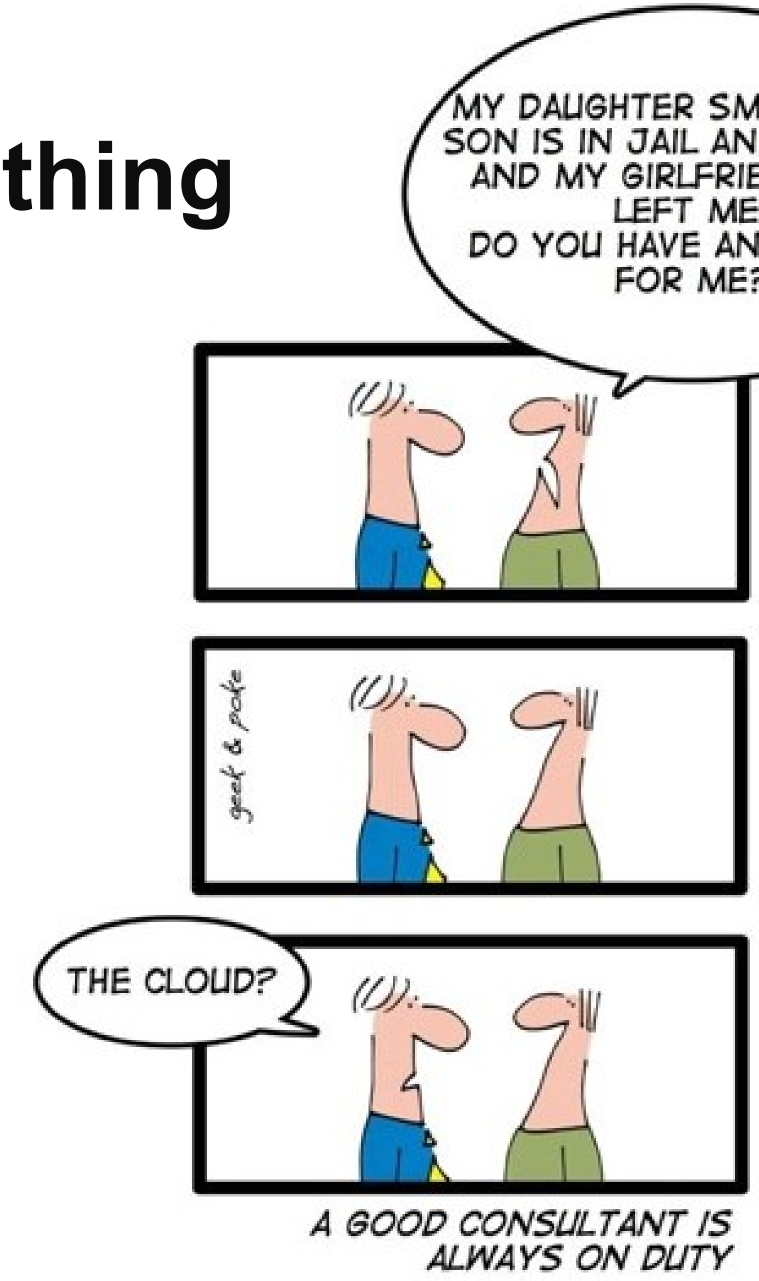


- **Four main components**:
  - one **Cloud platform**, with an externally available **interface accessed via web** to cooperate with the real or virtual internal infrastructure
  - one **virtualization infrastructure** and the management system for the control, monitoring, and billing for **client requests**
  - one internal **memory system typically via** a **database**
  - one internal **manager** to handle **external requests** (management, queuing, and controlling)

Cloud computing …

- **Goal and requirements**
  - **Cost reduction** (to minimize deployment cost, energy, storage, computing power, …)
  - **Scalability on demand** (resources handled in an “elastic way”, all **system resources** are **virtualized** as for **virtual machine, agreed** and **granted** in **SLA** (Service Level Agreement
  - **Automated provisioning and ease of use** (utility computing + infrastructure, platform, and SaaS)
- **Technical areas of intervention**
  - **Management** (system resources, power-saving, …)
  - **Interoperability & portability** (data, applications, and virtual machine images)
  - **Measurement and monitoring** (dynamic on line monitoring, accounting control, …)
  - **Security** (privacy/data control, reputation, …)

Cloud for everything


MY DAUGHTER SMOKES, MY SON IS IN JAIL AND MY WIFE AND MY GIRLFRIEND HAVE LEFT ME. DO YOU HAVE ANY ADVISE FOR ME?
geek & poke
THE CLOUD?
A GOOD CONSULTANT IS ALWAYS ON DUTY

Not exactly for everything ☺

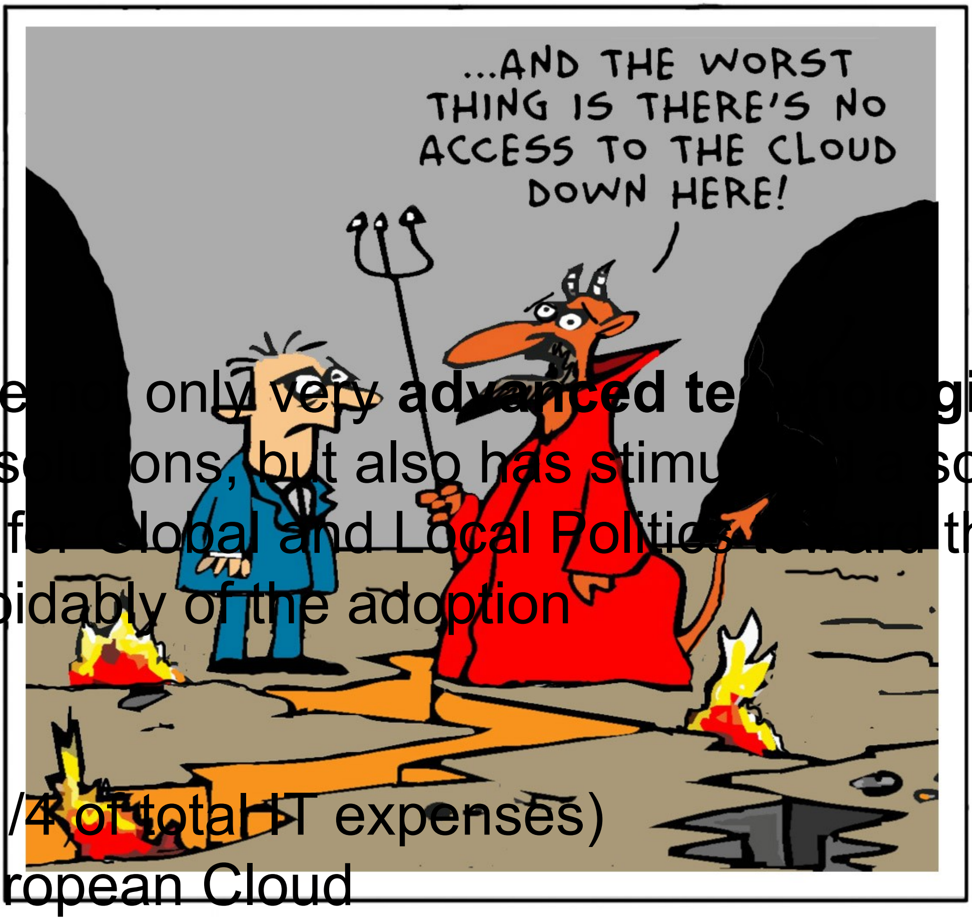
Cloud computing today

The **Cloud term and its related technologies have become very common also for non technical users**

- Advertising

- Humor

- Buzzword


...AND THE WORST THING IS THERE'S NO ACCESS TO THE CLOUD DOWN HERE!

