University of Bologna

Dipartimento di Informatica – Scienza e Ingegneria (DISI)

Engineering Bologna Campus

Class of **Infrastructures for Cloud Computing and Big Data M**

Goals, Basics, and Models

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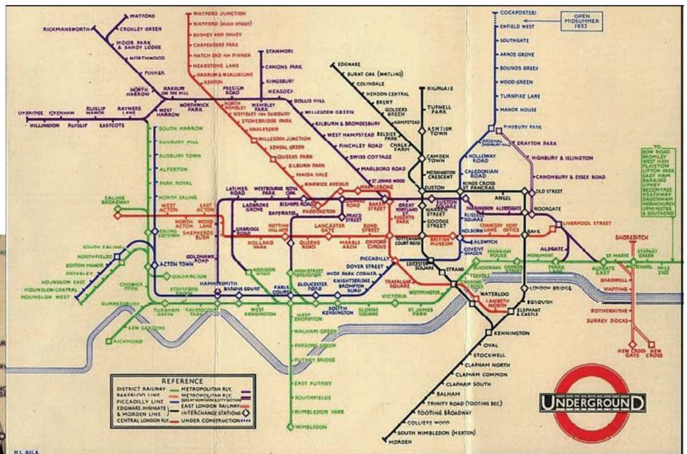
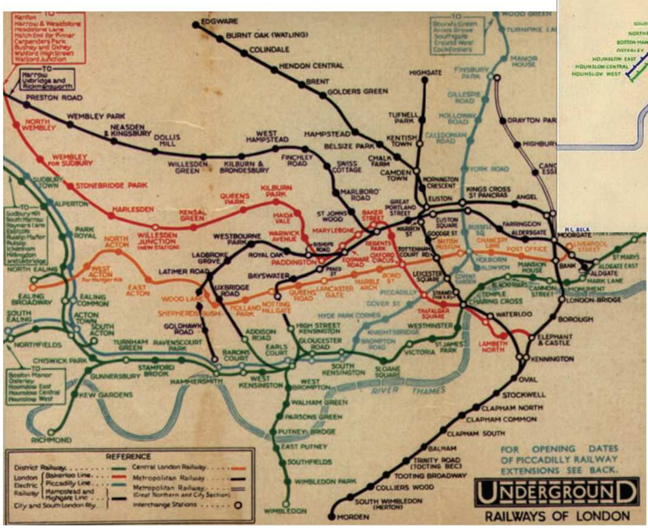
Academic year 2018/2019

A general guideline ABSTRACTION …





Specially interesting in **complex systems** to **focus** on the **right target**

TRANSPARENCY vs. VISIBILITY

TRANSPARENCY (*opposed to VISIBILITY*)

Access	homogeneous access to local and remote resources
Allocation	allocation of resources independent from locality
Name	name independence form the node of allocation
Execution	same usage of both local and remote resources
Performance	no differences in usage perception in using services
Fault	capacity of providing services even in case of faults
Replication	capacity of providing servicing with a better QoS via transparent replication of resources

Is **transparency** always an optimal requirement to consider?
at **any cost**, at **any system level**, for **any application** and **tool**

(??) **Location-awareness** to provide services that strictly depends on awareness and visibility of **current allocation**

TINA-C – Middleware for TLC

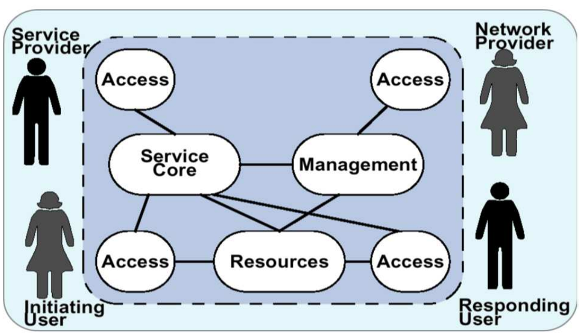
Telecommunications (TLC) Information Networking Architecture

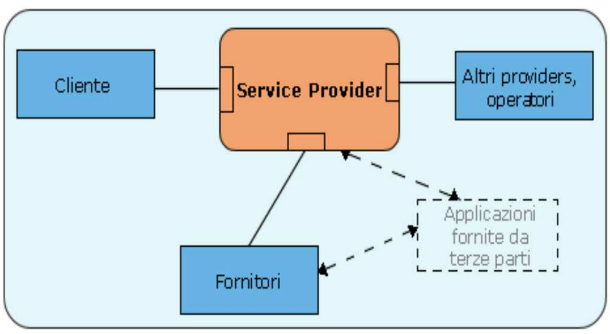
TINA-C defines a multiplicity of parties/roles involved in the communication service

Users and several communication and service Providers

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

user view **interaction view**

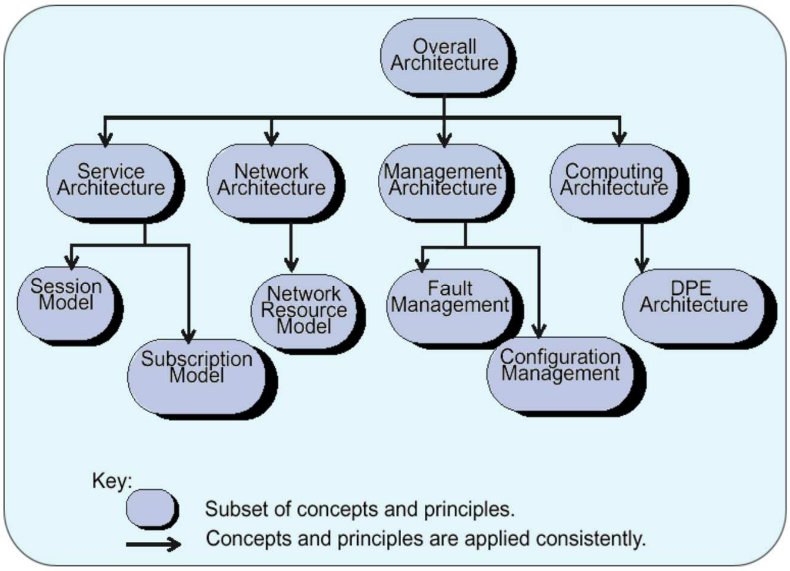




TINA-C – Architectures

Fundamental **architectures separate and interacting**:

Computing, **Service**, **Management, Network Architecture**



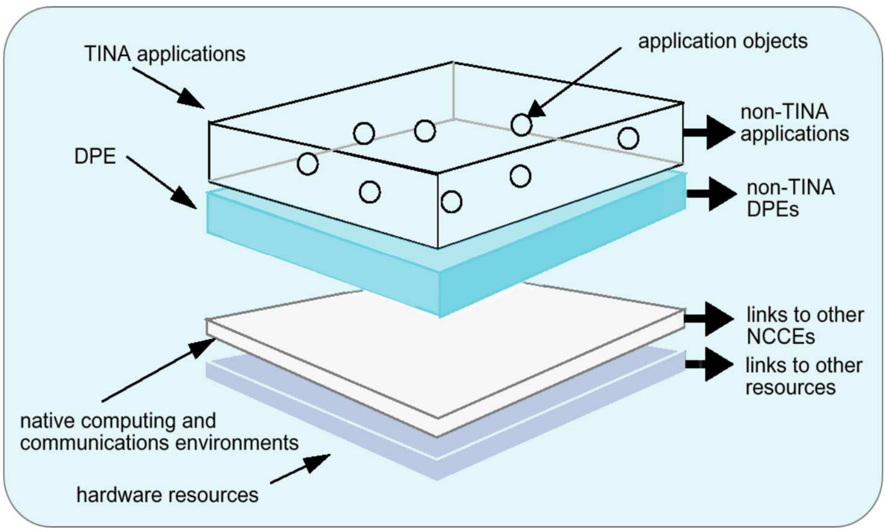
Interactions between the different architectures are present, of course

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

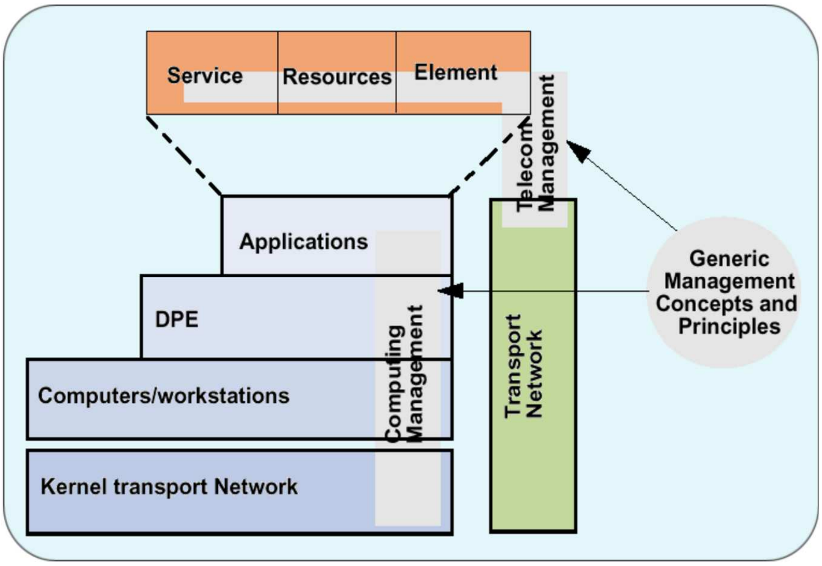


DPE **D**istributed **P**rocessing **E**nvironment

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

TINA-C – Transparent Architecture

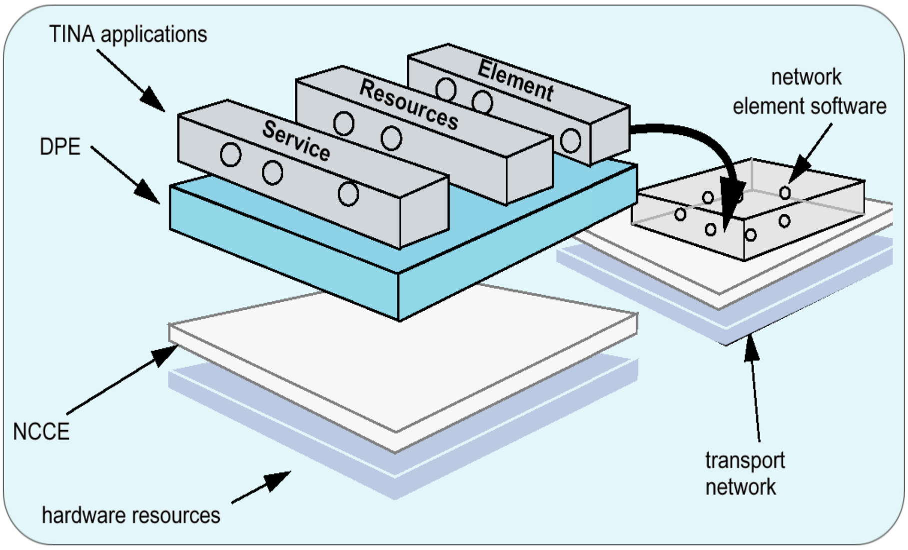
Applications and **services** are obtained atop physical resources exposed by various and heterogeneous local supports (NCCE) and integrated the DPE layer



An application is based on logical entities
- **Services**
- **Resources**
- **Elements**

TINA-C – Transparent Architecture

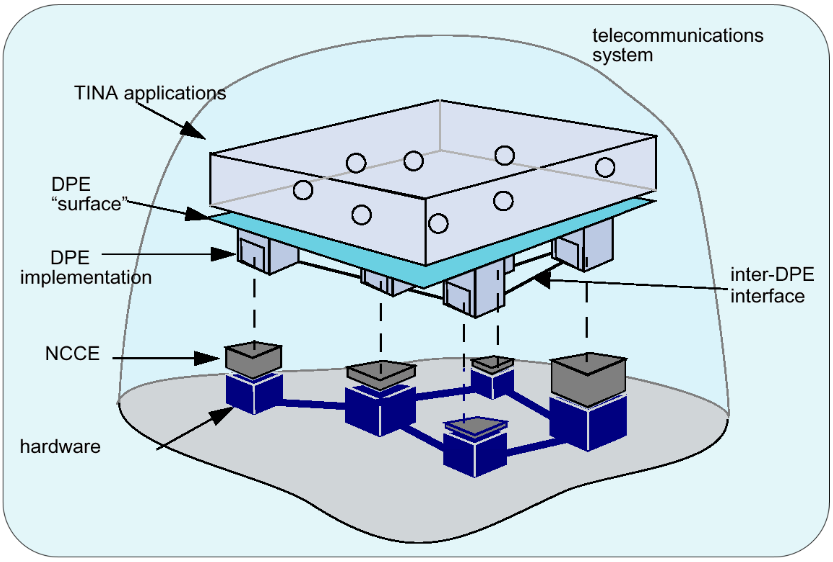
Transparent view of applications and services



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**

MODERN DISTRIBUTED SYSTEMS

Those are complex but very well spread… but still there are **unsolved issues**; that **is why they are interesting** ☺

We have to face **many challenges** and **problems** to be solved via a good design

As a few examples only of basic requirements

- **Scalability** and **Safe Answer and Service**
- **Predictability** and **Performance control**

But many difficulties

- **partial failure overcoming**
- **heterogeneity (at many levels)**
- **integration and standard**

…

SERVICES IN SYSTEMS and QUALITY

The first point in any system is to have a vision in terms of **services to be offered**.

