

Pervasive Computing

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Pervasive / ubiquitous ?

Pervasive

Ubiquitous



Pervasive / ubiquitous ?

Pervasive

everywhere

Pervasive Computing

technology that adapts to the user

Ubiquitous

invisible

Ubiquitous Computing

technology that is invisible to the user
no cognitive effort for using it
Mark Weiser 1991

human centric view of technology



Pervasive / Ubiquitous computing

- **Some definitions :**

- **Pervasive computing** aims at creating a **smart environment** with **embedded and networked computing devices**, providing human users with **seamless service access** [Raychoudhury 2013]
- **Pervasive computing** promotes the **integration** of electronic **devices** in our **living spaces** in order **to assist us** in our daily activities, be they professional or private [Lallanda 2020]
- **Ubiquitous computing** is about “**seamlessly integrating computers** into the world at large runs” [Weiser 1991]
- “**things disappear** in this way are **we freed to use** them **without thinking** and so to **focus beyond them on new goals**” [Weiser 1991]

- **Related concepts**

- Ambient Intelligence, Intelligent Environments, Embedded Intelligence...

Pervasive / Ubiquitous computing

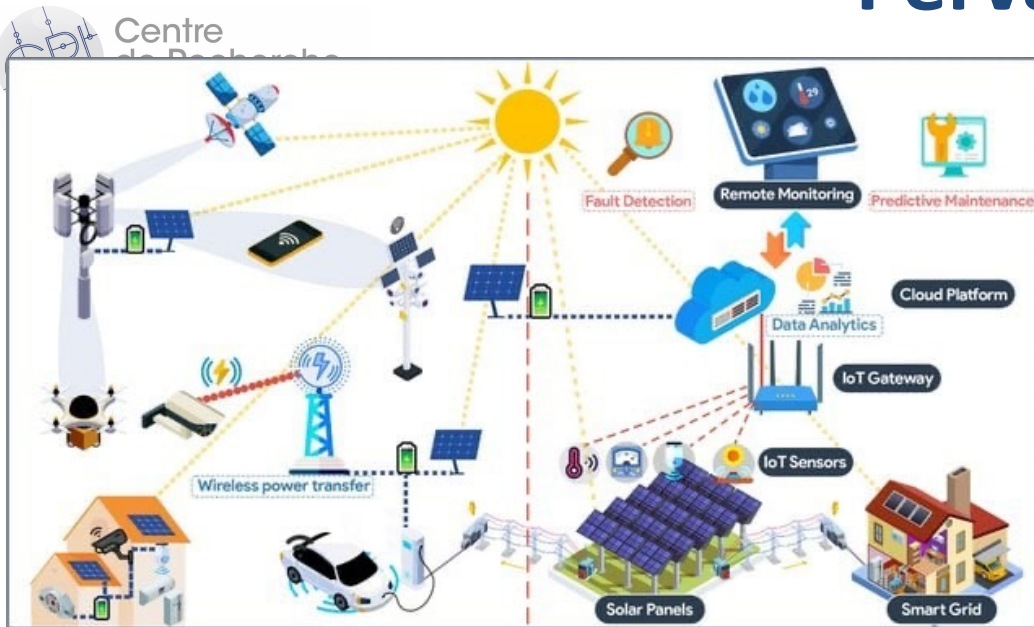
The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it
[Weiser 1991]

Integrating technology without being lost...



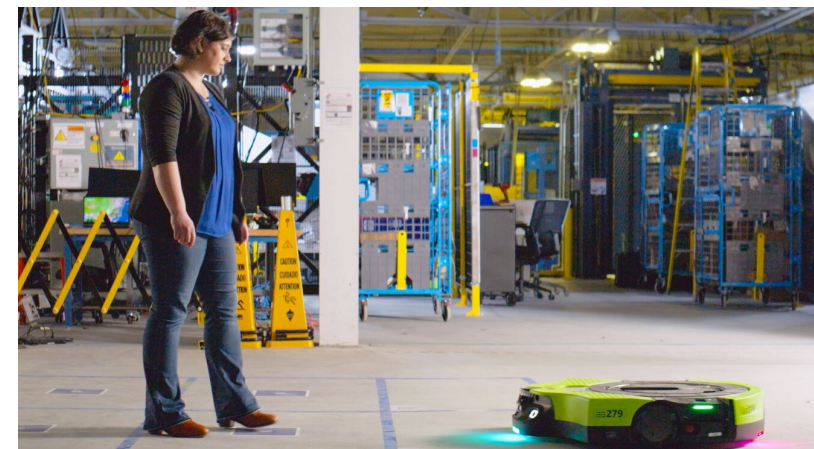
Pervasive environment

Pervasive devices



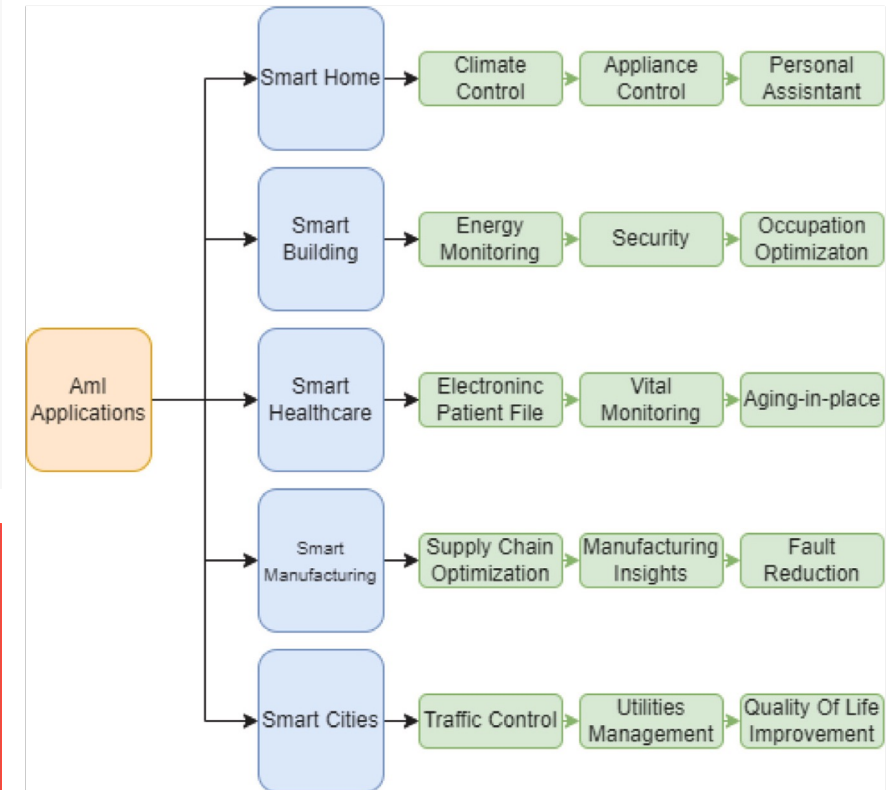
[Chinipardaz 2023]

