Università degli Studi di Bologna
Facoltà di Ingegneria

A Course for PhD students

Infrastructures and Support to Wireless Systems

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Course on Middleware for Wireless Systems

Generalities and New Scenarios

Adaptation and Composition of Services adapted to user needs and context

- Support and Systems for Semantic Adaptation
- Multimodal Systems and Context-aware Automatic Service Adaptation

Context-based and Mobility support

- Service Provisioning for Integrated Wired and Wireless Scenarios
- Infrastructures for Multimedia Systems towards Service Continuity

Generalities and New Scenarios

- **Wireless systems basic properties**
  - Resources and Service perspective
  - Context-aware systems
  - Pervasive and Ubiquitous services
- **Middleware as a solution**
  - Multichannel, multimodal, multipattern
  - Some desired properties of operations
  - Some related properties
  - **QoS and standard solutions**
- Some **unifying scenarios** and **future directions**

Some wireless systems and scenarios

- Many many many **wireless systems**
  - Different wireless technologies with different scopes
  - Different heterogeneous architectures
  - Different standards
- **Heterogeneity** of apparels and services
  - Different devices (cell phones, PDA, sensors, …)
  - Different operations and API
  - Different support systems
  - Different services
- No **unifying scenario**

Some typical offerings in scenarios

A typical use case

Let us take Alice, a student of Computer Science Engineering, typically attending classes together with some colleagues

- In the city she has several ways of connecting, Bologna Iperbole Wi-Fi, together with other sources, cellular networks, …
- In Campus she has several opportunities of connection, some Wi-Fi access points, Bluetooth connections, …

Her short term goal is a game of treasure hunt she is playing with her team, making her going around in finding hints in the Engineering buildings meanwhile attending classes

- Hints and advice are given all the day long and she has to get them asap and try to solve the puzzles quickly by connecting to any source of information that can help her

Depending on where she is, she intends to take advantage of any opportunity (**she is very competitive** ☺)

Typical opportunities

Alice has got many opportunities to access to information…

Within the Engineering area,

Alice can access to the Unibo Wi-Fi net, present via several access points dedicated to Unibo students

She has access to several labs with more limited access (Computer Engineering students) and dedicated resources (lab access points and some Bluetooth connections) she is authorized to use.

Alice share a groups with some colleagues students and they can interconnect to each other in several modes, to share information

Outside the Engineering area, she has enrolled in Iperbole Bologna Wi-Fi, has a cell phone, sometimes uses some localization GPS on her PC, …

Alice can take advantage of all connections …

Alice treasure hunt

Alice can take advantage of all connections available to continuously play the game with the other students of her team, competing with other teams for the entire duration of the games

- She has read the hints with coming to Engineering and has exchanged mails and messages with her team to identify some specific locations to be explored
- She attend classes and in the intervals she meet with her team to visit the identified places in the Engineering area to verify intuitions and ascertain the presence of new hints to follow
- She concentrates with her team about the proceeding of the hunt in the park, sharing and saving information on all team PCs after lunch at the canteen
- She study in the lab, and also access to the Web information that can help her about general involved issues
- She goes back home while reading through her notes and enriching them with more information coming from the Internet

Middleware as a solution

- **Extreme complexity** to deal with
- Innumerable **variety of entities and situations**

Need for a support capable of granting basic and advanced functions to different users ⇨

Middleware capable of enabling, putting together, offering to users

best opportunities, best conditions, most favorable apparels, systems, and services

Also the **possibility of choosing among different options**

The middleware is the enabling entity capable of organizing all opportunities of interest to users in such a way to be really available and viable for provisioning

User perspective

From a user point of view, in general, any of such systems is composed and proposes **a set of resources capable of giving services**

Some definitions

Resource, any entity available in our systems

Operation, any information or activity of interest

Service, the organization to provide the operation of interest

Client Server (C/S) relationship, the main accepted description of the way of getting a service

- Client the requestor of the service
- Server the service provider
- Some directories / repositories to find all available services

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 is the enabling 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