Along that, any situation of a relationship can be qualified by the **intended quality** to be provided for providers to requestors

We have to carefully define the **Q**uality **o**f the **S**ervice (**QoS**) to be granted in any situation and to operate on it

The QoS defines the whole context of the operation and how to quantify the operation results

- Of course it is not easy to find a **standard way** to specify services and their properties in a clear way
- **Telco providers define service levels** via **specific indicators**, such as **throughput, jitter**, and other measurable ones

QUALITY of SERVICE QoS

QoS description must take into account all the possible **aspects of a service, under many perspectives**

From the experience of telco, we may consider

- Correctness

- Performance

- Reliability

- Security

- Scalability

Some of the above aspects are mainly transport-related and tend to neglect **application and user experience (even if they have a larger meaning)**

Some areas are **more quantity-based and easy to quantify,** while others are more **subjective and descriptive**

QoS should take into account both cases

QUALITY of SERVICE INDICATORS

QoS must adapt to the different usage situations

QoS must be based on both kind of properties

- **Functional properties**
- **Non Functional properties**

The **functional ones** are easy to express and quantify

such as *average* packet delay (over a service), bandwidth, percentage of lost packet, … for one service

The **non functional ones** are hard to quantify

such as *long-term service availability*, *security level* for the information, *perceived user experience* in video streaming, …

Sometimes we refer to **Quality of Experience** (**QoE**) of a provided service

AGREEMENT IN SYSTEMS: SLA

One important point is to understand how to **express the complexity** and to **rule the relationship between different involved subjects**

SLA Service **L**evel **A**greement

A **typical indicator** to express and reach an agreement between different parties on what you have to offer and why

Of course it is not easy to find **a standard way** to specify serve and its properties in a both formal and clear way

Communication providers define service levels via Mean Time Between Failures (MTBF), for reliability and other indicators for data rates, throughput and jitter...

Service providers must define service levels via more tailored indicators that relates and qualify the service for users and also some user experience key performance indicators (KPIs)

GOOD SUPPORT to ENTERPRISE

Several principles and systems to provide and give a scenario for business services

Middleware as a support to all operation phases in a company, also in terms of legacy systems

Service Oriented Architecture (SOA)

All the interactions among **programs and component are analyzed in terms of services**

Any service should have a very precise **interface**

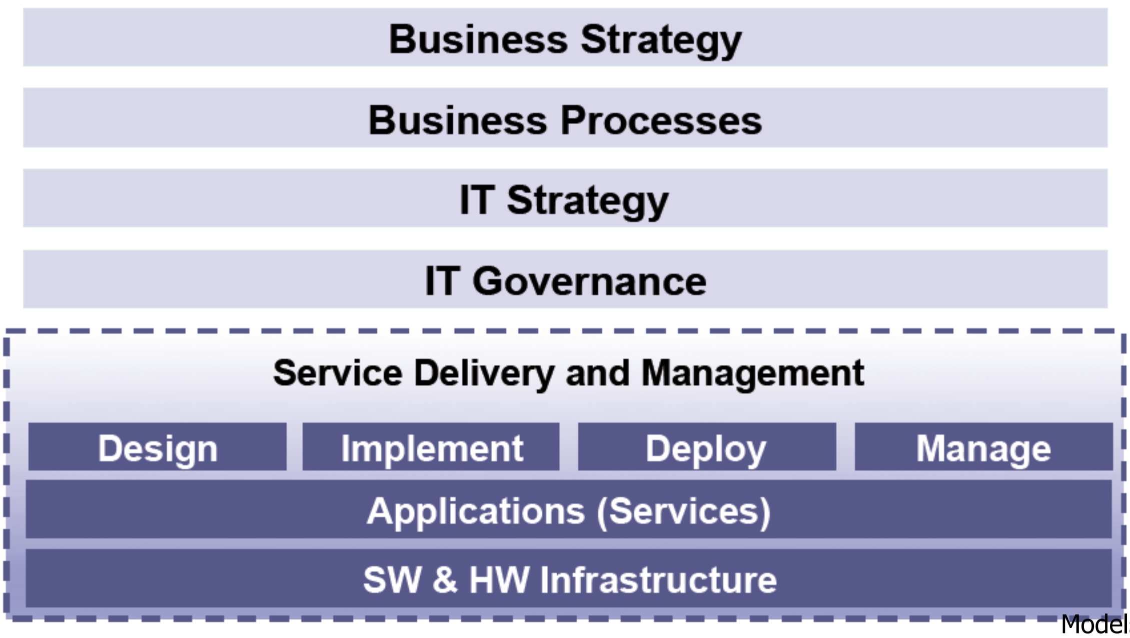
Enterprise Application Integration (EAI)

The need of **integrating the whole of the company IT resources** is the **very core goal**

That objective must be provided, while preserving Enterprise values

ENTERPRISE Information Technology

Modern Enterprise strategies require both existing and new **applications** to fast change with a critical impact on company assets



Typical different Applications in a Business

This list is only an idea, there are many other components

- **Supply chain** management (**SCM**)
- Warehouse and stock **management**
- **Customer** relationship management (**CRM**)
- Finance and accounting
- **Document Management Systems** (**DMS**)
- Human Resource management (**HR**)
- **Content Management Systems** (**CMS**)
- Web site and company presentation
- Mail marketing
- Internal Cooperation tools
- Enterprise **Resource Planning** (**ERP**)

And more….part of the EAI - **ROLE of IT in all areas**

Enterprise Application Integration

The idea of a complete Application integration or EAI is to have systems that produce a **unified integrated scenario** where all **typical Business applications programs and components** can be synergically provided

There are both:

- **Legacy components** to be reused
- **New components** to be designed and fast integrated

The easy and complete **integration** among **all business tools** has also another important side effect

The possible **control and monitor** of the **current performance** of any part of the whole business

- to have **fresh data** about performance
- to **rapidly change policies** and to **decide fast (re-)actions**

Service-Oriented Architecture

The basic interaction is via services defined as platform- and network-independent operations that must be cleanly available and clear in properties

Service-Oriented Architecture (SOA) is the enabling abstract architecture

A service must have an **interface to be called** and give back **some specific results**

The **format must be known** to all users and available to the support infrastructure

There are many ways to provide a SOA framework

SOA must offer basic capabilities for **description, discovery, and communication** of services

But it is not tied to any specified technical support

Service-Oriented Architecture or SOA

SOA is simply a model and it imposes some methodologies to obtain its goal of a fast and easy to discover service ecosystem

- Services are described by an **interface** that specifies the interaction abstract properties (API)
- The **interface** should not change and must be **clearly expressed** before any usage
- Servers should **register as the implementers** of the interface
- Client should **request the proper operations** by knowing the interface

Interaction is independent of any implementation detail, neither platform-, nor communication-, nor network-dependent

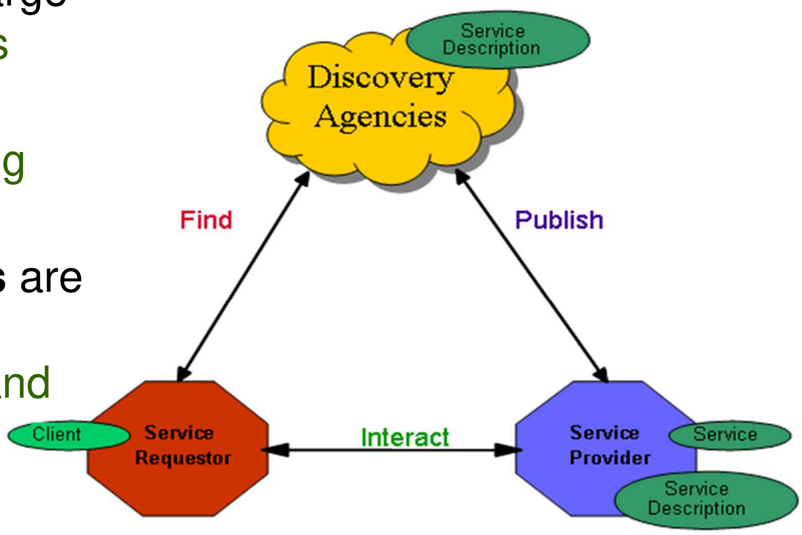
SOA actors or components

Service-Oriented Architecture SOA proposes a precise enabling architecture with three actors

Providers are in charge of furnishing services

Requestors are interested in obtaining services

Discovery agencies are responsible to give service information and full description of services



C/S Model as a SOA IMPLEMENTATION

Client/Server for any operation request
Intrinsically distributed as a model but
the model does not consider discovery agencies

Very high level communication rules where **client knows the server and interacts synchronously (result implied) and blocking (result awaited) by default**

Model with tight coupling:
interacting parties must be **co-present for some time**

Obviously we are interested only in models inherently distributed and deployed, and leading to deployment really always distributed

There are many weaknesses and rigidities in C/S typically these usage difficulties are **overcome by small variations tailored** to specific needs

Service Conceptualization

One service is an **abstraction of any business process, resource, or application**, that can be described by a standard interface and that can be published and become widely known (discovery)

Services are:

- **reusable**, in the sense that they can be applied in several contexts (no limitation, in general anyone)
- **formal**, they are not ambiguous in defining the contract specifications (clear and clean interface)
- **loosely coupled**, they are not based on any assumptions on the context where they could be used
- **black box**, they are neither specifying the internal business logic nor tied to any implementation details of a specific solution

SOA Design Principles

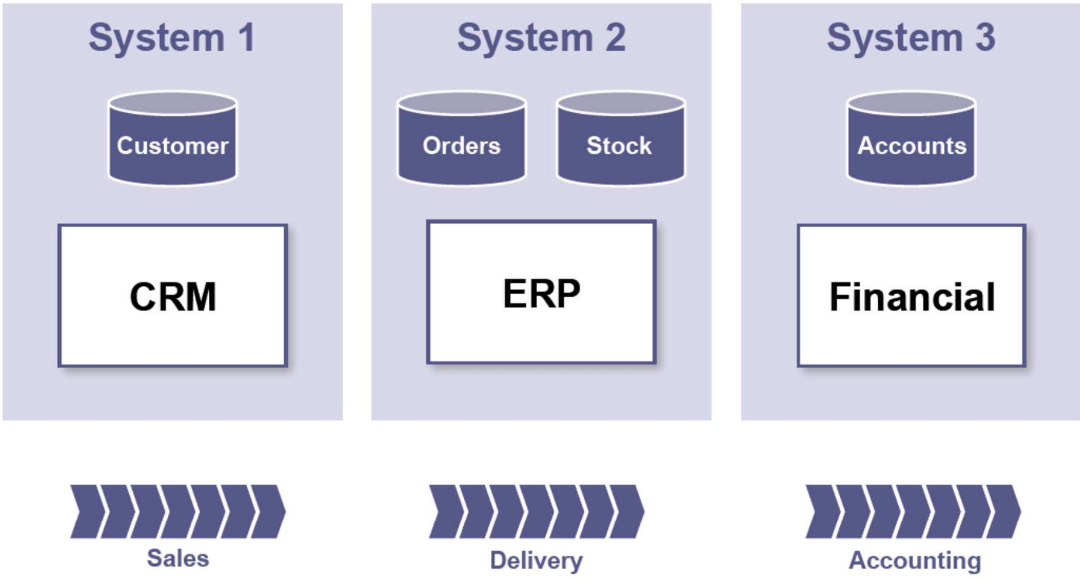
A service must be available by all **platforms that are offering it** to all the **ones in need** of it, if the requestor **asks for the interface** in the right way

Interfaces should be **widely spread and published** in some **discovery agencies**

Services must be:

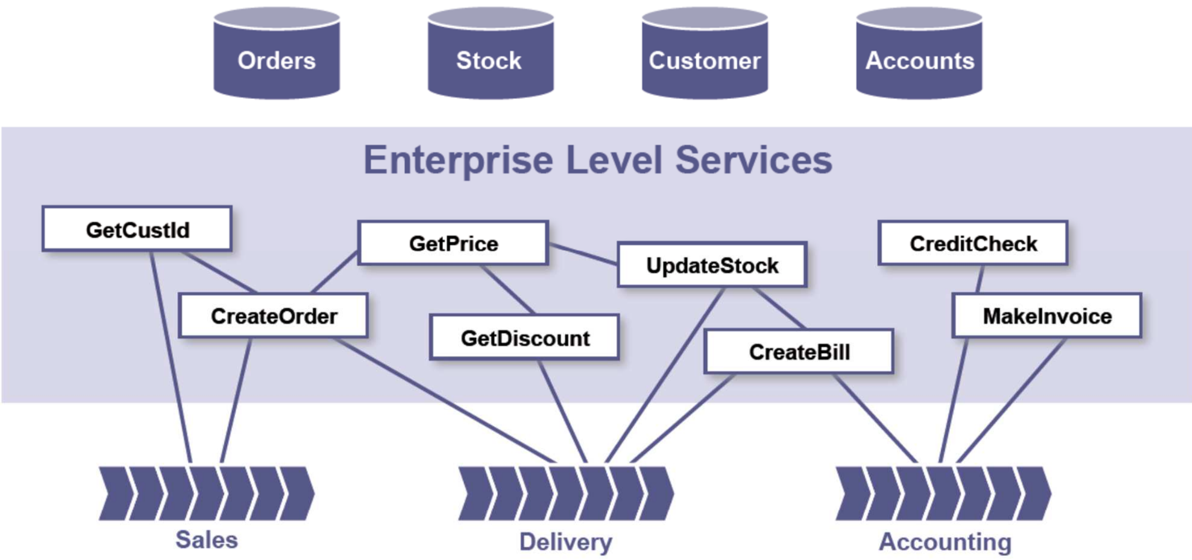
- **autonomous**, they must not depend on any context and should be capable of self managing
- **stateless**, the internal need of state should be minimized (eventually **stateless**); the client maintains the state
- **discovery-available**, all service must be found via opportune naming agents and must easy to retrieve and to use
- **composable**, existing services can be put together to produce a modular component to be invoked independently as a novel service (**composition to create new services**)