“Today’s schoolchildren don’t think of TVs and telephones as technology—they can’t imagine life without them. Tomorrow’s children will feel the same way about computers, the networks connecting them, and the services they perform.”
[Birnbaum 1997]



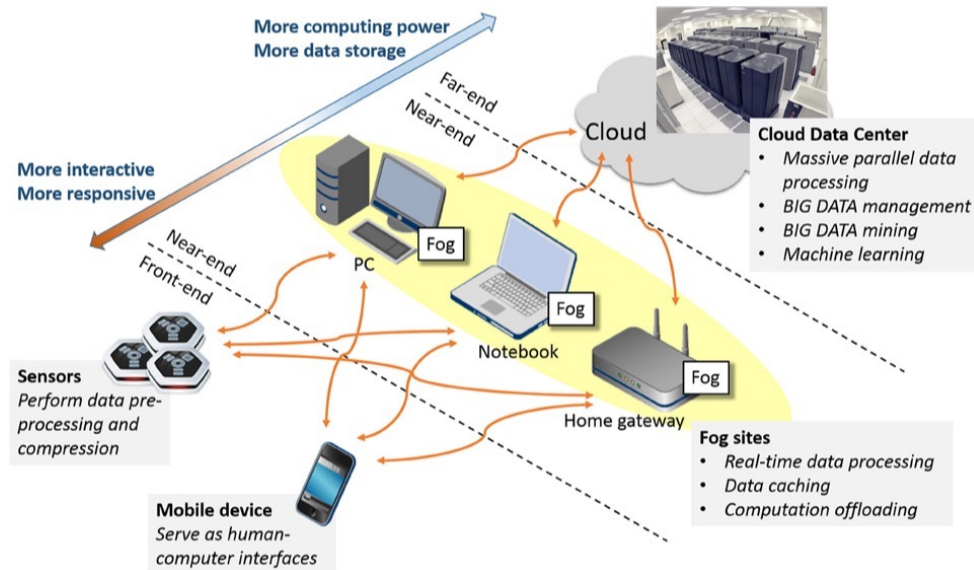
<https://www.aboutamazon.com/news/operations/how-amazon-deploys-robots-in-its-operations-facilities>