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

Web Services provide a framework for SOA, via WSDL, UDDI and SOAP respectively, based on XML as a standard unified representation

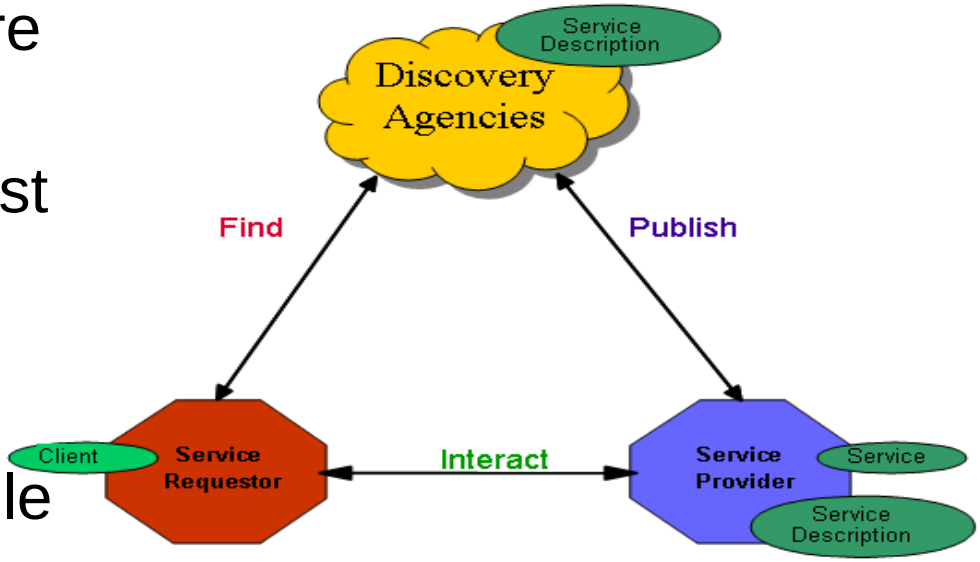
Web Services protocols

The three basic protocols are respectively specialized:

SOAP to interact and request providers available services

WSDL to fully describe any interesting service

UDDI to maintain all available and published services



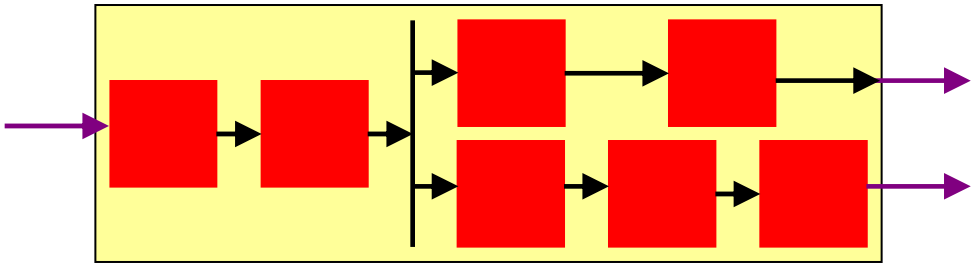
These protocols can only describe the above simple interaction, but leaves many open issues:
security and protection, authorization, reliability, quality of service, service coordination, transactions, …

Simple services and …

Even in general the problem of service provisioning is not completely addressed and solved…

Once you have a SOA scenario, you can provide services, ask for services, and so on…

> But services are typically **something you can put together**, for instance by feeding **one service output** to **another service input** (e.g., in a pipeline) or even something more complex in flow



Service Composition & Workflow

Workflow as a composition of different services to orchestrate a new service available for use

Each composed service belongs to its offering environment but can be properly put together for the general result

Any composition is based on **connectivity** (correctness in passing data from one service to another)

how to grant it? Automatically?

Any composition requires **non functional properties** such as timeliness, security, dependability, atomicity, etc.

how to grant it? Automatically?