Traditional Business Architectures



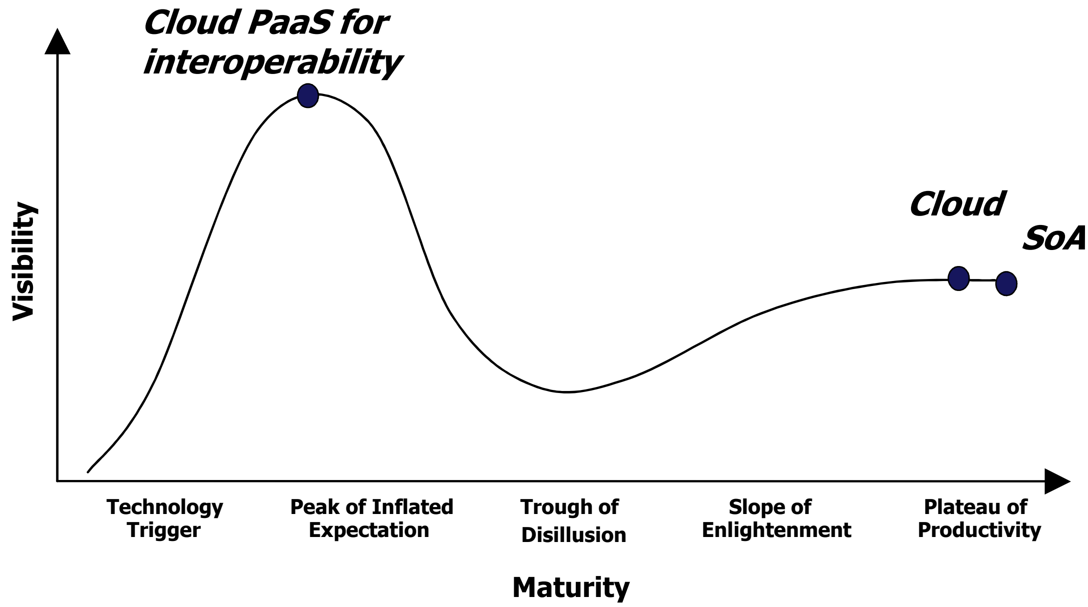



SOA-oriented ARCHITECTURES - EAI



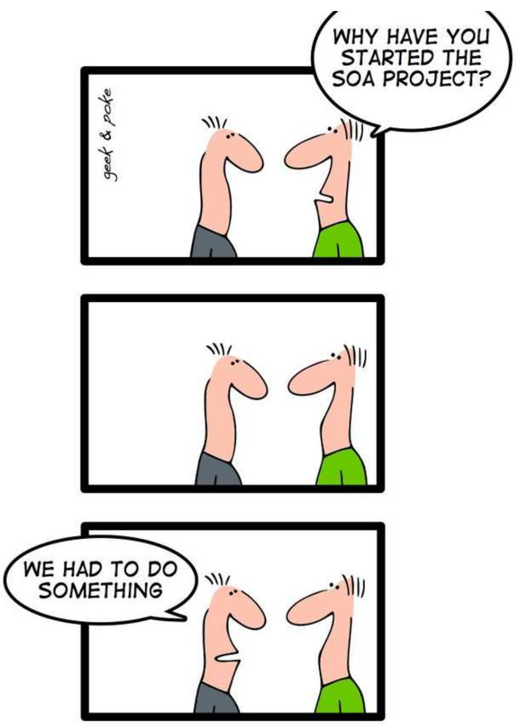


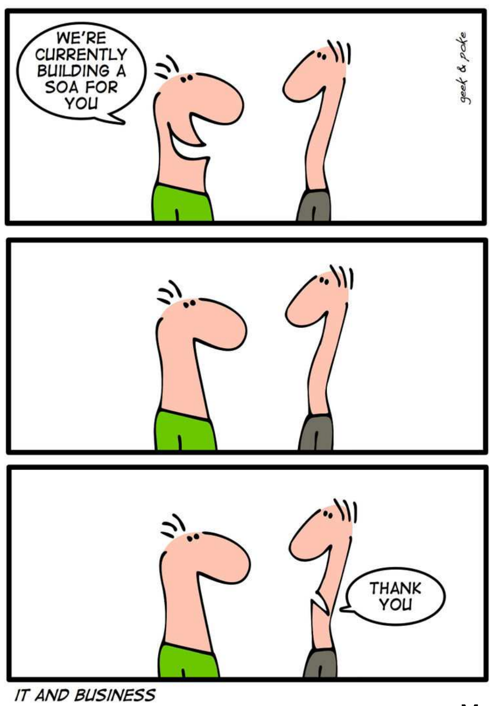

Evaluation and Evolution in Technologies



GARTNER trends or technology life cycle
Any technology has its own life cycle, with hypes connected

SOA enthusiasm





DISTRIBUTED SYSTEMS

We can understand **distributed systems** and **their operations** only by conceptualizing a model

A distributed system consists of resources *(all the resources that may be requested during execution to grant any visible result)*

Resources can be, for instance, abstracting from our experience of one machine:

- **Physical memory (RAM),**
- **Disk (some levels of persistence)**
- **Computing (CPU, even many)**
- **I/O and communication support**
- **Other equipment and devices (sensors, actuators, etc. in a smartphone)**

We have to open up our perspective, and think to the whole system, …

A first step is about all **available applications and services**

A BETTER SYSTEM DESCRIPTION

A **distributed systems** can consist of several machines

> ***A distributed system consists of many resources***, in an organization that put together **several machines in a locality (more or less confined)**

Resources can be, abstracting from our experience of a system for an organization:

- **Several computing and memory resources (and other ones)**
- **Disks (for local and global persistency)**
- **Connecting support (network with some granted bandwidth)**
- **Other & Application services (OS, Web, Applications, ad hoc services, application define services and clients,…)**

Virtual resources and also corresponding physical resources (all the resources that may be requested during execution to grant any visible result)

MORE COMPLEXITY in SYSTEMS

A **distributed systems** must consider also a larger perspective, both at a **lower** and at a **higher** level

Resources can be at **the lower levels**

- **Operating systems and low level services**
- **Virtual resources insisting on physical ones (not only Virtual machines and Physical ones, but any kind: Virtualized connections and network)**

An optimized management of that environment i**s hard** and must be **carefully designed**

Resources can be at **the higher levels**

- **Application system related services of any kind, from Web servers and services, Web containers, …**
- ***Real application, from management software, to final ad hoc software***

An optimized management of that **application environment is even harder** and must be **more carefully designed**

SYSTEMS and OPERATIONS

In a business perspective, a **distributed system** can be **hosted on premises**, and in charge of the owner organization

Many companies have an **internal data center that must take charge of all aspects**, from the hosting of hardware, installation, maintenance, operation, and also of the whole software components and their operations

Also all human resources must be handled

Resources must be managed and handled along a business strategy

In a business perspective, a **distributed system** can be **outsourced**, and managed by external service provider

Many companies exploit an **external data center that must provide some business services,** as if they were internal, also in a **transparent way**

OUTSOURCING vs. CLOUD

Companies are used to **outsourcing** some parts, since long ago (also maintaining other services as internal with the problem of their interconnection and integration)

The external data center must be always accessible and capable of giving service with the negotiated SLA and the requested QoS

Some aspects are well solved, others to be solved

In recent years, **Cloud** has opened up more that perspective by providing any kind of service remotely, by producing a more **organized model of all the offered services**

Access is always **via web** and in some **agreed form**

Many private people and small companies have available many 'low-cost' **external data centers to provide elastic, easy-to-use and pay-per-use services, *in a transparent way, as if they were internal***

RESOURCES

In a **DISTRIBUTED SYSTEM a central issue is Resource Management**

Definition of a resource

each component reusable or not, both hardware and software, needed for the application or system support

Classifications (many different properties and aspects)

- **low-level resources vs. application resources**
- **physical resources vs. logical resources**
- **physical resources vs. virtualized resources**
- **static resources vs. dynamic resources**

Resources have an external and an internal organization, based on **abstraction**

specification (visible interface) and **implementation** (not visible)

Different implementation, of course, …

Concentrated & Distributed organization toward the best service

RESOURCE MANAGEMENT

Systems are very **differentiated in requirements and** there is no **magic recipe** for all cases
There are **many implementation models**
and many different ways of operating and serving results

The design of one interaction is split into two phases
- the **static** that plans the operations and precede the real operations (before running and out-of-band ☺)
- **the dynamic** that is in the implementation of operations (while running services and in-band ☺)

Concurrency among **services** and **support actions** can produce **delays** and **overhead** but it may **produce an optimizing effect**

RESOURCE SERVICES

A resource can be available for providing its services with a typical interface (the simpler the better) as **SOA**
You become the client, and the service is provided to you by the server

The interface is deployed in two forms:

Service request
Distributed file system

Service Request
The client ask explicitly the server in a Client/Server approach

Distributed File System (DFS) or a middleware approach
Unique service available in a transparent way (allocation transparent)

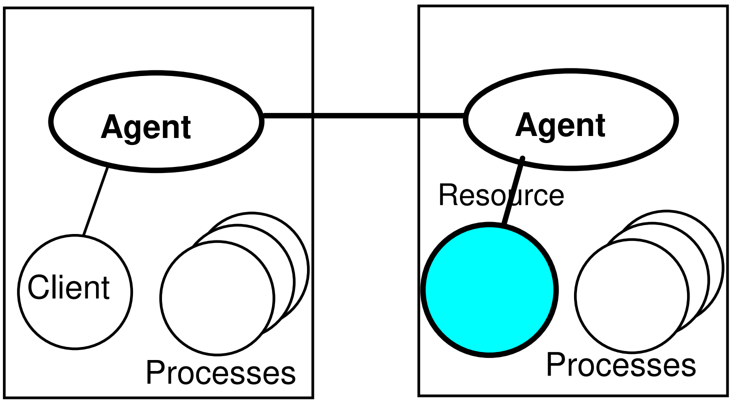
Transparency simplifies the interaction and users are freed of **responsibility**

MANAGEMENT by AGENT (DFS)

The deployment is a coordinate agent systems to provide a unique service

Agents must coordinate among themselves to operate and give the best result

Any kind of negotiation is possible among agents toward the final goal, also deciding to refuse the service



GENERAL MODELS

In **Distributed systems** maximum interest in **real operations, performance, distributed execution**

Models preventive vs. reactive ones

Preventive behaviors avoid a priori undesired events, but often introduce a fixed cost on the system (often computable) - **pessimistic**

Reactive behaviors allow to introduce less support logic (and **may limit** operation costs) if specified undesired events do not occur - **optimistic**

Models static vs. dynamic

Static behaviors do not allow to **adjust the system** to (even limited) **variations during execution**

Dynamic behaviors allow you to let the system evolve along (limited) **variations in execution but can cause higher costs** (overhead)

STATIC and DYNAMIC MODELS

Dynamic models / Static Models

User number is predefined and fixed before run

Users can be added and deleted during the execution

Process number is predefined and fixed before run

Processes can be added and deleted during the execution

Node numbers is predefined and fixed before run

Processors can be added and deleted during the execution

Clients and their number is predefined and limited before run

Client traffic can be added and deleted during the execution

Services and support are predefined and fixed before run

Servers and services can be added during the execution

Services can vary during execution

TOWARD A RESOURCE MODEL

Some usual (logical) resources for execution

Processes as entities able of expressing execution via

- **local actions** on an internal and confines environment
- **communication actions** toward other processes by using *shared memory* and *message exchange*

Also data can exist *externally* to processes themselves (limited confinement and insufficient abstraction)

Objects as entities to express abstraction, as ability of

- enclose and hiding **internal resources** (data abstraction) with externally **visible interface** only of **operations**
- act on **internal resources** to complete externally requested operations

Passive Objects **data abstractions** with external executing entities

Active Objects **entities capable of both execution** and **data containment**

CLASSES vs. INTERFACES

A trend in software architectures puts together:

- **interfaces** as the **agreed contract of interaction, uniquely specified and not negotiable**
- **classes** that describe different **implementations** (many different can exist also different in QoS in the same system)

  Distributed systems has spread since long ago the idea of having **interfaces as contracts** between different stakeholders - who also develop independent - and of keeping these separate from specific implementations (possibly multiple ones)

  middleware are **usually based on interfaces** and less on classes (and other their separate implementations, as the components)

