University of Bologna

Dipartimento di Informatica – Scienza e Ingegneria (DISI)

Engineering Bologna Campus

Class of

Computer Networks M

Middleware & Cloud models

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MIDDLEWARE

The term MIDDLEWARE has an obvious meaning

The set of tools that sit in the middle between the application and the support: i.e.,

hardware, local **operating system** and **technology**, …

The term **middleware** goes back to **1968**, to a famous **NATO** school on **Software Engineering**

Anyway, middleware was not so **significant until the 90'**, when **distributed systems** became widespread and commonplace

Middleware is a solution to design and support **complex, distributed, deeply heterogeneous systems** also suitable for **very heterogeneous organizations to provide very differentiated services**

MIDDLEWARE

a definition of MIDDLEWARE

The set of tools that allow integrating different application and services to be used in open **environment (heterogeneous) with an unlimited lifecycle, at least the whole organization life**

Middleware are offering and proposing the **support tools,** to **control** and **managing services during execution**, at all systems level, from physical one up the application level

RPC middleware (RMI)

They propose the usage of Remote Procedure Call as the unique communication tool among all available layers

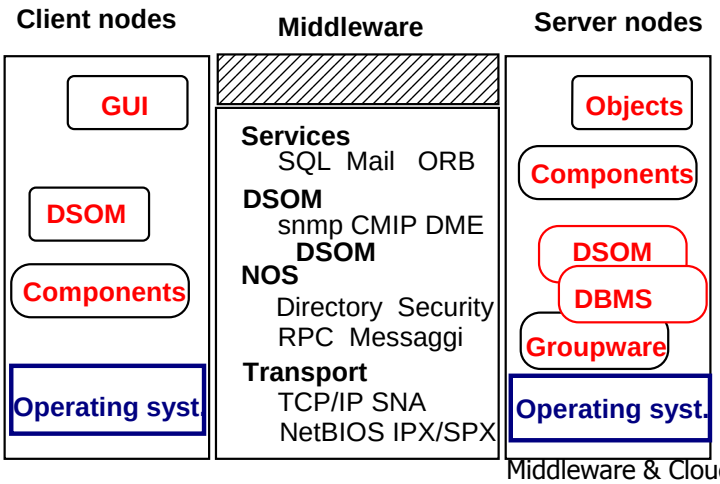
The interaction is both between systems and final users (B2B and also **B2C)**

MIDDLEWARE: HETEROGENEITY

It is a middleware the infrastructure to overcome the problems inherent to ad-hoc solutions, **ad-hoc approaches**

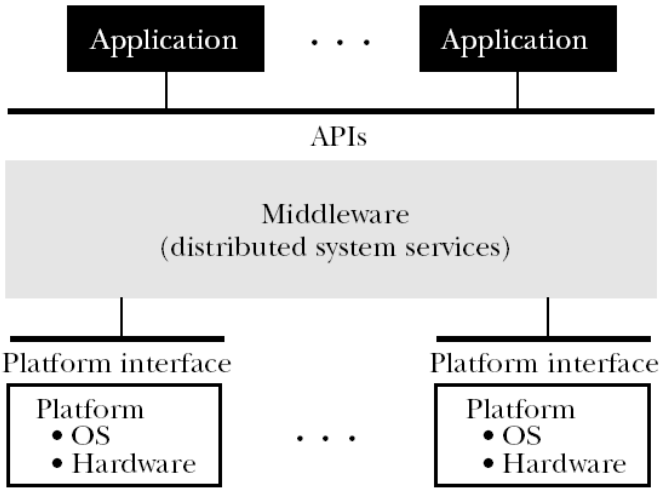
- custom conversion functions
- generic format conversions
- wrappers
- common protocols

Legend:
DSOM IBM management system
DME standard Open Software Foundation management system
SNA IBM network architecture
IPX/SPX Xerox network architecture
…



Another DEFINITION of MIDDLEWARE

The **software layer** resident between the **applications** and all local support levels: network **components, local operating system**, **heterogeneous hardware**, different application areas. That layer must grant any application area **operations**

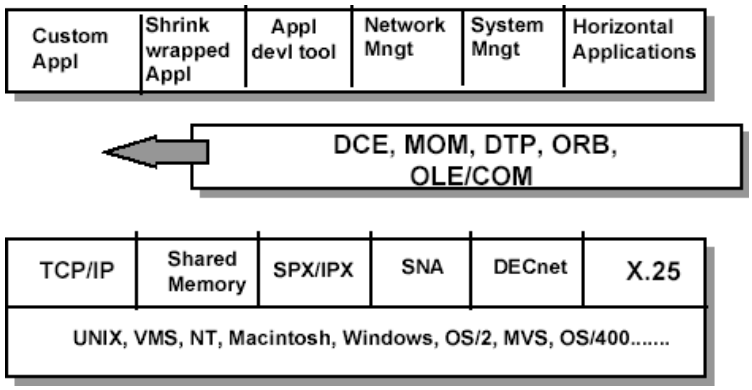


The decoupling layer among all system layers to permit a **continuous simplified design** of any **application part** (and also of the **support part itself**) and also allow any overcoming of the **intrinsic heterogeneity**

MIDDLEWARE

the Middleware is often invoked and activated in **a transparent and implicit way** to provide a **uniform access (API) to intrinsically heterogeneous local functions**

- Often used to **integrate legacy systems** since long available (obsolescent) but required by the **business logic**
- Often used as a **standard** (de facto or committee-based) **for a limited or even large community**



MIDDLEWARE DIFFUSION

The middleware market is still expanding in quantitative terms, according to Gartner

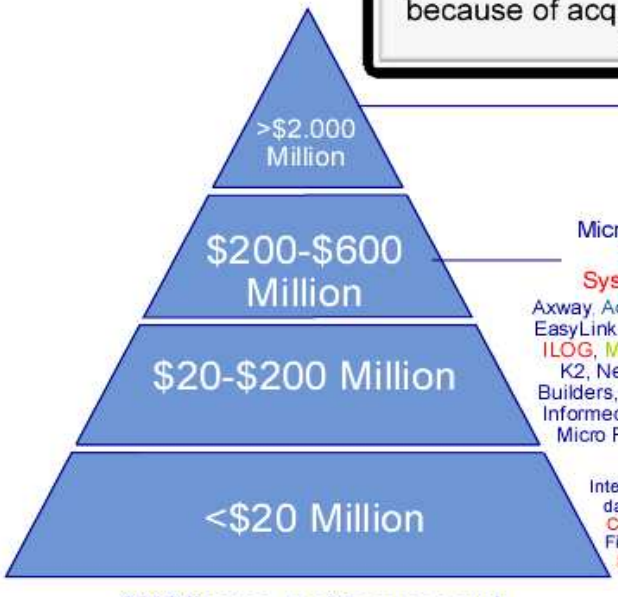
World increase of **16.4 %** from 2005 to 2006
In 2008, an increase of **6.9 %**, in 2009 of **2,8** %
In 2010, an increase of **7.3 %**, up to **17.6** billions dollars
In 2011, an increase of **9.9 %,** up to **19.3** billions dollars
In 2012, an increase of **5.2 %,** up to **20.3** billions dollars
In 2013, an increase of **7.8 %,** up to **21.9** billions dollars
In 2014, an increase of **8.7 %,** up to **23.8** billions dollars
The breakdown of sales percentages:

Enterprise	2006%	2007%	2008%	2009%	2010%	2011%	2012%	2013%	2014%
IBM	31,8	28,8	30,8	31,5	32,6	**32,1**	**30,9**	**29,8**	**29,1**
BEA Systems	10,5	9,3	2	oracle	oracle	oracle	**oracle**	**oracle**	**oracle**
Oracle	8,6	8,5	13,6	16,7	17,2	**16,8**	**16,1**	**14,8**	**13,8**
Microsoft	4,2	3	3,6	3,9	4	**5**	**5**	**5,1**	**4,9**
Software AG	2,4	2,2	2,9	3	2,8	**3,3**	**3,2**	**2,7**	**2,3**
Tibco	3,5	3	2,9	2,6	2,5	**2,9**	**2,6**	**2,5**	**2,4**
SAP						**1,2**	**2,7**	**2,4**	**2,2**
Salesforce						**0,7**	**1,6**	**2,2**	**3,1**
Altri	39	45,2	44,2	42,4	40,9	**38**	**37,9**	**40,5**	**42,2**
Total	100	100	100	100	100	**100**	**100**	**100**	**100**

MIDDLEWARE MARKET SHARE 2010-12

The Application Infrastructure Middleware Market: M&As Shape the Landscape

In 2010, $1.2 billion worth of sales changed hands because of acquisitions; in 2011, it was $480 million, in 2012 over $300 million



IBM, Oracle

Microsoft, Software AG, SAP, Tibco, Salesforce.com, SterlingCommerce, Sun Microsystems, BEA Systems, Fujitsu, GXS, Hitachi, NEC, Pegasystems

Axway, Adobe, Progress Software, IDS Scheer, Inovis, Sybase, OpenText, EasyLink, Global 360, Fujitsu Siemens, Compuware, Vmware, Seeburger, ILOG, Metastorm, Red Hat, TMax, Vitria, Borland, IONA, Appian, Kofax, K2, NewGen, Magic Software, Cast Iron, SOA Software, Information Builders, CA, Fico, Rocket Software, Informatica, DST Systems, Intel, Be Informed, Lombardi, Singularity, AmberPoint, Cordys, Savvion, Vignette, Micro Focus International, HP, Crossgate, Kabira, Microgen, BizFlow, Liferay, Generix,

InterSystems, HandySoft, nuBridges, Corel, Ultimus, BizAgi, PNMsoft, Layer 7, data interchange, Chordiant, SPS Commerce, Pramati, Extol, IVANS, Cape Clear, Liaison, Talend, Cisco, Totvs, ECOutlook, Softwired, B2B Servicios, Fiorano, Intesa, Cleo Communications, Elemica, Covast, Polymita, Eptoris, Fusesource, Voderl, Mashery, Active Endpoints, Telelogic AB, Kingdee, WebMethods, Abaxx, Apama, LongJump, Streambase, etc.

2012 license, maintenance and subscription revenue

Gartner

Red denotes companies acquired between 2008 and 2010. Green denotes companies acquired after 2011.

MIDDLEWARE SUPPORT

MIDDLEWARE sits on the local operating systems and tend to give support to:

Hide component and resource physical distribution

To make transparent the split of the application in different parts executing on different machines

Hide heterogeneity

To make transparent the distribution of the application over different hardware, different operating systems, different protocols, …

Provide common interfaces

The entire application can be obtained by putting together legacy parts, already available, by sub setting and composing added parts toward the maximum of interoperability

Provide basic services

The application must have available a directory of available functions to avoid duplication and favor collaboration

Grant necessary availability and QoS

MIDDLEWARE typical SERVICES

MIDDLEWARE provide very different services in very differentiated areas to fulfill user needs

Presentation Management	(print, graphics, GUI, user interaction)
Computation	(common procedures, char services internationalization, sorting, …)
Information Management	(file manager, record manager, database manager, log Manager, …)
Communication	(messaging, RPC, message queue, mail, electronic data interchange…)
Control	(thread manager, scheduler, transaction manager, …)
System Management	(accounting, configuration, security, performance, fault management, … event handling)

MIDDLEWARE in a layered view

MIDDLEWARE between
Applications and Operating Systems

Application layer

Domain-specific Middleware Service

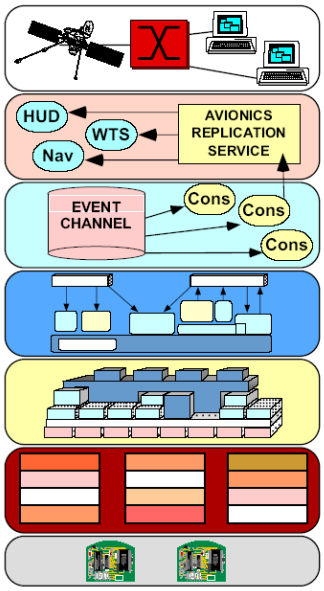
Common Middleware Services

Distribution Middleware

Host Infrastructure Middleware

Operating Systems

Hardware

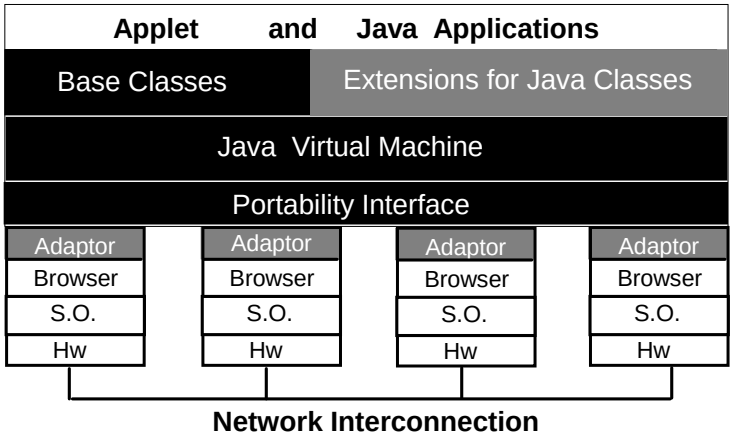


MIDDLEWARE layers: Host Infrastructure

Host Infrastructure Middleware

This layer encapsulates and prepares for the common services to support distribution and to ease necessary communication

Examples: JVM, .NET, other local models



Some APIs are provided toward a unified support in different environments

MIDDLEWARE layers: Distribution

Distribution Middleware

This layer provides the programming models for distribution and to ease the applications in configuration and management of distributed resources

Examples: RMI, CORBA, DCOM, SOAP, …

Those systems allows an easier **communication and coordination** of all nodes taking part in the system, by introducing a **resource model** and

- some **communication APIs** , by proposing and enforcing a new conceptual model
- other basic functions for **communication, name support, discovery**, …

MIDDLEWARE layers: Common Services

Common Middleware Services

Added-value services, typically higher-level to facilitate the duties of the designer and to enforce a component-oriented perspective fully supported and aided

Examples: CORBA Services, J2EE, .NET Web Services

Some additional functions are inspired to a common architecture idea and to a unified support model

Several additional services are available in terms of components that you can add at any time depending on your needs

events, logging, streaming, security, fault tolerance, …

MIDDLEWARE layers: Specific Services

Domain-specific Middleware Service

A set of application tools ad services grouped according to specific domains

Examples: Some task force are defining **ad-hoc functions for different areas** with very tailored goals, depending on the needs of specific groups, but always defining standards

Task Force within OMG (Object Management Group)
- Electronic Commerce TF,
- Finance (banking and insurance) TF,
- Life Science Research Domain TF,

Syngo Siemens Medical Engineering Group,

Boeing Bold Stroke within CORBA (flight and flight transport),

…

CLASSIFICATION of MIDDLEWARES

MIDDLEWARE

RPC / RMI middleware

Message Oriented Middleware (MOM)

Distributed Transaction Processing (TP) Monitor

Database Middleware

Distributed Object Computing (DOC) Middleware

Adaptive & Reflective Middleware

Other special-purpose middlewares:

Mobile & QoS Multimedia Middleware

Agent-based Middleware

***see:* computingnow.computer.org**

A PIONEER MIDDLEWARE !?