Web services basic protocols define no answer, left to the extensions Web-*protocols

Web Services * approach

Web Services has introduced several additional protocols, collectively called WS-* to address more urgent issues

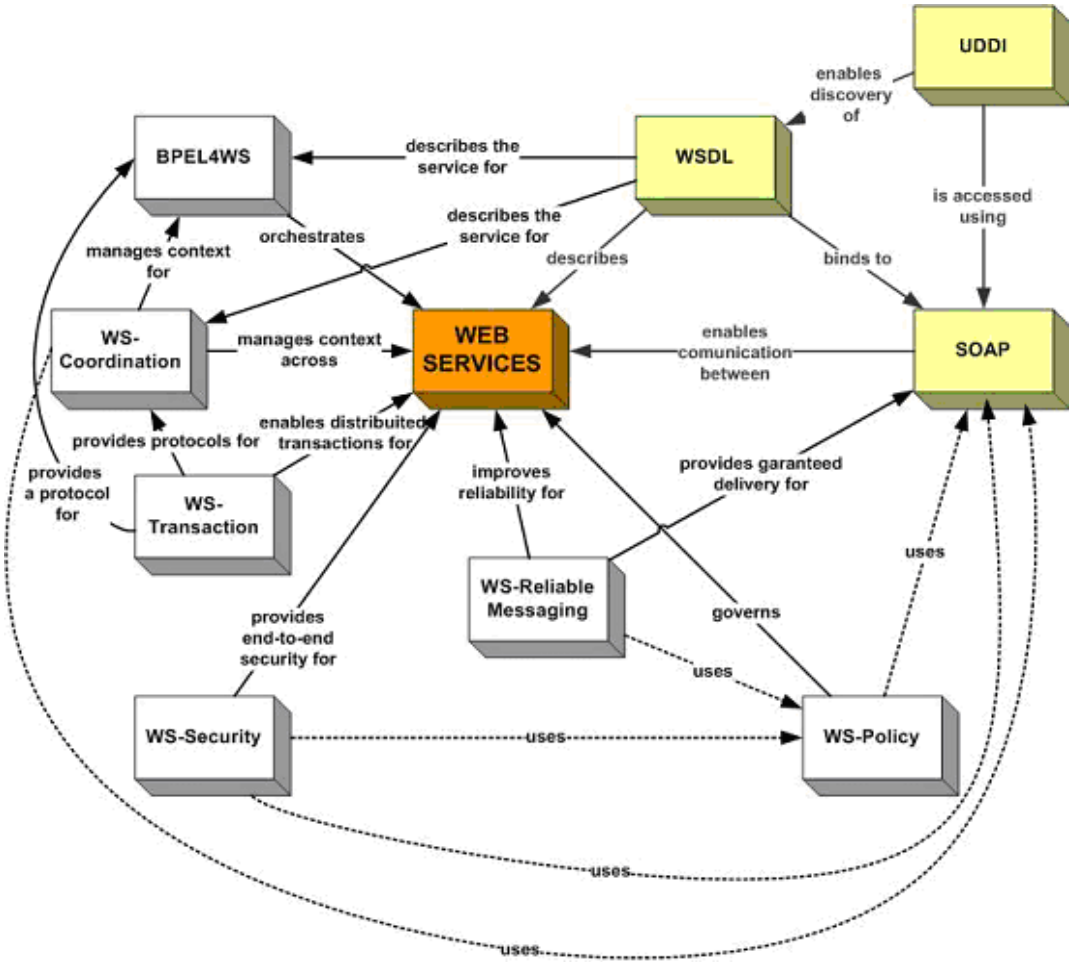
WS-Transaction

WS-Coordination

WS-Reliable Messaging

…

Business Process Execution Language for Web Services (BPEL4WS)



Aggregation of Services

There is no accepted standard and tool for **service composition**

- Workflow languages: BPEL and graphical counterparts

- Semantic approaches: semantic description of services to ease their classification, via ontologies and markup information

- Formal and Algebraic approaches: Algebraic tools and notations, Petri net theories, Finite state machines, …

They tend to ease correctness, automatic composition and grant quality related properties, such as scalability, fault tolerance, …

Pervasive Computing

Pervasive computing as the scenario where many different **computing sources and resources** are available and used in **concurrent activities** by users, even without **their awareness** (not much involvement)