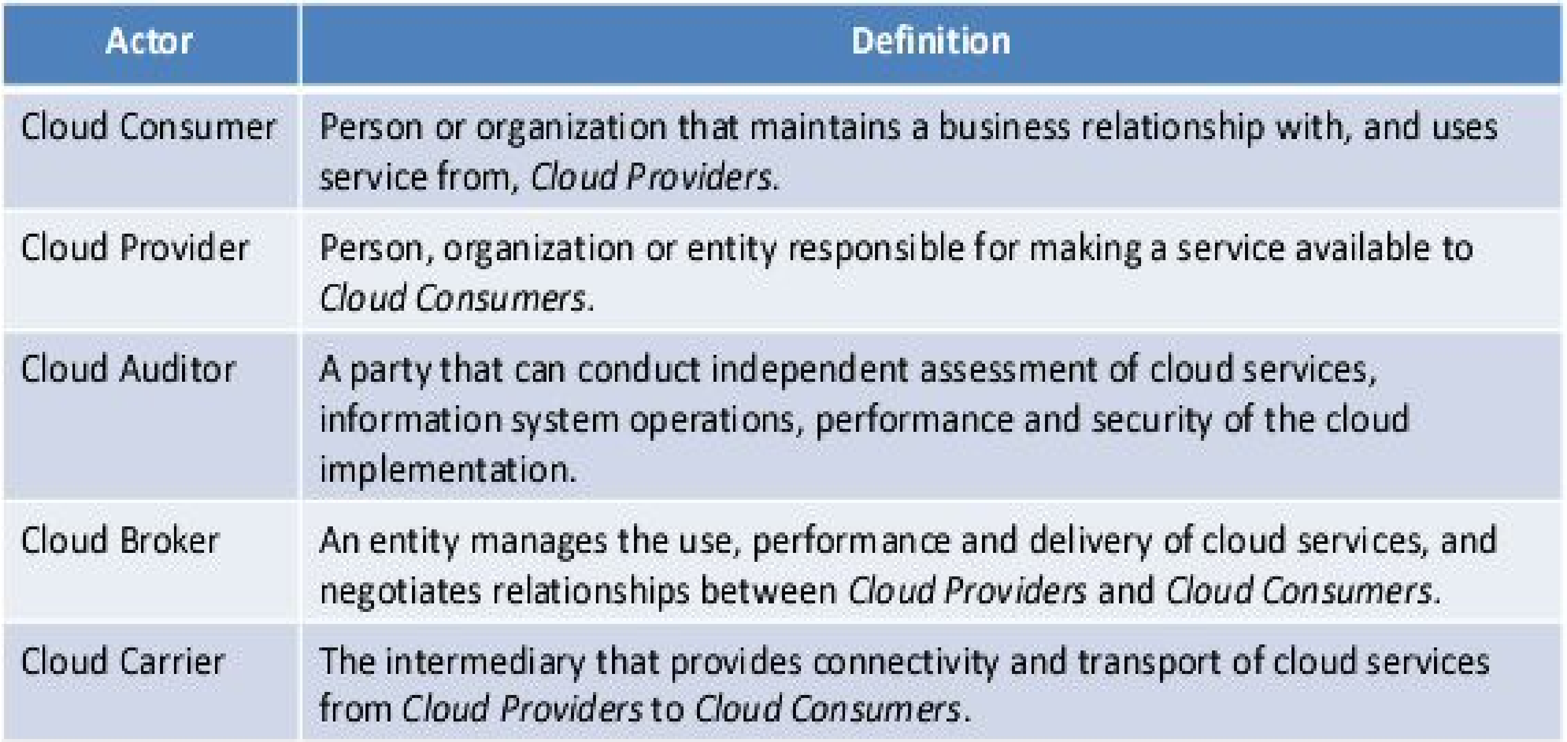
Cloud has provided have not only very **advanced technologies also very widespread** solutions, but also has stimulated some directions as guidelines for Global and Local Politics toward the necessity and the unavoidably of the adoption

- G Cloud in UK
- USA: Federal Cloud (1/4 of total IT expenses)
- UE pushing toward European Cloud

New Business models (NIST - March 2011)

New business roles stemming fromCloud

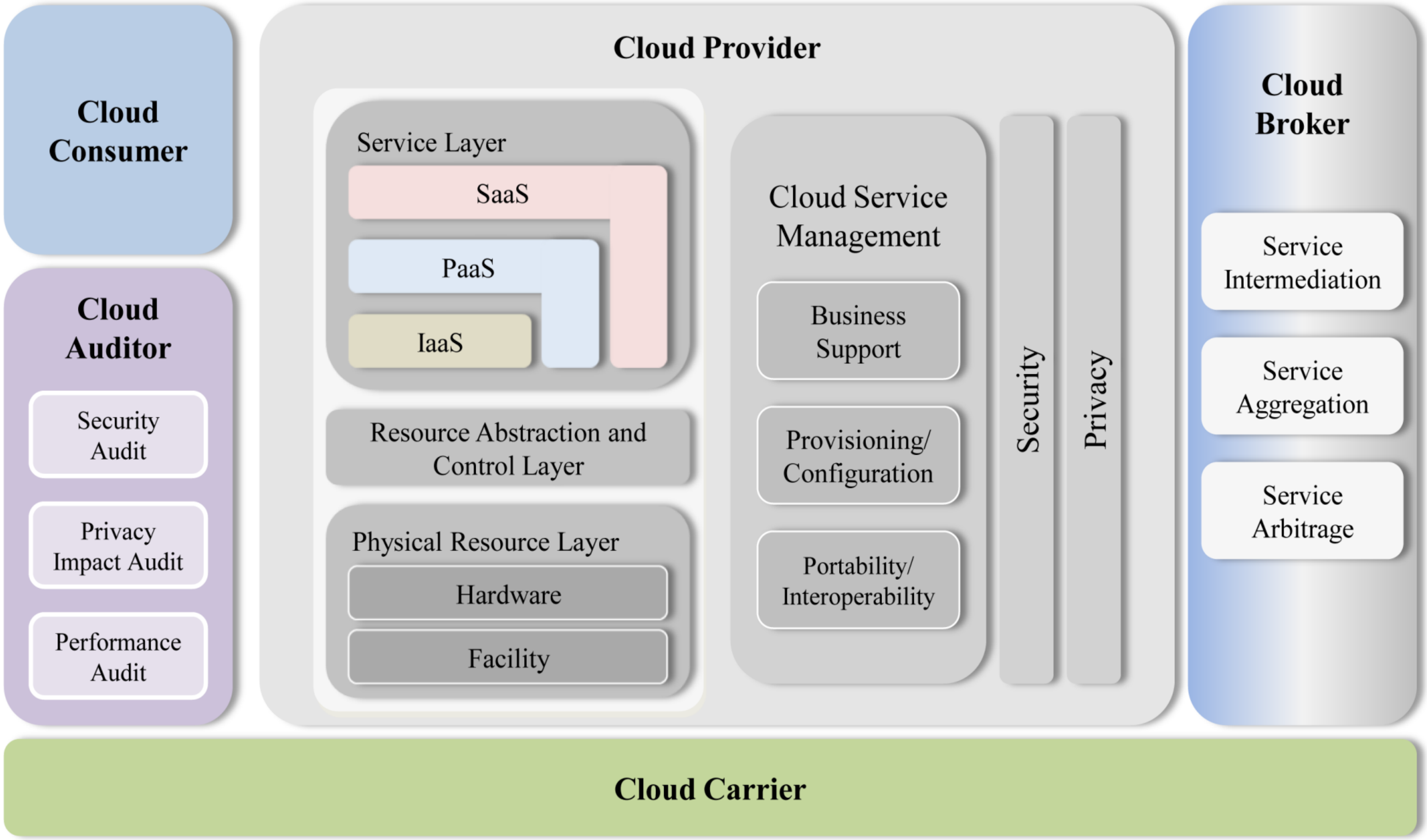
- Consumer, Provider,
- Carrier, Broker, Auditor



Actor	Definition
Cloud Consumer	Person or organization that maintains a business relationship with, and uses service from, *Cloud Providers*.
Cloud Provider	Person, organization or entity responsible for making a service available to *Cloud Consumers*.
Cloud Auditor	A party that can conduct independent assessment of cloud services, information system operations, performance and security of the cloud implementation.
Cloud Broker	An entity manages the use, performance and delivery of cloud services, and negotiates relationships between *Cloud Providers* and *Cloud Consumers*.
Cloud Carrier	The intermediary that provides connectivity and transport of cloud services from *Cloud Providers* to *Cloud Consumers*.