In OO languages, that separation **came later, but modern languages have incorporated quickly,** especially in **languages designed for distributed systems**

In general, **object langages answer in-the-small requirements**

OBJECTS vs. COMPONENTS

We tend to refer to **Object models**, see Java and other usual languages

The Object model is not so confined and very dependent from the containing environment (fine-grained objects)

With the class relationship and subclassing

  The distribution requires to **confine better objects boundaries and interactions** with the **containing environment**

The Component Model (coarser grain) succeeds

  In defining more **self-contained** entities and more **transportable to different environment**

Definition of component: **static abstraction of a confined entity communication with the external world via ports**

COMPONENTS

A component is

- **Static**, having its own life and being independent from application
- **Abstract**, without any visibility of the component internal structure by showing externally only input output ports
- **Communicate only in a disciplined way by ports** as the only way to communicate to the external world (**IN** and **OUT**)

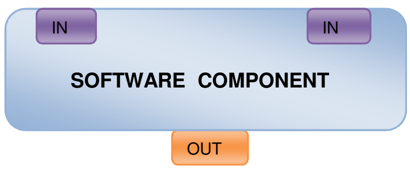
Effect of

better reusability, with easy transportability from one container to another (no hidden interactions, only visible and declared ones)
capacity of substitution, one implementation can replace another (dynamic replacement) without any container change

Toward SOA (**S**ervice **O**riented **A**rchitecture o **SOA**) ⇨ ports are tag for methods visibly accessible and very easy to be externally invoked

AGAIN COMPONENTS

Again a component definition



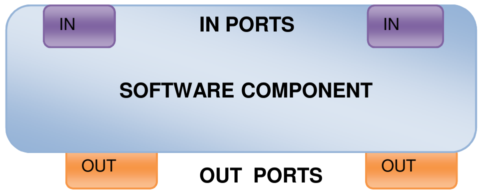
"A component is an object in a tuxedo. That is, a piece of software that is dressed to go out and interact with the world"
Michael Feathers

A **component** typically is one entity with **coarser grain** than one object, and it is typically more **self-contained** & capable of **operating** in very different **environment** …

Often it should work within a **container**, i.e., a **support server** capable of hosting the component to provide it **several needed functions; components focus only the business logic**

J2EE, **EJB** are containers that can host components and can provide most common support functions (initialization, finalization, …)

COMPONENT PROPRIETIES



A component has a **very disciplined interface** and must **declare the contract of interaction via ports** that regulate **accepted inbound requests (in ports)** and the **services you can ask outward (out ports)**

This interface rules precisely and statically the interaction with the outside world in an explicit (and not hidden) approach

A **component** is **self-contained** but must handle only **some features** and should delegate **other functions** to an **enclosing container** that is **able to reply and to manage it**

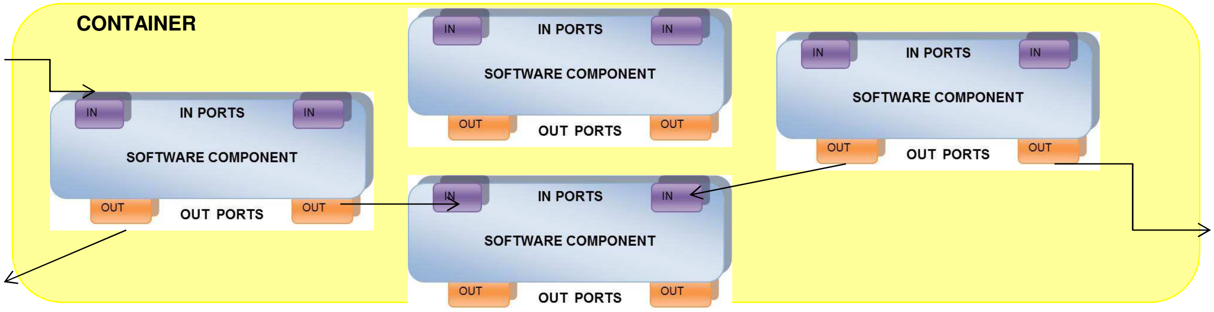
There is a **separation of roles** among the container and its internal components

SYSTEMS with COMPONENTS

A system with components can provide several functions to the hosted components

- **Life cycle;** the container can activate and deactivate components on need
- **Resource sharing;** resources are shared via container provisioning and encapsulation
- **Composition;** the container can help in forming newe components by putting together existing one
- **Activity support;** any interaction between components can be supported via container-offered activities
- **Control;** the container helps in monitoring, handling, and controlling components
- **Mobility;** the container has the capacity of extracting and moving components already executing

COMPONENT PROPERTIES



Externally the only way **to access to one component** is **via its container** that rules the interaction and offer many management services (life cycle, control, migration, …)

Inside a container component **work internally** and, when in need of external services, must pass through the container in a **very disciplined and checkable way**

- The interaction of components within one container is precisely **disciplined** and **governed** by the **container strategies**
- The container can choose and **operate autonomously**

CONTAINER MODELS

CONTAINMENT

Often many features cannot be controlled directly from the application but left as **responsibilities to a delegated supervisor entity (container)** who deals with them,

- often introducing policies by default
- while avoiding typical user failures
- controlling external events

Containers (entities with many names, also called containers, **ENGINE, MIDDLEWARE**, ...) can take care of automatic actions that relieve the user responsibility from repetitive actions, that can be easily expressed

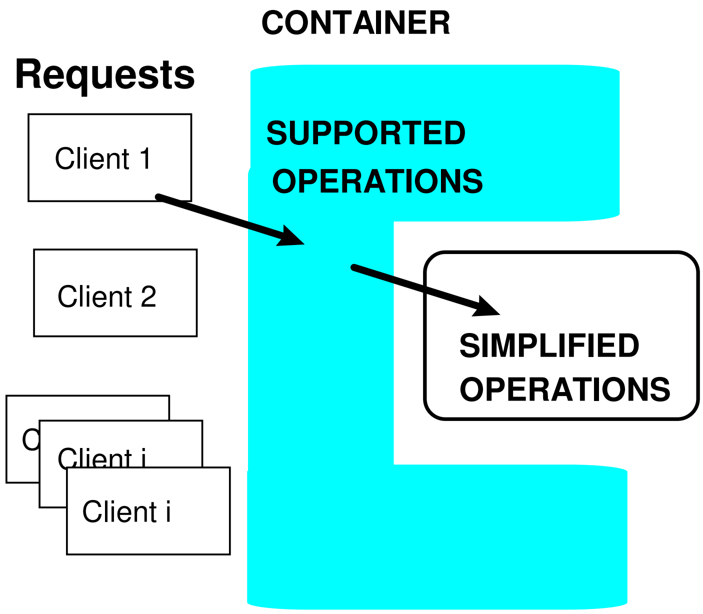
A user can then specify only the high-level part not repetitive, highly dependent from the application logic

MODELS FOR CONTAINMENT

CONTAINER

a service user may be integrated in an environment (middleware) that deals independently of many different aspects

See
CORBA all C/S aspects
Engine for GUI framework
Container for servlet
Support for components



Container can host **components more transportable & mobile**
One goal is also to **move around components between different containers** and allows that inter-container mobility

DELEGATION to CONTAINER (Middleware)

The container can provide "**automatically**" many features to support service

- Lifecycle Support

- **activating the servant/deactivate/**
- **maintaining state**
- **persistence and retrieval of information (interface with DB)**

- Support to the name system

- **the Discovery of servant/service**
- **Federation with other containers**

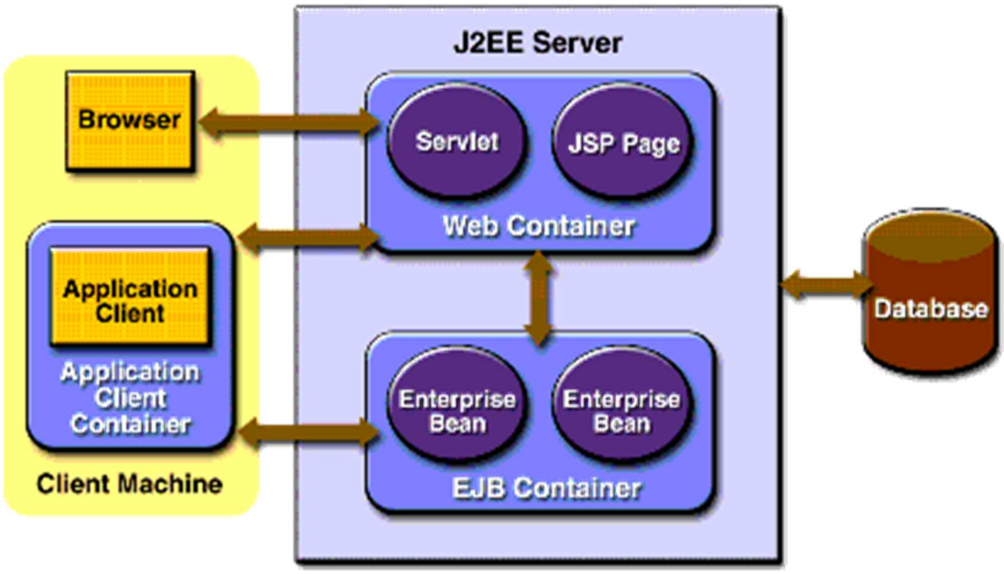
- Support to the QoS

- **fault tolerance, selection among possible deployment**
- **control of negotiated and obtained QoS**

...

J2EE – Java 2 Enterprise Edition

A container may **also be able to facilitate the execution of different components** such as servlets, JSPs, beans of various architectures and types



MODERN DEPLOYMENT: DEVOPS

Developing **Op**eration**s**

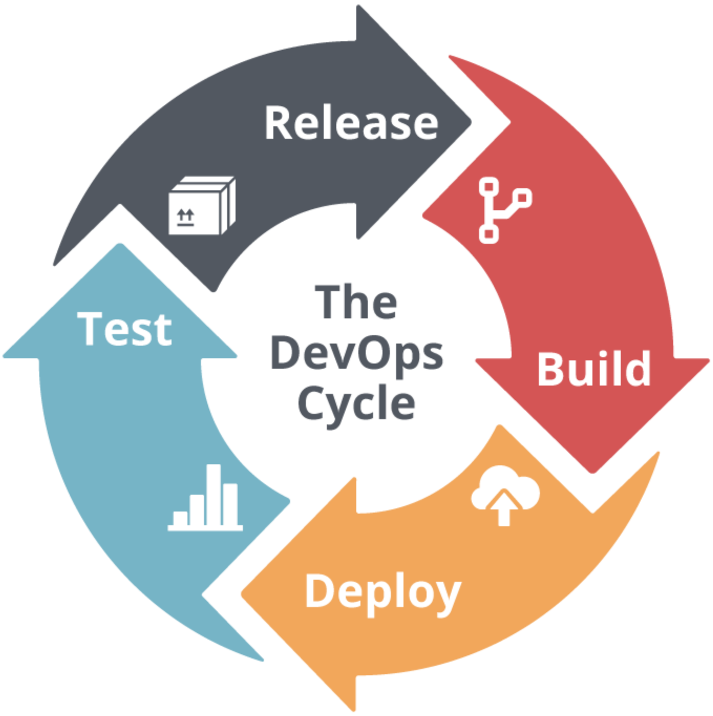
In the last years, **DevOps** became a buzzword to indicate the necessity of coupling and putting together **the application part** (user designed) and **the infrastructure part**

Especially in environments in which you have to change the application very often

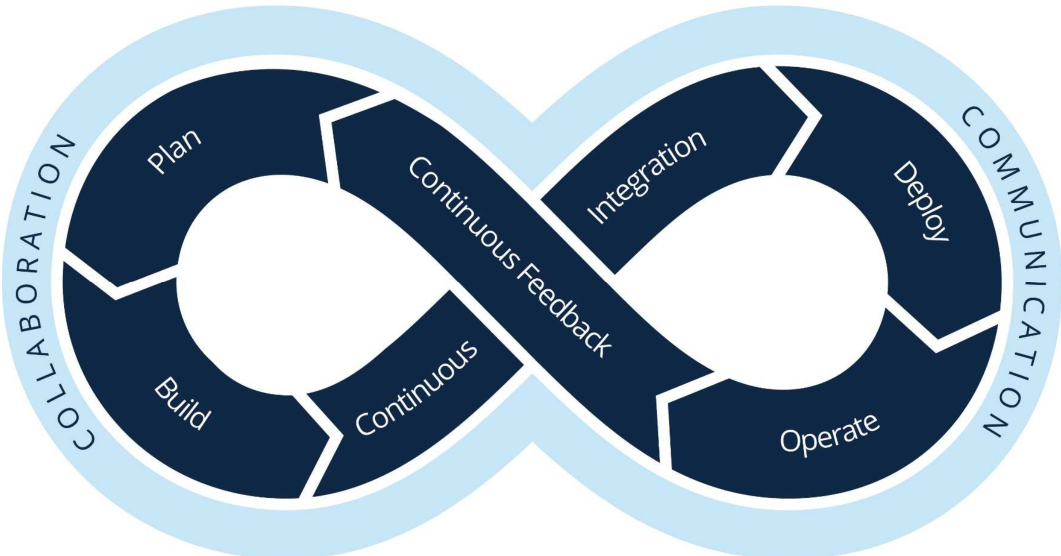
To be more realistic, even if **devops** is connected with agile and other developing methodologies, the idea that you want to prepare the environment by which you can **control new releases and install them in a very facilitated way** was a **paramount requirements of large systems**