Pervasive Computing,

Business intelligence,

Wireless Sensor Networks (WSN),

Self-configuring wireless network,

Ecosystems of services,

Internet of things,

…

More Pervasive Computing and WSN

It is very common to consider scenarios where there are many sensors capable of sending different environment information … to be taken into account

Sensors (RFIDs) and **Wireless Sensor Networks** (WSNs) are becoming part of the **whole environment**

They allow to get different information about aspects of current environment, but also give the opportunity of intervening on it, via actuators and effectors

One main point is not only the **integration in a unique picture of the whole bunch of devices** (by aggregating and propagating data), but also to **minimize consumption and saving energy**, for the **best quality** (and timing) of operations

Ad-hoc networks

Two ways of using wireless networks single hop

- **Infrastructure**, with one central entity devoted to the intercommunication (AP in Wi-Fi and BP in UMTS)
- **Ad-hoc**, with direct visibility of entities

Ad-hoc networks are more **decentralized and impromptu in communication**, and sometimes can better model and accommodate intermittent behavior of mobile nodes

Ad-hoc net are typically **single-hop**, so you have to provide **routing** for any multiple-hop need, to reduce **energy consumption**, to grant nodes with **significant roles** (router) and **functions** (persistency), to enhance **scalability**, …

Ad-hoc operations

First usage scenarios for **ad-hoc networks** are all the opportunities where there is the need of impromptu and unforeseen communications, because either temporary or urgent, and there not enough available (provided by already wired networks) connectivity

Emergency situations are the first challenges, such as warfare applications, but also disaster recovery for city spots or difficult to reach locations

- Urban intervention to help elderly and impaired people in need of urgent assistance while awaiting for more professional personnel
- Faraway intervention in case of disaster by creating cooperative wireless networks of firemen and civil defense rescue men

Context-aware Systems

The first ideas tied to context stem from mobile systems where people can roam around while receiving services

Computing context: network connectivity, communication bandwidth, communication costs, close resources, …

User context: user profile, other people around in proximity, current social situation, …

Physical context: position, traffic condition, people speed, noise level, temperature, lighting, …

Time context: time of the day behavior, …

All these properties can be taken into account as indicators to build a better service (more suited, tailored, and acceptable, i.e., more adapted to user needs)

Systems can use Context to provide a better service to users either unaware or participating to decision choices

Context-aware Computing

The concept of context has allowed to think to furnishing a service that encompasses the ideas of a general purpose result to give a service but can be adapted to not only to your preferences, but to your **social environment**

- where you are
- who you are with
- which resources are nearby

So, if you are close to your boss, maybe your productivity tools can be stressed and focused

while, if there are only friends / colleagues around, more gaming windows can be shown and exhibited

Systems can use Context to provide proximate selections, adapted context actions, and automatic reconfiguration

Context definition and awareness

Several definitions of context

Set of environment states and settings that either determines application behavior or where an application event occurs and is relevant for the user

Automatic reconfiguration (active awareness)

The system adapts behavior without user assistance

User requested reconfiguration (passive awareness)

The system presents the new data to users that are in charge of deciding when and whether to use the new information

Different degrees of user context-awareness for different capacity users and heterogeneous involvement

Context representation

One basic problem (and still unsolved) is the **representation of the context** itself

> How to represent context, it is a very important choice because it can influence many other aspects about how to handle and manage such information

Several models outstands and are widely proposed and accepted (poorer and richer):

- Key-value pairs
- Markup schemes (CC/PP standard)
- UML representation and Object-Oriented models
- Formal logic models (to express derivation)
- Ontology based models (to express relationships)

Location-awareness

Several systems have been **tailored to ascertain and measure location** (of entities) as a first goal

Those **location-aware** or **location-based systems** must work in any condition with user specified parameters

- outdoor and indoor
- required precision
- tolerated cost

  There are several technologies, more or less expensive: GPS, ad hoc designed devices, wireless network domain based (Wi-Fi cells, Bluetooth, …), based on several indicators related to mobility (RFIDs and other sensors)