Wide Area Distributed Middleware (Web)

A global Middleware to allow easy reading actions to distributed data and also writing operation, in accessing to a global set of information

The web put together a global 'transparent' system with

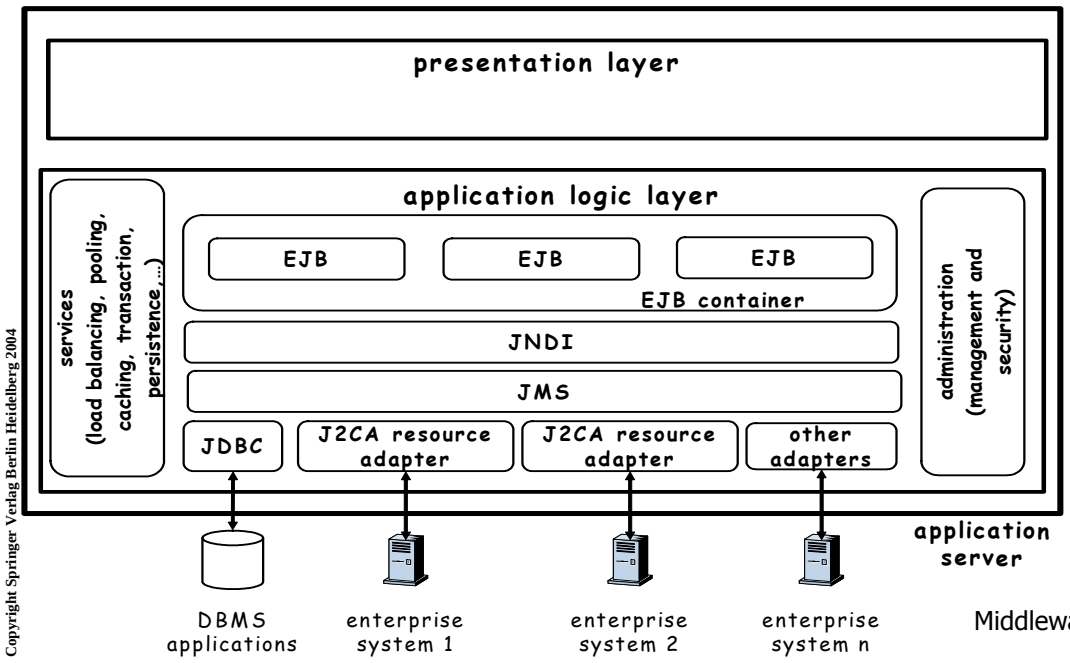
- an enormous number of administrative domains
- an enormous number of users
- an enormous number of host and machines
- an enormous heterogeneity of bandwidth, connections, **…**

The Web it is not a real middleware even if the most widespread and very legacy now

Web as a core example because of its extreme diffusion

WEB MIDDLEWARE !? and J2EE

Java-oriented vision **J2EE**: **J**ava **N**aming & **D**irectory **I**nterface, **J**ava **M**essage **S**ervice, **J2**EE **C**onnector **A**rchitecture

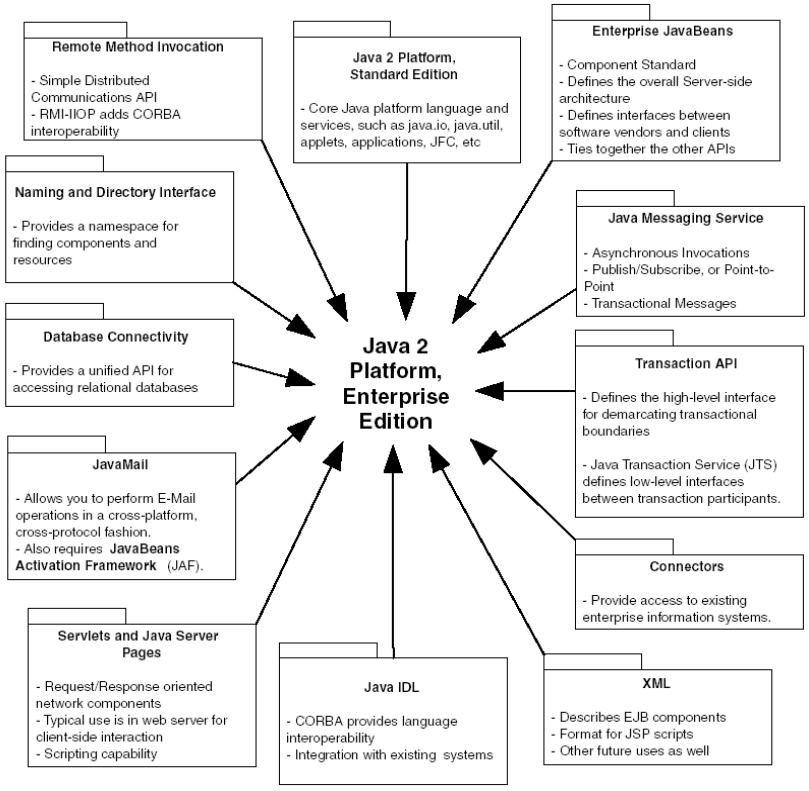


J2EE as an integration of modules

Java2 Enterprise

As a set of components

- databases and more
- naming systems
- components (Beans)
- integration of components via XML
- messaging systems
- communication
- JSP & servlet
- …



RPC MIDDLEWARE (…RMI)

Remote Procedure Call as C/S tools

- **I**nterface **D**efinition **L**anguage (IDL) to define the contract
- **Synchronicity**: the client is blocked synchronously while waiting for the answer (result) from Server
- **Heterogeneous** data handling
- **Stub** as envelopes to achieve Transparency
- **Binding** often static (and not so dynamic)

The RPC Model is too **rigid, not scalable & replicable** with **QoS**

The server design must be explicit and any activity provisioning must explicitly defined

No optimization easy to grant shared and private resources

Not so flexible, with the growing extensions of services

MOM MIDDLEWARE

Message Oriented Middleware (MOM)

Data and code distribution via **message exchange** between **logically separated entities**

Typed & **un-typed message exchange** with **ad-hoc tools** both **synchronous** and **asynchronous**

- **wide autonomy** between components
- **asynchronous** and **persistency** actions
- **handler (broker)** with different strategies and QoS
- easy in **multicast, broadcast, publish / subscribe**

Example: Middleware based on messages and queues
MQSeries IBM, **MSMQ Microsoft**, **JMS** SUN

OO e DOC MIDDLEWARE

Distributed Object Computing (DOC) Middlewares

Data and code distribution via **operation requests and replies** between **clients and remote servers**

DOCs use objects within a **framework** and a **broker** as an intermediary for operation object handling

- **the object model** simplifies design
- **the broker** provides both base services and additional ones
- **some operations** can be completely **automated**
- system **integration** is **easier and effective**
- **open source technology** is usually adopted

Examples: **CORBA, .NET e COM, Java Enterprise**

DTP MIDDLEWARE

Distributed Transaction Processing (TP-) Monitor

Middleware to declare and support **distributed transactions**

TP monitors optimize database connections hiding applicative decisions to obtain coordinated and transactional access to data

- specialized interface **for queries** by **lightweight clients**
- **Standardized** actions and **ad-hoc languages**
- **multi-level applications** adopting flexible RPC (various configurations beyond only-synchronous semantics)
- ease in providing Atomicity, Consistency, Isolation, and Durability (**ACID**) guarantees
- efficiency in **addressed applicative area**

Examples: **CICS** (**IBM**), **Lotus Notes**, **Tuxedo** (**BEA**), **…**

DB MIDDLEWARE

Database Middleware

Middleware for **integration** and eased usage of **information stored in heterogeneous and different DBs**

to hide implementation-specific details and use standard interfaces

Open DataBase Connectivity ODBC standard

- **without** requiring to modify **existing DBs**
- **efficient support actions** (not much emphasis on optimizations and transactions) in terms of **data access**
- **only synchronous and standard operations**
- evolutions toward **data mining**

Examples: **Oracle Glue, OLE-DB Microsoft**

MIDDLEWARE – more and more…

Adaptive & Reflective Middleware

Middleware able to (self-)adapt to the **specific application** also in a **dynamic, reactive and radical way**

*In some cases the **visibility of underlying levels** can become crucial **to reach optimization***

- **Static variations**, typically **component-dependent**
- **Dynamic variations,** typically **system-dependent**

Via **reflection**, **action policies are expressed and visible** in the **middleware itself** and can change as **system components**

Obtains **adaptation and flexibility at execution time**

Examples: **non widely diffused yet**

SPECIALIZED MIDDLEWARES

Middleware to support mobility

components designed to ease **transparent allocation and re-allocation** (working cross-layer, from network to application layers)

Middleware to support enterprise interactions

components designed to overcome issues typical **of enterprise services** and tackling **specific business models**

Middleware to support Real-Time (RT) applications

components designed to **guarantee response times** and **deadlines for the development of services in the RT area**

Middleware to support ad-hoc networking

lightweight components and algorithms designed for environments with **limited resources** and **consumption capacities**

ENTERPRISE MIDDLEWARE

MIDDLEWARE to provide business services

Enterprise Application Integration (EAI)

Need to ease the **integration** across **existing enterprise tools** and their expanded applicability and availability in the enterprise

EAI as environment for **fast and accurate integration** of applications and existing legacy subsystems

Also interfaces for **rapid prototyping** of new aggregates/mash-ups

Systems to grant **easier enterprise workflows (in heterogeneous envs)**

enterprise management (administration and management actions: SAP)

IT and resource management (development functions and application support: Websphere, Oracle)

Service Oriented Architecture (SOA)

AUTONOMIC COMPUTING

Complexity of computing systems makes really difficult to plan interventions and with which precision, whose involvement, …

Model such systems as human bodies where the system is capable of taking care of itself

Complex systems must organize themselves as entities capable of self-managing and self-administration

Also termed self-X properties (related to computer agents)

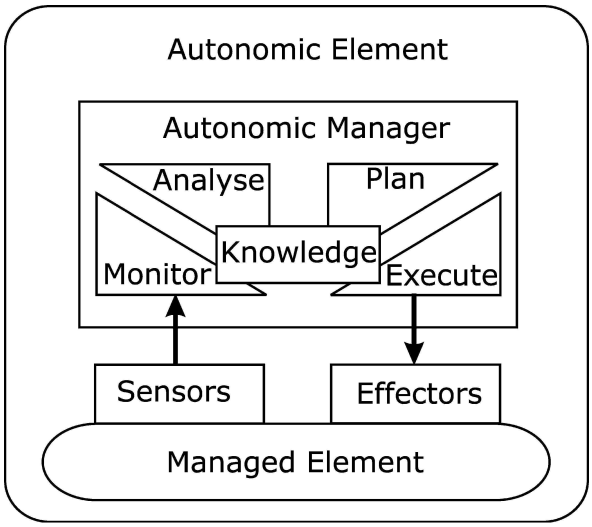
- self-configuration (**autonomy**)
- self-optimization (**social ability and cooperation**)
- self-healing (**reactivity**)
- self-protection (**proactiveness**)

MAPE-K Architecture

The **MAPE-K** architecture based the named phases:

- **M**onitor, **A**nalyze, **P**lan, **E**xecute, **K**nowledge

assume a model where the manager goal is to operate on the managed element, by sensing and affecting it, by controlling the element, and intervening in a closed loop on it



TINA-C – Middleware for TLC

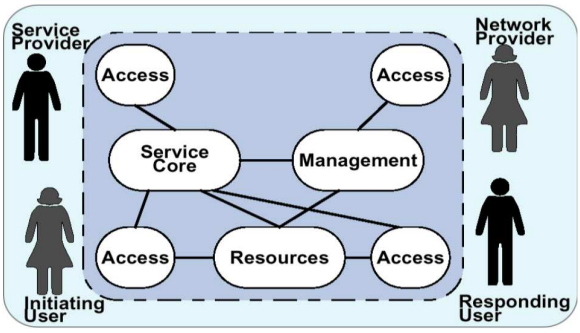
Telecommunications (TLC) Information Networking Architecture

TINA-C defines a multiplicity of parties/roles involved in the communication service

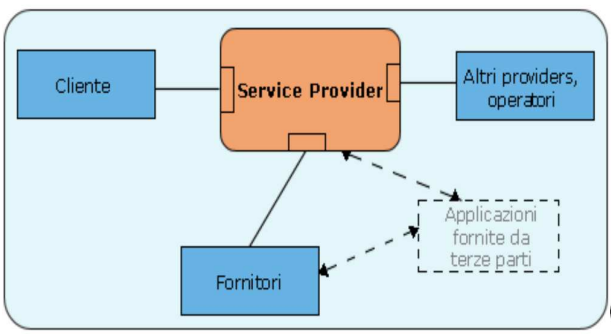
Users and several communication and service Providers

taking into account **quality di service** to provide **(after initial negoziation)**

user view

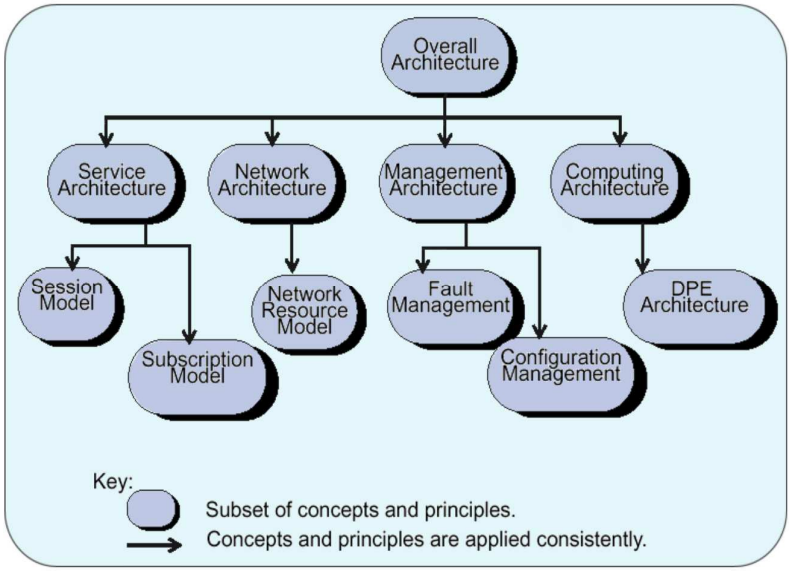


interaction view



TINA-C – Architectures

Fundamental **architectures separate and interacting**:
Computing, **Service**, **Management, Network Architecture**