Of course with QoS and safely, by avoiding problems and crashes

DEVOPS CYCLE



CONTINUOUS DEVOPS



An application can be continuously upgraded while in execution, without interfering on the current application

New release and twin system

MODERN DEPLOYMENT: MICROSERVICES

In the perspective of having **very portable and scalable applications**, it is very important to express the application in terms of

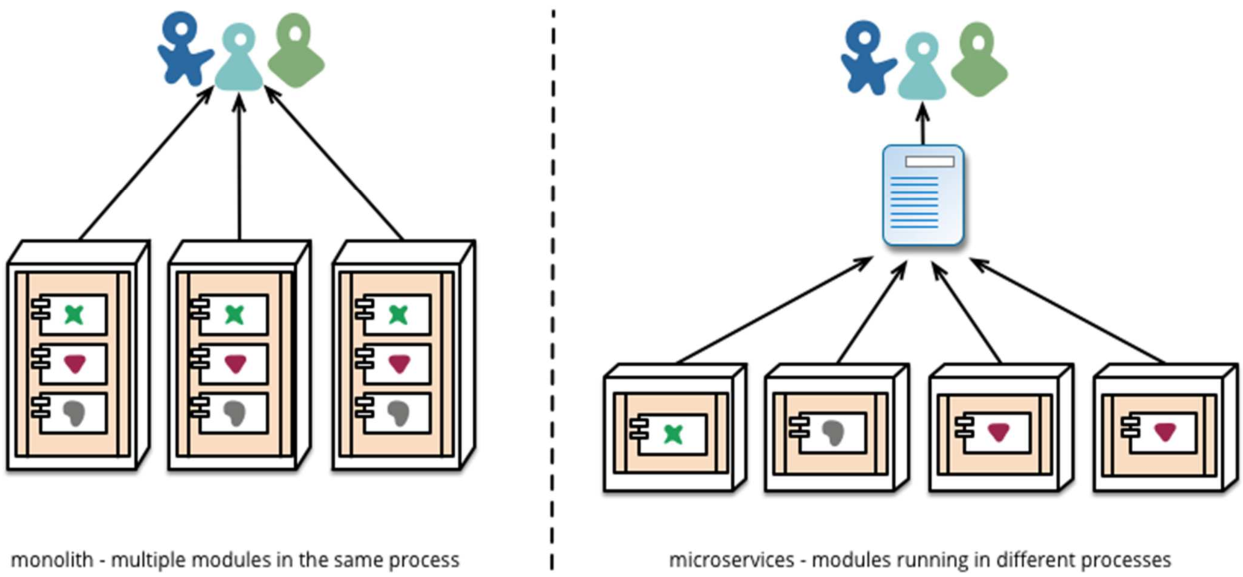
Microservices (as components)

Compose one distributed application made of separately deployable services that perform specific business functions and communicate over web interfaces

Microservices are small, reusable small blocks of code to compose the application with the goal that

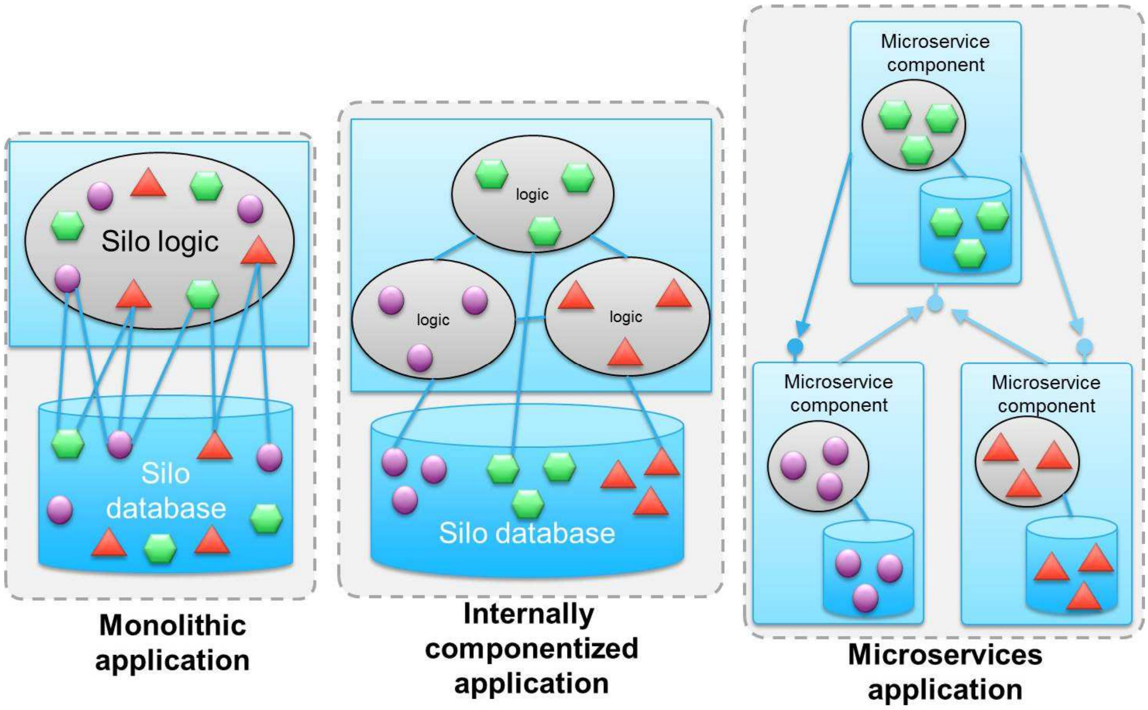
the entire application is scalable and less affected by the increase in the velocity of deployments in the DevOps environment

MICROSERVICES



Microservices make **components available and easy to compose**

MICROSERVICES: not so new



MICROSERVICES WHERE?

Microservices are small components:
agile and easy to be executed
Microservices are a new idea in which the design from remote is easier

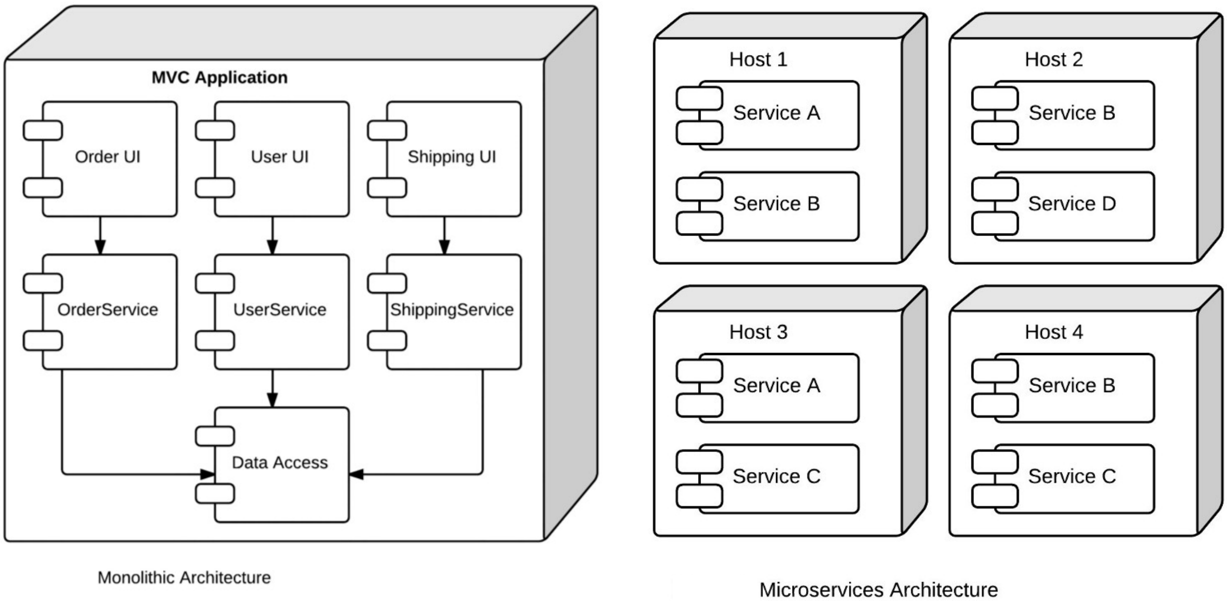
But they need to be **safe,**
so that they can work correctly in their environment
Microservices must execute in a context capable of offering the whole environment they are in need of

Microservices must safely execute in and together within a container

A **container** is a **suitable environment** for microservices execution and also for **letting in** new microservices and **letting them** out

DIFFERENT DESIGN MODELS

Microservices can be easily deployed and also moved from one container to another



CONTAINERS

DEVOPS and MICROSERVICES

Changes of perspective

Devops makes you think to the **support of your application**

Microservices makes you think in terms of **small components**

The coupling of the application part to its support part have spread the idea of new containers for microservices

- **Microservices** make easier the preparation of the ***whole package (application and support)*** to be **configured and delivered from remote to any deployment environment**
- **CONTAINERS** also mean an **intrinsic capacity of moving** parts at any time everywhere

There are many offers of **microservices** that are available and break the boundary between the **application and the support environment** and **enlarge the scope of users** (from only application, to the control of the support, putting those together)

NEW MODELS FOR CONTAINMENT

New forms of containment available

There are **several tools** that can not only provide the hosting, but also allow the **management of the container** and the control of the **migration of components**

A container can host and control **those components in easy way and also can suggest advices** in designing and packing autonomous components

Docker is a popular tool to specify **what it is to be installed and its components**

- **Microservices as small components capable of being hosted in different machines** and **easily managed**
- **Containers** makes possible to define, contain and give access via **web functions** ot its hosted **microservices**, **easy to be installed and re-installed remotely**

NEW MODELS FOR CONTAINMENT

Docker is a microservice language and set of tools (for a Linux container) that allows to **design, host, control, and optimize services (both statically and dynamically)**

Docker is tool with which you can specify an **entire application (its support) and its dependencies as a container** (so it becomes more portable and easy to be packaged)

Some requirements are crucial for microservice viability and operations:

- Possibility of **managing services from outside** (monitoring and handling of internal services)
- Easy **deployment with limited interference** (simplest interface possible)

APPLICATION DEPLOYMENT

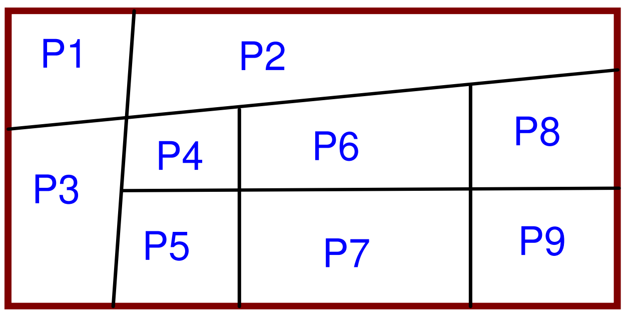
An application is developed as an organization of entities, **objects components**, and **classes**

if you are not working on a single machine, one must decide **a deployment on multiple machines** that must decide on how to

- partition the application **into constituent components**
- rely on a **support for remote references**

The application is divided into resources that represent partition (P1-P9) to be mapped on the specific deployment resurces

Application



Possible partitioning of the resources

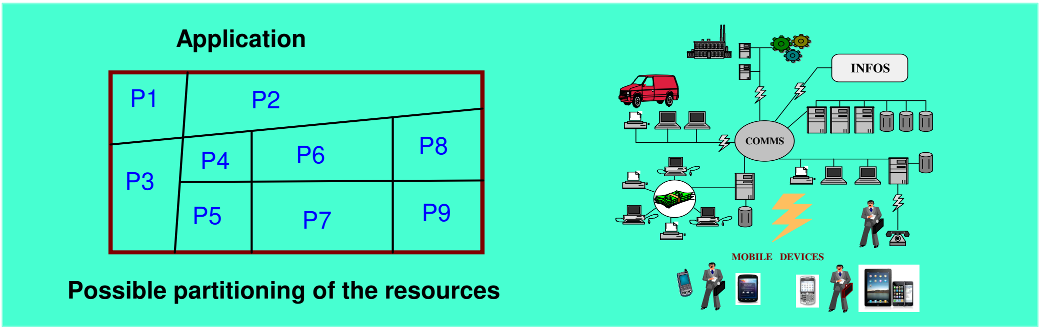
MODERN DEPLOYMENT

So, when you have an application, you must try to decide at best the way of deploying it

the approach is:

- **You have the partitioning possible**
- **You have the configuration for it**

You must decide how to map the application onto your possible hardware resources



Who is in charge of it???? The application designer? The support? The system???

