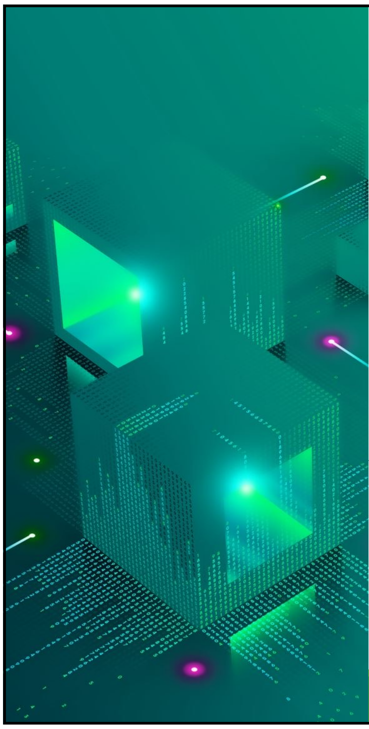

Sistemas de Computação Móvel e Ubíqua

2021/2022

FCT - UNIVERSIDADE NOVA DE LISBOA

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Mobile Computing

2021/2022

introduction

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Mobile Computing

Computing environment where hardware components are expected to be taken from place to place **during normal usage…**

… and hardware and software **has to be designed** to leverage that mobility and mitigate its issues.

Usually integrated in a distributed system.

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Classic examples

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Mobile Computing

Is a technology-driven science, made possible by many advances and trends in several key technological areas:

- processing & storage, lightweight displays, high-density batteries, wireless networking
- further improvements, in sensors & actuators, are driving us ever closer to **ubiquitous and pervasive computing**

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Body devices

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Wearable devices

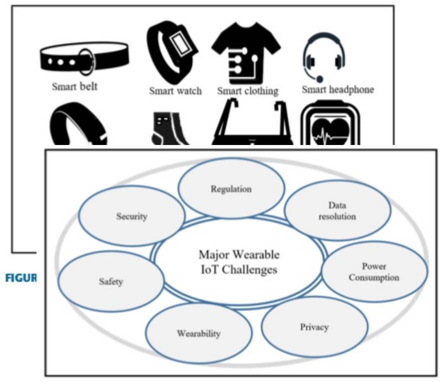

FIGURE 5. Major challenges of wearable IoT technology.

https://www.electronicdesign.com/technologies/iot/article/21801943/develop-wearable-devices-on-the-iot-cutting-edge

https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9058658

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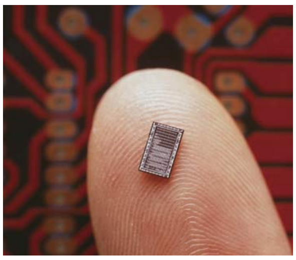
Advances: More Resources

Moore's law "… is the observation that, over the history of computing hardware, the number of transistors, in a dense integrated circuit, doubles approximately every two years"

- …more processing capacity, storage, diverse functionality in the same space
- …smaller transistors allow less energy usage, under higher frequency operation

Smaller and Smaller and Smaller



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Advances: More Resources

Thanks to nanotechnology, some transistors are smaller than a virus.

- These microscopic structures contain carbon and silicon molecules aligned in perfect fashion that help move electricity along the circuit faster.
- Eventually, the temperature of the transistors make it impossible to create smaller circuits, because cooling the transistors takes more energy than what passes through the transistors.

Experts show that computers should reach physical limits of Moore's law sometime in the 2020s.

Advances: More Resources

In the future, applications and software can improve the speed and efficiency of human activities, rather than physical processes.

Cloud computing, wireless communication, the Internet of Things and quantum physics, may all play a role in innovating computer technology and new applications.

https://www.investopedia.com/terms/m/mooreslaw.asp

Advances: Display Technology

Display technology has leveraged advances in new light emitting materials…

- bright,
- deformable,
- high-fidelity
- efficient

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Advances: Wireless Networking

Wireless networking has also seen tremendous advances, in speed, reliability, and energy efficiency