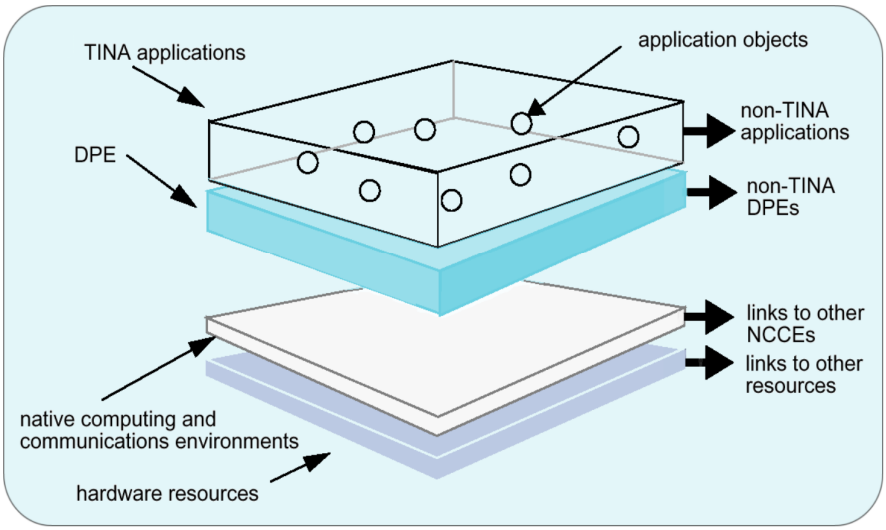
Interactions between the different architectures are present, of course

Similarly, there are common management goals

TINA-C – Layered Architecture

In an **architectural view**, starting from the network

Each node must host needed function that extend its capabilities to be part of the distributed system

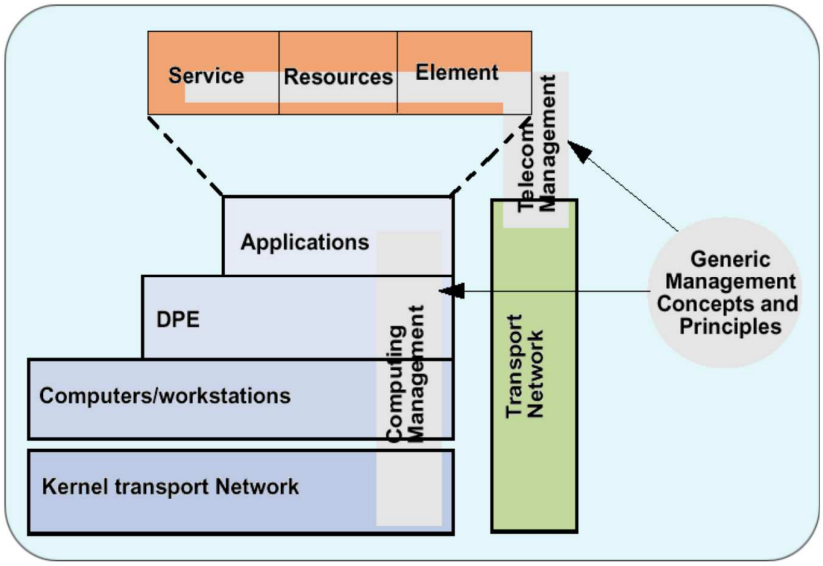


DPE **D**istributed **P**rocessing **E**nvironment

NCCE **N**ative **C**omputing **C**ommunication **E**nvironment

TINA-C – Transparent Architecture

Applications and **services** are obtained atop physical resources exposed by various and heterogeneous local supports (NCCE) and integrated the DPE layer

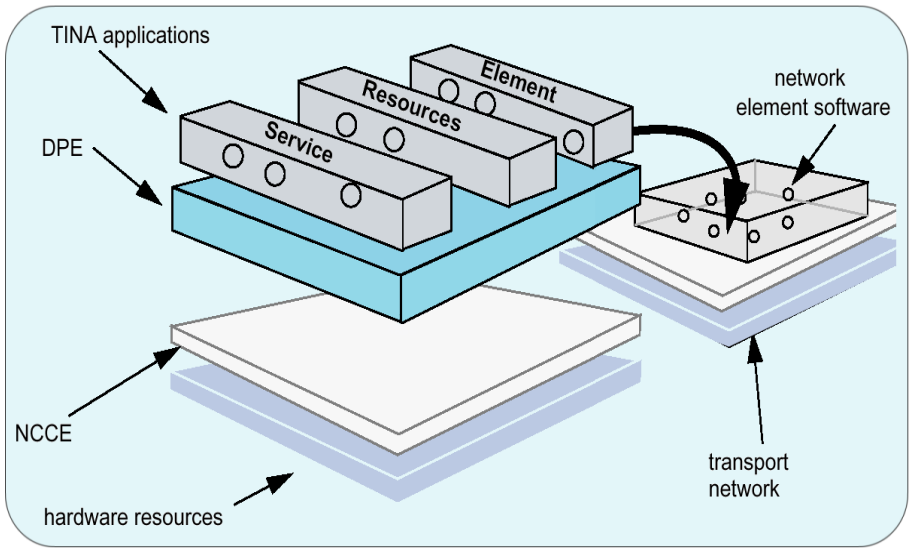


An application is based on logical entities

Services
Resources
Elements

TINA-C – Transparent Architecture

Transparent view of applications and services

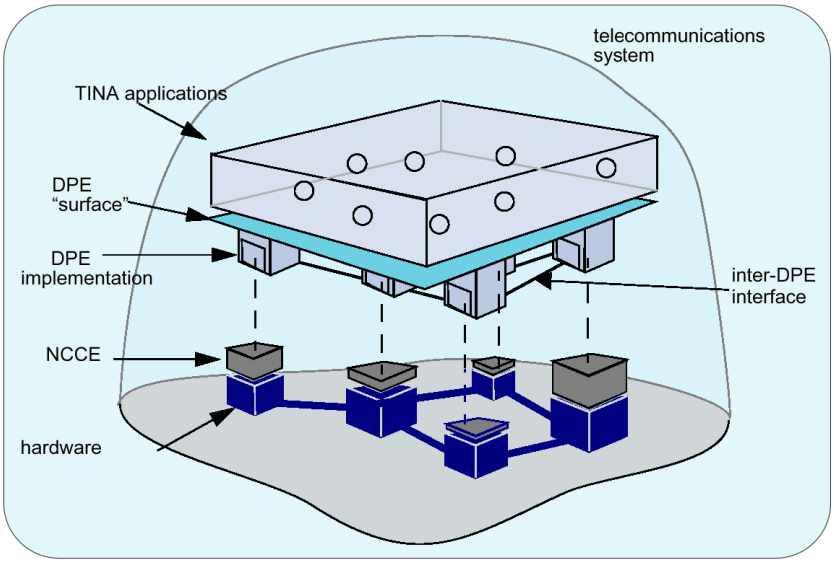


An application is based on logical entities

Services
Resources
Elements

TINA-C – Non-transparent Architecture

It is also possible a non-transparent view with complete visibility needed in the design and development phases



An application is based on

DPE
Inter-DPE
NCCE

MIDDLEWARE DESIGN – ISSUES

The **design of middlewares** tend to consider more and more some critical factors that descend from the intrinsic complexity of possible solutions

The first issue is the **increasing set of functions** (objects, resources, etc.) that make **scalability** a very tough problem

- Middlewares tend to introduce **indirect and dynamic mechanisms (interception)** to enable management, introducing an **overhead that is unfortunately high and to be minimized**
- Middlewares tend to introduce **management costs** that require **increasingly sophisticated tools to be continuously adjusted and updated** (monitoring, accounting, security, control, etc.)
- Middleware include **mobile and dynamic mobile devices,** with need for **continuous adaptation to the current context and situation**

Middleware usage SCENARIOS

Middleware propose an **architectural model** and **tools**, according to a **vision of precise use**: in this way, middlewares are suitable for very different situations of use and imply an **applicative exploitation** and **recommended use** by those who adopt them

Indeed, it is possible to think of general use cases, but there is always a but there is always a clear idea of who will be users and their requirements

- Middleware developed for **a specific application and that has to work in a precise, inflexible and isolated way: low cost and low intrusion requirements**
- Middleware developed for **applications that have to work in synergy with the middleware, in a flexible way: fast integration and eased communication requirements**
- Middleware that **represents the organization** and requires **continuous evaluation** of internal services with multiple **applications and adequate services**: **life time requirement**

MINIMUM COST MIDDLEWARE

A first scenario is that of **minimum cost middleware**, that drives the configuration of **an application**, according to an **internal interaction model**, without dynamic scenarios

Users require the configuration of the architecture and to obtain the functionality of **an application in a closed way and with no changes** with MW services at **very low intrusion and very low cost**

Disappearing middleware

MOM Middleware are within this category

It defines an application that involves a number of nodes and that only provides some participants **statically determined** (only hw resources and provided for specific architectural components), with **default interaction**, **rigid** and non-adjustable and optimized with **very low costs**

No need for **services to support dynamicity** as service names or other

No support for possible inputs and/or **dynamic reconfiguration, turn-on and turn-off of resources**

MIDDLEWARE for FAST APPLICATIONS

A second scenario is that of **middleware** for **very streamlined and optimized applications** that require services and get them quickly and efficiently

- Applications can **provide each other services**, middleware uses its functions and those currently available dynamically
- Support for **dynamic management** of resources and **applications** that self-adapt to fit to the current usage situation

Middleware to facilitate integration of applications

- Middleware Microsoft are within this category
- Middleware **installed on demand** for applications that can **interact in various ways** (DOC) with **other active applications** running at execution time
- Support the **dynamism and even possible optimized choices implemented automatically or based on user indication**
- **Middleware life time tied to application life cycle**

MIDDLEWARE for CONTINUITY

A third scenario is that of a **middleware** that needs to **extend the lifetime** of the service, seeing them as the set of all the features that an organization can make available for **coarse-grained and facilitated applications**

- Applications can also add **services** that become part of the **middleware** and can be used by everyone so also **dynamically**, eventually
- Support for **dynamic management** of resources and applications

Middleware for infinite life cycle

Middleware CORBA in this category

- The middleware is **initially installed** and is also **populated by different applications** (DOC), **enriching through the introduction of new services**, incrementally and seamlessly
- The support allows use of services with varying degrees of **dynamicity** and **possible choices adapted automatically**
- **Middleware life time maximized (no downtime)**

MIDDLEWARE for CLOUD (?)

A **CLOUD** solution, from the **user** perspective, is the provisioning of a scenario of **virtualized resources** to obtain in an elastic and fast way resources needed to serve each phase of users request (user 1 - 1 provider)

From provider perspective, need to provide **services (-aaS)**, according to agreed SLA and following two principles:

- **Efficiency** to respond to all users
- **Effectiveness** in carefully using available resources

In general, every provider uses **its resources** and finds the best mapping of configurations and QoS for better service.

Scenarios to trend: **many to many**

– Federation between **Cloud providers** to exchange services and resources
– Customers interested not only in having resources of a provider but of **more providers,** but also in **balancing** in accordance with their internal **policies**
– **Cloud as integrator of software resources (full stack or IPaas, Integration Platform as a Service)**

Middleware resource management

Middleware as a **container** and **manager of resources, more and more autonomous,** and **self-handling**

Main managing operations

- **Automatic configuration**
- **System monitoring**
- **Context management**
- **Resource discovery**
- **Resource composition and integration**
- **Resource reconfiguration**

An index of middleware success is its **invisibility**:

the more it disappears, the more the main support goal is met

Deployment problems

The middlewares must **solve all problems related to heterogeneity** and **deal with all involved resource levels**:

- hardware devices
- communication and interconnection technologies
- different hardware/software stack layers
- different hosting environments
- **different deployments with different components**
- **different software sharing strategies**

to provide users the best services with the best quality (QoS)

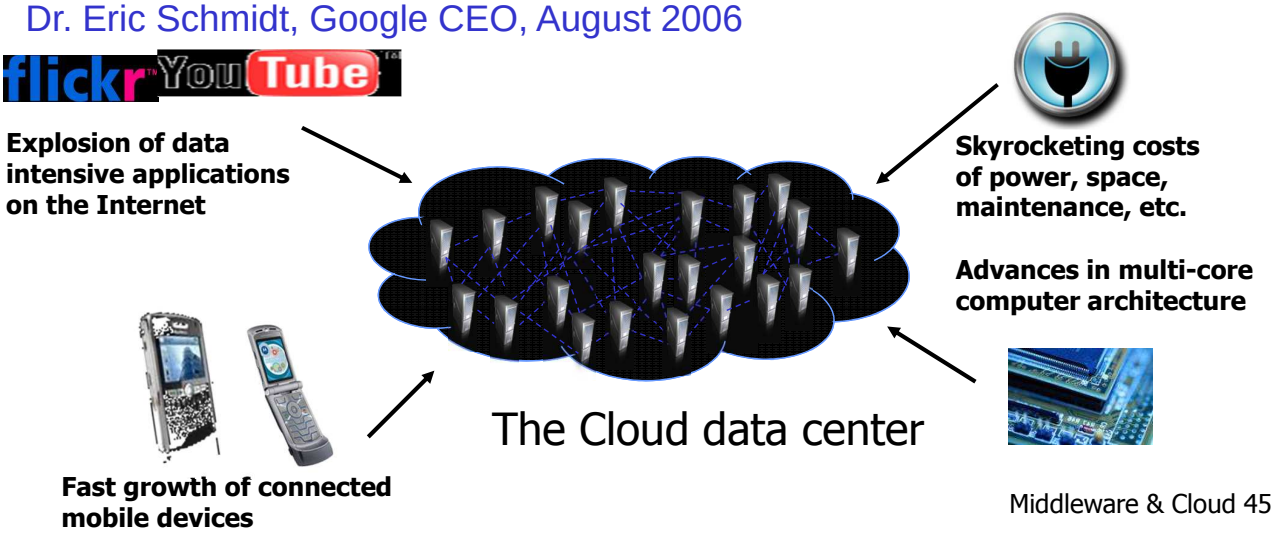
QoS-related properties

These **non functional properties** are **crucial to solution acceptance** (even necessary on the **long term**)

- **Correctness**
  - ⇨ consistency, stability, timeliness, …
- **Efficiency**
  - ⇨ optimal usage of resources, prompt answer, …
- **Scalability**
  - ⇨ dynamic usage of resources, limited operating costs, …
- **Robustness**
  - ⇨ fault tolerance, replication, availability, reliability, …
- **Security**
  - ⇨ access control, privacy, integrity, …

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



Cloud Concepts

- IT on demand pricing
- Best benefits in a reliable context
- Pool of virtualized computer resources
- Rapid live providing while demanding
- Systems on scaling architecture