PARTITIONS in the APPLICATIONS

An application must be deployed on a **number of processors** and you have to decide how to **group its components into partitions for processors themselves**

The application involves both:

Static resources (**represented in previous slide**) easy to group as needed, so **start executing with the components already allocated**

Dynamic resources (previously not represented) that may be created during the execution or may not even be created at run time

For instance, the processes or the resources that depend on the execution and that only some runs can create, depending on the application state and the progress of applications, other runs not

ALLOCATION STRATEGIES

Allocation

One application can use two different policies

either *static* or *dynamic ones* (**maybe *hybrid***)

Static allocation: specified a configuration (deployment), those resources are decided **before runtime**

Dynamic allocation: those resources are decided **at runtime**
⇨ **dynamic systems that can decide at run time**

Static allocation

Pros the allocation cost precede the execution

Cons the predefined allocation is inflexible

Dynamic allocation

Pros the allocation cost impact on the execution

Cons the allocation can adapt to the current situation and is only made by need (an on need)

MODELS for ALLOCATION

Allocation strategies

Static resources

always to be decided statically
and **eventually optimized**

Dynamic resources

either **statically decided** (with a policy to be actuated on need)
or **decided at runtime**

In dynamic systems, one can create **not forecast dynamic resources** and you can **think of to reallocate existing resources** (migration): resources can move around and setting can change during execution

Heavy moment of resources re-allocation

DEPLOYMENT SUPPORT

- *MANUAL*

→ **the user determines each individual object** and passes it **on the appropriate nodes** with the proper **sequence of commands**

- *FILE SCRIPT APPROACH*

→ you must write and run **some script files** (some **shell language,** bash, Perl, Python, etc.) with the command sequence to drive the configuration **by steps** and **in phases** that usually specifies **dependencies between objects**

- *APPROACH based on MODEL or MODEL-DRIVEN*

→ **automatic configuration** support through **declarative languages or working models** to obtain the configuration (e.g., SmartFrog and Radia)

(USER?) ALLOCATION MODELS

- *EXPLICIT APPROACH* **(user-driven)**

→ the user provides **before the execution the mapping for each resource** to be potentially created

- *IMPLICIT APPROACH* **(automatic)**

→ the system takes care of the **application resource mapping** **(both at deployment time and during execution)**

- *HYBRID APPROACH*

→ the system adopts a **default policy** applied to both **static and dynamic resources,** initially for the allocation of **new resources** and also to **migrate during run**

→ possible **user indications and advice** are taken into account to improve performance (please allocate together another resource: 2 VMs together on the same PM)

MODERN DEPLOYMENT

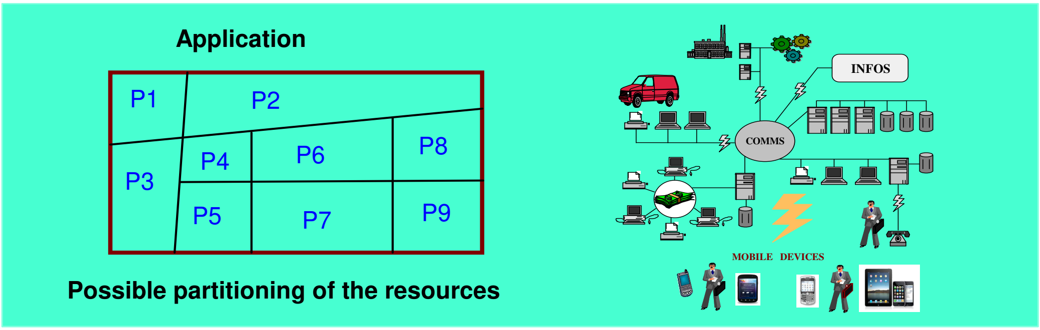
If an application is to be supported, it must typically be **deployed for a specific configuration**

Traditionally the approach is:

We define how **to *configure applications*** taking into account the specific system resources available *(you specify for the environment)*

A novel approach is:

We ship together **the application with its required configuration** so they can be ported to different possible support environments (**microservices** and **docker** approach, **Cloud** approach)



docker

DEPLOYMENT for an APPLICATION

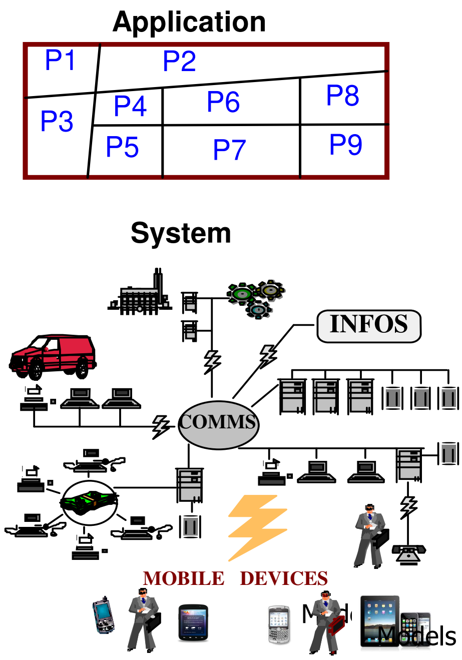
An application consists of very different logical and concrete resources: **processors, network, and also processes, objects, components**, ..., **up to service and request to them**

Application resources are many and differentiated too:

- **processes**
- **components**
- **objects and classes**

System resources are many and differentiated:

- **processors**
- **networks**
- **interconnected cluster**
- **cloud**



RESOURCE HANDLING → PROCESSES

Management with different costs and different goals
Allocation & (dynamic) re-allocation of processes

LOAD SHARING ⇨ a priori defined, before the run
(eventually actuated afterwards, at resource creation)
Resource allocation, *without* ***moving*** *any* ***resource once allocated (static allocation)***
LOAD BALANCING ⇨ done during the execution
After a specific allocation and a first execution, **already allocated and active resources** *can* **migrate** *to obtain a better global efficiency* ***(dynamic allocation)***

The **static case** can be studied in a more precise way, being out-of-band, while the **dynamic** must compete with the application execution

PROCESS ALLOCATION

Specifically, the cost considerations are crucial to identify a cost model and function

Memory	m_i
Execution cost	x_i
Bandwidth	b_i

Any processor with **memory, execution capacity, and bandwidth** can be seen as a **bin /bucket to be filled**
Up to which level? In general a heavy limit

But linear models and also more complex ones
The communications can be mapped taking into account the reachability of the different processors in a **non linear way**
That makes computing of **placement strategies** longer and longer

PROCESS ALLOCATION

Specifically, the cost considerations are crucial for:

Static evaluations
In that case, we work **'out of band'** (**before** the **deployment**)
and we can also use very precise (complex and long) **algorithms** to define the best allocation
Precise algorithm for allocation face the **NP-complete problem**
Heuristic algorithms ⇨ **Genetic, Tabu search**
Often these strategies are too expensive to be applied during the execution

Dynamic evaluations
goal ⇨ **overhead reduction**
Simple policies to respect the minimal intrusion
⇨ local policies and with the lowest implementation cost

MONITORING

MONITORING as an enabler for control & manage

To give fresh information on the system current load, observing the current situation

Picking up and collecting **load information** on
processors, resources & communication
* by observing on **limited intervals (all values)**
* by using **statistic** and **historical data (summarizing data)**
* by using **events (discretization)**

The monitoring gets info on the current load, by assuming continuity of application behavior and limited graceful gradients
collected information used to forecast next situations of resources in the future (**continuity assumption -** natura non facit saltum)

There is an obvious need of limiting the cost of the information collection and maintenance to limit intrusion (minimal intrusion)

SUPPORT INTRUSION

To Monitor a component or an entire application is an exampl**e of an internal function** **very important to manage a system**

In general-purpose systems (so the ones we are interested in) **the support does not have dedicated resources, but it has to use with the one exploited for the application**

That competition suggests to limit to the maximum the engagements of those resources so to **limit the percentage** of them **subtracted to the application**

The general principle stemming from the above is

the **minimal intrusion principle**

Any support function must limit its operation cost to the minimum, compatibly with the achievement of its goal, so to intrude minimally with the application

COURSE OBJECTIVES

In **distributed systems** we focus on all the aspects related to **execution** and **operations**

Of course, you have to develop software, before execution

For instance, there may be classes and components that have no influence and correspondence during run

their importance for us is very limited, because we focus on the facets that impact during execution

We are interested in everything that has impact during at run time and that remains significant and vital by favoring, fostering, and enabling the distributed deployment (and makes us understand how they do)

for example, there are classes that then become **active processes and components** and will be distributed around, during the **application lifecycle**: those are the entities that interest us because they represent a part of the **run-time system architecture**

We focus the dynamic architecture, and in understanding how it is and how well it works

AGAIN for the CLASS PERSPECTIVE …

In distributed systems we seek for **performance** and **quality (QoS) and to grant them**

*For a specific architecture, we expect that there are involved **resources** and particularly **significant cases***

For example, RMI has a very **strong impact on the cost and scalability** of the overall system

the direct use of the socket and the lower level tools ensures less overhead and greater efficiency

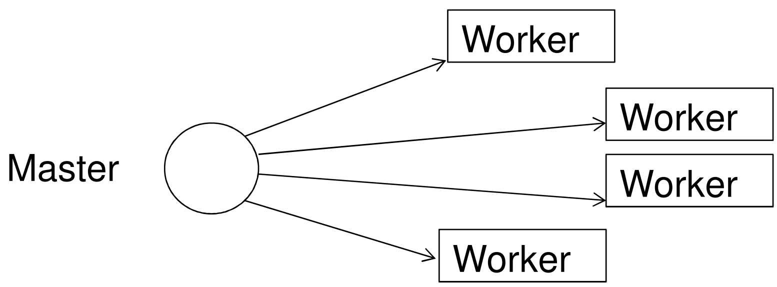
During execution, we are interested in bottlenecks, as the critical points and parts that may misbehave and are unsuitable toward a good system behavior

To adopt **a tool such as RMI** (or an expensive remote request) instead of a message exchange one in an **occasional rare communication** (maybe only once per run) tends to introduce a **potential bottleneck** to consider and to control in a project

the architecture should be checked and tested a priori and a posteriori on the field to quantify execution

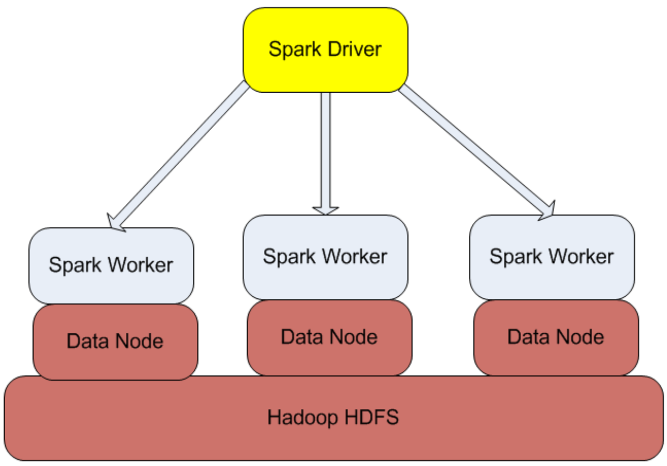
LOAD SHARING VIA FARM

Let us refer to a pattern called Farm, with a Master and several Workers, a pattern present extensively in many situations



Typically you have a master that can distribute the load to workers that execute in parallel and finally get results back

As in Spark where you have a front end that distributes load to other nodes
The Spark driver is the master and try to find the nodes that can work on specific searches in parallel



(STATIC) LOAD SHARING

If an application consists of *entities (processes)*

Load Sharing means to identify
the processes and when and where to allocate them

The static policy can apply only at process creation to find the available processors

Static decision does not allow any reallocation after the first decision

We may have many different allocation policies, either static or dynamic, on processors

Processors in a **logical ring**	static one
Processors in **logical hierarchy**	static one
Processors with free links (**worm**)	dynamic one

LOAD SHARING

Logical Ring and token (token bus strategy)

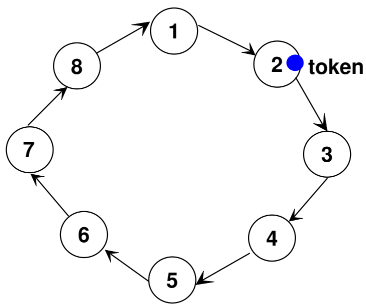
We consider available processors in a logical ring

The **ring** represents the research space to find allocation for processes before creation

To identify a dynamic role, a token allows the current owner to become the **current strategy maker**: the ring must be passed around after a maximum permanence in a node

The current manager can initially broadcast to all processors a request for their load state and then the load is distributed via the ring

Static and proactive organization
easy to maintain and also
to restructure fast to recover
in case of fault

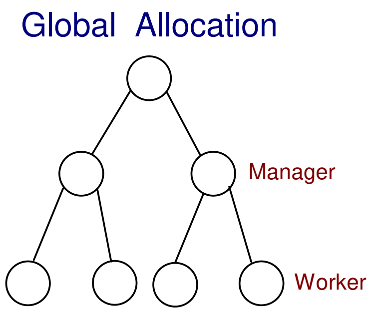


LOAD SHARING in MICROS

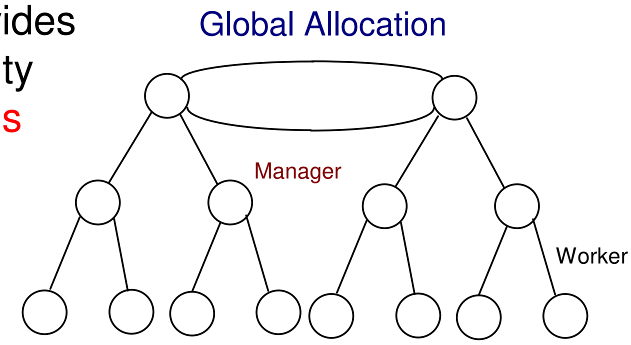
MICROS uses a logical hierarchy
The architecture is logical and the nodes are logically connected
Organization with roles in a farm