4G LTE 5G

Wi Fi® Wi Fi™ DIRECT

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Mobile Devices

A mobile radio telephone

Martin Cooper photographed in 2007 with his 1973 handheld mobile phone prototype

Source: https://en.wikipedia.org/wiki/History_of_mobile_phones

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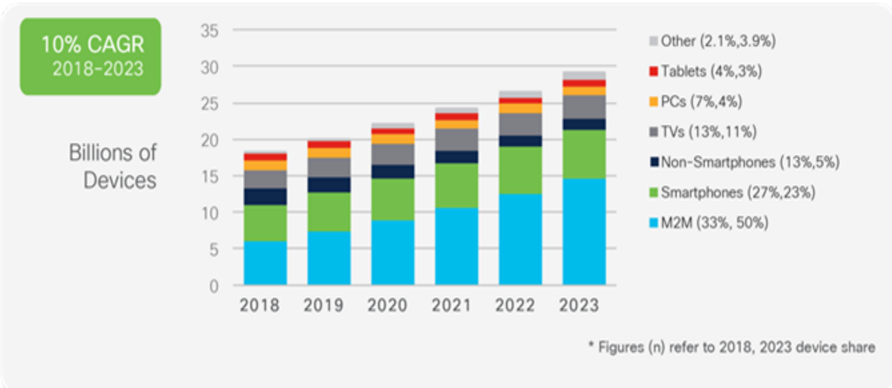
Global Mobile Devices and Connections Growth



Source: Cisco Annual Internet Report (2018–2023) White Paper
https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html

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Mobile Computing Goals

Leverage paradigm strength

Mobility and portability as the basis for…

- ubiquitous usage
  - e.g.: gaming, communication, work, …
- rethinking of conventional solutions
  - e.g.: maps, photos, home automation, logistics, …
- novel applications
  - e.g.: live-blogging, location-based services, fitness tracking

Mobile Computing Goals

Mask or mitigate issues

Mobility constrains the device's form-factors, which in turn have a cascading effect

- display sizes, input capabilities, autonomy, processing speed, connection limitations, etc.

Mobile devices can be **hazardous**

- by drawing user attention from physical danger
- by proving a too convenient recipient of personal information
- another attack vector to privacy and security

Mobile Devices Characteristics

Mobile devices tend to be **resource-poor** relative to static devices, relying on a finite and limited energy source

Processor speed, memory size, disk capacity, screen size tend to be smaller due to restrictions from power, ergonomics, size, weight

In absolute terms, mobile devices can be very powerful, comparable to static devices of a decade ago

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Mobile Devices Characteristics

Connectivity is highly variable in **performance** and **reliability**

Connectivity changes with location and may vary over time, affecting both throughput and latency

Sometimes **not available**, but disconnection is not always undesirable

Multiple heterogeneous networking providers may be available at a given time

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Mobile Computing Challenges

Shared with traditional (distributed) systems include:

- scale, heterogeneity,
- fault-tolerance,
- high-availability,
- security,
- remote communication

These challenges are made harder by the characteristics inherent to mobile devices

Mobile Computing Challenges

Novel challenges include:

- Mobile networking and information access
- Location sensitivity and context awareness
- Energy-awareness
- UI and Adaptive requirements

And:

- Process the highly amount of data generated by mobile devices

Mobile Networking

Wireless and wired networks behave differently and required new or revised protocols

Ad-hoc networking is important for scenarios where infrastructure is absent or damaged

Energy-awareness

Mobile computing only last as long as the device's battery

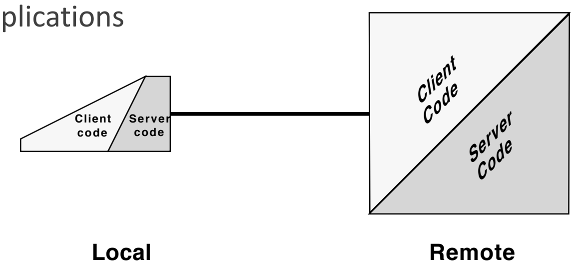
Conserve energy by powering down unused hardware (display, sensors, …), throttle down CPU speed, …

Offload some of application logic elsewhere (cloud, infrastructure)

Mobile Information Access

Interaction with remote services and data may need to mask weak and intermittent connectivity

- pre-fetching, caching and disconnected operation support, are in order
- high-latency implies the same for achieving responsive interactive applications



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Location sensitivity and context awareness

Leverage onboard sensors and external services to reason about context

Device position, orientation, user-actions, mindset

Anticipate user intents to improve user-experience in applications

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Adaptive Software

Applications need flexible rules of operation, allowing for runtime adaptation of behavior

- Display characteristics/orientation
- Connectivity (failures or limitations)
- Environment (location, time of day or activities)

Process Generated Data

Mobile devices are currently being used as small personal computers, generating a considerable amount of data, such as photos and videos

- But also, location, application usage, etc

We leverage on the increased processing and storage capabilities of such devices to process, at the edge, the data generated at the edge

- Examples:
- photo and video record and light processing
- Data sharing at local network

Ubiquitous and Pervasive Computing

2021/2022

introduction

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Ubiquitous and Pervasive

From Cambridge dictionary:

Ubiquitous = seeming to be everywhere

Pervasive = present or noticeable in every part of a thing or place

- Ubiquitous computing when you can use your applications everywhere and anytime
- Pervasive computing when all your environment and devices include computing capabilities

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Ubiquitous and Pervasive Computing

Pervasive or ubiquitous computing is many times seen as synonymous

Refers to a model of computing in which computing is integrated in everyday objects and activities.