Cloud keywords

on demand, reliability, virtualization, provisioning, scalability

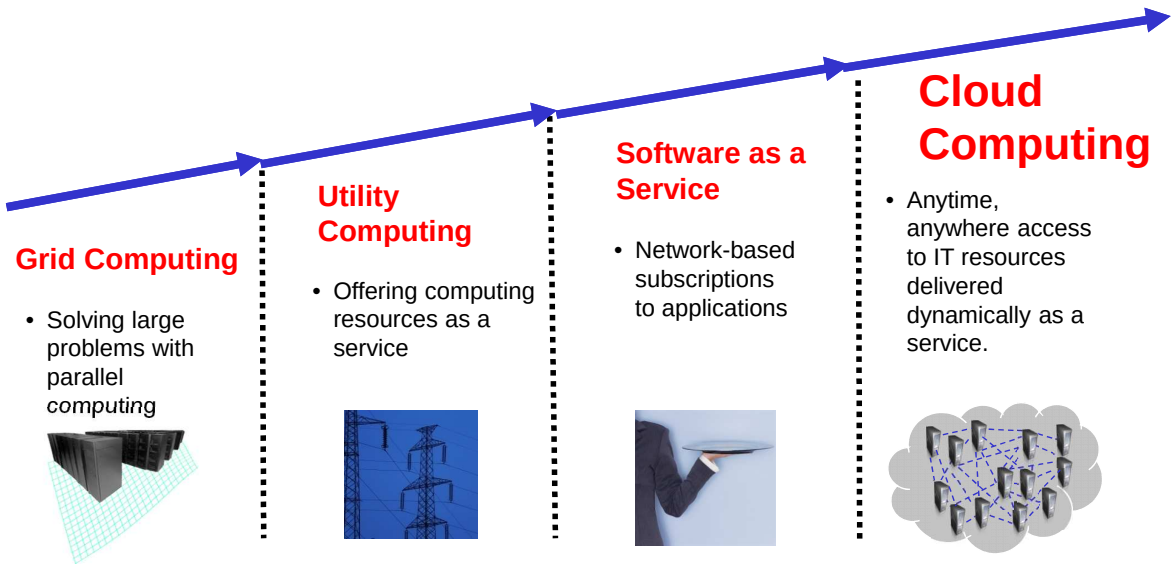
What is a Cloud

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

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

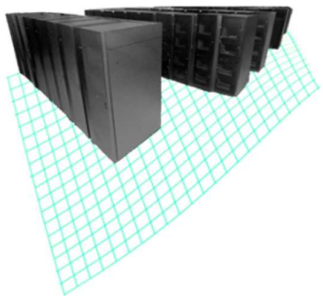
- a **user interface** that makes the infrastructure underlying the service transparent to the user
- reduced **incremental management costs** when additional IT resources are added
- **services oriented management** architecture
- **massive scalability**

A bit of history



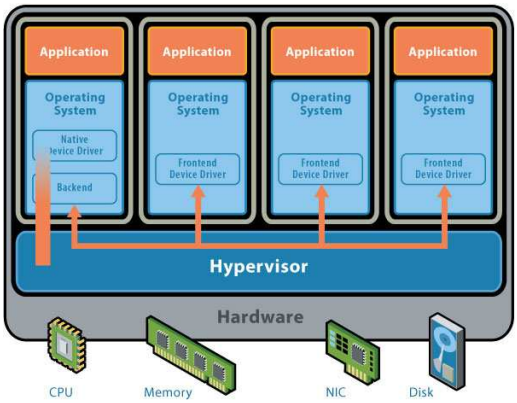
Before Cloud computing: GRID

- **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, …)



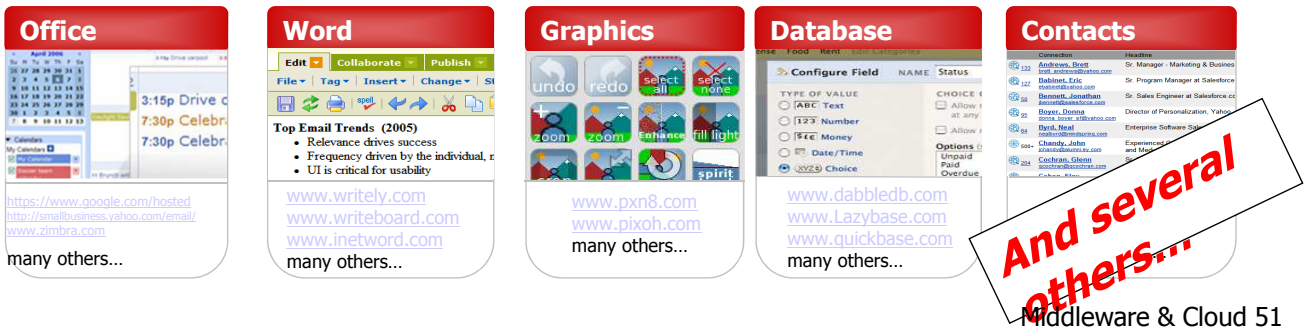
Before the Cloud: Virtualization

- **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 **a**s **a** **S**ervice ☺)



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

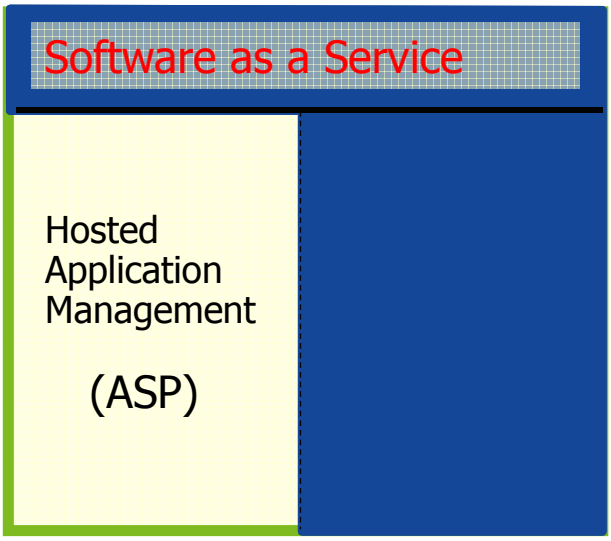
On-Demand Utility

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

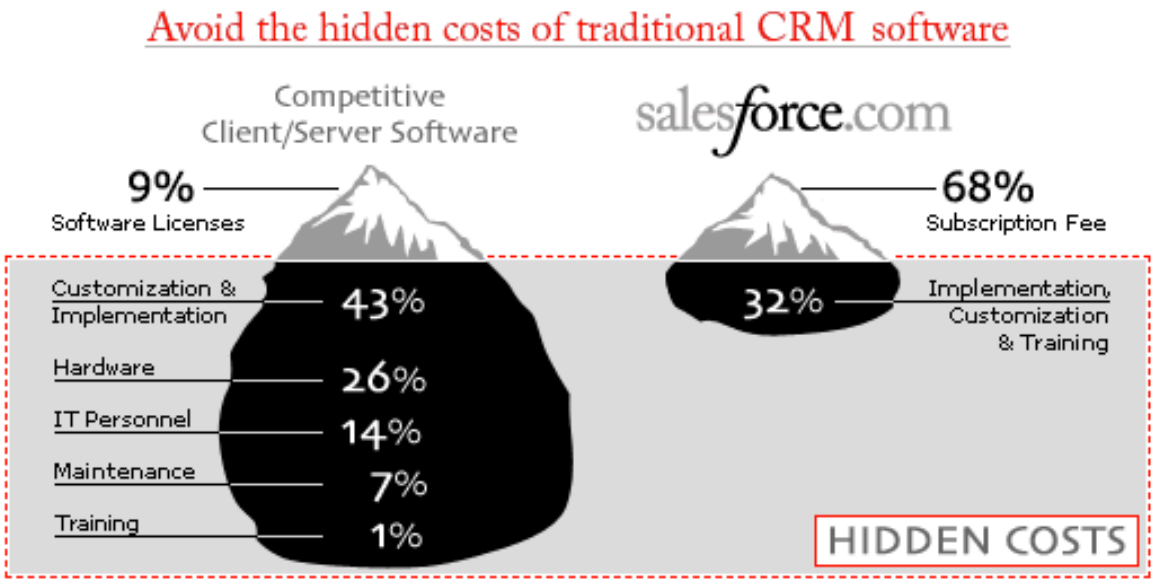


- Built for one-to-many delivery over Web
- Applications not deployed in-house
- Shared public infrastructure
- Little customization
- Subscription fee or advertising-supported

Time →
Perpetual license → Subscription
One-to-few → One-to-many
Private infrastructure → Public infrastructure

Source: IDC, 2006

Hidden Cost of IT



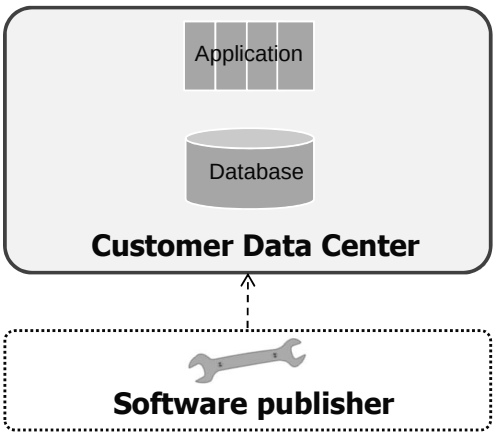
SaaS - Software as a Service

- **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



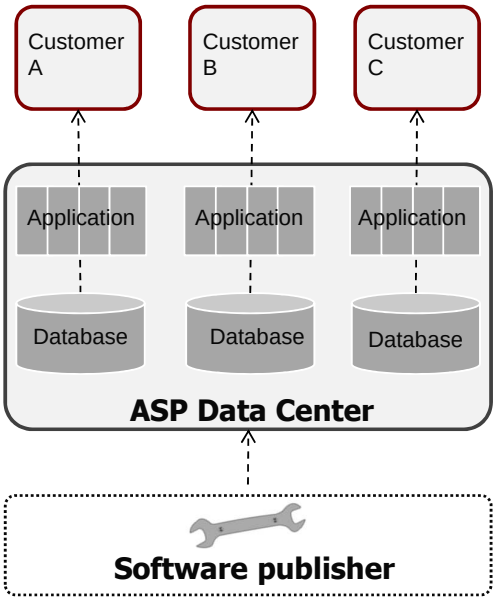
Details

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

Examples

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

Application Service Provider (ASP)



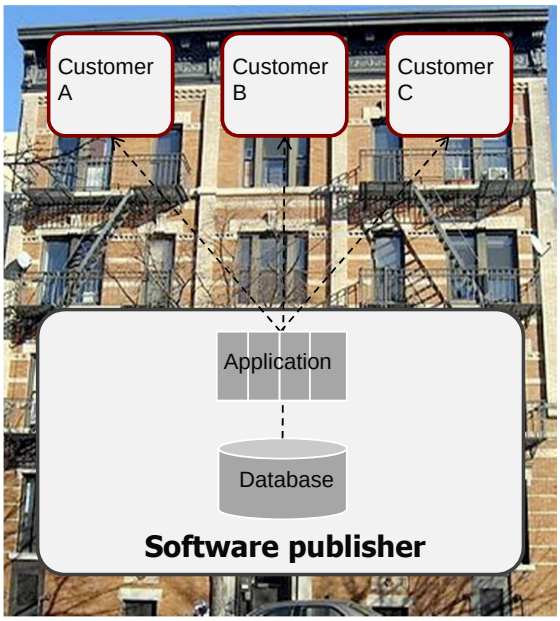
Details

- 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



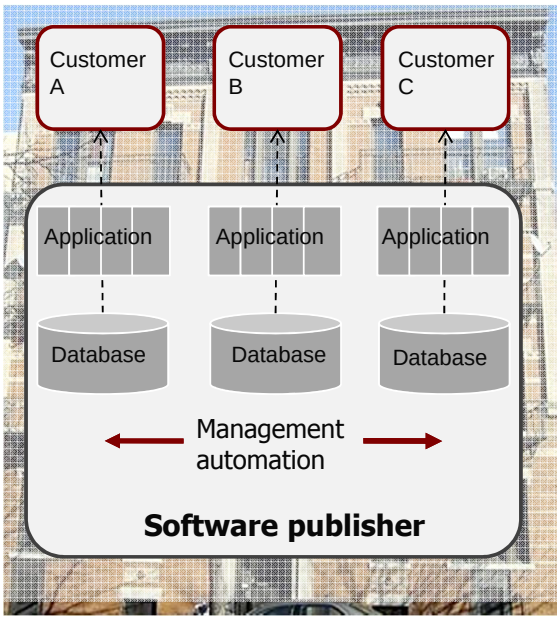
Details

- 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 **a**s **a** **S**ervice

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

PaaS **P**latform **a**s **a** **S**ervice

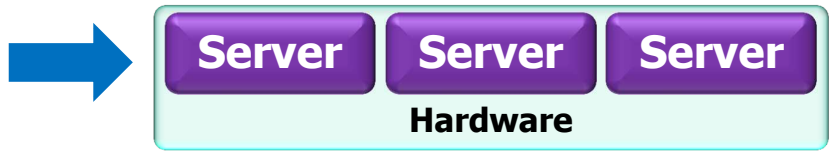
- Resources are **whole software platforms available** for remote execution, i.e., several programs capable of interacting with each other

Iaas **I**nfrastructure **a**s **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**