https://artemis-ia.eu/key-technologies.html#secure_iot_and_systems_of_systems

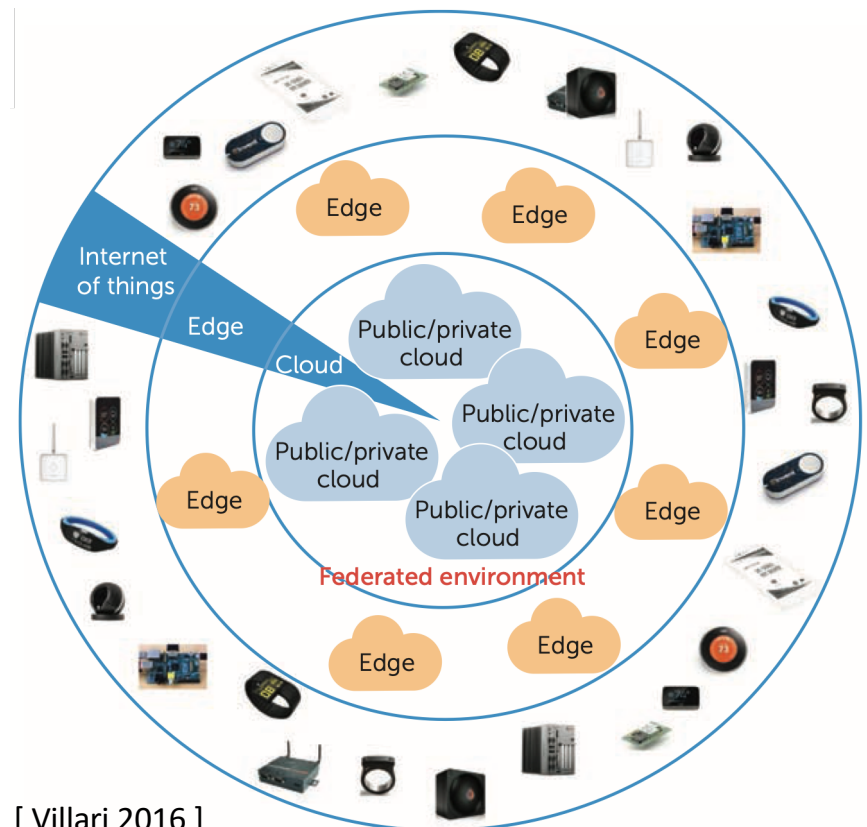


<https://iot-analytics.com/number-connected-iot-devices/>

Technologies and applications



<https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2014.00370/full>

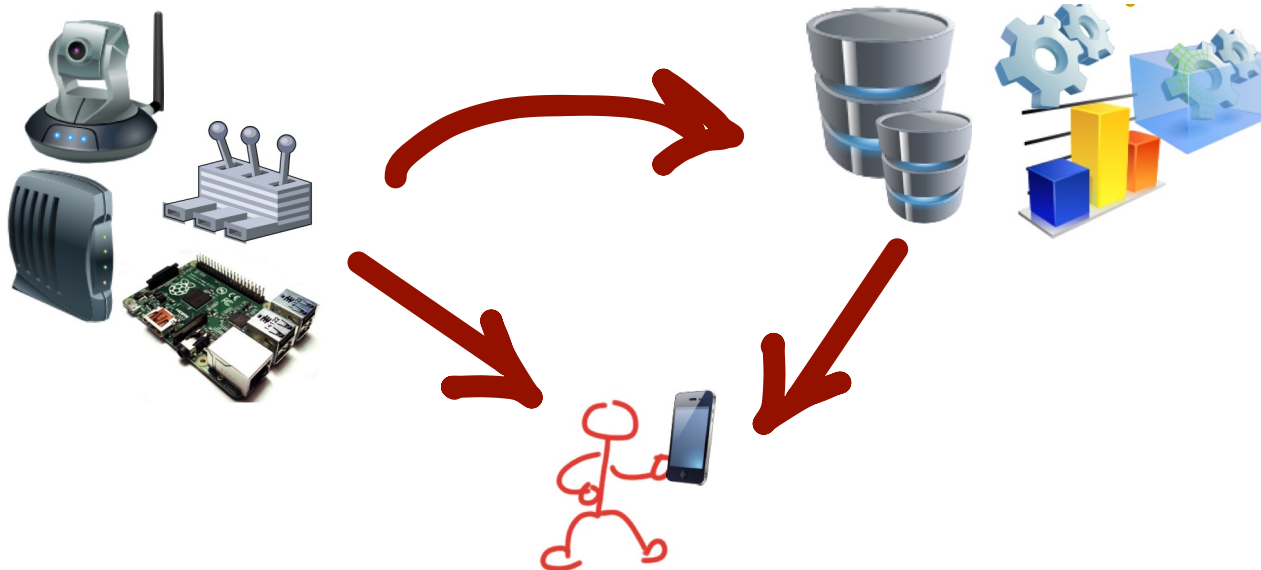


[Villari 2016]

FIGURE 1. Edge and cloud computing for the Internet of Things.

Pervasive devices

Pervasive devices collect contextual information, **run** local computation, and, in some cases, **directly act** upon the **environment**. This allows the implementation of simple, **reactive services** like opening an emergency door when a triggering condition is detected. [Lallanda 2020]



Pervasive computing

Pervasive Computing is about...

Adaptation

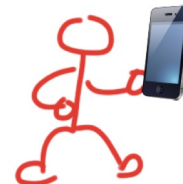
Smart devices...



... sensing / observing the environment...



*... using such information for
adapting application / services*



Context-aware Systems

Adapting system behavior to the environment



Context-awareness

Context-aware systems are systems able to **adapt their operations** to the **current context without explicit user intervention** and thus aim at **increasing usability** and **effectiveness** by taking environmental context into account. [Baldauf 2007]



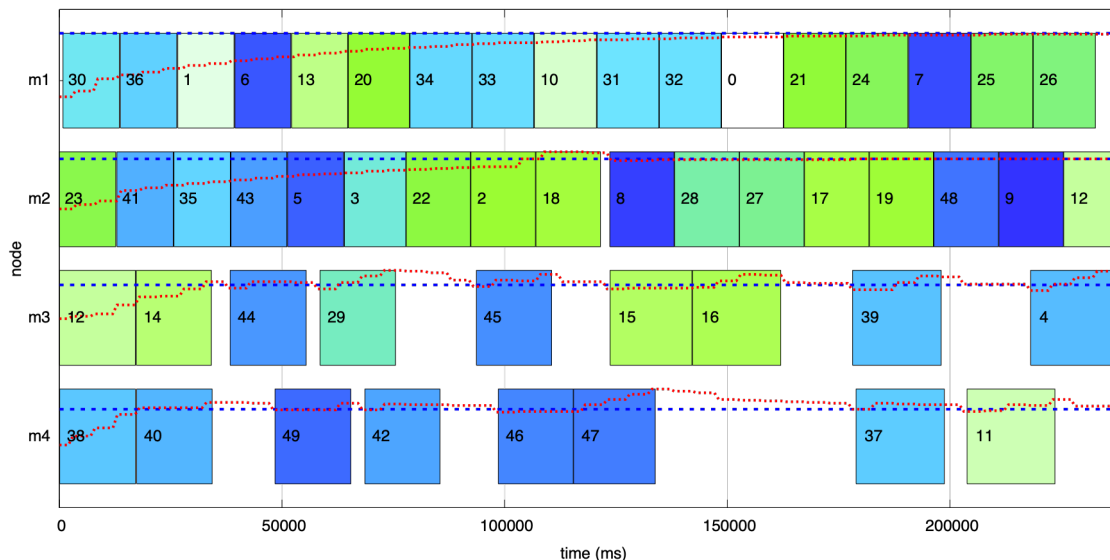
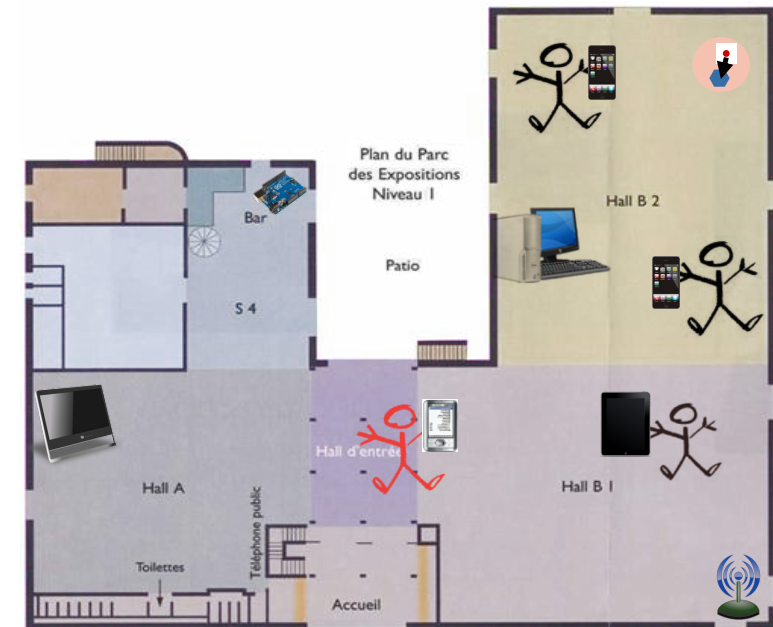
Variability

Context-aware Systems

Application deployment

inspired by [Da 2014]

Dynamically deploying an application
according available surrounding devices



Using available resources

[Steffenel 2021]

- Executing tasks according nodes' capabilities
- **Defining constraints for task (service) execution**

Context-aware Systems

Adapting system **behavior** to the environment

Content

Interface
Interaction

Functionalities
Services

Structure

Team work:

Finding 5 examples
Home/personal,
Company/professional,
Public



Context-aware Systems

Context is the key



Context information

Any information that can be used to **characterize the situation** of entities (i.e., whether **a person, place or object**) that are considered **relevant** to the **interaction** between **a user** and an **application**, including the user and the application themselves
[Dey, 2001]