- **Worker** → computing duties (**slave**)
- **Manager** → handling and controlling role

The level number of depends on the workers



For **fault tolerance, MICROS** provides several managers and the possibility of introducing new nodes and levels by need
After the initial organization, the hierarchy can **shrink and expand**



WORM LOAD SHARING

Some more dynamic approaches are novel and less statically planned

The work strategy of allocation is based the **cloning of worm segment on different close nodes**

- **A Worm is a set of multiple segments** (each one executing a process) who can also communicate with each other **for load sharing goal**
- A worm tend to colonize a node by installing a segment of the worm in the new node (one copy only)

The worm strategy is not planned in advance but expand in a dynamic discovery

- the worm tries to expand by **finding close free nodes to clone there**, by using prompts and acceptance messages (called probes), sent by local decisions of segments that want to expand

LOAD BALANCING (DYNAMIC ONE)

GOALs of TRANSPARENT (to user) MIGRATION
- **Better, more efficient and more correct** resource usage
- **Balancing of computational and communication load**
- **Dynamic decisions and long term policies**

Requirements

Performance	to use resources at the best
Efficiency	limited overhead
Continuous operation	minimal intrusion

In general, the migration is part of the 'system functions' and it is not under user control but

Migrations can **interfere with normal application execution**

Transparency and **automatic migration** decisions toward a minimal cost and intrusion

MIGRATION – Some Considerations

The point is migrating or moving already established resources at run time with a minimal overhead

Any entity is in principle subjected to migration

DATA, OBJECTS, COMPONENTS, …PROCESSES MIGRATION

PROCESSES move from one node to another one

the point for process is that we have an initial state and many updates when executing: which and how to move

Pre-emption

Priority to local usage

Multiple Migrations

To make in parallel many concurrent migrations

Avoid residual dependencies

The system must not have any trace of the moving of resources

Avoid thrashing

Avoid to move the same process without any execution of it

PROBLEMS in MIGRATION (INTERNAL)

In case of migration, the process must prepare the mobility phase and manage all resources previously available

→ Environment change of the mobile resource

- State identification

the process must identify which internal resources to carry on to the new location and begin to determine their internal state

- Block of the process itself before mobility

the process may have one part of state not transportable so to close before moving

Actions of closing local files or code to be managed (last wishes)

Actions of storing resources that can be moved and found in the new node to be enabled there again

- Block of the activity to move

Completion of the activity on the old node and activation of mechanisms of movement on the new node

MIGRATION PROBLEMS (EXTERNAL)

In case of migration, during and after the migration

… there are messages to be forwarded and to be given back

→ Change of name of mobile resources

- **Message redirection** *pessimistic/proactive strategy*

The origin node keep track of the move and keep receiving messages and forwarding them to the new location

Chain of forwarding can grow for mobile processes

- Requalifying of allocation *pessimistic/proactive strategy*

The origin node keep track of the move and receive messages and forward them to the new location only during the transfer

Client nodes receive the new location at reference

- Client Recovery *optimistic/reactive strategy*

The origin node does take any action.

Client messages can fail and it is client duty to find the new location

FIRST LESSON FROM MIGRATION

DETERMINE (for **processes**) **who, when, how, where** to migrate

Some criteria

- ***not all processes can migrate***

  Fixed are acyclic (short) ones and node dependent ones

- ***It is opportune to have in any node a migration handler***

Migration is based both on **policies**, and on **mechanisms**

MECHANISMS

Depend on the computational model and specificity of system

POLICIES

More general-purpose, independent from system

KEEP STRATEGIES and MECHANISMS SEPARATED

The latters system-tailored and immutable (if possible), the formers can vary under user control

MECHANISMS to ENABLE MIGRATION

Who migrates?

processes, passive objects (**file**), active objects, components, servers

RESOURCE composition and organization - discovery

Initial state: code + data (initial data)

Current state: data + visible resources (local and remote)

Computation block

Block of arriving messages: messages are either refused or forwarded

Transfer & Copy

There are two copies, an old and a new one: there is an activity of synchronization of the two data

Obsolete references

Requalification or other strategies

MIGRATION POLICIES

There are typically three phases

EVALUATION of load (**V**)

local load vs. global load

TRANSFER (**T**)

who to transfer and when to do it

LOCATION (**L**)

Where to migrate and re-insert the process

T & **L** are often intertwined and interdependent

NEED of integrating and interacting with local scheduling

There is an impact on the scheduling on both nodes of origin and arrival because of the competing with common resources

The planning can ease those steps

WHICH POLICIES of MIGRATION

STATIC **predefined** and a priori decided (**low cost**)

V *fixed threshold* as load (e.g., number of processes)

T moving of the *"newer" process*

L migration always from a *source node to a predefined sink node*

SEMIDYNAMIC predefined with **limited dependences** from **current state** – also using probabilistic policies (**limited cost**)

V *variable threshold* as load

T *cyclic identification* among processes

L *cyclic* allocation on sink node

DYNAMIC strictly **dependent on current state** (**even high cost**)

V comparison of load with neighbors (dynamic average load)

T information on process state

L discovery of sink nodes via messages in the neighborhood

MIGRATION POLICIES

POLICIES: SIMPLE vs. COMPLEX ONES

V T L for processes **acyclic** vs. **cyclic (normal duration vs daemon)**

V → fixed threshold vs. neighborhood comparison
T → process suitable for a specific neighbor or random choice
L → usage of **message called probe**

random, probabilistic, cyclic, shortest queue
unconditioned acceptance
probing, bidding
conditioned acceptance

probe: message to send to neighbor to ascertain possibility of moving
PROBING (**T & L together**)
to identify possible candidates to receive processes and pre-evaluate their reinsertion effect

DECISIONS in IMPLEMENTING MIGRATION

CENTRALIZED with a **unique entity for controlling migration**
DECENTRALIZED coordination of many different entities

implicit or explicit collection of information and distributed decision based on compared of state information (piggybacking)
favoring local movements in a neighborhood

RESPONSIBILITY couple SENDER-RECEIVER

SENDER initiative: the overloaded node must find the potential sink one (RECEIVER), asking for nodes receiving load
RECEIVER initiative: the underloaded node must find the potential source one (SENDER), asking in the neighborhood for load

MIXED solutions

SENDER initiative → more suitable for **low** system load
RECEIVER initiative → more suitable for **medium-high** system load

MIGRATION feasibility - LESSON

IMPORTANT RESULT

Migration has a cost, … but it may be effective

Even **with simple policies** one can obtain **significant enhancements in a system (compared with the no migration case)**

ANOTHER IMPORTANT RESULT

More sophisticated policies do **NOT obtain significant enhancements** and cannot be **generally applied, apart from in very specific (not so common) situations**

Some specific goals

- **STABILITY** avoid thrashing
- **EFFICIENCY** simple algorithm to compute and actuate
- **OPTIMALITY** not a real goal, but only sub optimality

COMPUTATIONAL MODELS

INTRINSIC COMPLEXITY of the algorithms

dependence from problem dimension called **N**
complexity in time CT(n) (abbreviated as **T(N)**)
complexity in space CS(n)

Let us think to potentially parallel multiprocessor solutions (with **P** as **parallelism degree**), all to be considered for any specification and execution that can accommodate computation (i.e., as part of computing of the algorithm)

COMPLEXITY

T(1,N) **sequential** solution $T_1(N)$
T(P,N) **parallel** solution **with P** processors $T_P(N)$

SYNTHETIC INDICATORS

SPEED-UP *Improvement from sequential to parallel*

S(P,N) = T(1,N) / T(P,N) **$S_P(N) = T_1(N) / T_P(N)$**

EFFICIENCY in *resource usage*

E(P,N) = Speed-up / Number of Processor

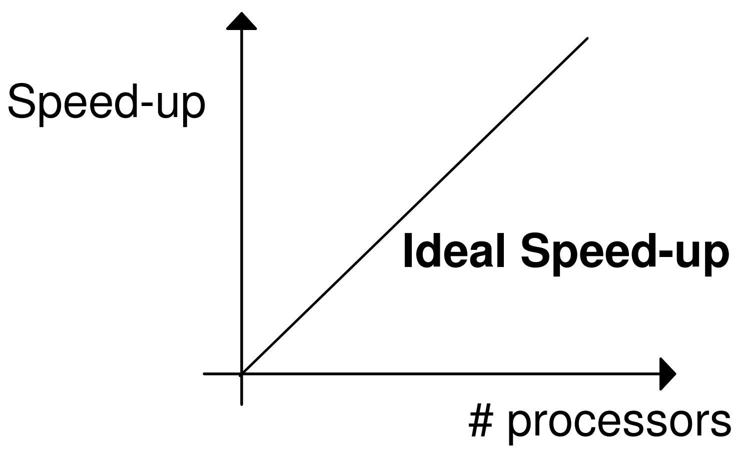
E(P,N) = $S_P(N)$ / P **$E_P(N) = T_1(N) / P * T_P(N)$**

*$S_P(N)$ up to **P at most** and $E_P(N)$ **1 at most***

The speed-up is the **potential improvement** when you introduce a **variation in processor numbers**, i.e., **real parallelism**

IDEAL INDICATORS

We assume and consider **average values**
ideal both SPEED-UP and EFFICIENZA



We are interested in the full range of results, so we average them bearing in mind that there may be specific cases of for only special cases depending on the algorithm

GROSCH LAW & LOADING FACTOR

Grosh law
The best deployment for a program is
a sequential execution by using a unique processor

N and P correlation:
We can assume N independent from P, or dependent from P
Loading factor or L = N / P

dependent size (N function of P)
independent size ***(very interesting at N growing)***
identity size (N == P)

GOAL
Which is the best choice and how to find the best approximation for any algorithm we want to explore in behavior

SPEED-UP

Which is the best **speed-up** possible when passing from a sequential execution to parallel ones…
So how to get **optimal advantage from parallelism**

Amdhal law
the speed-up limit stems from the intrinsic sequential part

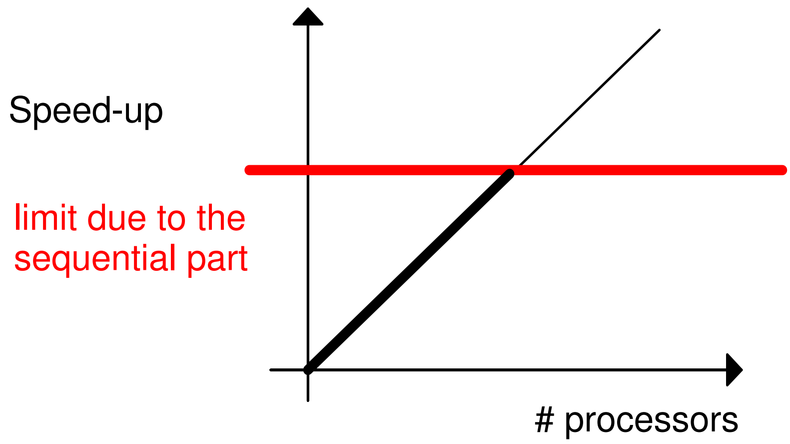
Any program can be split into two parts:
one **(potentially)** ***parallel*** **part** and ***sequential*** part
the latter is the limit to the speed-up

If a program consists of 100 operations with
80 ops can go parallel and
20 ops must be executed in sequence

With any number of processors, even 80 →
speed-up cannot be better than 5
Of course, it can be worse that that ….

MORE ON INDICATORS

Considering both **SPEED-UP** and **EFFICIENZA**



We cannot exceed the limit of speedup due to Amdhal's law

The speedup is limited, as well as the efficiency

We have first a linear zone at P growing (of growing in speed-up) then, we may have a **constant speed-up** with **lowering efficiency**

SPEED-UP (OPTIMAL?)

Is there any general low to get optimal indicators?

