Smart Spaces

Chapter 1:

Ubiquitous Computing: Internet of Things, Smart Services, Multi-agent Systems

Outline

§1. Computing paradigms

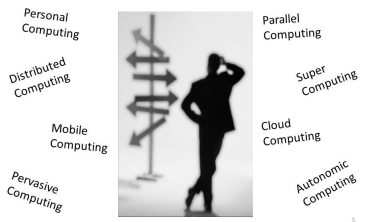
§2. Smart Components

§3. Features, Challenges, and Approaches

§1. Computing Paradigms

- Ubiquitous computing
- Pervasive (embedded) computing
- Mobile computing
- Web services
- Internet of Things (IoT)
- Ambient Intelligence (AmI)
- Semantic Web and Linked Data
- Multi-agent systems
- Machine-to-Machine (M2M)

Existing computing paradigms



Ubiquitous computing

- Mark Weiser introduced the term "ubiquitous computing" around 1988
  - Specialized elements of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence.
  - The purpose of a computer is to help you do something else. The best computer is a quiet, invisible servant
  - The more you can do by intuition the smarter you are; the computer should extend your unconscious
  - Technology should create "calm"

Calm Technology

- We live in ***a Digital World***
- Many computational devices and systems
- Information processing is thoroughly integrated into everyday objects and activities
- Machines that **fit the human environment** instead of forcing humans to enter theirs

Technology does not require all our attention, just *some of it*, and *only when necessary*

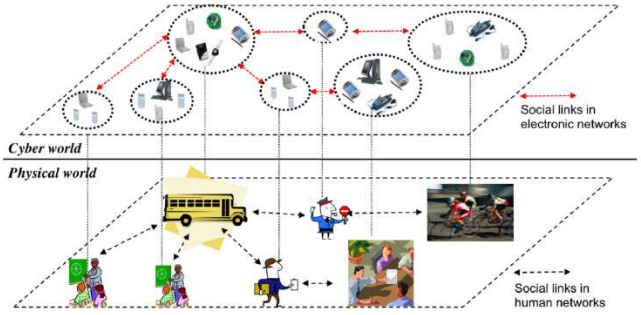
Technology informs/assists

Technology makes the use of periphery

Pervasive Computing

- World of embedded devices, consumer electronics, …
- Moving beyond the personal computer to everyday devices with embedded technology and connectivity as computing devices become progressively smaller and more powerful
- Almost any device, from clothing to tools to appliances to cars to homes to the human body to your coffee mug, can be imbedded with chips to connect the device to an infinite network of other devices
- Predecessor paradigm for IoT

Pervasive Computing

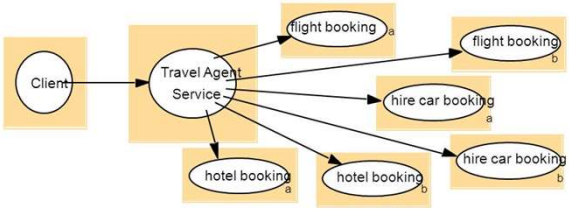


Mobile Computing

- Smartphones, tablets, laptops (carried personal computers)
- Wearable devices (carried digital equipment)
- Implantable devices (e.g., medical sensors)
- Digital convergence: one device can access all services

Web services

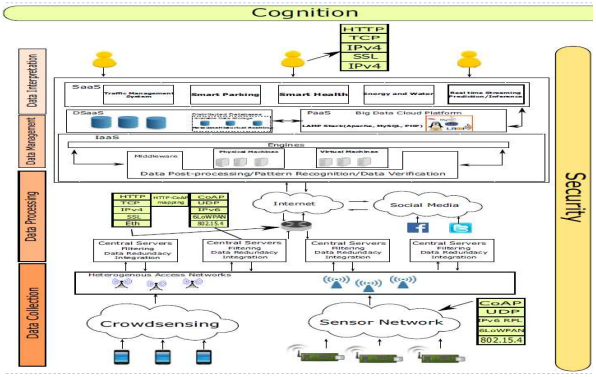
- Internet is a global information/knowledge store
- Composition of services to satisfy a particular need (requires puzzle solving)



Internet of Things (IoT)

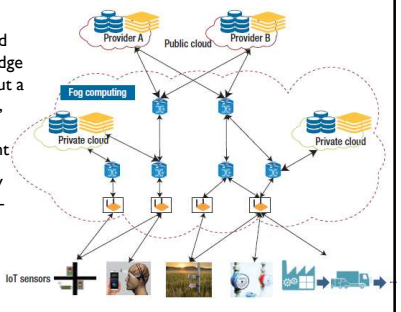
- Interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure
- Smart object:
  - Physical thing
  - It can "think" as individual or autonomously (computing facilities)
  - It can understand the surrounding state (sensing and interpretation)
  - It can communicate with others (network facilities)
  - It can make actions (as physical thing, own decision-making)

