

# Introduction to Pervasive Computing

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# Pervasive Computing: the vision

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

Mark Weiser  
*The Computer for the 21st Century*



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# Distributed Pervasive Systems

- A distributed system with the following main features
  - it includes unconventional nodes
    - (possibly mobile) objects with computing and communication capabilities (smartphones, smart appliances, smart meters, sensor networks, ...)
  - adaptivity
    - the system logic considers the current context and adapts the system behavior for optimizing the system goal



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# they are ... volatile systems

Systems that exhibit high volatility:

- failures of devices and communication systems
- changes in the characteristics of communication such as bandwidth
- creation and destruction of associations between software components resident on the devices



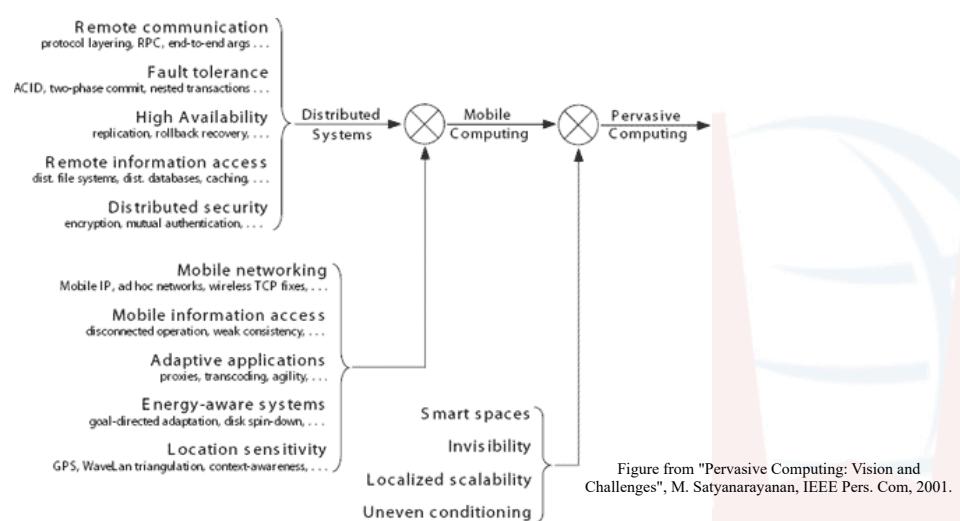
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## From Distributed to Pervasive Systems



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# Mobile Computing

- Main issues:
  - limited resources (energy, CPU, memory, ...)
  - different types of interfaces
  - high variance in connectivity
  - variable location



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# Mobile Computing

- Main research topics:
  - Networking (Mobile IP, Mobile networks, ad hoc networks, ...)
  - Mobile information access (disconnected operation, proxy architectures, bandwidth adaptive access, ...)
  - Mobile data management (spatio-temporal data management, LBS, context-awareness, privacy and security, mobile cloud services)



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# Mobile Computing

- Main research topics:
  - ...
  - Positioning (indoor and outdoor localization, proximity, tracking)
  - Software (App and mobile services design, development and testing, scalability)



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# Pervasive Computing

From mobile nodes to embedded computers and affordable Internet connected sensors and actuators, listening and affecting the physical world



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# Examples of Pervasive Systems

- Smart Environment (Home, Building, City) Systems
  - Smart Home services
  - Smart energy management
  - Smart transportation
    - e.g., using *crowdsensing* through smartphones and sensors
- e-Health systems for
  - Tele-healthcare
  - independent living and ageing well
  - accessibility