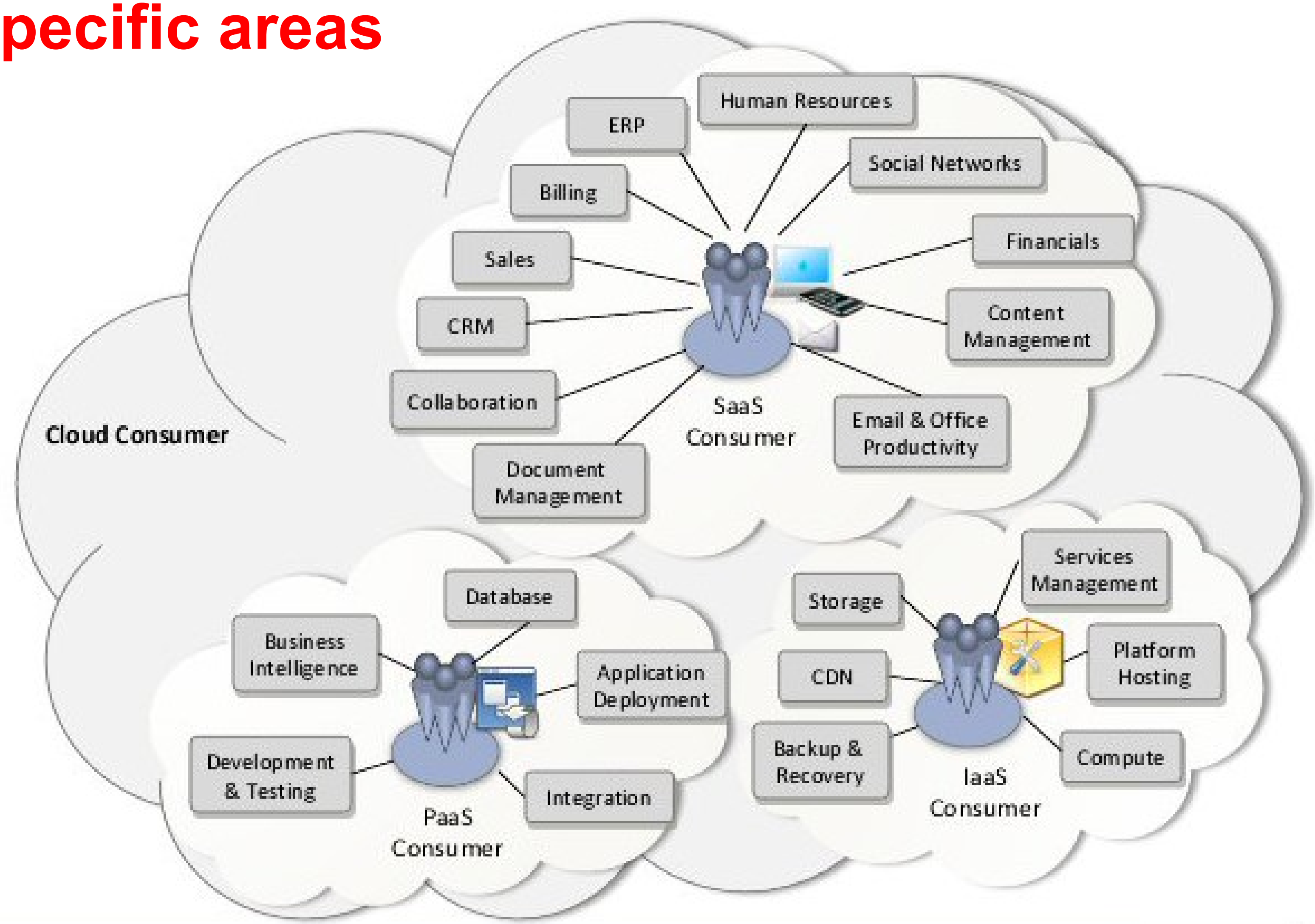
Complete model of service

Some roles and offerings are still not so widely available



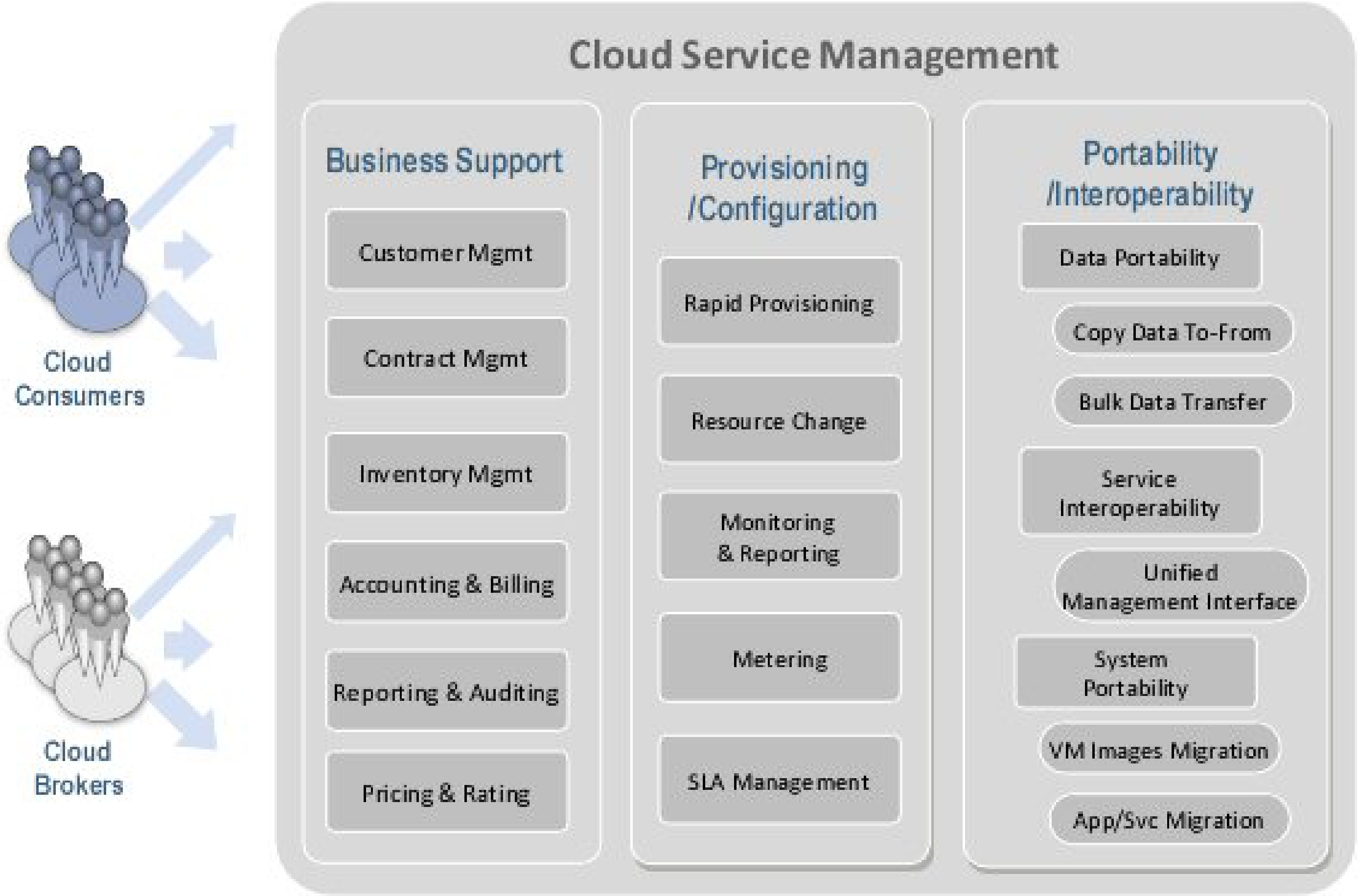
Typical areas of service offering

Clients tend to receive services in some specific areas



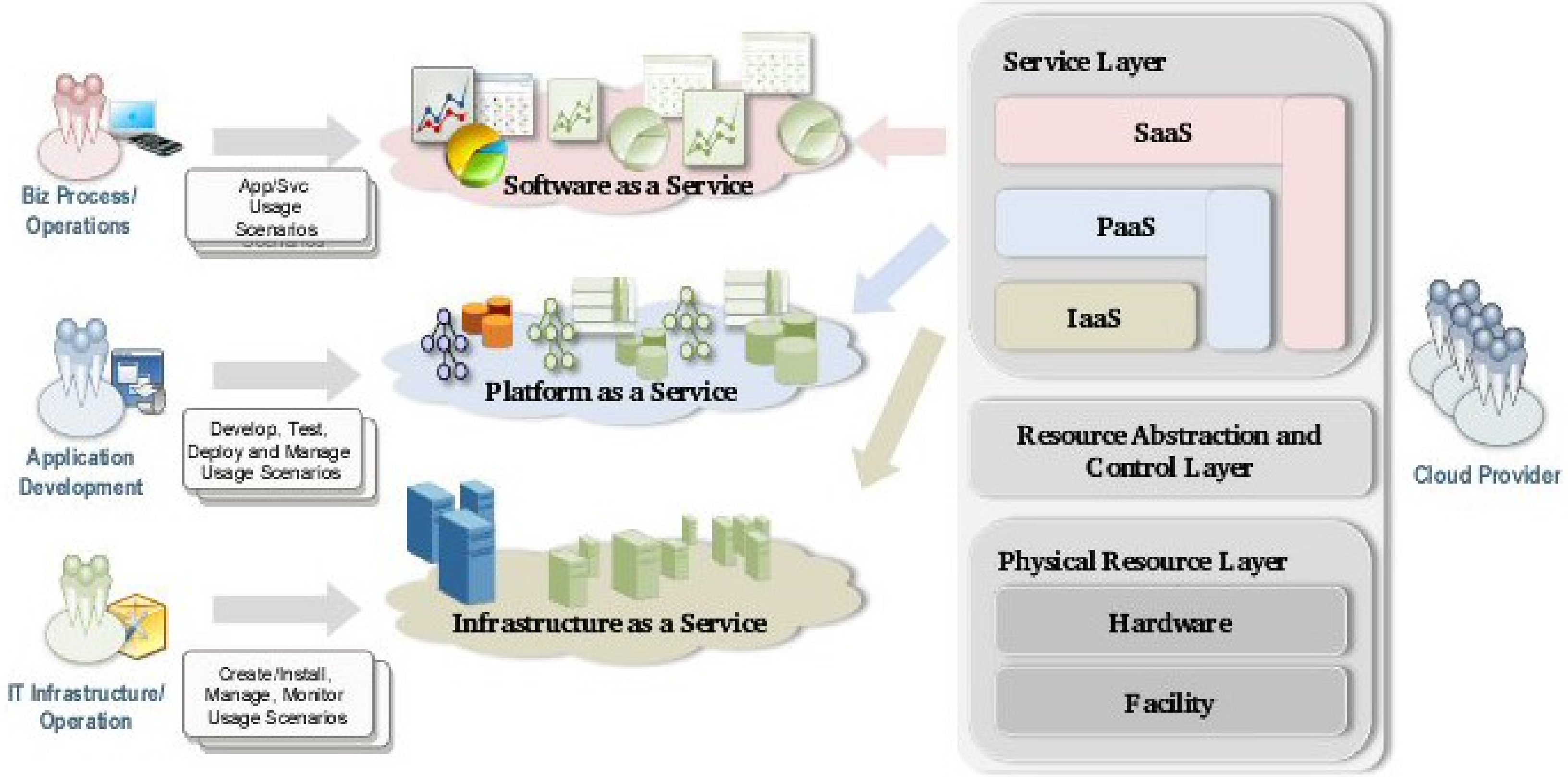
Cloud Provider – Service Handling