Execution
context

*Memory, CPU, screen,
library & data
availability...*

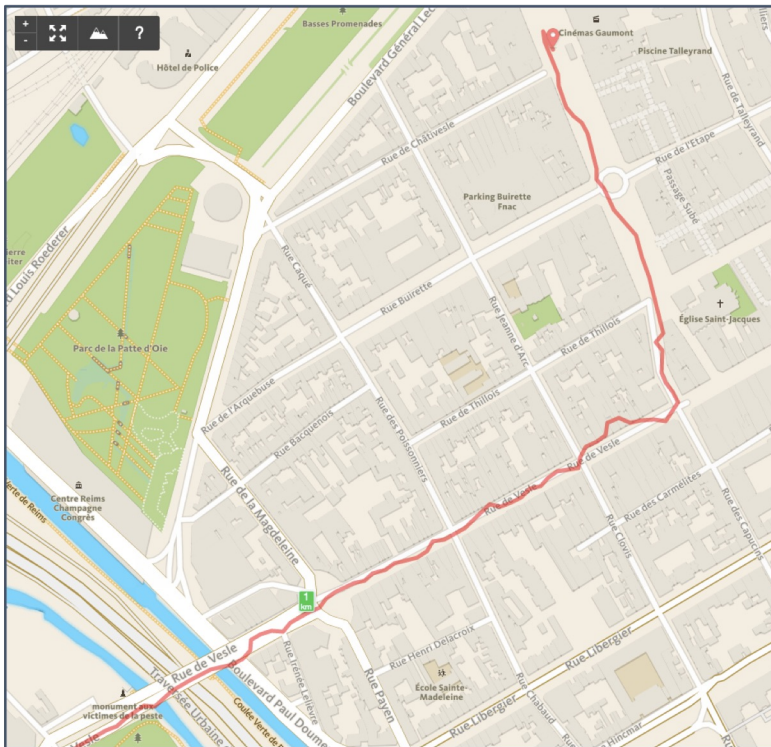
Physical
context

*Location,
temperature,
humidity, noisy...*

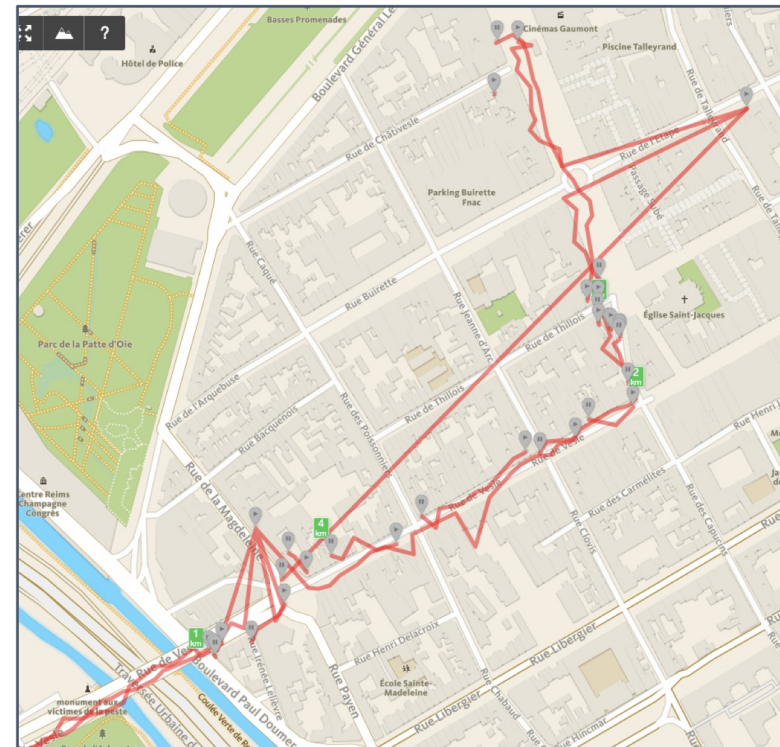
Organizational
context

*Role, tasks, teams,
projects, shared
objects...*

Context-aware Systems



(a)



(b)

[Kirsch Pinheiro 2021]

Context-aware Systems

- **Context information challenges**

- **Heterogeneity**

- Different kinds, formats and representations
 - Evolution (new kinds of data, new formats, new representations...)

- **Dynamicity**

- (Constantly) Evolving data
 - Freshness, runtime nature

- **Uncertainty**

- Incomplete, unsure

- **Quality concerns**

- **Quality of Context**

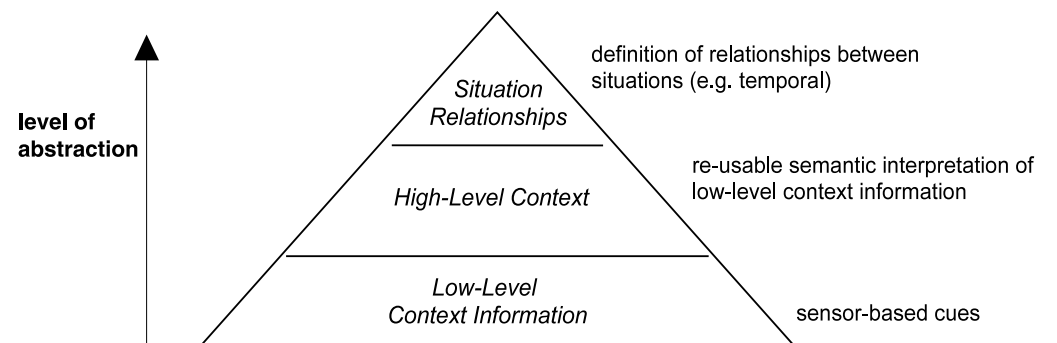


Fig. 2. Overview of the different layers of semantic context interpretation and abstraction.