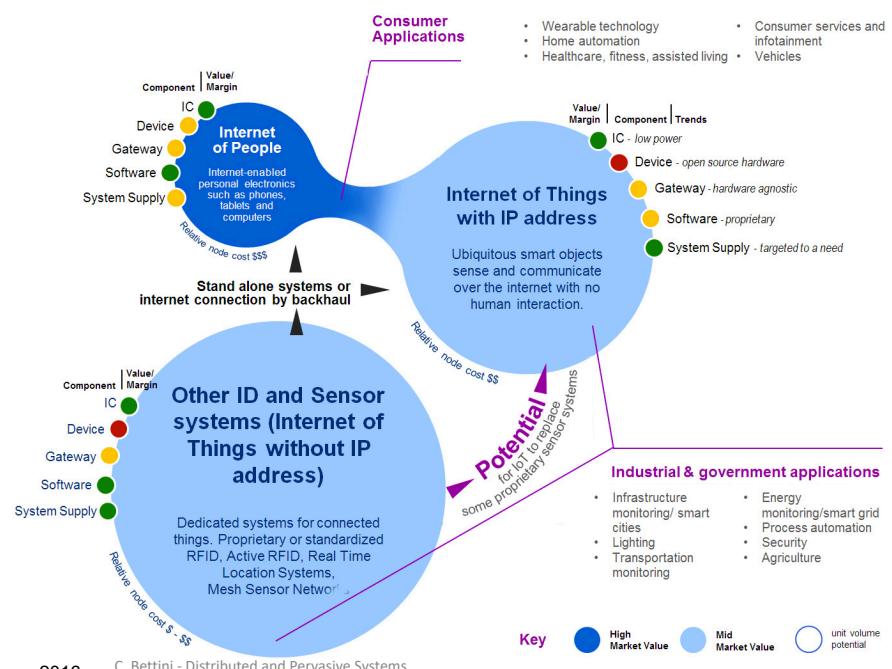


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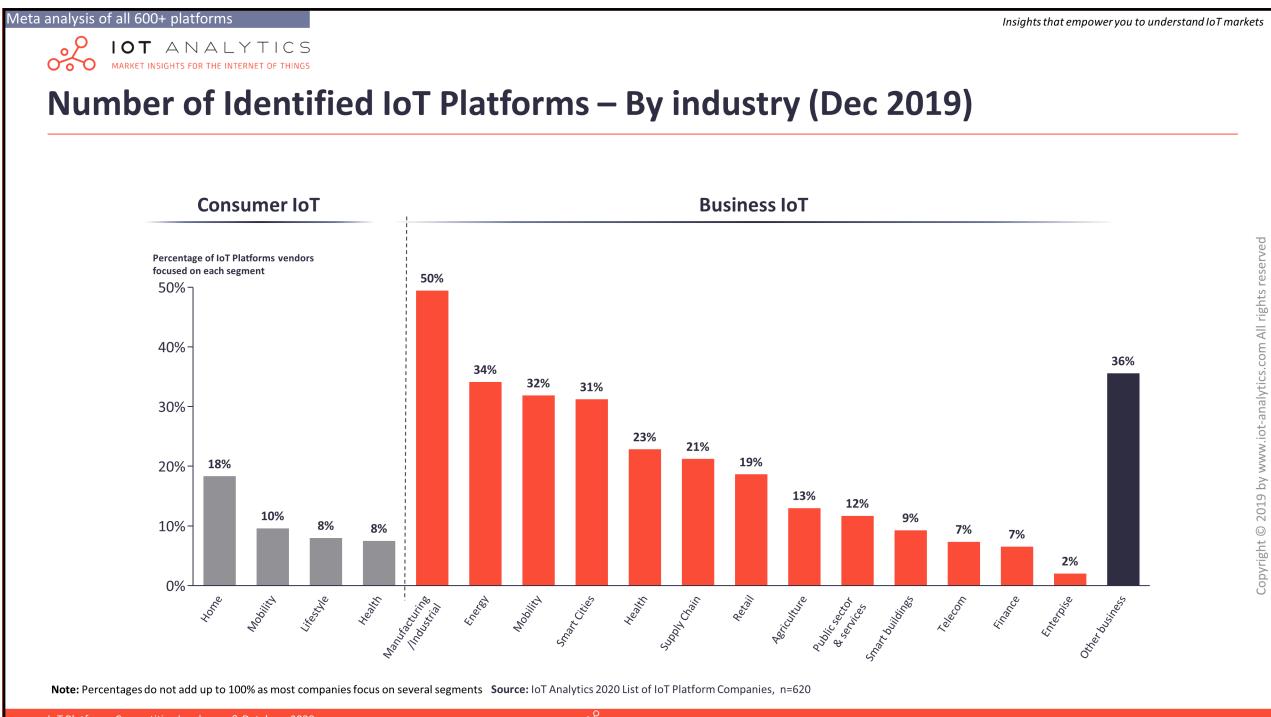
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## IoT



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## Why "smart"?

- Connected to the Internet
  - remote access, invocation of services, cooperation, ...
- Running algorithms (locally or remotely) to analyse data and understand "context" by exploiting AI techniques.
- Offering *personalized context-aware* services

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## "Smart" Appliances



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## Smart ... everything

SmartWatch, SmartScale,  
SmartLocks, SmartSleep ...