Providers must grant QoS of services, by assuring portability, interoperability and security, apart from performance

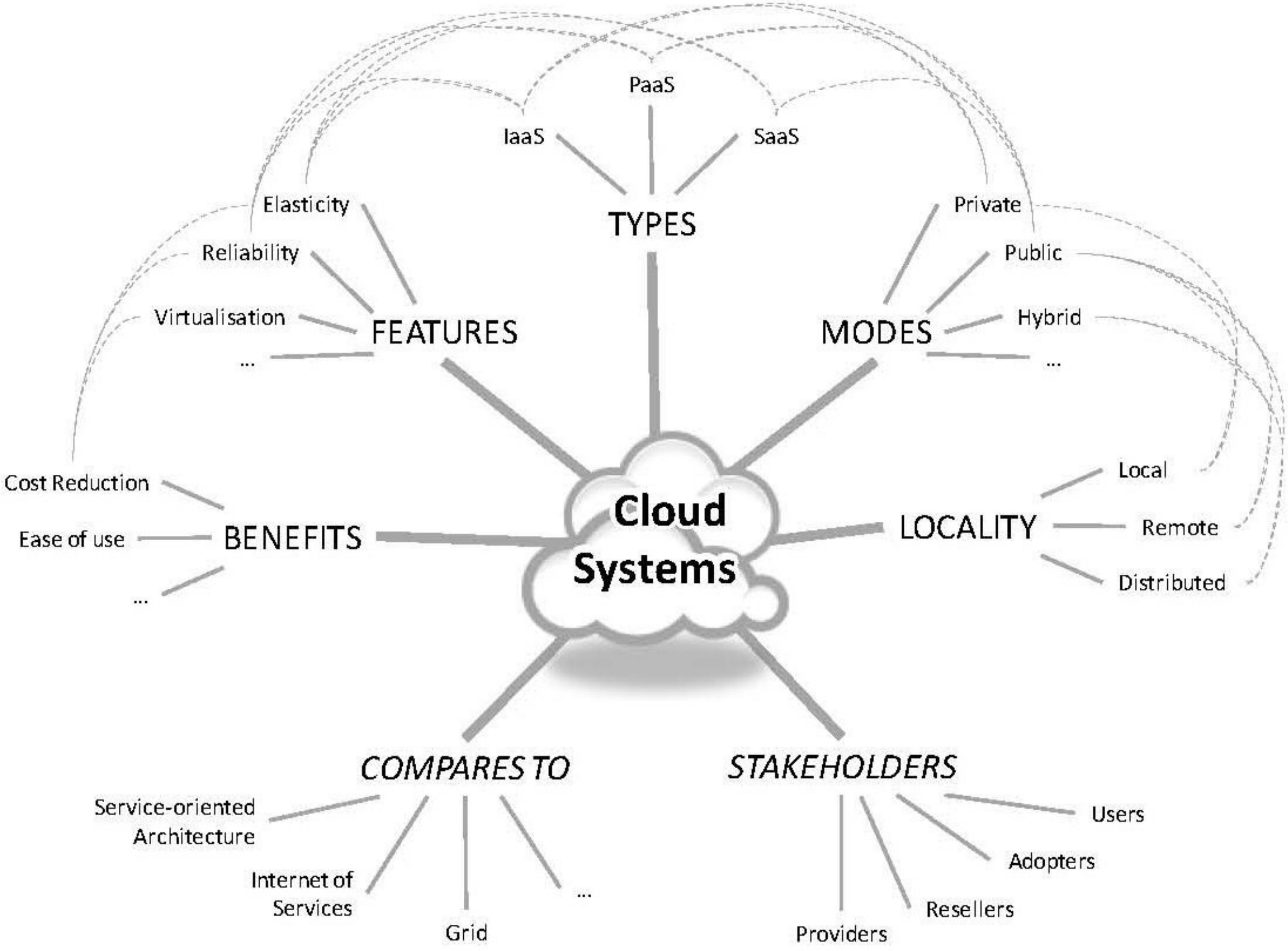


Cloud Providers - Orchestration

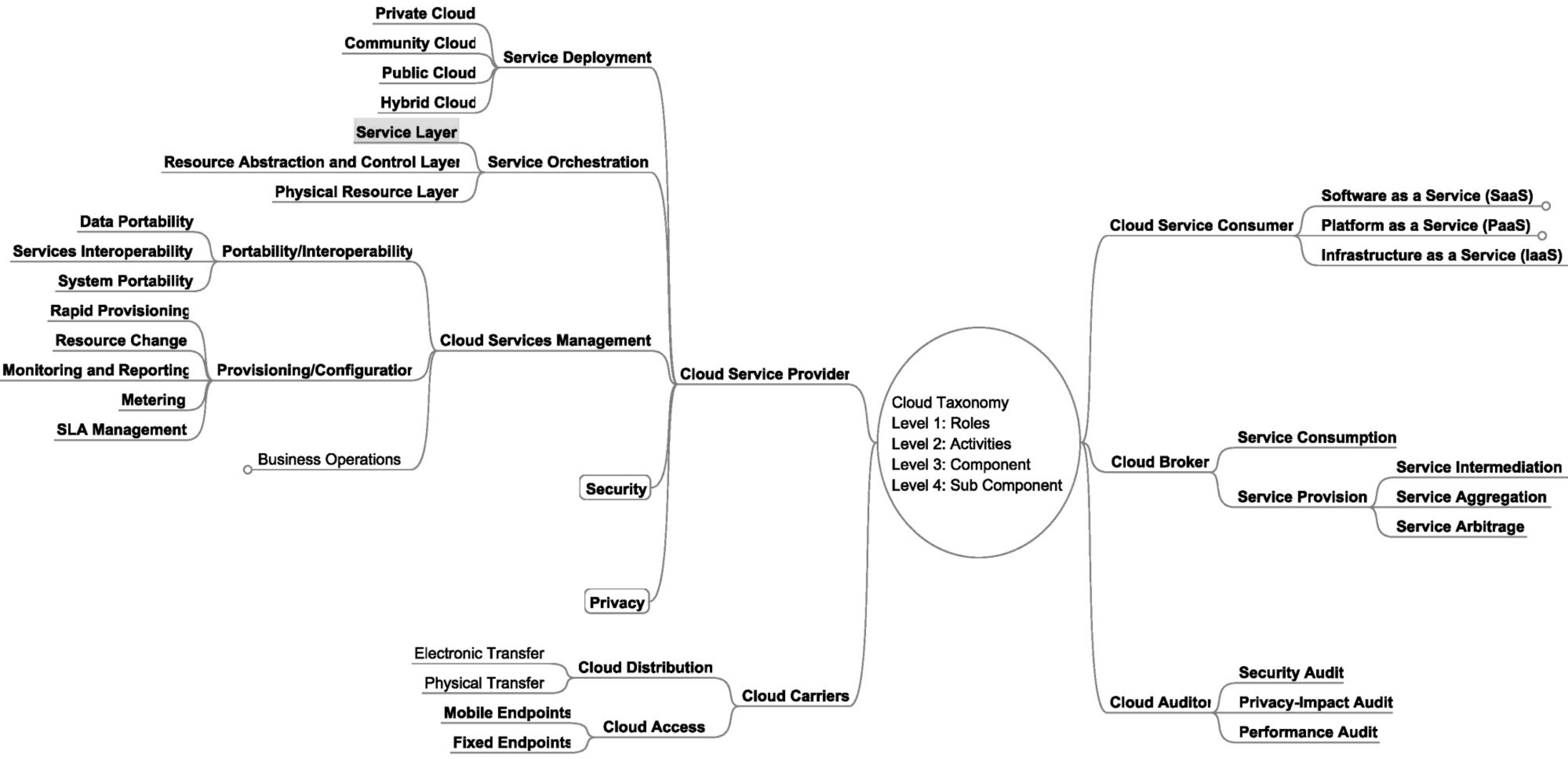
Providers should (could) coordinate offered services, implementing aggregation, intermediation, control and monitoring