State of the art techniques tend to **use fusion and combination of different sensor** to identify positioning

Context-awareness

Location can also be dealt with at two levels

Low level indicators (physical), to ascertain and sense:

time, nearby users and resources, bandwidth, orientation, …

High level indicators (symbolic), or logical indicators related to high level context information:

Logical activity, specifically timed actions, user habits and agenda, also visual information, …

The two levels must be interrelated and closely connected

Location can be considered as a key item for the **concept of context** to **produce forms of additional knowledge about user behavior and needs**

Also via AI techniques, inferences, induction, …and via rule-based systems capable of assisting in elaborating that knowledge

Historical evolution chain

- Distributed Computing
  - Mobile network
  - Mobile information networks
  - Adaptive applications
- Mobile Computing
  - Context-awareness (location awareness)
  - Ad-hoc networks
  - Wireless sensor networks and smart sensors
- Ubiquitous computing

Ubiquitous computing

Weiser definition (1993)

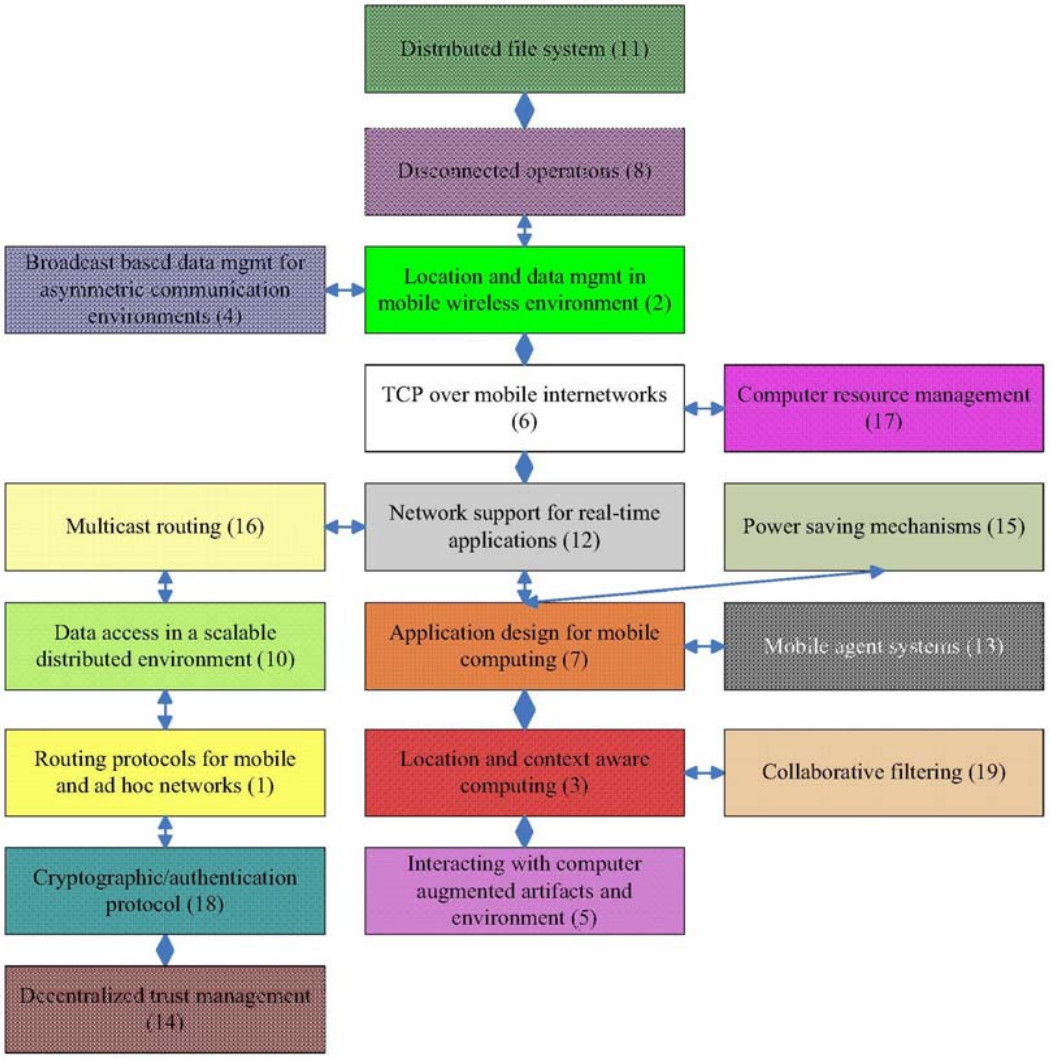
"*Ubiquitous computing is the method of enhancing computer use by making* ***many computers available throughout the physical environment****, but making them* ***effectively invisible to the user***"