It involves connecting devices and appliances with embedding microprocessors to get information and to control.

Ubiquitous computing focuses on removing the complexity of computing for automation and increasing efficiency for different daily activities.

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Pervasive Computing

"The main focus of ubiquitous/pervasive computing is the creation of smart products that are connected, making communication and the exchange of data easier and less obtrusive."

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Example:

Home devices

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Pervasive Computing
Some key features

- Consideration of the human factor and placing focus in a human environment
  - rather than in the computer or the application
  - Capture of real-time attributes
  - Includes local/global, social/personal, public/private and invisible/visible features and considers knowledge creation, as well as information dissemination
- Use of mobile devices and embedded low-cost processors with reduced resources but some sensors/controllers

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Pervasive Computing
Some key features

- Relies on wireless technology and advanced electronics
- Can be based on totally connected and constantly available computing devices
- Increased surveillance and possible restriction and interference in user privacies, as the digital devices are wearable and constantly connected
- As technology progresses, the reliability factor of the different equipment used may be impacted

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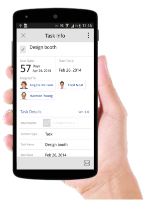
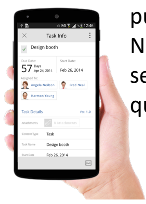
Pervasive Computing Challenges

Mask uneven conditioning

Same service may present different functionalities and QoS in different places

At home: Good service quality





In some public places: Not so good service quality

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Pervasive Computing

"Ubiquitous Computing (ubicomp) is a post-desktop model of human-computer interaction in which information processing has been thoroughly **integrated into everyday objects and activities**. In the course of ordinary activities, someone "using" ubiquitous computing engages many computational devices and systems simultaneously, and may not necessarily even be aware that they are doing so… More formally, ubiquitous computing is defined as "**machines that fit the human environment instead of forcing humans to enter theirs**." ~ Wikipedia

Pervasive Computing Challenges

Invisibility

"The most profound technologies are those that *disappear*. They weave themselves into the fabric of everyday life until they are indistinguishable of it."

"Ubiquitous computing enhances computer use by making many computers available throughout the physical space, while making them effectively invisible to the user"

Pervasive Computing Challenges

in other words…

Users in a pervasive computing environment will engage with multiple computational sensing/actuator devices simultaneously without being necessarily aware of the fact

British writer Arthur C. Clarke formulated three "laws" of prediction. The 3rd of the three is:

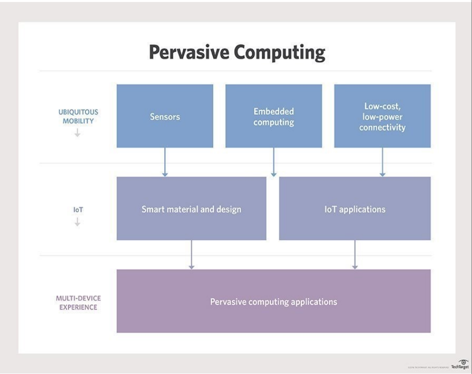
> **"Any sufficiently advanced technology is indistinguishable from magic…"**

Pervasive Computing and IoT

The internet of things (IoT) has largely evolved out of pervasive computing.

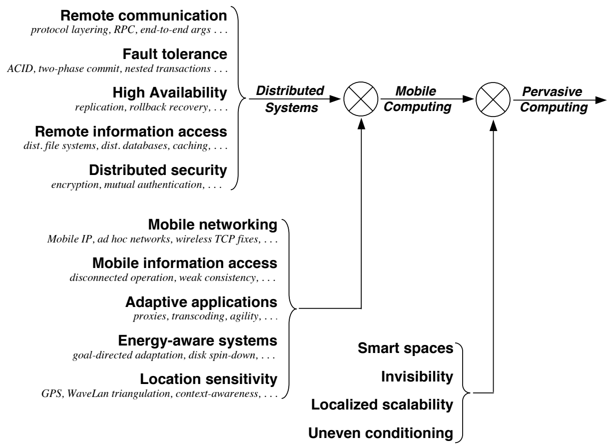
Allows internet access to devices/appliances

The IoT is on its way to providing the pervasive computing vision and turning common objects into connected "smart" devices.



https://internetofthingsagenda.techtarget.com/definition/pervasive-computing-ubiquitous-computing

Challenges - summary



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Applications domains

- Wearables
- Health
- Traffic monitoring
- Fleet management
- Agriculture
- Hospitality
- Smart grid and energy saving