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## Smart Home

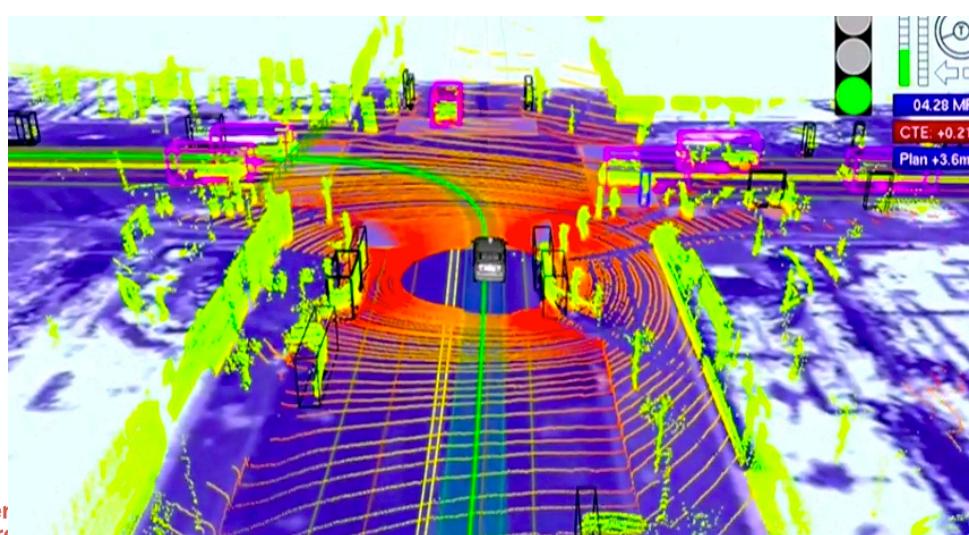


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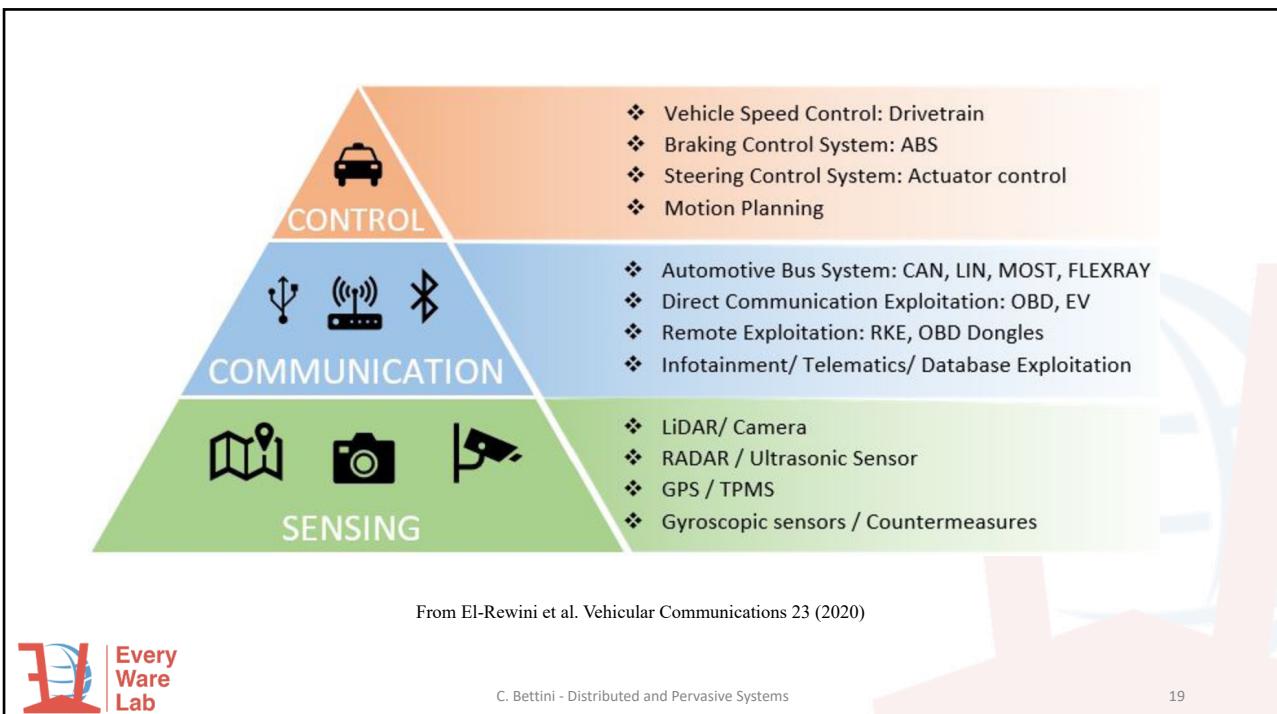
## Smart vehicles