[Bettini 2010]

Context-aware Systems

Architectural elements

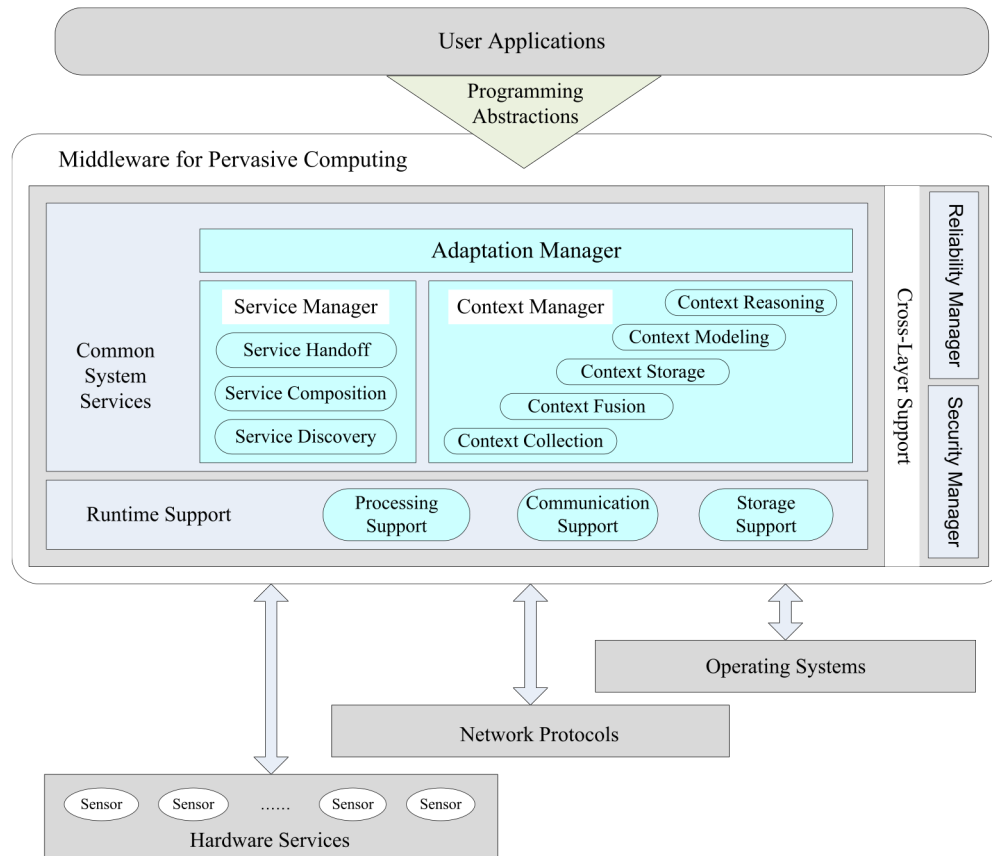
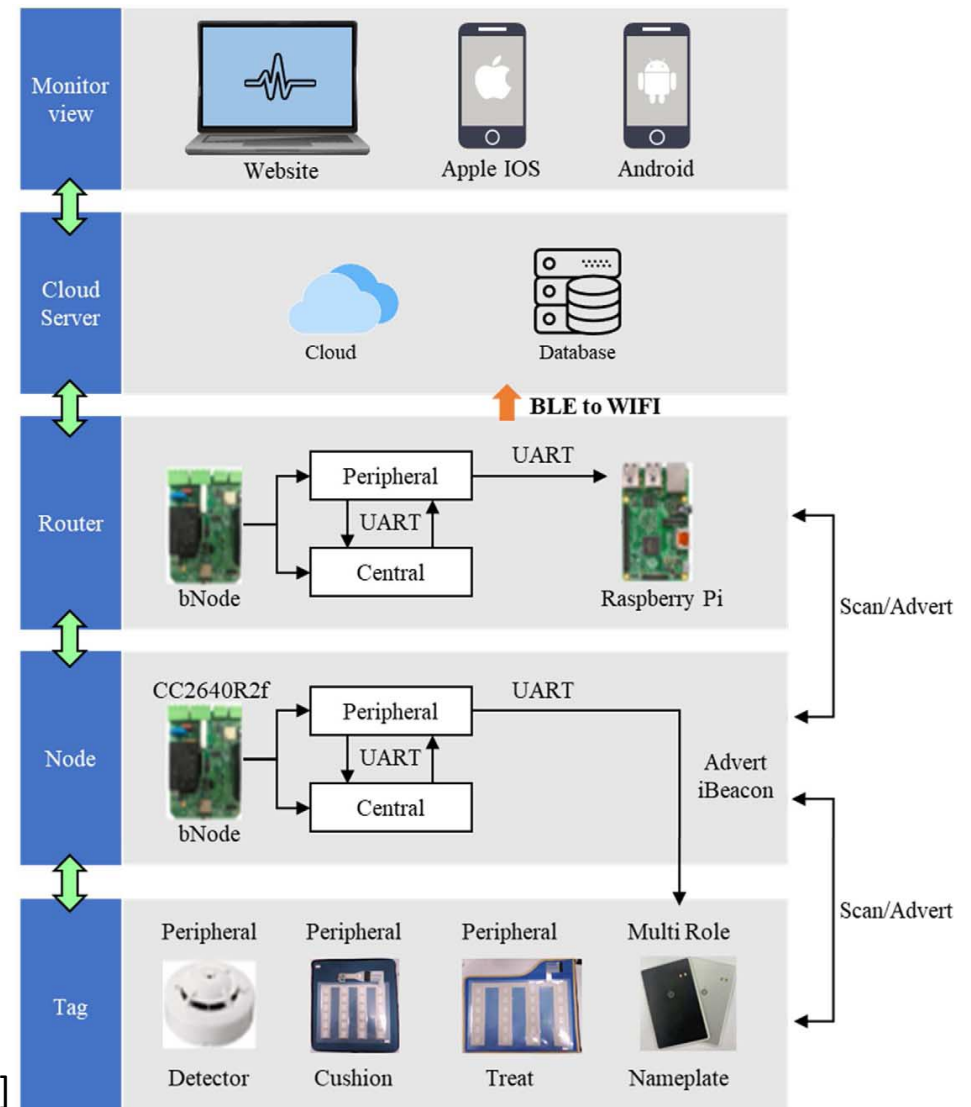


Fig. 2. Reference model for PvC middleware.