A first scenario of Internet as a backbone, a few PCs, several small devices with different wireless connection, to build a whole interconnected organization, secure, robust and efficient (1996)

Maybe something like that has been built, maybe not entirely general, but with some constraints, we start having some examples of such usage scenarios (2009)

Ubiquitous computing

Interrelationship among differently related issues and subtopics for ubiquitous computing obtained via the classification of main papers (last decade from 2009)
Chen & Yen ☺



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)

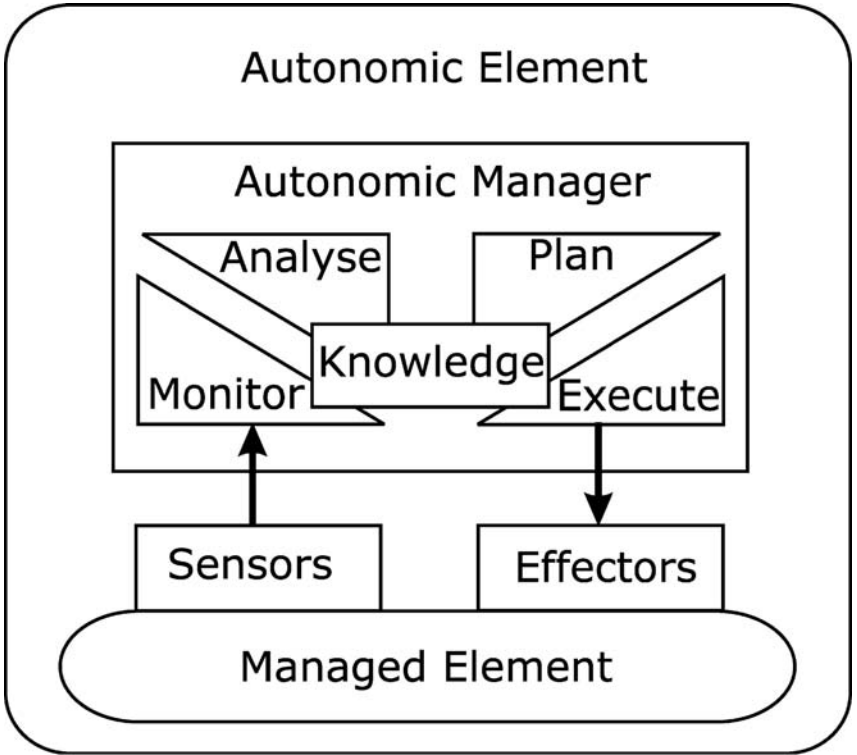
- self-configuration (**autonomy**)
- self-optimization (**social ability and cooperation**)
- self-healing (**reactivity**)
- self-protection (**proactiveness**)

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



How to manage such complexity?