Heavily Loaded Limit $\mathbf{T_{HL}(N)} = \inf_P \boldsymbol{T_P}(N)$

HL is for the ***P*** with which we get the least complexity of the algorithm (i.e., in our case the minimal T)

Typically, the optimum is when **N/P** is very **high**, i.e., if all processors are **very loaded,** anyone with a heavy **load to carry out** *(considering the limit of the limit of the sequential part)*

$T_P(N) = \mathbf{T_{CompP}} + \mathbf{T_{CommP}}$ $\mathbf{T_{CompP}} = T_{CompPar} + \mathbf{T_{CompSeq}}$

$T_P(N) = T_{CompPar} + \mathbf{T_{CompSeq}} + \mathbf{T_{CommP}}$

Amdhal law bases on the ratio between the two parts of the algorithm (sequential and parallel) to identify the bottleneck

A small CASE STUDY (N==P)

Problem of dimension N by using P processors
The algorithm is the *sum of N given integers*
Complexity of sequential solution O(N)
Complexity of parallel model *identity size* (N == P)

We made available a number of processors P connected in a binary tree: any leave machine gets two integers and pass up the sum of them upwards; the root gets the final result by summing its two numbers and passes it to the final user

$N = 2^{H+1} \sim= P = \mathbf{2^{H+1}-1}$ (N values ~= P processors in the tree)

$H = O(\log_2 P) = O(\mathbf{\log_2 N})$ i.e., $H = \mathbf{\log_2 N} =\sim \mathbf{\log_2 P}$

$T_P(N) = O(H) = O(\mathbf{\log_2 N}) =\sim \mathbf{2 \log_2 N}$

Values flow from **leaves up to the root**, and any machine in the tree sum them up at **any step when they get data** (of course, we have to consider the time for the data communication)

Again for the CASE STUDY (N==P)

Efficiency goes to zero

$L = N / P = 1$

$\mathbf{S_P(N)} = T_1(N) / T_P(N) = O(N) / O(\log_2 N) = O(\mathbf{N / \log_2 N})$
$\mathbf{S_P(N)} = O(P / \log_2 P)$

$\mathbf{E_P(N)} = T_1(N) / P\, T_P(N) = O(1 / \log_2 P) = O(\mathbf{1 / \log_2 N})$

The larger the number of processors
(the speed-up increases) but the less is the efficiency

The processors work effectively for a fraction of the total time, much less of the entire solution time
(EP(N) decreases when P increases)

The CASE STUDY (independent size)

Problem of size N using P processors

If we can divide the problem, by putting together a **local work** and the **communication part**, where the **local computation can engage all processors** in any phase**,** we can obtain **better indicators**

Any processor has **some local work load factor** (to compute the sum locally) and a phase of **exchange of information** (Comm) to combine the results

$L = N/P$

$T(P,N) = O(N/P + \log_2 P) = O(L + \log_2 P)$ ossia $T_{Comp} + T_{Comm}$

$\mathbf{S_P(N)} = T_1(N) / T_P(N) = O(\mathbf{N / ((N/P) + \log_2 P)}) =$

$O(\mathbf{P / (1 + P/N \log_2 P)})$

$\mathbf{E_P(N)} = T_1(N) / P\, T_P(N) = O(\mathbf{1/(1 + P/N \log_2 P)})$

N>>P **speed-up goes to P and efficiency goes to 1**

MORE on the CASE STUDY

A more precise computation of indicators in the case of the sum of N integers with P processors with both local load and communications of data

Let us consider the same unit cost for any sum and communication

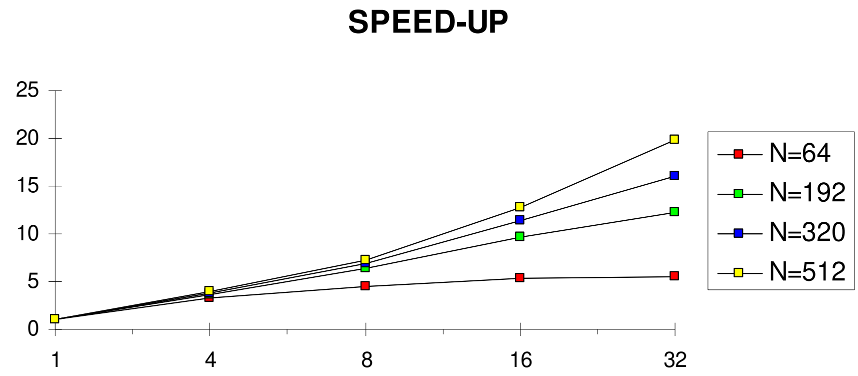
$\mathbf{T_P(N)} =\sim N/P + 2 \log_2 P$ total number of nodes $P = 2^{H+1}-1$

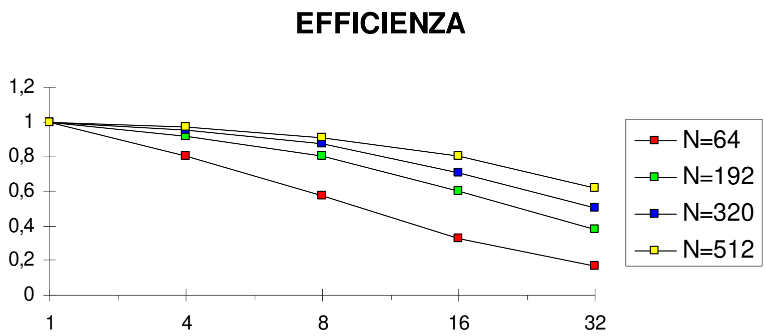
$\mathbf{S_P(N)} = N / (N/P + 2 \log_2 P) = \mathbf{N P / (N + 2 P \log_2 P)}$

$\mathbf{E_P(N)} = \mathbf{N / (N + 2 P \log_2 P)}$

Both indicators depends both on **P** and **N**

In graphical terms





SPEED-UP and EFFICIENCY INDICATORS

PROBLEMS

- we consider the O() so with a constant factors
- the worst case is not considered (it can be important)
- we neglect several issues outside

We also neglect
Moving of I/O data &
mapping (specific deployment)

In the real world →
We need also consider other communications for the application (also before and after the application run)

Initial transfer of data values
Print & manage of intermediate values
Harvesting and handling of final results

MORE on the CASE STUDY

Complexity of the parallel model *heavily loaded limit*
At L growth **$T_{P\ HL}$ (P,N)** = O (L + $\log_2$ P) ⇨ O_{HL} (L)

$S_{P\ HL}$ (N) = O(LP) / O(L + $\log_2$ P) ⇨ **O_{HL} (P)**

$E_{P\ HL}$(N) = O(LP) / O(LP + P$\log_2$ P) ⇨ **O_{HL} (1)**

If intuitively we overload all node
Then, the loading factor L is very high ⇨
We can also reach both
an ideal speed-up and an ideal efficiency
by loading at the best all processors, without leaving any node with a low level of load, and the risk of becoming idle

MAPPING

Let us assume to have made a mapping in an optimal way (**configuration** and **deployment**)
Too often we cannot decide the best allocation
Typically we have dynamic problems in communications in the run
We can consider a new function the **Total Overhead, or T_0**

To keep into account the time and resources spent in other actions, such as ***communication***
T_1(N) sequential execution time
T_p(N) parallel execution time
T_0(N) = T_0 (T_1, P) = P * T_P (N) - T_1(N) = |P * T_P (N) - T_1(N)|
When you work at the optimal efficiency, you have no overhead
T_0(N) = 0 => P * T_P (N) = T_1(N)

OVERHEAD TIME

$T_0(N) >= 0$ ⇨ $T_1(N) <= P * T_P(N)$ i.e.,

$$P * T_P(N) = T_0(N) + T_1(N)$$

T_0 indicates the lost work

$T_P(N) = (T_0(N) + T_1(N)) / P$

$S_P(N) = T_1(N) / T_P(N) = P * T_1(N) / (T_0(N) + T_1(N))$

$E_P(N) = S / P = T_1(N) / (T_0(N) + T_1(N))$

$E_P(N) = 1 / (T_0(N)/T_1(N) + 1) = 1 / (1 + T_0(N)/T_1(N))$

We should make very extensive campaigns of data collections to find out the **real dependencies** of $T_0(N)$ from N and from P

AGAIN for the CASE STUDY

More, in the case of the addition of N numbers with P processors

Let us consider unitary the cost of any sum and any communication

$T_P(N) =\sim N/P + 2 \log_2 P$ total number of nodes $P = 2^{H+1}-1$

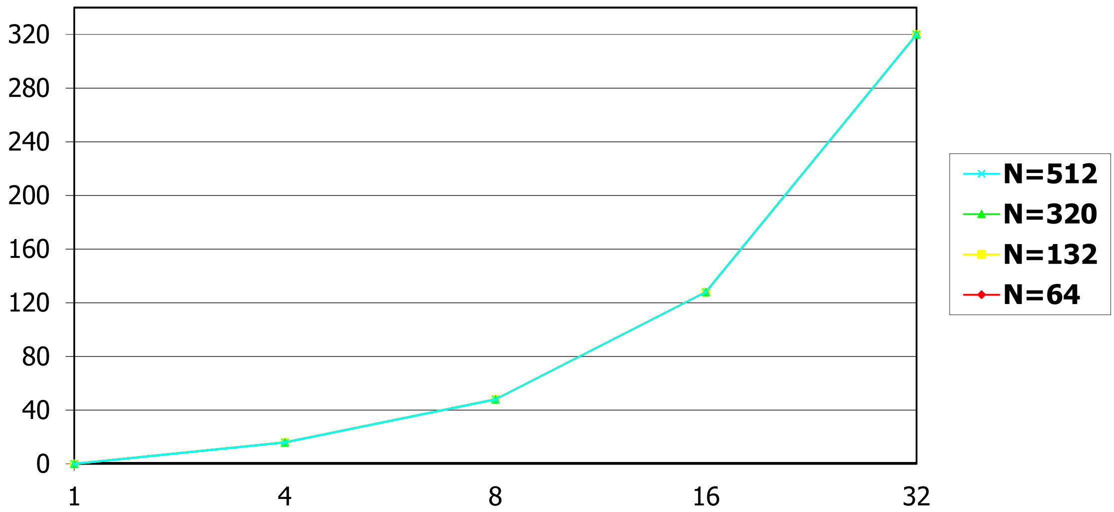
$T_0(N,P) = P\, T_P(N) - T_1(N) =\sim P (N/P + 2 \log_2 P) – N$

$T_0(N,P) =\sim 2 P \log_2 P$

The T_0 overhead depends mostly on the **number of engaged processors**

The growth stems from the necessity of coordinating the application workflow, bot for the initial phases, during main execution, and after for results collecting

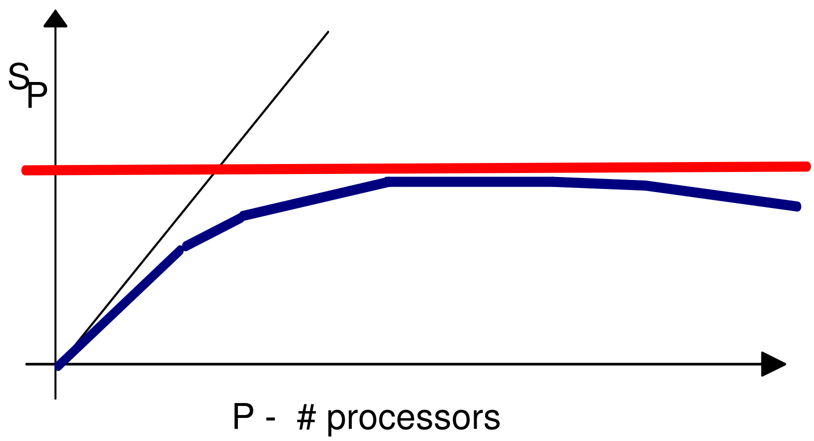
Graphically for an example T_o



The curves are the same

MORE REAL INDICATORS

Considering the real **SPEED-UP in a less ideal scenario**



We cannot get for long an ideal speed-up

The speed-up is usually constrained because of the overhead

Typically, we have an initial linear **behavior**, the a **constant growth**, then a **slow diminishing due to the overhead**

ISOEFFICIENCY

E_P(N,P) = **1**/ **(**$T_0(N)/T_1(N)$ + **1)** **T_1(N)** as the useful work

Goal ⇨ to **keep costant** the **efficiency**
$T_0(N)/T_1(N)$ = ***(1 – E)*** / ***E*** $T_0(N) = (1 - E) / E \; T_1(N)$

T0(N,P) = ((1 – E)/ E) $T_1(N,P)$ **= K T1(N)**

T_0(N,P) = K T_1(N) by using a constant (?) **K factor**

The costant K (?) is an indicator of system behavior

In the example (1 node /1 value) K non costant al all
For the tree case, K depends both on P & N
and it is approximately (**2 P $\log_2$ P** / **N**)

ISOEFFICIENCY FACTOR

Isoefficiency function
If we keep N constant and vary P, **K can indicate whether a parallelizable system can maintain a constant efficiency**
→ i.e., potentially **an ideal speed-up** ☺☻☹

if K is small ⇨ ***high scalability is possible***
If K is high ⇨ ***less scalable system***
K non constant ⇨ **non scalable systems (mostly all)**

In the tree case, K is $2 P \log_2 P / N$
so the system is scarcely scalable (if any)

In general, all reals systems are all non scalable (sic ☹)

A MEDITATION CASE

Let us assume that we are a system manager of a data center and have a **general application (proposed by a user)** and we know it **consists of Q processes**
We have a **very large number of processors available**
HOW TO manage the processor allocation?

To state a policy on the processor number to be used, you may consider (if relevant and it is feasible):

How are the processes?
how they interact?
How to load any single node?
Application need QoS, replication, objects, classes?

the Grosh law says that the best way is to use one processor, if it is possible

NEVER POSSIBLE!

A REFLECTION CASE

Tyr to consider the experience of a data center where many applications arrive to be run fast and resources must be kept into account, and ***always be used at best***

heavily loaded limit is a good target
good efficiency can steam from high loaded processors

Keep in mind your experience of PC and personal users.
The Grosh law
The detail of the applications are important for efficiency?
How approximate the loading factor in terms of processes and processors? Define an expression in term of them

But try to discuss **how many processes** are reasonable and effective