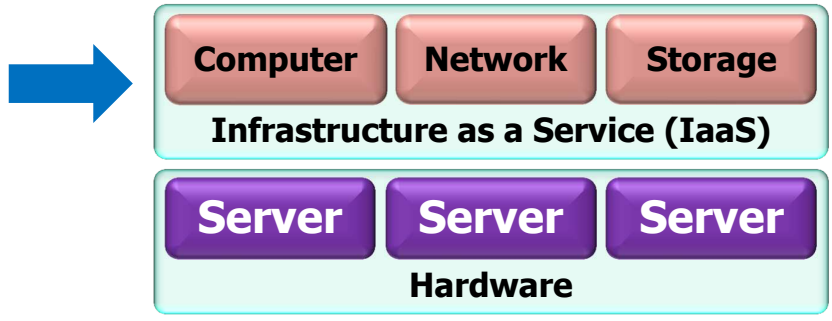
Layered Architecture: IaaS, PaaS & SaaS

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



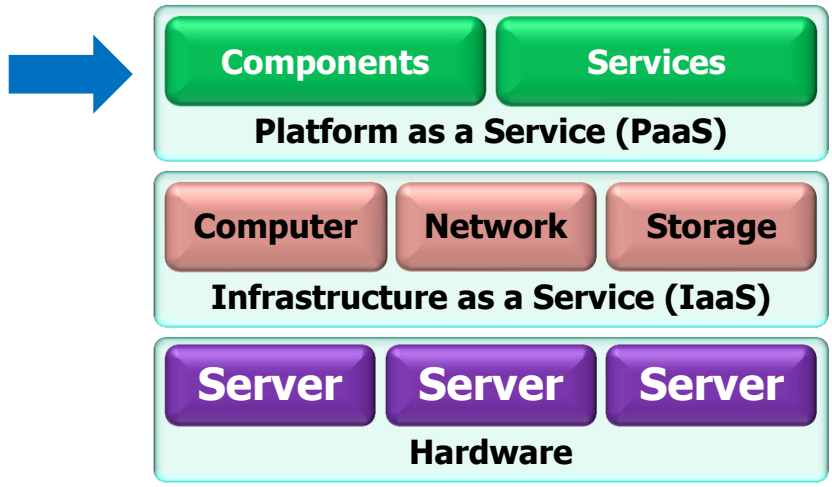
Layered Architecture: IaaS, PaaS & SaaS

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



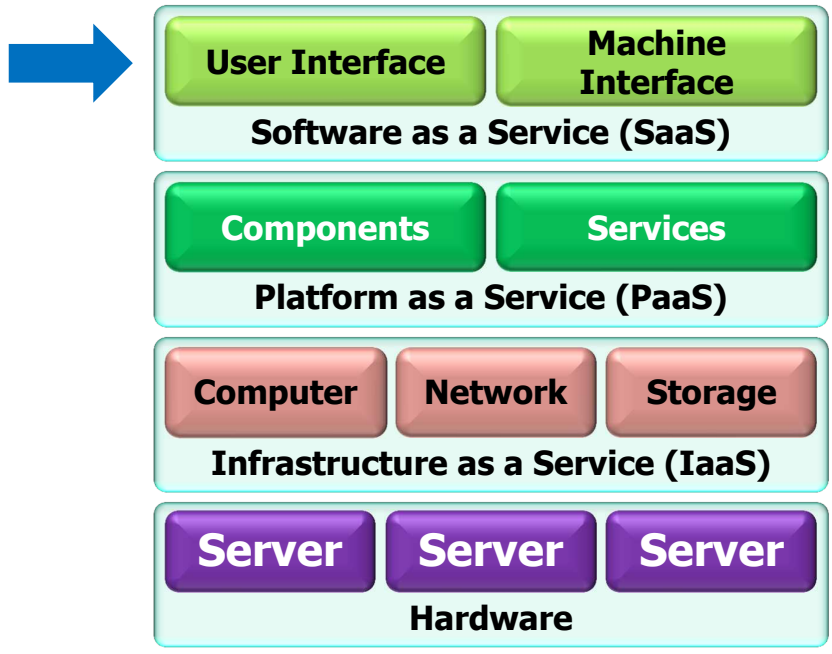
Layered Architecture: IaaS, PaaS & SaaS

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



Layered Architecture: IaaS, PaaS & SaaS

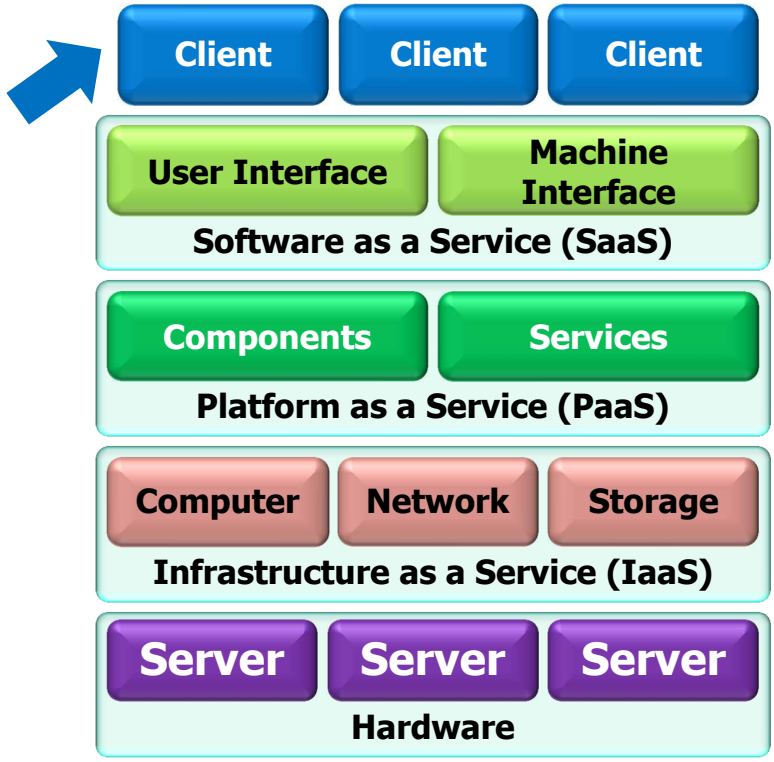
- **Application**: layer to install applications, to be available via Web and Internet via Cloud



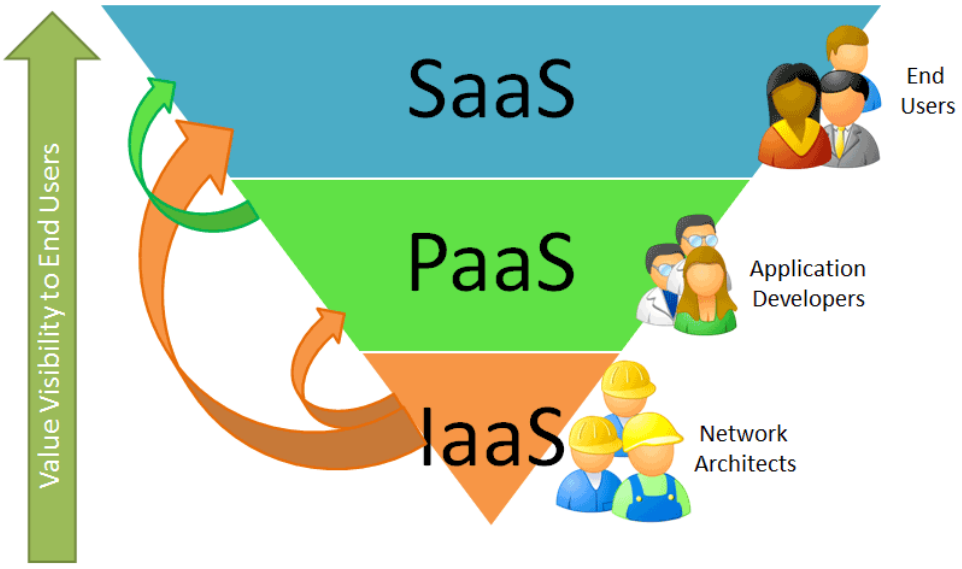
Layered Architecture: IaaS, PaaS & SaaS

- **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

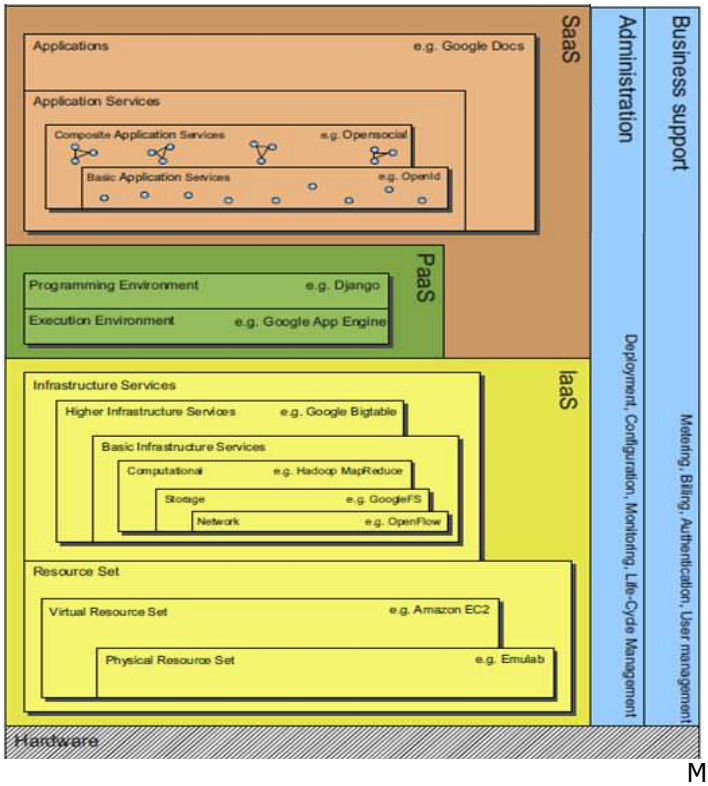
Several examples, with virtualization services, **Amazon Web Services** (S3), **Elastic Computing Cloud** (EC2), to several management and monitoring desktops to control execution (Sun global desktop, Zimdesk, …)

Technology wrap up

SaaS
- Google docs

PaaS
- Google App Engine

IaaS
- Google Bigtable
- Hadoop MapReduce (Yahoo)
- GoogleFS
- Amazon EC2



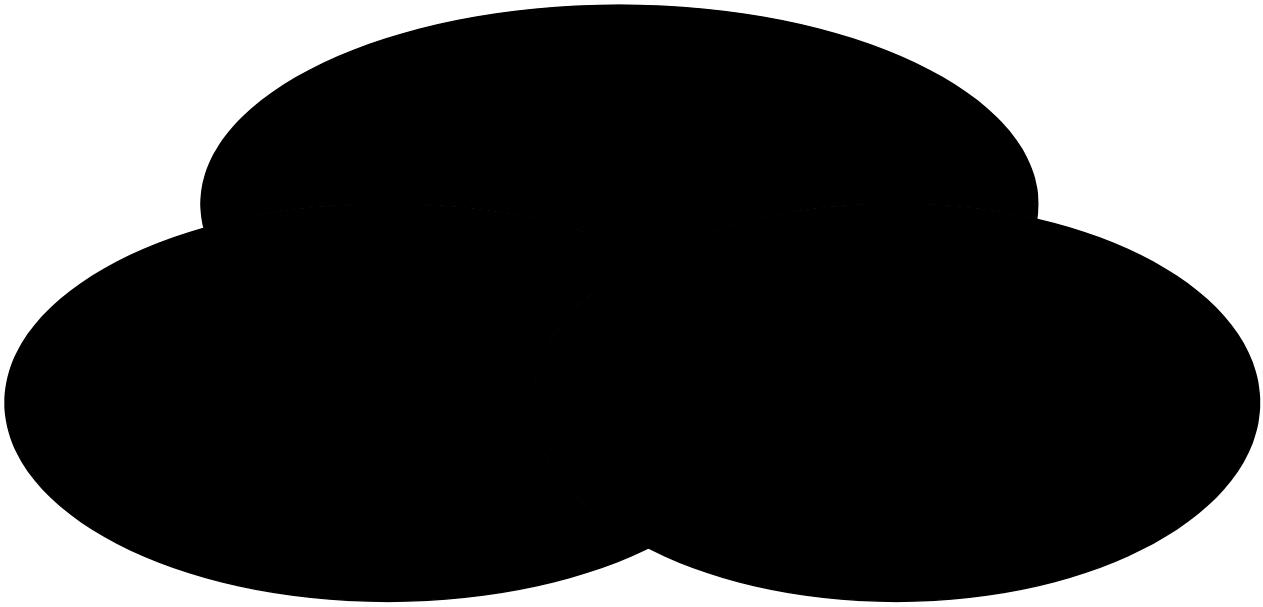
Support functions for all levels

Cloud different from …

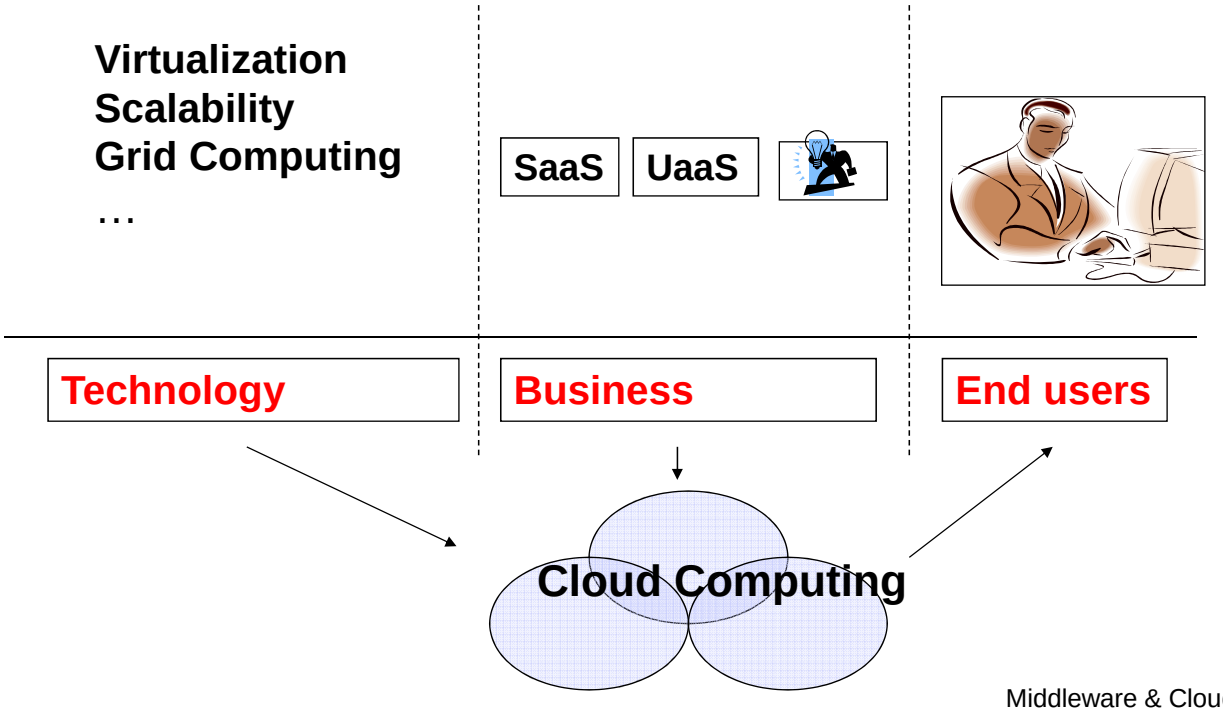
- **Grid Computing**
  - A cloud is more than a **collection of computer resources** because a cloud provides a mechanism to manage those resources

  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



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 and widening 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?