Some significant aspects



A taxonomy



- Cloud Taxonomy
  - Level 1: Roles
  - Level 2: Activities
  - Level 3: Component
  - Level 4: Sub Component

- Cloud Service Provider
  - Service Deployment
    - Private Cloud
    - Community Cloud
    - Public Cloud
    - Hybrid Cloud
  - Service Orchestration
    - Service Layer
    - Resource Abstraction and Control Layer
    - Physical Resource Layer
  - Cloud Services Management
    - Portability/Interoperability
      - Data Portability
      - Services Interoperability
      - System Portability
    - Provisioning/Configuration
      - Rapid Provisioning
      - Resource Change
      - Monitoring and Reporting
      - Metering
      - SLA Management
    - Business Operations
  - Security
  - Privacy
- Cloud Carriers
  - Cloud Distribution
    - Electronic Transfer
    - Physical Transfer
  - Cloud Access
    - Mobile Endpoints
    - Fixed Endpoints
- Cloud Service Consumer
  - Software as a Service (SaaS)
  - Platform as a Service (PaaS)
  - Infrastructure as a Service (IaaS)
- Cloud Broker
  - Service Consumption
  - Service Provision
    - Service Intermediation
    - Service Aggregation
    - Service Arbitrage
- Cloud Auditor
  - Security Audit
  - Privacy-Impact Audit
  - Performance Audit

Some open technological probems

Many aspects have been solved, not all of them are, some still hard to tackle

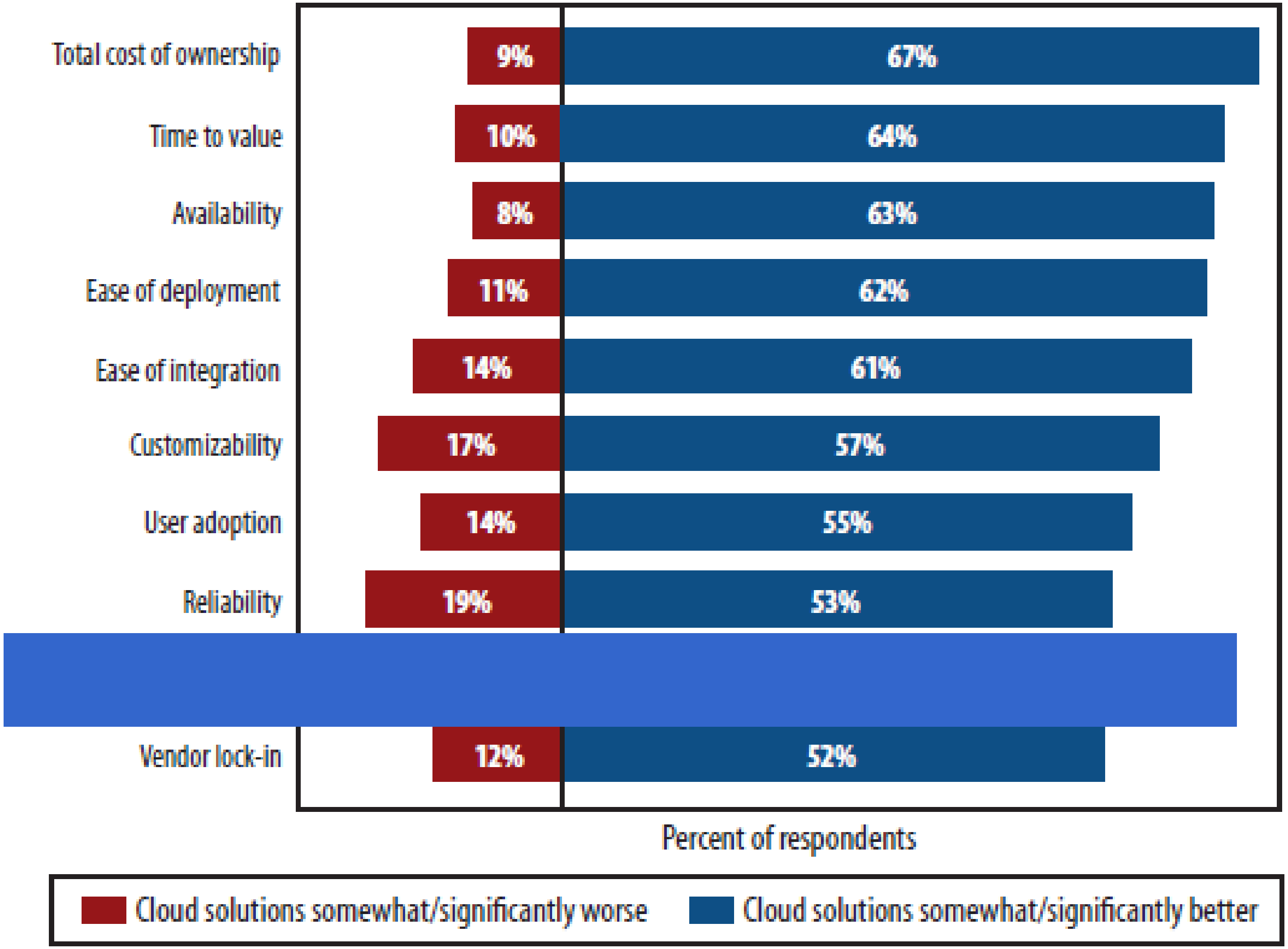
- Virtualization
  - New forms of resource virtualization
- Differentiated and global resource localization
  - Federation and coordination of global resources
- Security, Privacy and SLA adherence
  - Verifiable and trusted assurance policies
- Easy Control, handling and management by user
  - Easy-to-use and user friendly actions and tools
- Data and QoS management
  - self-* and automated system capable of adaptation
- API and platform enhancements
  - New platforms e new interaction modes

Related Issues and Areas

Several directions and guidelines can be applied coming from neighbor areas

- Mobility
- Green e sustainability
- Novel business models
- Open-source and globally-available resources
- Peculiar legal aspects