IoT and Cloud Computing



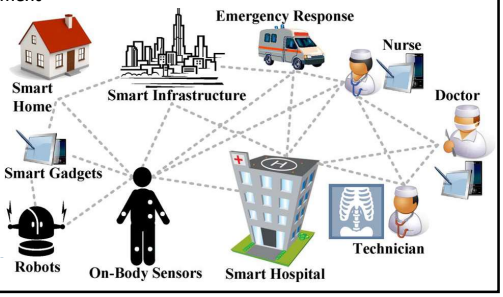
IoT and Fog Computing

- Cloud-like services at the network edges
- Sensed IoT data are processed locally by utilizing clients or edge devices near users to carry out a substantial amount of storage, communication, control, configuration, and management
- Fog devices—including nearby gateways and private clouds—dynamically conduct data analytics.



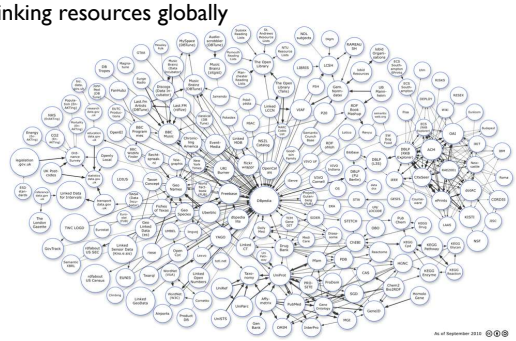
Ambient Intelligence (AmI)

- Electronic environments become sensitive and responsive to the ***presence of people***
- Support of people in carrying out their everyday life activities ***using information and intelligence*** that is hidden in the environment



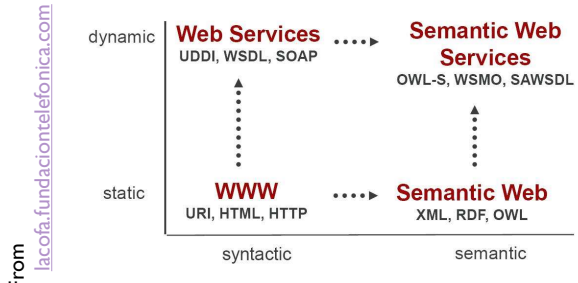
Semantic Web: Information World

- Linking resources globally



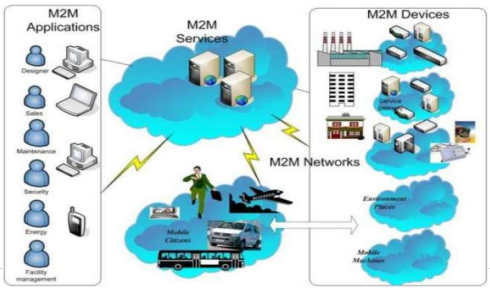
Semantic Web: Technology

- Linking resources globally



Machine-to-Machine (M2M)

- Allowing both wireless and wired systems to communicate with other devices of the same type
- Expanded beyond a one-to-one connection and changed into a system of networks that transmits data to personal appliances



Multi-agent systems

- Software entities running on a computer device
- They act on behalf of humans, physical, and informational objects
  - Making devices smart
- Fusion of Physical (things), Information (virtual), and Social (human) Worlds
  - Cyber-Physical-Social systems

Waves of Computing

1. Mainframes era (Past)
   Each machine shared by lots of people
   One computer, many people
2. Personal computing era (Present)
   One person, one desktop
3. Ubiquitous computing (Future)
   Technology recedes into the background of our lives
   One person, many devices

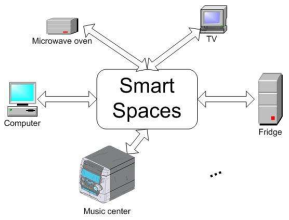
Mark Weiser, The Computer for the Twenty-First Century, 1991

- Personal computers are only a transitional step toward achieving the real potential of information technology
  - Such machines cannot truly make computing an integral, invisible part of the way people live their lives
- A new way of thinking about computers in the world, one that takes into account the natural human environment and allows the computers themselves to vanish into the background
- Computer disappearance is a fundamental consequence not of technology, but of human psychology
  - when things disappear such that we use them without thinking and then we focus beyond them on new goals

One big *space*

All kinds of devices and networks, anywhere, anytime:

- Sensors, active badges, cards, phones, laptops, embedded controllers, robots, PCs, Internet servers, ...
- *Pervasive computing:* Small and inexpensive processing devices, distributed at all scales throughout everyday life
- *The Internet of Things:* networked interconnection of physical (everyday) objects