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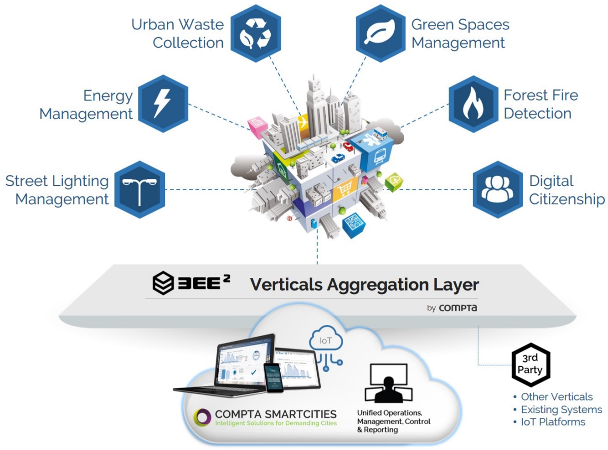
Challenges

Smart cities



https://www.ceb-solutions.com/wp-content/uploads/2017/08/Compta-Smart-Cities-Overview-2.jpg

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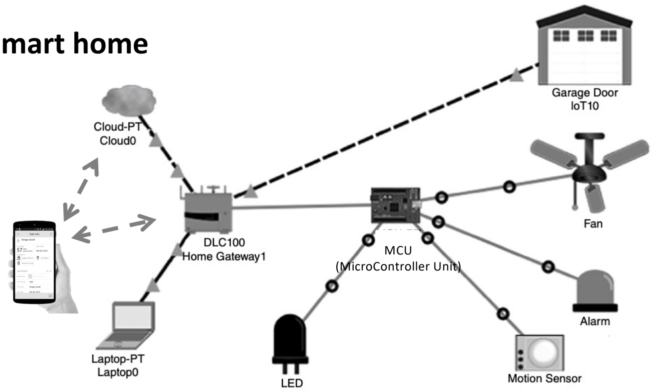
Challenges

Smart home



Adapted from:
Enabling the Internet of Things: Fundamentals, Design, and Applications, *Iqbal , et.el., 2021*

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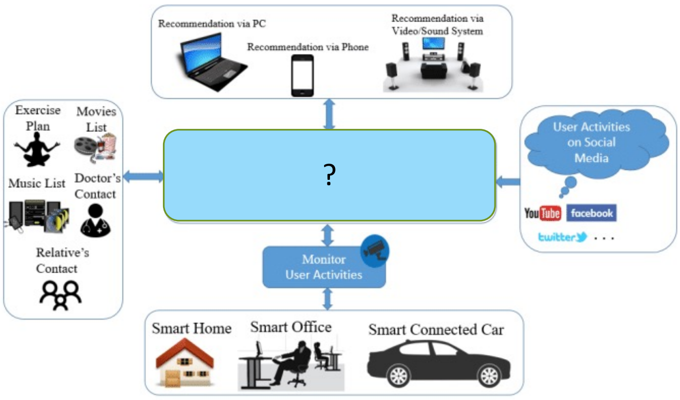
Challenges

Smart spaces



https://www.researchgate.net/publication/320263975_Smart_Spaces_Recommending_Service_Provisioning_in_WoO_Platform

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... because sometimes technology needs a long time to catch up with ideas...

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Matthew Halpern, Yuhao Zhu, Vijay Janapa Reddi: **Mobile CPU's rise to power: Quantifying the impact of generational mobile CPU design trends on performance, energy, and user satisfaction.** HPCA 2016, IEEE Computer Society, 2016.

Frank Adelstein, et. al. Fundamentals of Mobile and Pervasive Computing. McGraw-Hill. 2005. **Chap 1**.

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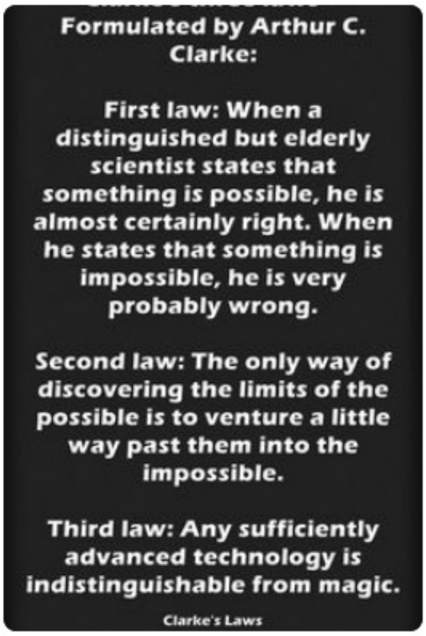
just for curiosity ☺



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Sensors

examples

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