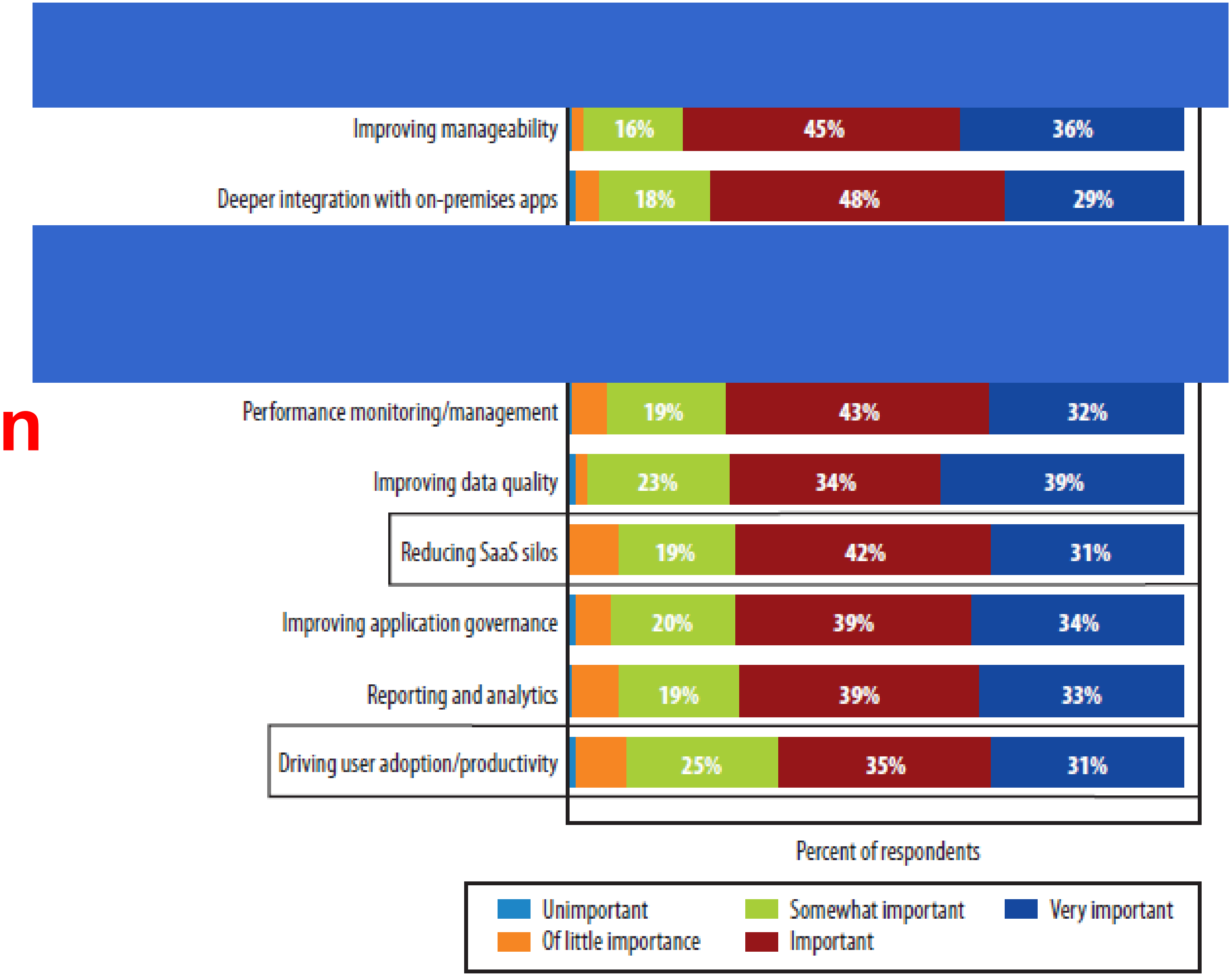
Cloud computing: pros and cons



Cloud : perception and challenges

Security

Integration



Standard: a necessity

Cloud as a new sector, unavoidable in expansion and spreading, but acceleration can be favored by standard acceptation

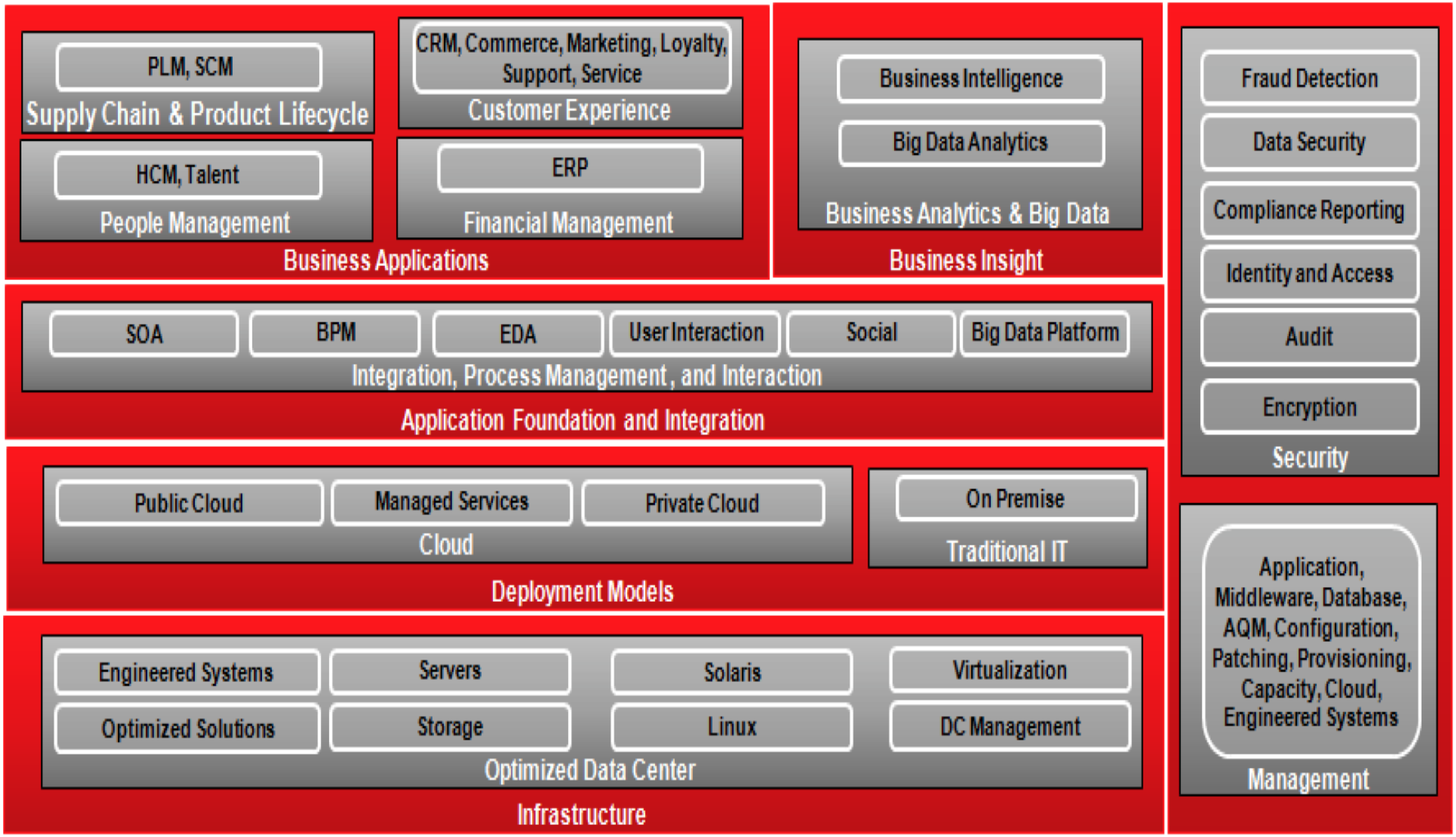
- **Clarity about new roles and responsibility**
- **Open source standard and implementations**
- **Integration with existing protocols (mobile …)**
- **Supports for sustainability**
- **Global and local legal clarity**

- **Ties with other areas:**

  Big Data, Open Data, and **Smart City**

Cloud offer ecosystem

A possible **Cloud portfolio of offered business applications**



PLM, SCM

Supply Chain & Product Lifecycle

CRM, Commerce, Marketing, Loyalty, Support, Service

Customer Experience

HCM, Talent

People Management

ERP

Financial Management

Business Applications

Business Intelligence

Big Data Analytics

Business Analytics & Big Data

Business Insight

Fraud Detection

Data Security

Compliance Reporting

Identity and Access

Audit

Encryption

Security

SOA

BPM

EDA

User Interaction

Social

Big Data Platform

Integration, Process Management, and Interaction

Application Foundation and Integration

Public Cloud

Managed Services

Private Cloud

Cloud

On Premise

Traditional IT

Deployment Models

Application, Middleware, Database, AQM, Configuration, Patching, Provisioning, Capacity, Cloud, Engineered Systems