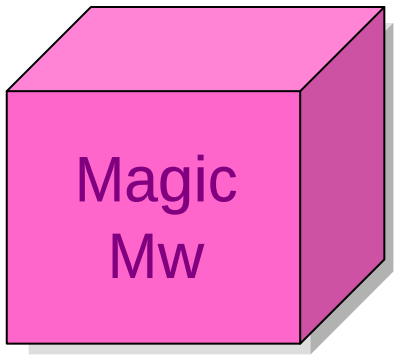
There are still problems in dealing with all above systems, for all above areas, made up of:

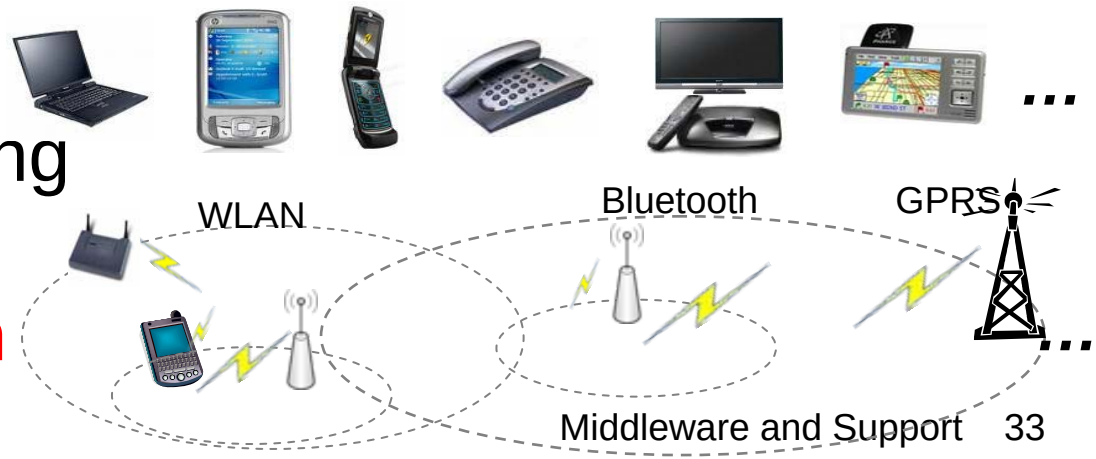
- heterogeneous devices and sources of information
- different communication boards and sensors
- wired and wireless technologies for communication
- different communication suites and OS supports
- heterogeneous services to be provided
- heterogeneous user requirements and preferences
- different software integration solutions

Middleware must assist, manage, and **integrate…**

Magic Middleware

Any user will buy a **Magic Middleware** capable of **harmonizing** all **services (all resources)**, made available to **any device** via **any interconnection** by integrating everything almost **without user involvement** and **with no user intervention**





Magic Middleware Properties

GOAL

Availability of all services, to anyone, anytime, anywhere, 24/7, … without intervening on services themselves

Multichannel

All potential interconnections (channels) are usable by need, without any user effort

Multimodal

Any service can exploit **several channels even at the same time**, for quality sake (redundancy, replication, …)

Multipattern

All forms of communications are possible depending on user needs, favoring the most suitable provisioning (C/S, pull, push, pub/sub, …)

Magic Middleware approaches

- **Context awareness**

  to adapt services to any user current, expressed, unexpressed, inferred requirements

- **Spontaneous Interoperation**

  Middleware hosts services than can discover autonomously other services to find the best integration and deliver new solutions

- **Disappearing Middleware**

  Middleware operate behind the scene, by using already available tools, referring to already defined user services

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, …

Big challenge

To design, create, deploy **middlewares** general enough to apply to any **wireless/wired scenario** that can provide

best integrations

correct functions

dynamic decisions

(almost) **without user intervention**

That issue is still largely unsolved but … **many research efforts are going along that direction and some solutions are appearing**

We need also courage to apply those solutions,
some (public and private) funding,
some innovation efforts from industry, …

Next days

Thursday 17th, 9 - 13

Alessandra Toninelli: “Context-aware Semantic Middleware Solutions for Pervasive Applications”

Samuele Pasini: “Ubiquitous Computing Middleware: design and implementation principles”

Stefano Monti: “System composition and reconfiguration in Ubiquitous Computing scenarios”

Friday 18th, 9 - 13

Carlo Giannelli: “Context-aware Middleware for Multi-hop Multi-path Heterogeneous Connectivity in Social Sharing Scenarios”

Luca Foschini: “IMS-based Infrastructures for Mobile Multimedia Systems towards Service Continuity”

Final

Either a final in class on Friday

Or a post course dissertation on a topic negotiated with teachers

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