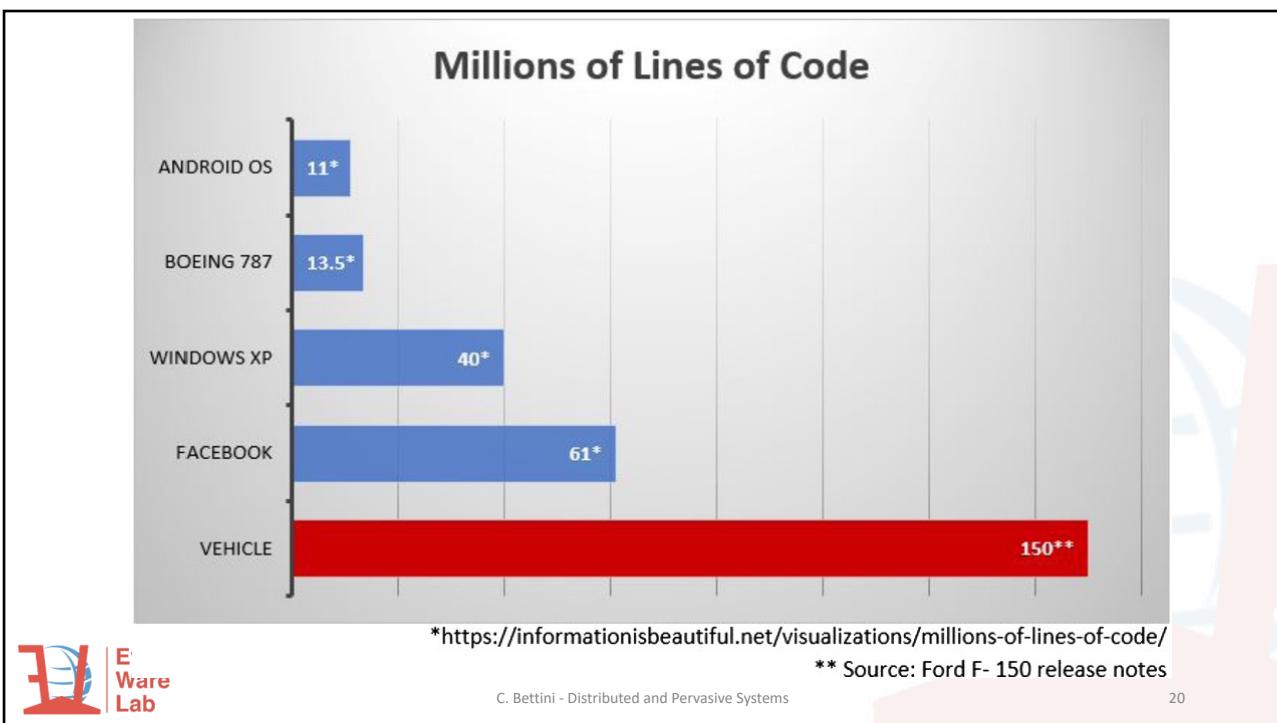
[Image from Google self driving cars]

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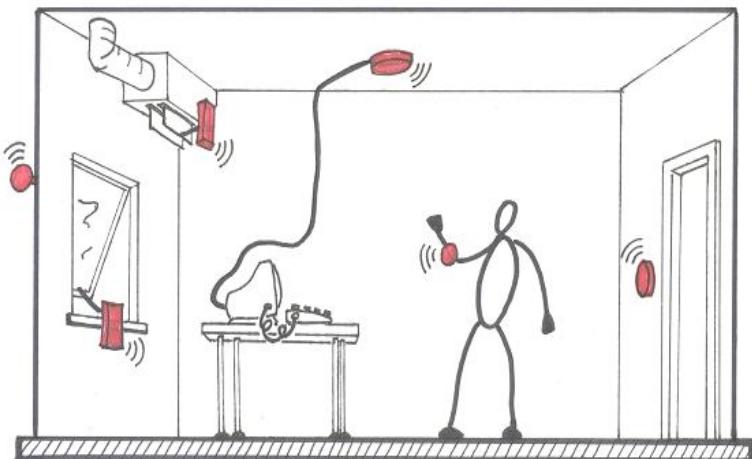


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## Sensors and actuators



Source: <http://resenv.media.mit.edu/>

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## Wearable sensors



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## Sensor Networks

- SN are important components of pervasive systems
- Sensors can also be part of smart objects (smartphone, car, ...)
- Questions concerning sensor networks (next class):
  - How do we (dynamically) set up an efficient tree in a sensor network?
  - How does aggregation of results take place? Can it be controlled?
  - What happens when network links fail?