Management

Engineered Systems

Servers

Solaris

Virtualization

Optimized Solutions

Storage

Linux

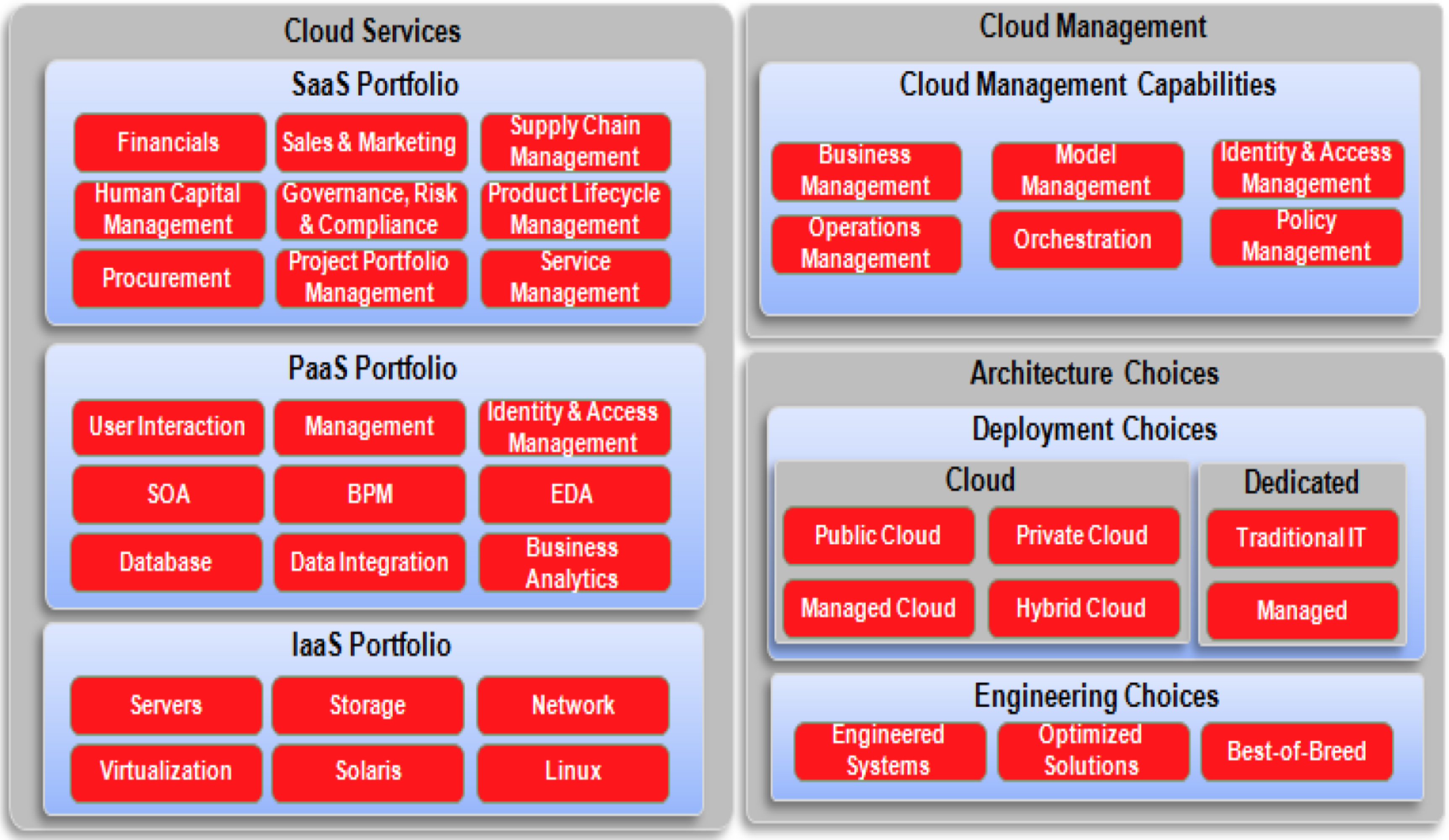
DC Management

Optimized Data Center

Infrastructure

Cloud Solution scenario

A possible **Cloud offer portfolio in internal organization**



Cloud Services

SaaS Portfolio

- Financials
- Sales & Marketing
- Supply Chain Management
- Human Capital Management
- Governance, Risk & Compliance
- Product Lifecycle Management
- Procurement
- Project Portfolio Management
- Service Management

PaaS Portfolio

- User Interaction
- Management
- Identity & Access Management
- SOA
- BPM
- EDA
- Database
- Data Integration
- Business Analytics

IaaS Portfolio

- Servers
- Storage
- Network
- Virtualization
- Solaris
- Linux

Cloud Management

Cloud Management Capabilities

- Business Management
- Model Management
- Identity & Access Management
- Operations Management
- Orchestration
- Policy Management