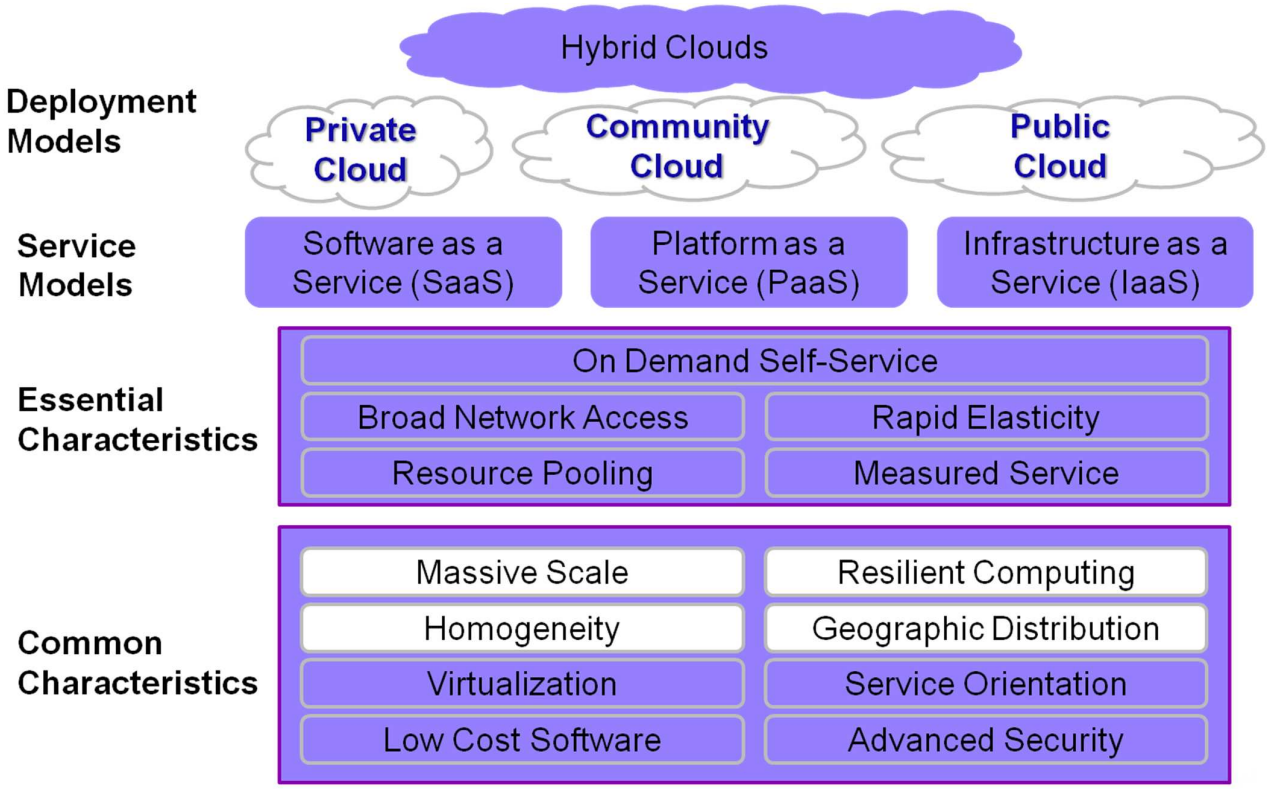
- How do we manage 100,000's of machines with **minimal human intervention**?
- How can we make the most **efficient** use of all the compute resources in a data center?

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

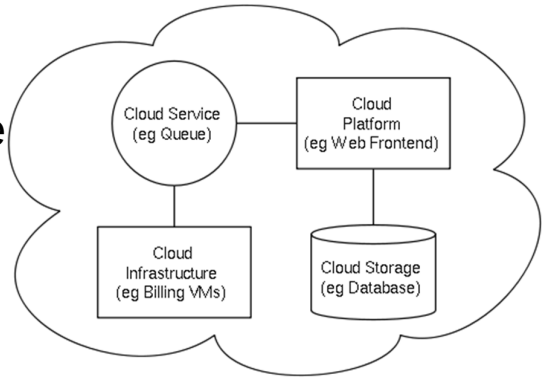
The NIST Cloud Definition Framework



National Institute of Standard and Technology

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)



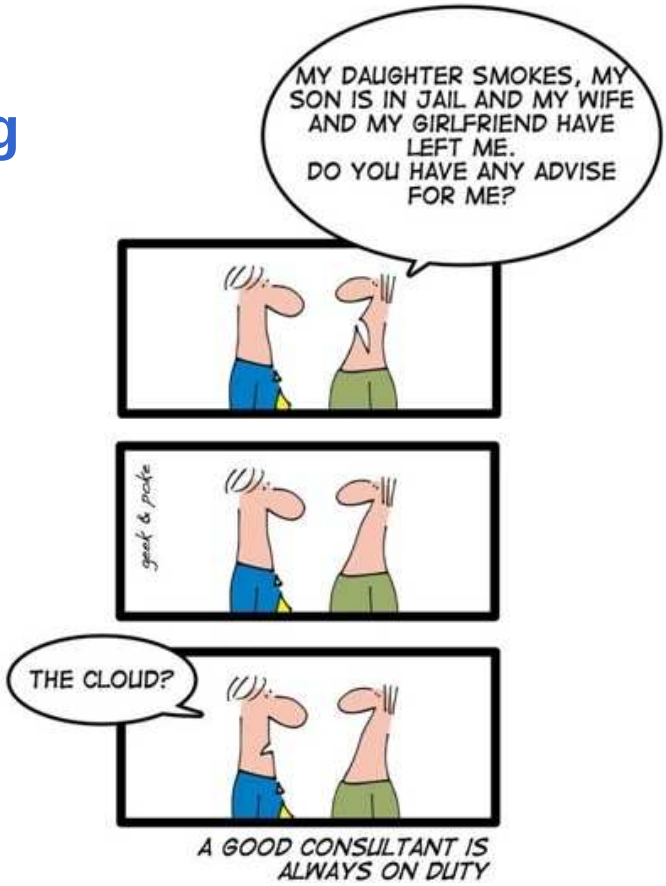
- **Four main components**:
  - one **Cloud platform**, with an externally available **interface accessed via web** to cooperate with the real or virtual internal infrastructure
  - one **virtualization infrastructure** and the management system for the control, monitoring, and billing for **client requests**
  - 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

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**

Cloud has provided have[illegible] only very **advanced te[illegible]gies also very widespread** [illegible]tions, but also has stim[illegible] some directions as guide[illegible]s for Global and Local [illegible]oward 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)

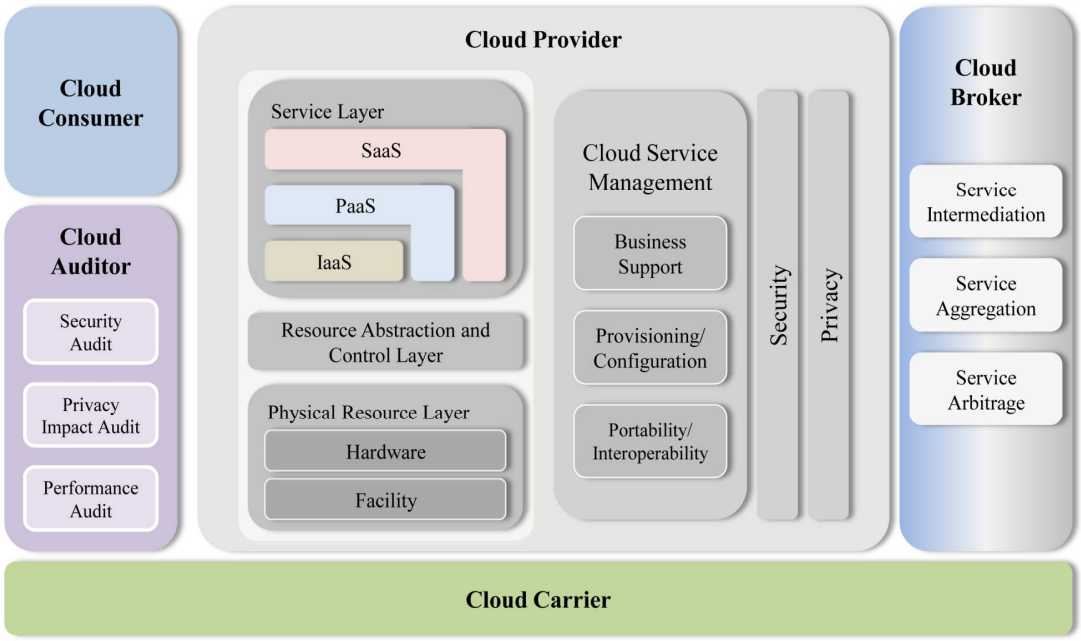
New business roles stemming fromCloud

- **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*.