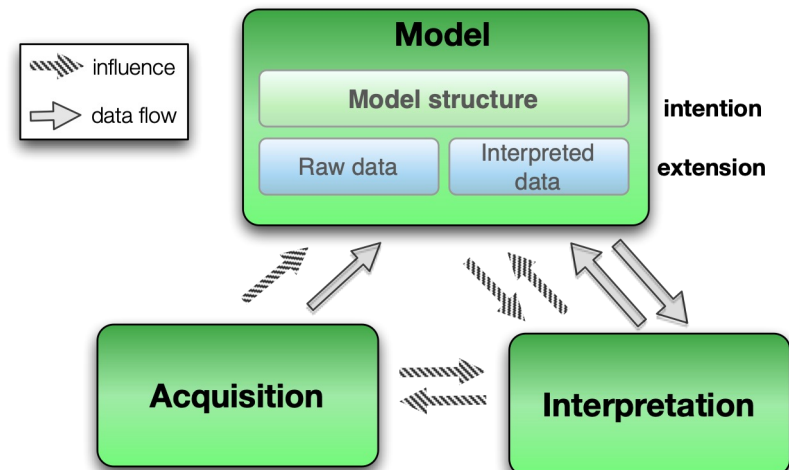
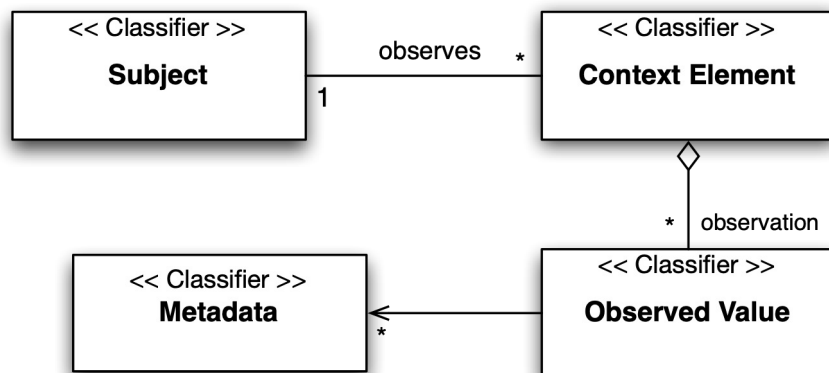
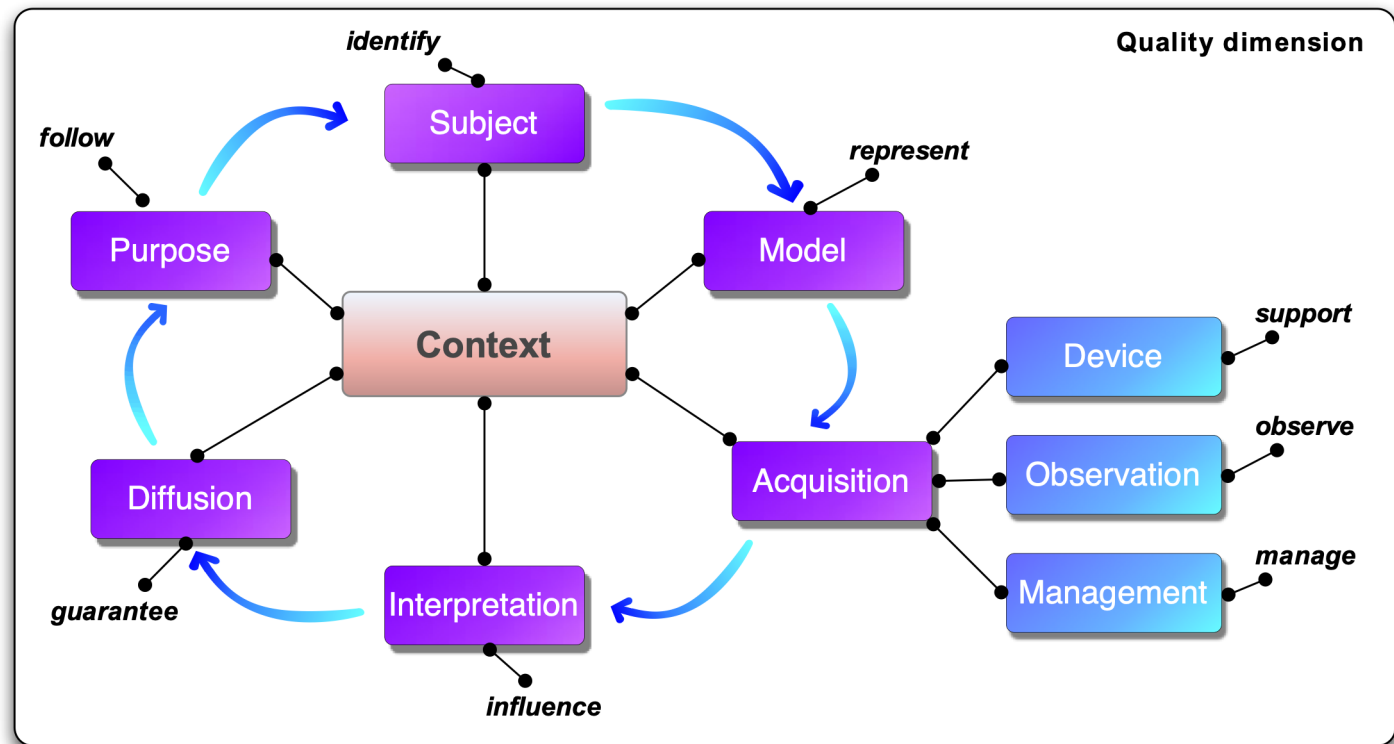
[Raychoudhury 2013]



[Lin 2022]

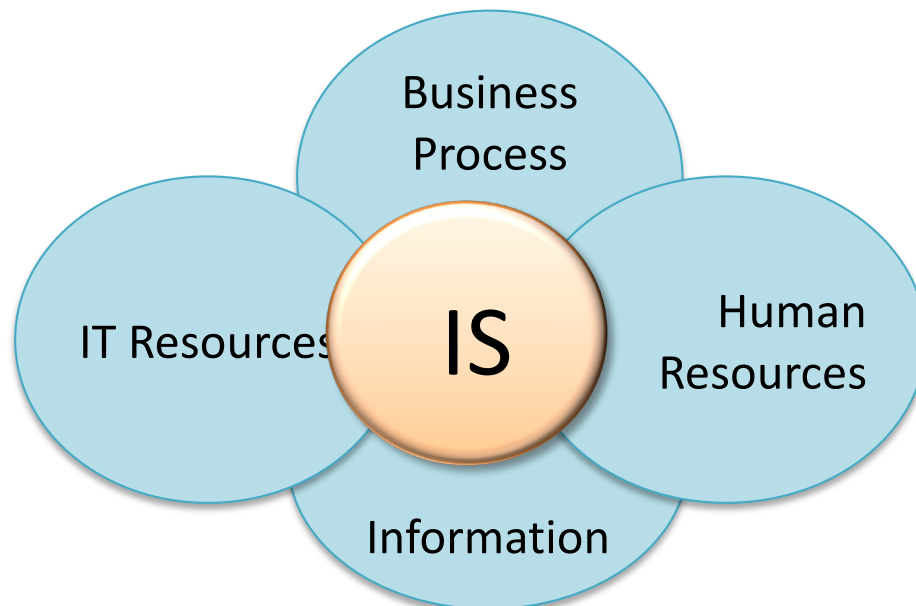
Fig. 1. The architecture of IoT healthcare system.