Architecture Choices

Deployment Choices

Cloud

- Public Cloud
- Private Cloud
- Managed Cloud
- Hybrid Cloud

Dedicated

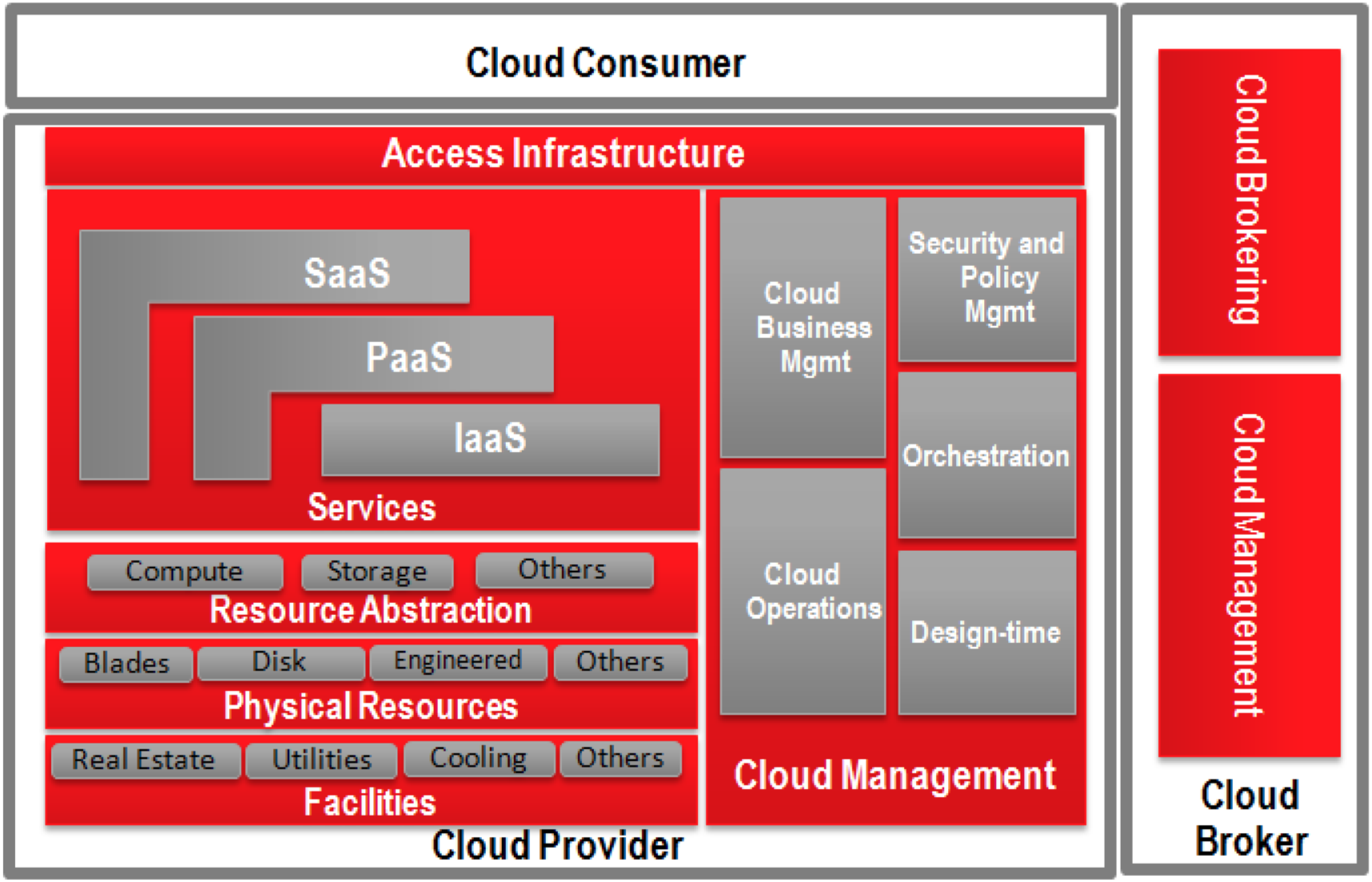
- Traditional IT
- Managed

Engineering Choices

- Engineered Systems
- Optimized Solutions
- Best-of-Breed

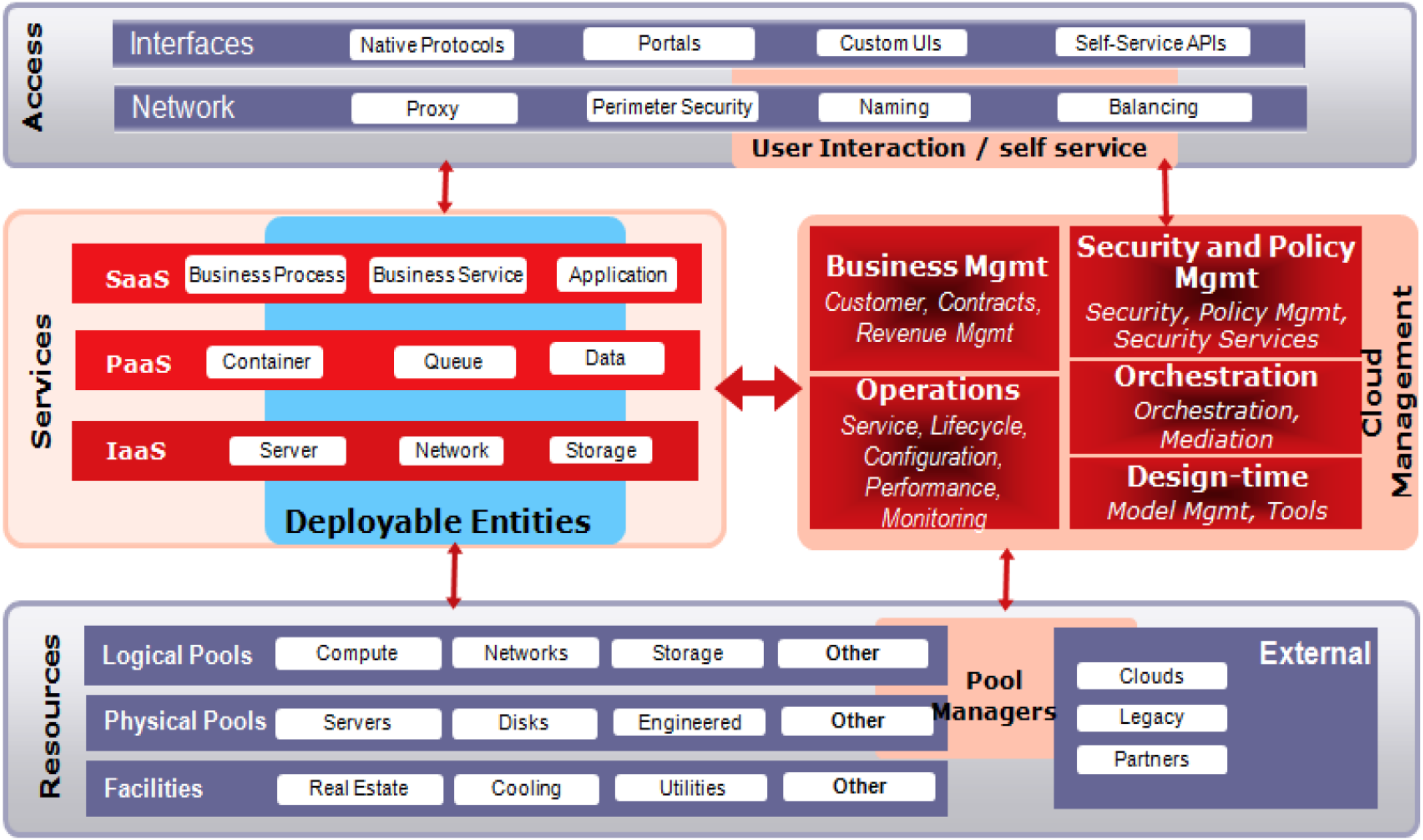
Cloud Solution roles

A possible **Cloud set of scopes**



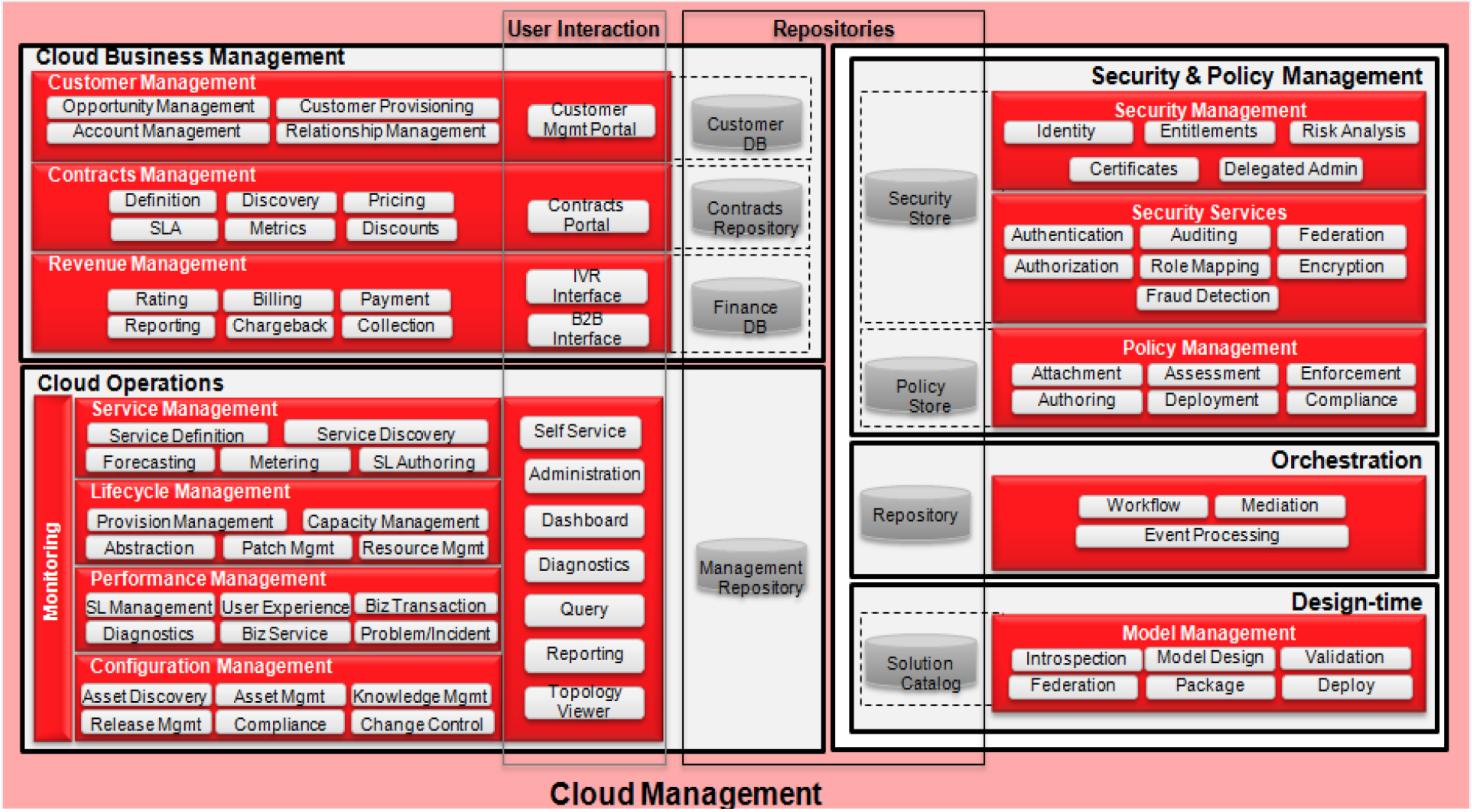
Cloud Components

A **Cloud-layered infrastructure in Cloud components**



Cloud Management

A **Cloud-layered infrastructure for management**



User Interaction

Repositories

Cloud Business Management

Customer Management
- Opportunity Management
- Customer Provisioning
- Account Management
- Relationship Management
- Customer Mgmt Portal
- Customer DB

Contracts Management
- Definition
- Discovery
- Pricing
- SLA
- Metrics
- Discounts
- Contracts Portal
- Contracts Repository

Revenue Management
- Rating
- Billing
- Payment
- Reporting
- Chargeback
- Collection
- IVR Interface
- B2B Interface
- Finance DB

Cloud Operations

Monitoring

Service Management
- Service Definition
- Service Discovery
- Forecasting
- Metering
- SL Authoring

Lifecycle Management
- Provision Management
- Capacity Management
- Abstraction
- Patch Mgmt
- Resource Mgmt

Performance Management
- SL Management
- User Experience
- Biz Transaction
- Diagnostics
- Biz Service
- Problem/Incident

Configuration Management
- Asset Discovery
- Asset Mgmt
- Knowledge Mgmt
- Release Mgmt
- Compliance
- Change Control

- Self Service
- Administration
- Dashboard
- Diagnostics
- Query
- Reporting
- Topology Viewer

Management Repository

Security & Policy Management

Security Store

Security Management
- Identity
- Entitlements
- Risk Analysis
- Certificates
- Delegated Admin

Security Services
- Authentication
- Auditing
- Federation
- Authorization
- Role Mapping
- Encryption
- Fraud Detection

Policy Store

Policy Management
- Attachment
- Assessment
- Enforcement
- Authoring
- Deployment
- Compliance

Orchestration

Repository
- Workflow
- Mediation
- Event Processing

Design-time

Solution Catalog

Model Management
- Introspection
- Model Design
- Validation
- Federation
- Package
- Deploy

Cloud Management