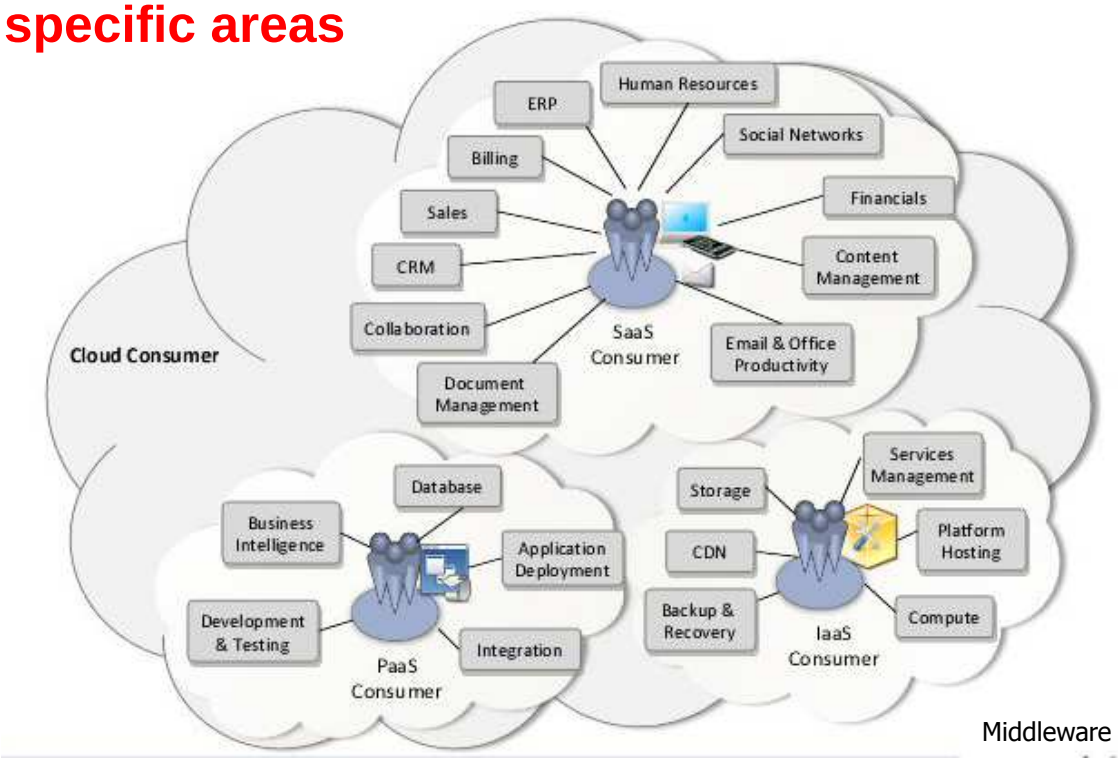
Complete model of service

Some roles and offerings are still not so widely available



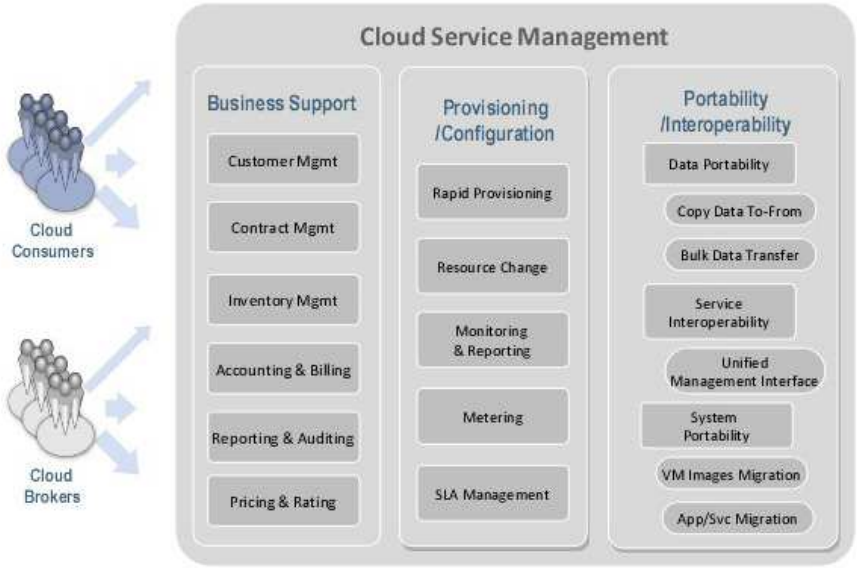
Typical areas of service offering

Clients tend to receive services in some specific areas



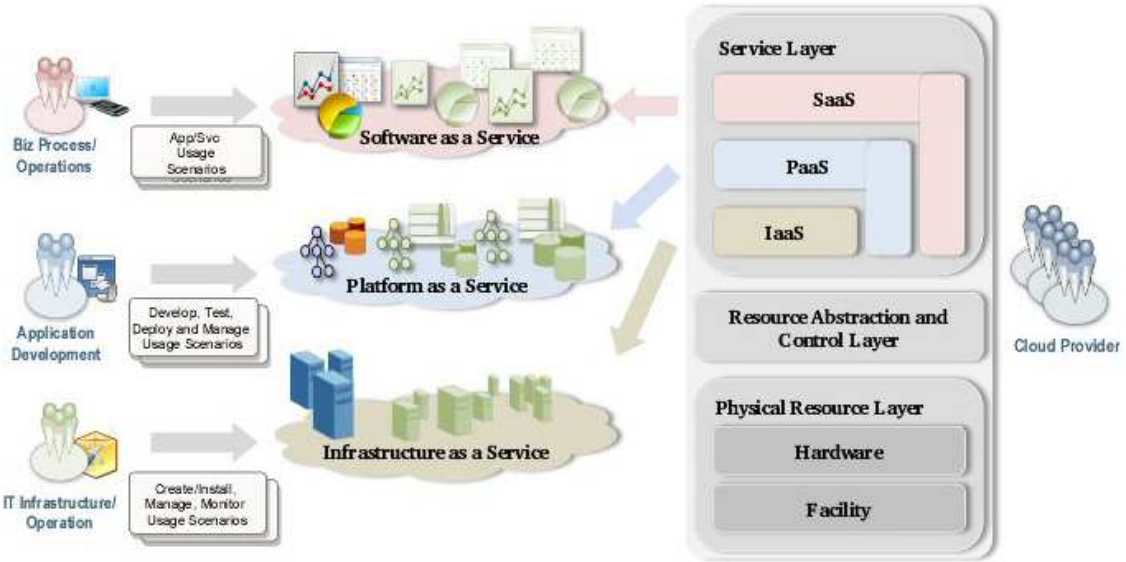
Cloud Provider – Service Handling

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

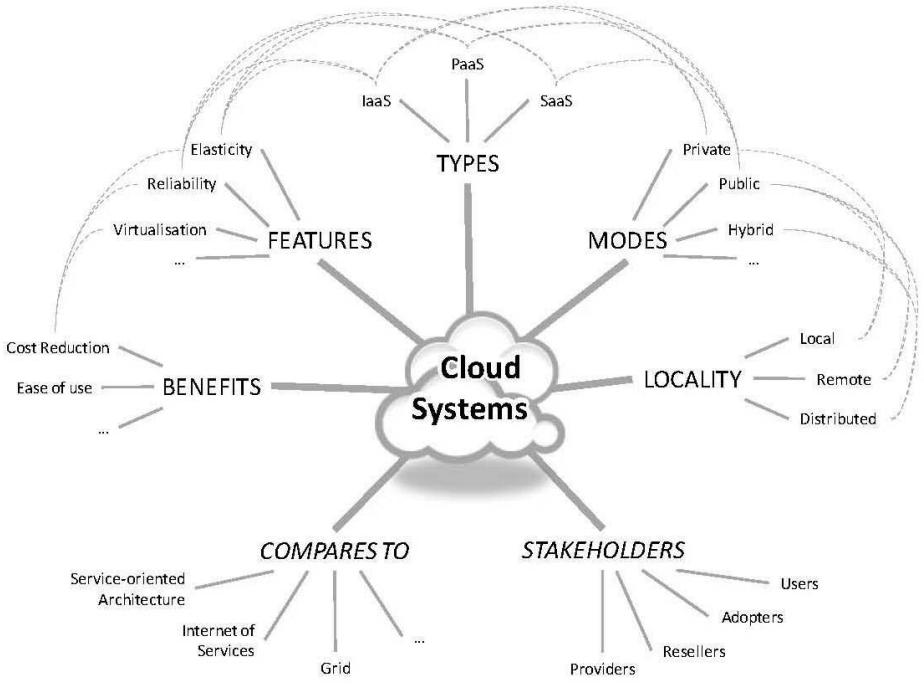


Cloud Providers - Orchestration

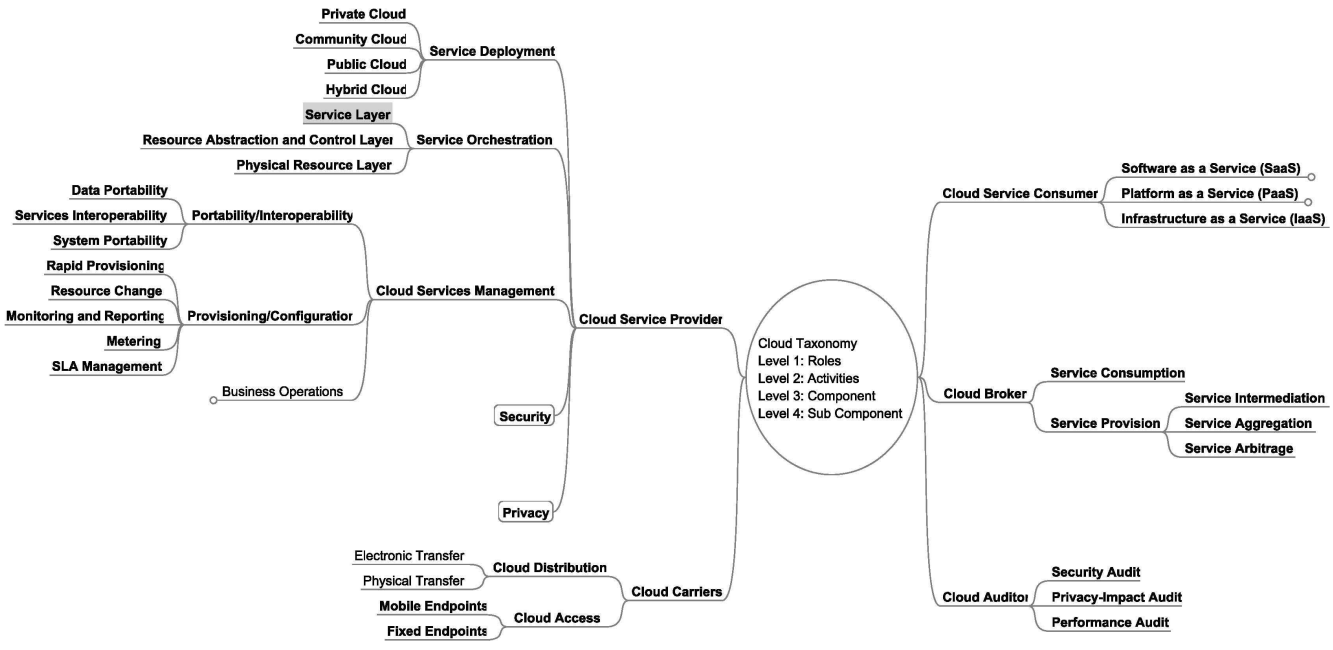
Providers should (could) coordinate offered services, implementing aggregation, intermediation, control and monitoring



Some significant aspects



A CLOUD TAXONOMY



Some open technological problems

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

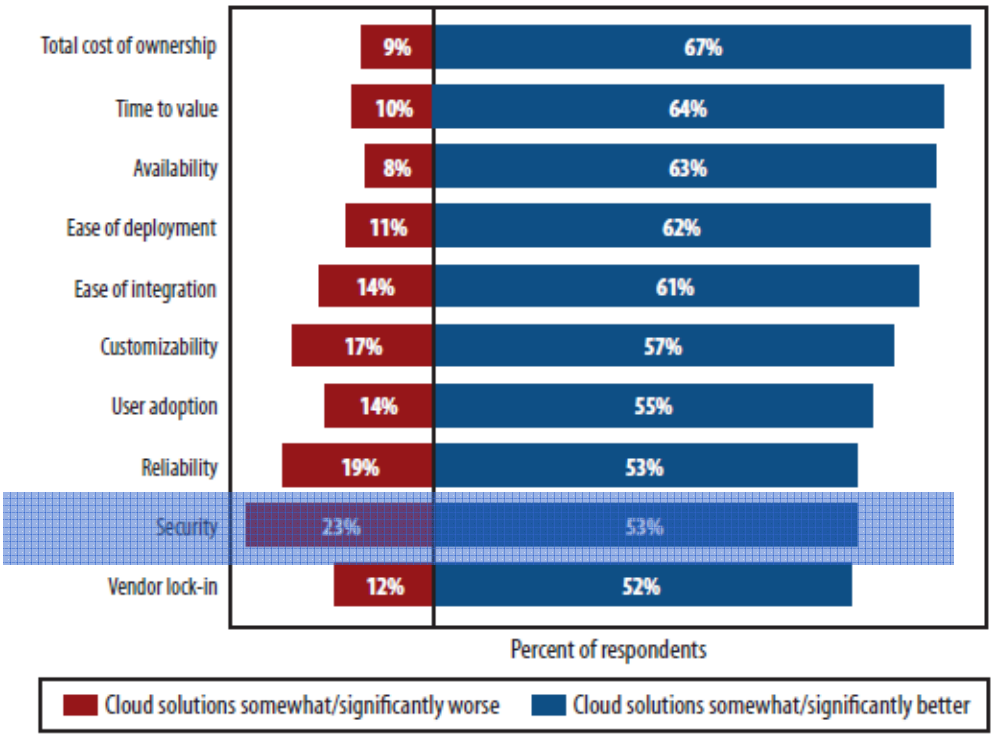
- Virtualization
  - New forms **of resource virtualization**
- **Differentiated and global resource localization**
  - Federation and coordination of **global resources**
- Security, Privacy and SLA adherence
  - **Verifiable and trusted assurance policies**
- Easy Control, handling and management by 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**

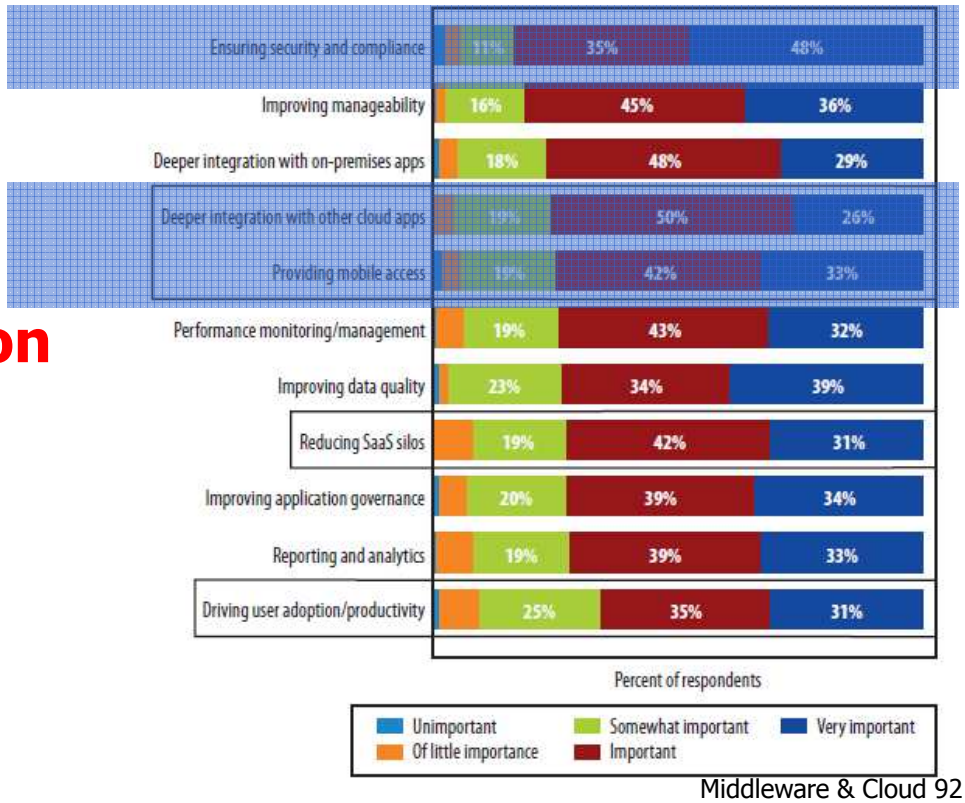
Cloud computing: pros and cons



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

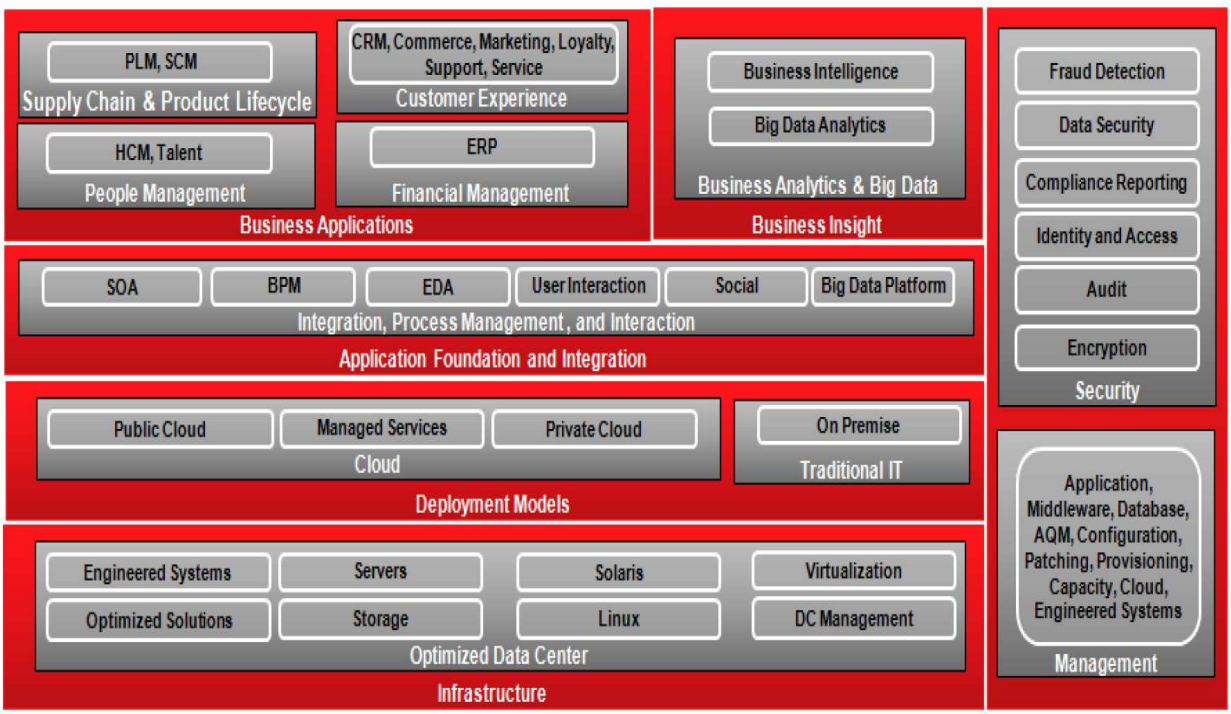
- Clarity about new roles and responsibility
- **Open source standard and implementations**
- Integration **with existing** protocols **(mobile …)**
- **Supports for sustainability**
- **Global and local legal clarity**