Engineering context-aware systems



What about “Information System”?

- **Information Systems are not only about software**
 - Applications, data, resources and process contributing to the organization goals
 - **A complex ecosystem evolving with the organizations and their needs**



IT trends on Information Systems

- IT evolution in the last decade
- Towards a generalization of a “smart” behavior

Cloud Computing

Big Data

Edge Computing

Internet of Things

Artificial Intelligence

Data
revolution

usages
evolution

Physical
world

New
infrastructures



Pervasive + Information + Systems

“Pervasive Information” Systems

- Information everywhere
- IoT as source of data

“Pervasive” Systems

- Observing and reacting to physical environment
- Adaptability

Pervasive “Information Systems”

- Information system everywhere
- Extending IS out of organization boundaries



Pervasive Information System

*“it is not the technology itself that is pervasive [...], but the **access**, **delivery**, and **consumption** of a wide variety of **information services**.”*

[Rao 2009]

Value chain → customer's point of view

*“**pervasiveness** can be powered (or **delivered**) by an **infrastructure** of networks, databases and servers, and an **outer edge of devices** interfacing the **customer**.”*

[Rao 2009]



Customer's point of view, but not only !

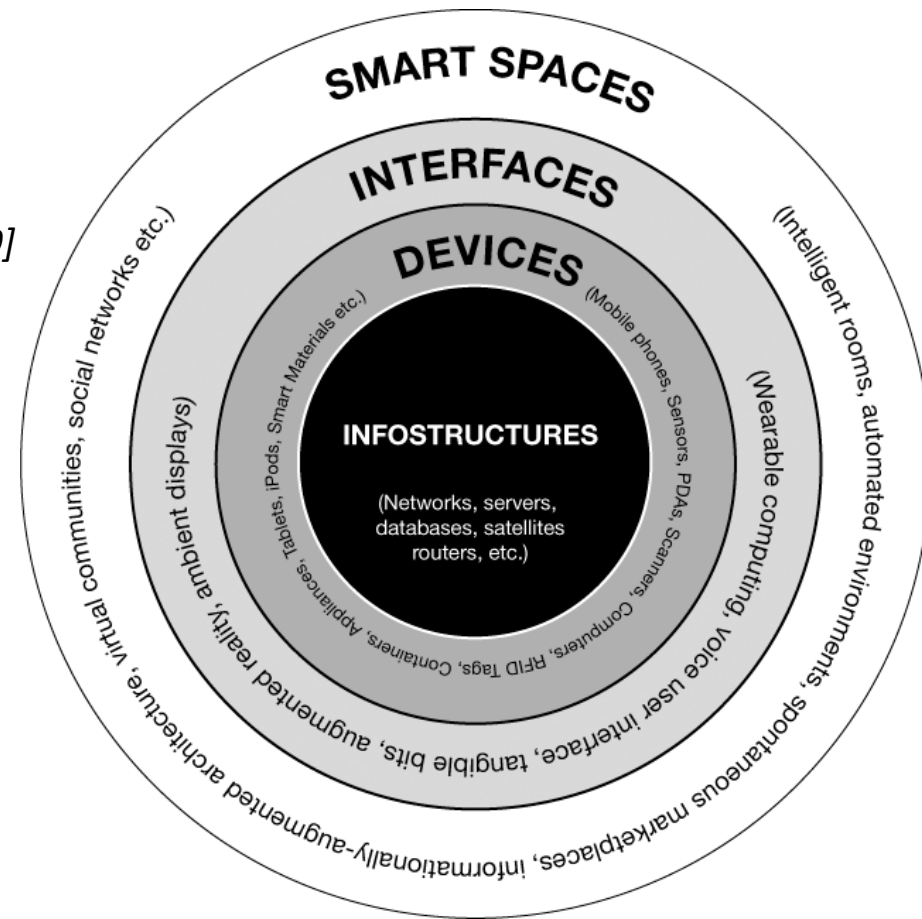


Fig. 1. The pervasive information systems value chain.

[Rao 2009]

Mobile Information Systems

*Spatial mobility, multi-channel
support, user orientation and
personalization*

[Krogstie 2004]

Information Systems Timeline

Pervasive Information Systems

*“**emerging class** of Information Systems where Information
Technology is gradually **embedded** in the **physical environment**,
capable of **accommodating user needs** and wants when desired.”*

*“they encompass a **complex, dynamic environment** composed of
multiple artefacts instead of Personal Computers only, capable of
perceiving contextual information instead of simple user input,
and **supporting mobility** instead of stationary services”*

[Kourouthanassis 2006]

Pervasive Information Systems

*“To become truly pervasive, **information technology** [...] must become
intuitively accessible to ordinary people and **deliver sufficient value** to
justify the **large investment** needed in the **supporting infrastructure**.”*

*“people could **pay for their computing by usage**, modulated by
guaranteed response requirements. This is an enormous paradigm shift,
changing what is now a **capital investment into a competitive service**,
like electricity and water.”*

[Birman 1997]

Defining Pervasive IS

- Pervasive IS is an “Information system” in which pervasive environments are integrated :
 - to **improve business** processes with IT devices
 - to **improve interactions** of users with IT devices & physical environments
 - to **adapt the IS support** to the user’s situation
 - to **capture** data on its **physical environments**
 - to **capture** data on the **IT infrastructure**

[Kirsch Pinheiro **2022**]

PIS Requirements

Managing heterogeneity

- Supporting a wide variety of technical devices and services
- Heterogenous IT devices & technologies
- **Managing heterogeneity is complex but essential**

Transparency

- **Hide the complexity and heterogeneity** of its environment from the users
- Easiness of use
- Reaching Ubiquitous Computing view
- **Invisible computing** → low cognitive effort

Fulfillment of Requirements

- Meeting **business and users' needs**
- Making users more productive, focusing on her/his own tasks

Adaptation

- PIS should **manage variability** on **services** and **infrastructures**

Context awareness

- PIS must perceive the evolution of its execution environment and adapt itself accordingly

PIS additional characteristics

Opportunist

- Dynamic environment → new resources, services...
- Opportunistic strategies to use resources, data & services
- Exploring all available items (resources, data, and services) in order to fulfill business goals