Smart space

- Ubiquitous computing:
  - The vision of incorporating sensing, computation, and communication into everyday things in order to make them and their surroundings "smart"
  - Smart things can detect where they are, sense what is around them, detect and communicate with other smart things, remember what they were used for previously, and reason about the kind of future actions they might likely be used for
- Smart Spaces are a realization of ubiquitous computing vision (with IoT on the bottom layer)
  - Digital entity that makes services available for each user in a seamless way using the most suitable available resources
  - Relevant real-world information is stored and kept up to date

Smart Space Application

Three kinds of capabilities to assist the everyday life of the users

1. Information sharing among participants
2. Monitoring the physical and logical surroundings
3. Control in a way that is meaningful for users' situations

§2. Smart Components

- Smart devices (autonomous computers)
- Smart environments (network of computers)
- Smart interaction (beyond the pure data transfer)

Candidate Smart Domains

Domains at different Granularity levels:

- City
- Confined Spaces
  - Private House
  - Public Buildings
  - Specialized Sites
    - Hospitals
    - Museums
    - ...
- Personal Spaces
  - Vehicles
  - ...

... and cross domain...

(Taken from Sofia project)

Smart Devices

- Tab, Pad, Board
- Embedded devices, sensors, implants
- Mobile devices
  - Multi-purpose ICT devices: mobile phone, camera, games console, ...
  - Loosely-bound to users (accompanied) or tightly-bound to users (wearable, implanted)
  - Personalized, configured to a specified owner
  - Single portal to internal and external services
  - Service access: Open service discovery and Intermittent resource access

Smart Environments

- Replacing physical labor, repetitive tasks, and hazardous work with automated agents
  - *Virtual computing environments:* smart devices access pertinent services anywhere and anytime
  - *Physical environments:* embedded with a variety of smart devices of different types including tags, sensors, and controllers
  - *Humans environments:* humans accompanied by smart devices
- Device-equipped environment with associated "digital representation"

Smart Environments

Three kinds of capabilities to assist the everyday life of the users

1. Information sharing among participants
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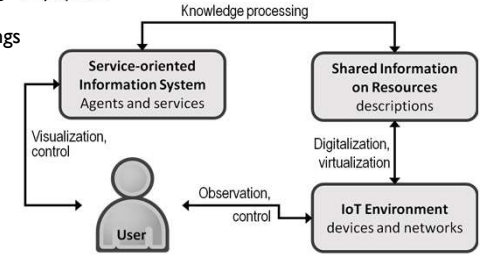
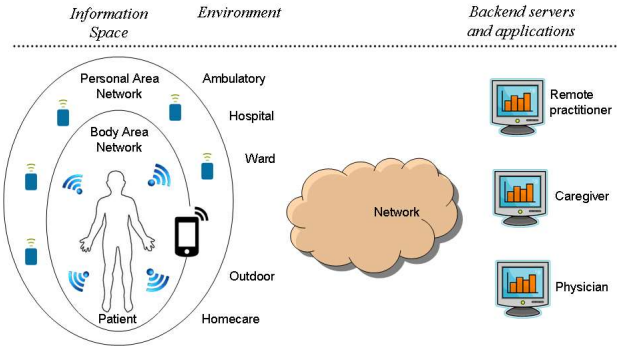
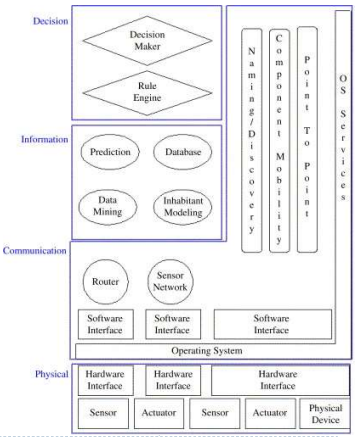


Example: Mobile Healthcare System Architecture



Components of a smart (intelligent) environment

D.J. Cook, S.K. Das. How smart are our environments? An updated look at the state of the art. Pervasive and Mobile Computing 3 (2007)



Smart Interactions

- Remote control of devices
- Resource discovery
- Information dissemination
- Predictive and decision-making capabilities
- Sensing physical environment and adapting behavior accordingly
  - where you are
  - who you are with
  - what resources are nearby

Gerrit Niezen's Definition

- A **smart space** is a physical space that contains networked electronic devices (smart objects, IoT objects) which continuously and autonomously
  - monitor the environment,
  - react according to contextual reasoning on the gathered data
  - adapt themselves to enhance user experience in the environment, by means of providing services
- Sensed contextual information can be used to control and configure services in a physical space according to user preferences
- Contextual information can be stored in a repository and be used for reasoning about user interaction events occurring in the smart space
- A smart space is distinguishable by its ability to use contextual information for the process of learning, reasoning and adapting its behavior