- **Ties with other areas:**

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

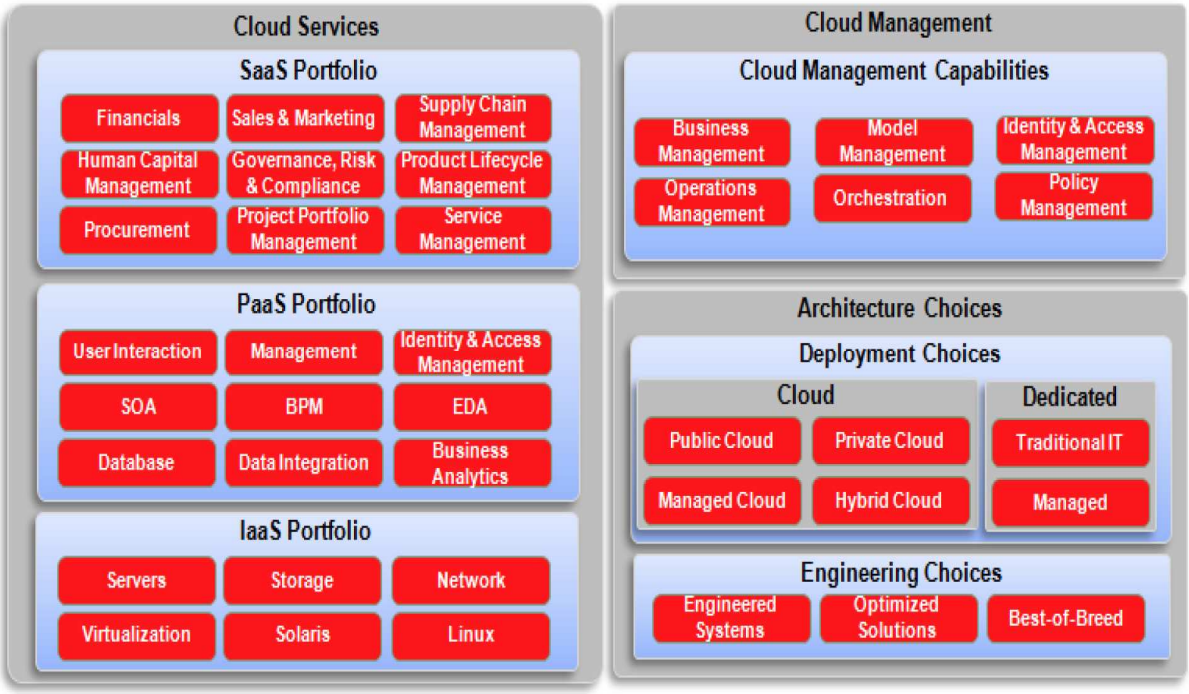
Cloud offer ecosystem

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



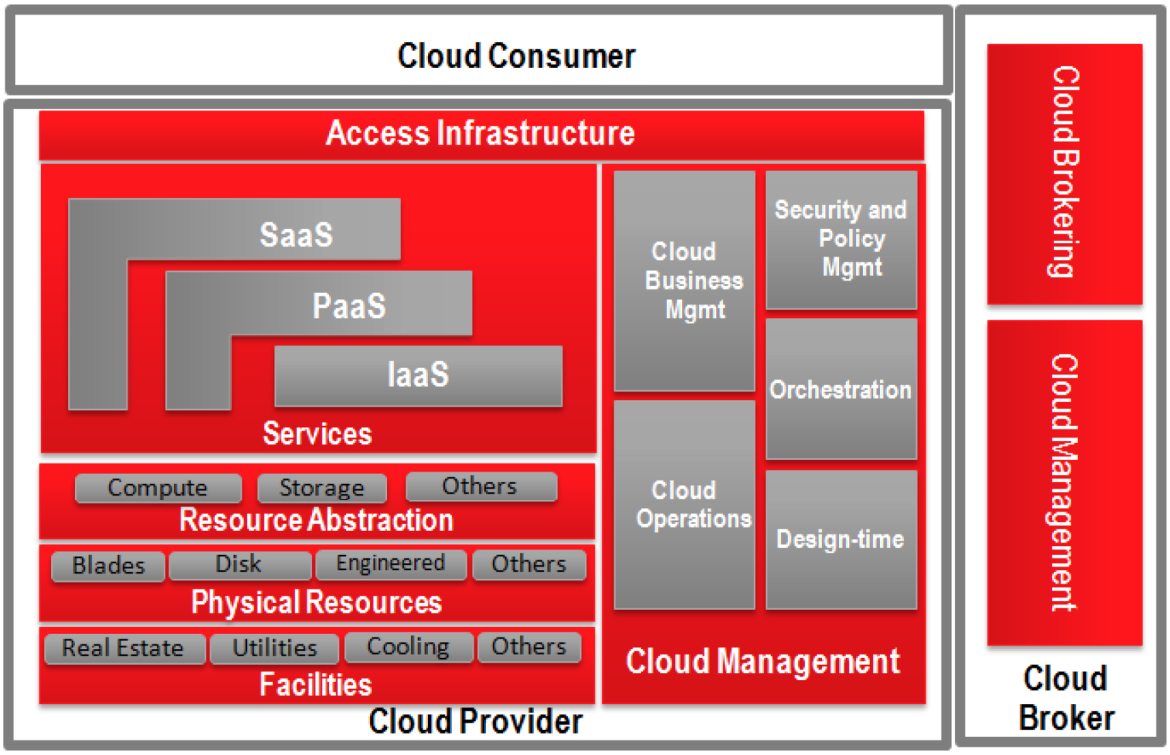
Cloud Solution scenario

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



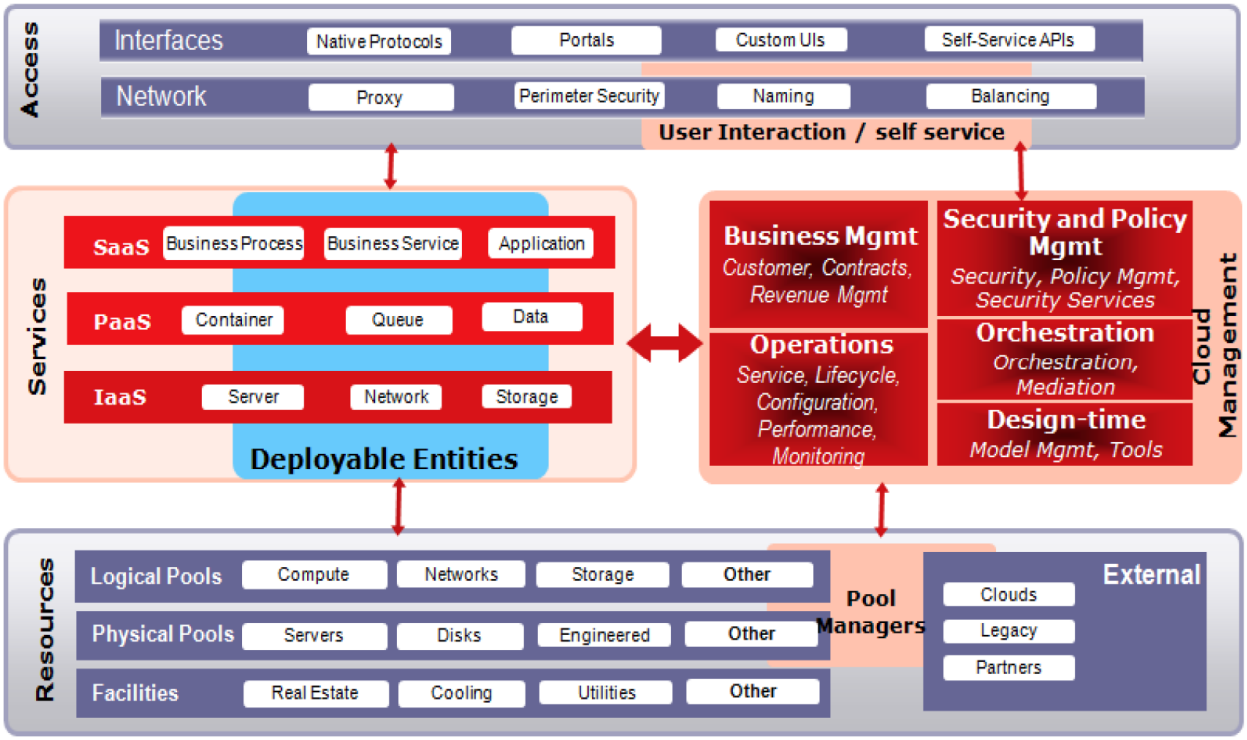
Cloud Solution roles

A possible **Cloud set of scopes**



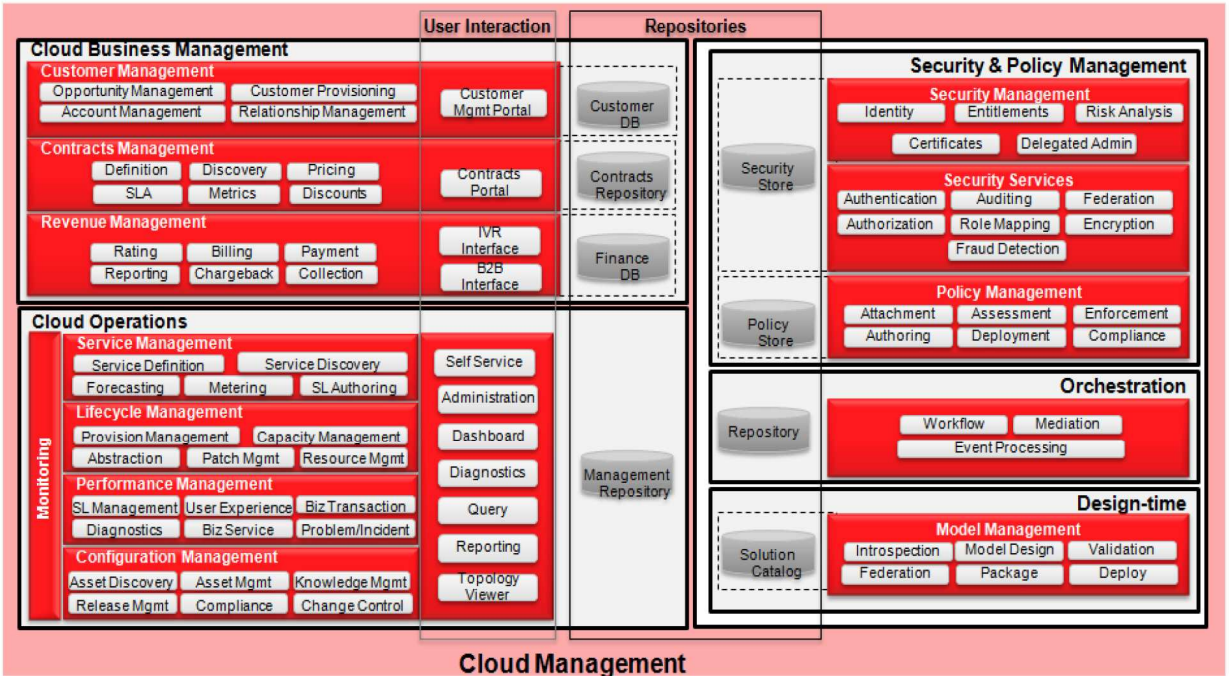
Cloud Components

A Cloud-layered infrastructure in Cloud components

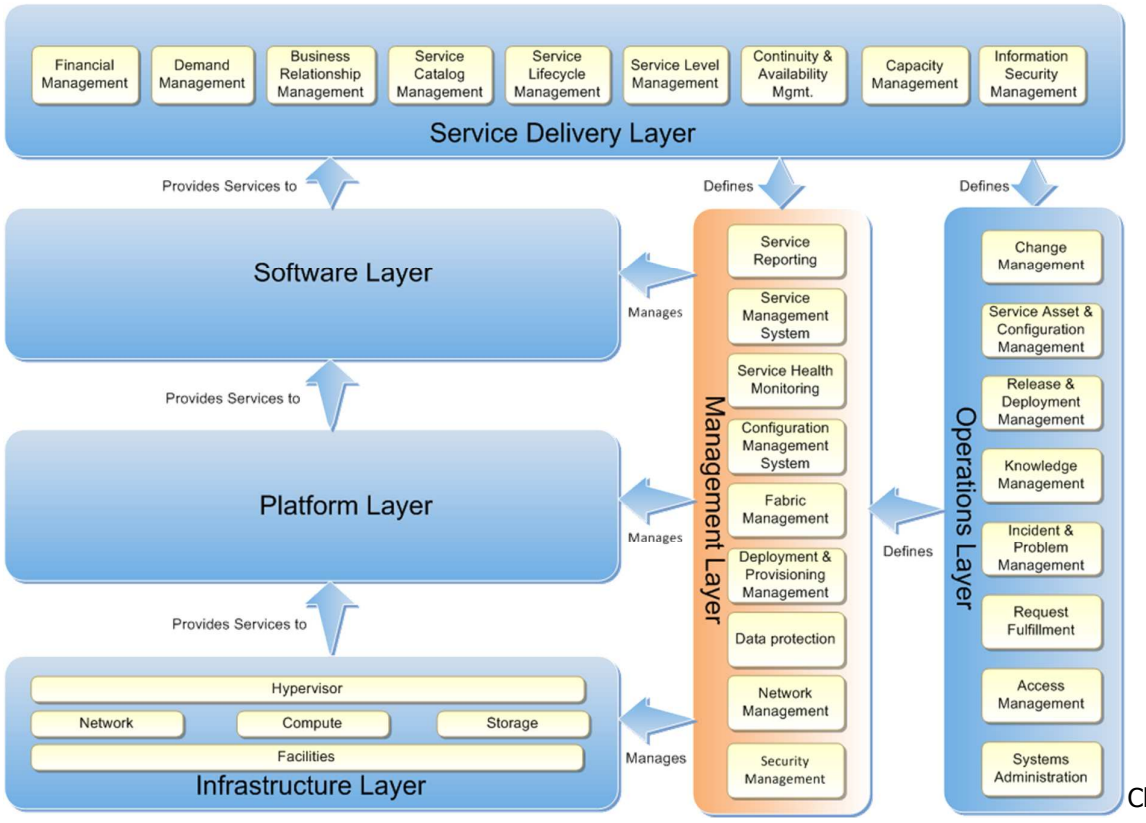


Cloud Management

A Cloud-layered infrastructure for management

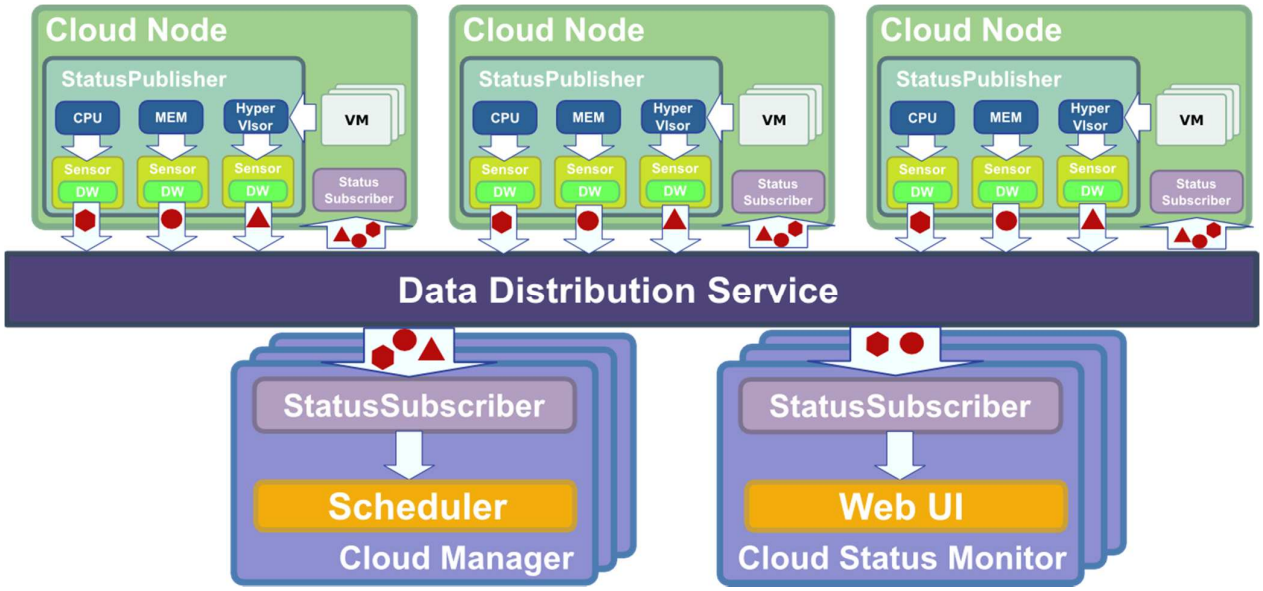


Cloud Management: a cross-layer view



Cloud Monitoring

Monitor and **manager components** (several possible deployments)
Physical and **virtual resource** monitoring
Many-to-many communication for **fine-grained local monitoring**



Readings (and more to come…)

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A. Lenk, M. Klems, J. Nimis, et al., "***What's inside the Cloud? An architectural map of the Cloud landscape*****,** ICSE Workshop on Software Engineering Challenges of Cloud Computing, 2009.

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