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## Pervasive Computing

- New issues
  - smart spaces need to be effectively used (adaptiveness, context-awareness, anticipation of needs)
  - invisibility: interaction with users should be minimized (system transparency)
  - resources in a pervasive environment should be discoverable and dynamic association/collaboration should be enabled



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# Current research topics in pervasive computing

- Context and Activity Modeling and Recognition
  - how to represent rich context and how to reason with context
  - how to recognize human activities from streams of sensor data, ...
- Crowd Sensing
  - distributed acquisition of data from users (from their smartphone, their car, their home, ...)
- Energy Analytics
  - analysis of smart-meter data and enabled services



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# Current research topics in pervasive computing

- Pervasive Health
  - wearable devices and environmental sensors enable continuous monitoring
  - goals
    - early detection of health problems
    - monitoring health conditions in chronic diseases
    - facilitating rehabilitation at home
    - extended independent living (reminders, alarms, intervention, ...)



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## Current research topics in pervasive computing

- Pervasive Transportation
  - road sensors, car sensors, driver smartphones coupled with inter-vehicle communication enable new services
  - Goal: mobility optimization, emission reduction, hazard detection
- Edge Computing
  - Local scalability: Move computation closer to the data source
- Security and privacy
  - IOT devices are currently an easy target
  - A huge amount of sensitive information is stored in the cloud



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## SmartHome System Demo

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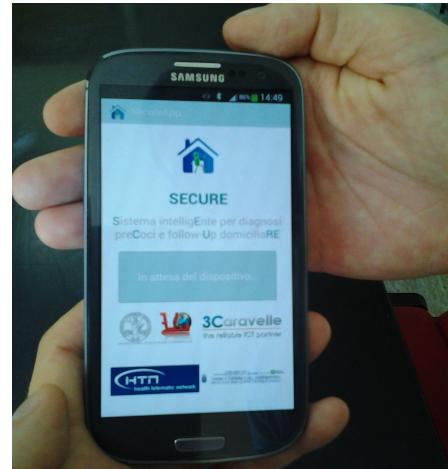
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## "SECURE": example of eHealth project

### SECURE: Sistema intelligENTE per diagnosi preCoci e follow-Up domiciliaRE

- Funded by MIUR and Regione Lombardia
- 4 partners
  - Health Telematics Network
  - FatebeneFratelli IRCCS
  - EWLab, Università Statale di Milano
  - 3 Caravelle



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## SN Design and Control



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## SN in real environments

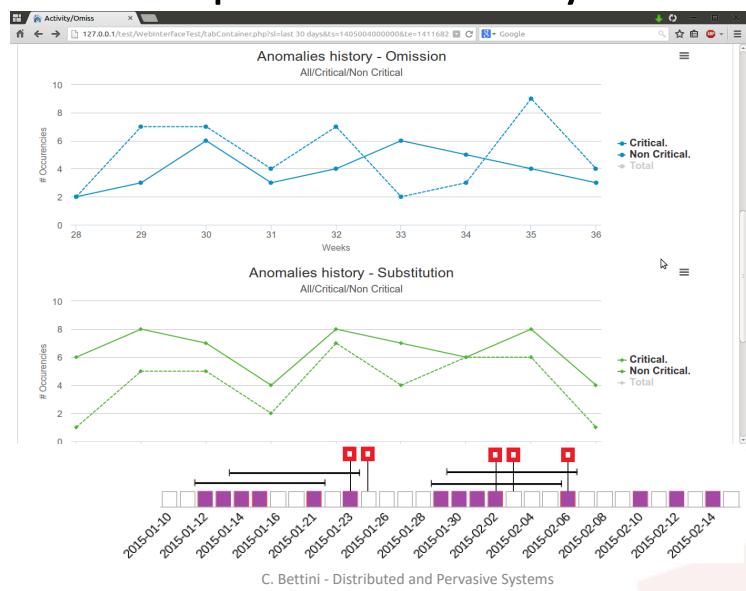


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## The hard part: data analysis



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## References

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