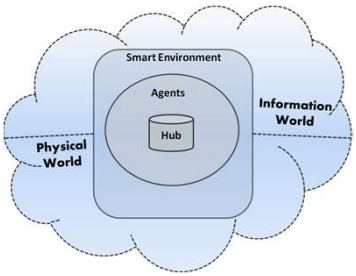
Summarizing: Smart Space

A ***smart space*** is a virtual, service-centric, multi-user, multi-device, dynamic interaction environment that applies a shared view of resources

Information hub: semantic relation vs. duplication from original data sources

There can be several smart spaces encompassed in the same digital environment

Summarizing: Terminology



- Computing environment
  - IoT-environment
  - Local / Localized / Global

  +
- Smart space

  =
- Smart environment
  - Smart application: service construction and delivery
  - Service: informational and control
  - Fusion of Physical and Informational Worlds

More examples

- Smart home
- Smart meetings
- Car smart space
- Smart traffic environment
- Building maintenance
- Smart city
- Healthcare smart space

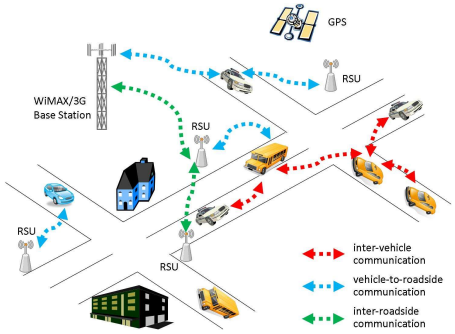
! Exploit these ideas for discussion

Smart Home

Smart Meeting

http://www.penketh.com

Smart Traffic Environment



§3. Features, Challenges, and Approaches

- Embedded, Mobile: many networked devices are integrated into the environment or they dynamically join/leave
- Sensible and Context aware: devices can recognize you and your situational context
- Personalized: they can be tailored to your own individual needs
- Adaptive: they change in response to you
- Proactive, Anticipatory: they understand your desires without conscious mediation

Technology models

Re-thinking of almost every aspect of computing needs to be done

- mobile wireless networks
- service-oriented computing
- human-computer interaction
- autonomous systems, context-awareness, artificial intelligence
- micro-electromechanical systems, sensors, robots

Lack of common standards

- Huge number of participating devices, vendors, product domains, and produced information
- Semistructured information:
  The same information can be used according with different structures

! Ontology-based approach can help here as we'll see later

No global central control

- Peer-to-Peer or Clouds?
- Various levels of hierarchy can help
  - Information division
  - Composition/decomposition
  - Multiple agents, small or relatively big

Human-computer interaction

- Previous models are inappropriate to the ubiquitous case
  - command-line
  - menu-driven
  - GUI-based
- New model has yet to emerge
  - Preliminary ideas appear in mobile phones, consumer electronics devices, radio-frequency identification tags (RFID), interactive whiteboards, automobile systems

Privacy and Security

- Is it good that the computers are invisible?
- Who can turn them off?
- Who controls the flow of information, and who has access to it?

People always try to misuse a technology to realize their own benefits

The opposite of virtual reality

- Virtual reality puts people inside a computer-generated world
- Ubiquitous computing forces the computer to live in the world with people

A very difficult integration of human factors, computer science, engineering, and social sciences

Smart Space Application

1. Many diverse devices
2. Localization, multi-source data
3. High dynamics (e.g., mobility)
4. Customization (personalization)
5. Context-awareness
6. Proactive service delivery

Use these properties in your projects!

Часть 1 проекта

Постановка задачи

- Концептуальная модель (визуальная схема).
- Основные функции (сервисы для пользователя).
- Построение сервисов взаимодействующими агентами (сценарии построения сервиса).
- Используемая аппаратура для запуска агентов.
- Близкие существующие решения по умному приложению.
- Как проявляется интеллектуальность.
- Размерность приложения (количественный состав агентов, пользователей, объемы данных).

Literature

- Mark Weiser. The Computer for the Twenty-First Century. Scientific American, pp. 94-104, 1991
- Diane Cook and Sajal Das. How smart are our environments? An updated look at the state of the art. Pervasive and Mobile Computing, pp. 53-73, Elsevier, 2007.
- Jon Mitchell. Inspiring The Internet Of Things: A Comic Book, 2011. http://www.alexandra.dk/uk/services/Publications/Documents/IoT_Comic_Book.pdf
- 50 Sensor Applications for a Smarter World http://www.libelium.com/resources/top_50_iot_sensor_applications_ranking/