Interactive

- Exploring new interaction modes

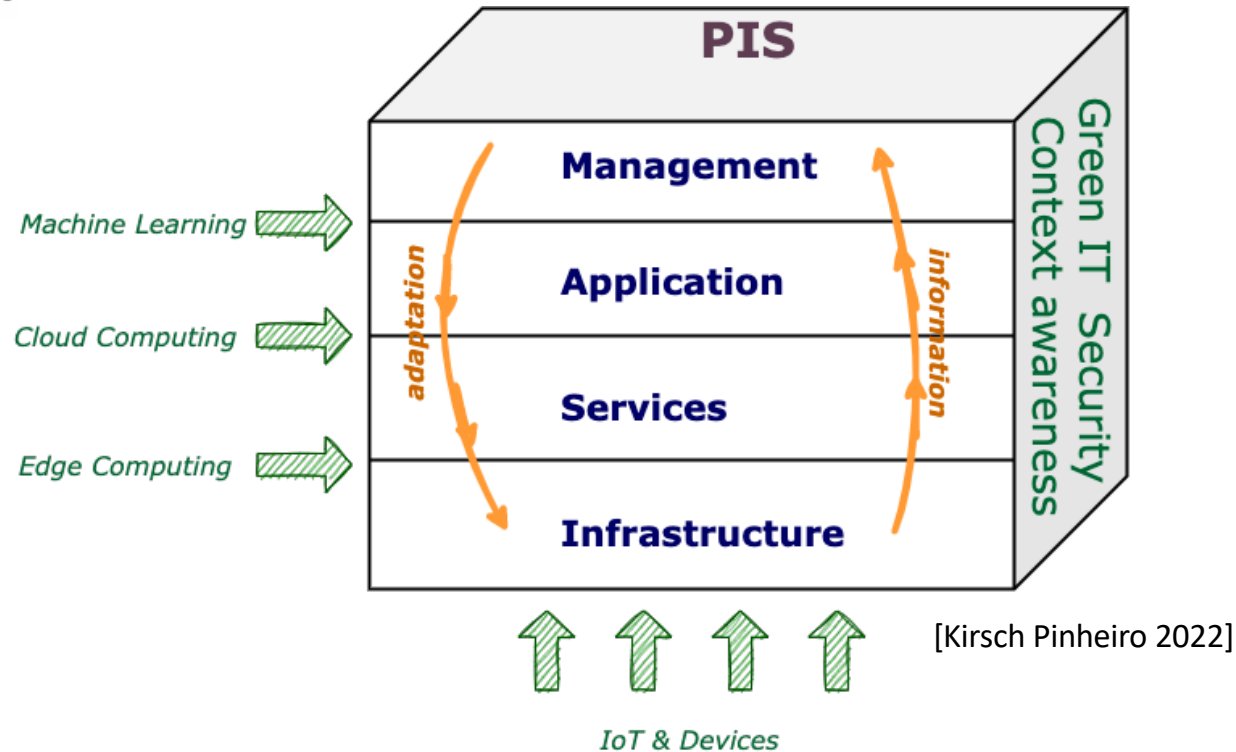
Determinism

- PIS remains an IS → under business control
- Satisfying business needs in a predictable and controlled manner

Autonomic

- Automatically collect and processing heterogeneous data
- (IoT) Data management

Pervasive Information Systems



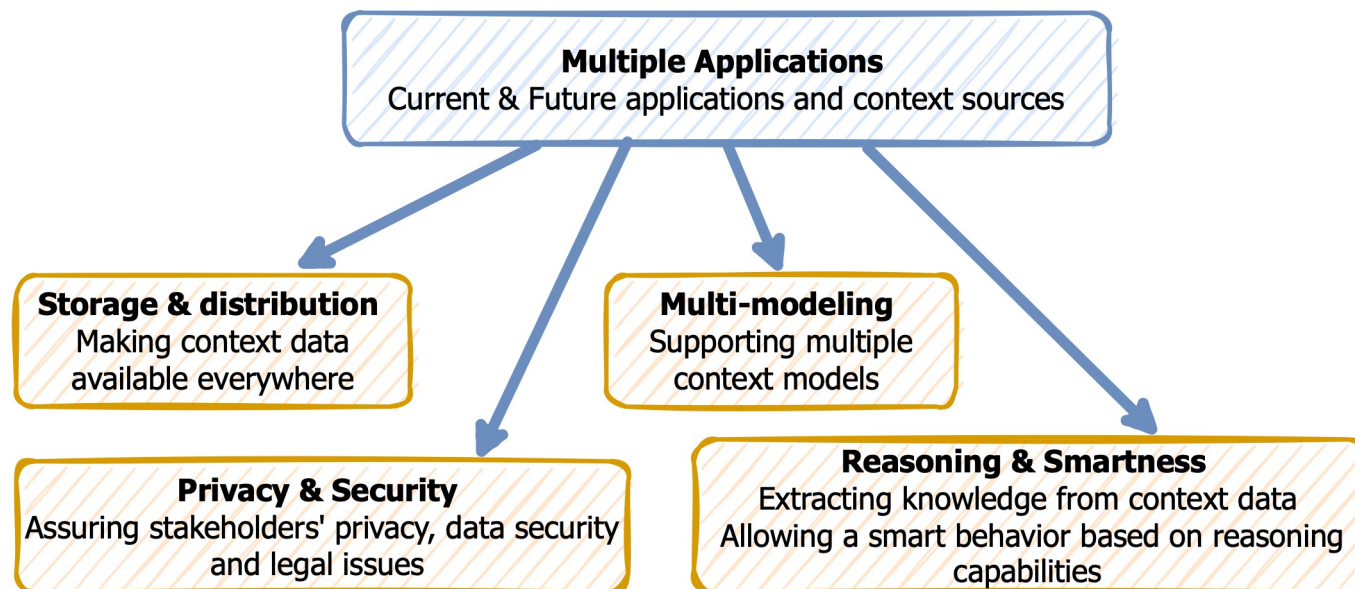
*Information Systems extending **beyond the physical (and logical) boundaries** of the organization, integrating new technologies and a **pervasive environment** (in the technologically charged sense) in a **transparent** way, and from which users expect an **intelligent behavior**, both **reactive** and **proactive***

[Kirsch Pinheiro 2021]

Pervasive Information Systems



Holistic view



Pervasive Information Systems

Multiple concerns...

Technical concerns

Architectural

Software architecture

Enterprise architecture

Data management

Data quality

Context management

Reasoning

Artificial Intelligence

Regulations & conformity

Scalability

Business concerns

Risk management

Hyper automation

Societal concerns

Energy consumption

Sustainability

User's responsibility



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