Beyond Weiser’s Vision of Ubiquitous Computing

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Overview

- **Ubiquitous Computing: achievements √**
- Beyond Weiser’s model: Smart DEI model of Ubiquitous Computing
- Research Examples

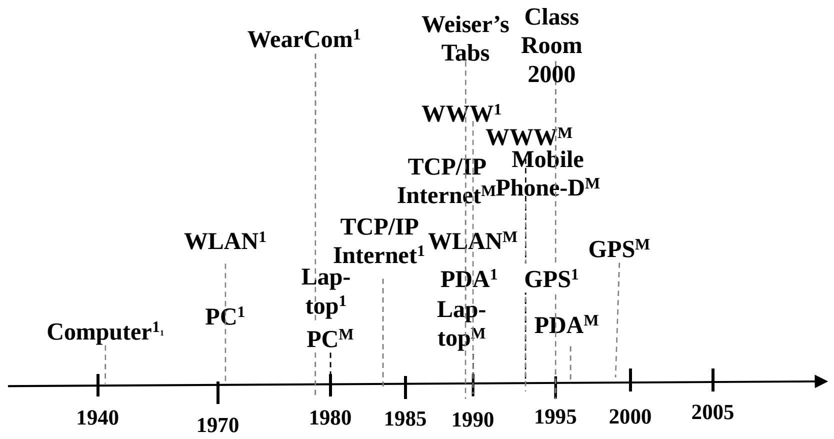
Ubiquitous Computing (UbiCom)

- The term ubiquitous, meaning appearing or existing everywhere, combined with computing forms the term Ubiquitous Computing (**UbiCom**)
  - Term introduced by Marc Weiser in early 1990s
  - Synonyms: pervasive computing, etc
- UbiCom describes a vision for computing to
  - Enable computer-based services to be made available *everywhere*
  - Support intuitive human usage but yet, appear to be *invisible* to the user.
  - *Situated* in physical (and human) world environments

What were ICT Environments Like?

- In the late 1980s, when much of the early work on UbiComp started
  - people were often unreachable if away from a fixed phone point
  - computing was only available at a desk computer, attached to the wired Internet.
  - some early models of personal computers but no laptops were available
  - no pervasive wireless networks were available
  - little location-determination for non-military personnel was available
- Let's look at the history of the main ICT development trends
  - A distinction is made between the availability of 1st prototypes (1) vs. 1st widespread commercial uptake of an ICT product (M).
  - Difference between the (1) and (M) phases is about 10 years.

Short History of ICT Technology



Could also note when specific PC technologies arose, e.g., hard-disk, mouse, removal memory cards, etc

Early UbiCom Research Projects

- Smart Devices: CCI
  - PARC Tab, MPad & LiveBoard; Active Badge, Bat and Floor
- Smart Environments: CPI and CCI
  - Classroom 2000, Smart Space and Meeting Room, Interactive Workspaces and iRoom, Cooltown, EasyLiving and SPOT, HomeLab and Ambient Intelligence
- Smart Devices: CPI
  - Unimate and MH-1 Robots, Smart Dust and TinyOS
- Smart Devices: iHCI
  - Calm Computing, Things That Think and Tangible Bits, DataTiles, WearComp and WearCam, Cyborg
- Other UbiCom Projects

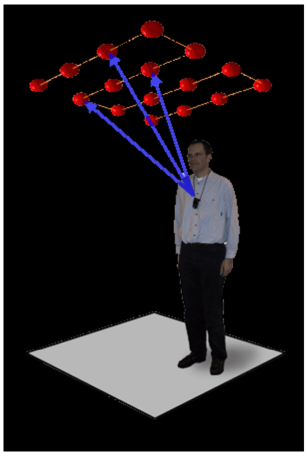
Active Badge, Bat and Floor

Active Bat

- Uses ultrasound, greater accuracy ~ 3 cm.
- Base station asks Bat for a signal that is then measured in multiple ceiling receivers (must add to environment), position determined using trilateration

Active Floor

- Unlike, Badge & Bat, identified someone by their type of walk or gait, not by carry an identifying token. Cons: scalability, accuracy
- Floor design requires a careful analysis to specify an appropriate spatial resolution and robustness to allow users to walk on sensors without damaging them.



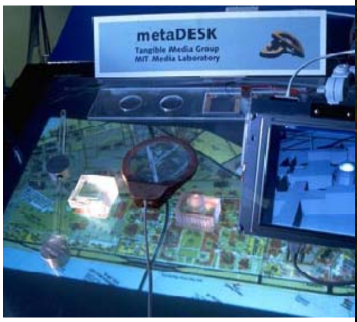
Cooltown

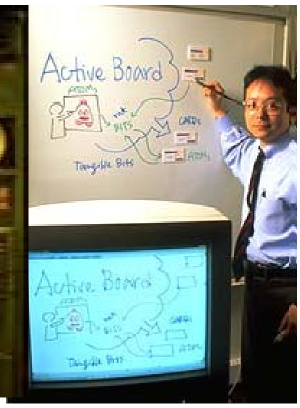
Car is one of 5 Cooltown demos. Here car detects it is low on fuel whilst on the way to a business meeting and guides user to a convenient filling station

iHCI: Calm Computing

- Example of calm technology was the “Dangling String” created by artist Natalie Jeremijenko, situated at PARC
- 8 foot piece of plastic spaghetti that hangs from a small electric motor mounted in the ceiling.
- Motor is electrically connected to a nearby Ethernet cable so that each bit of information that goes past causes a tiny twitch of the motor.
- Hence the degree of twitching indicates the degree of network traffic in that Ethernet segment.

Tangible Bits



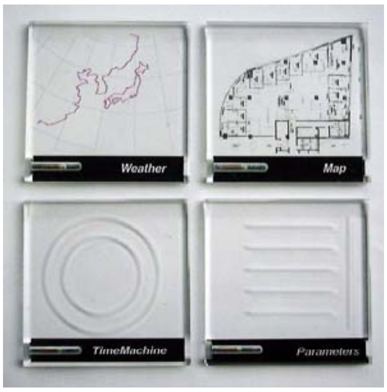


MetaDesk: tangible map

AmbientRoom:
Light patches
Bottles, Clock, Water ripples, handles

transBOARD:
Networked digital interactive whiteboard
Graphically view & record
Drawings, tagged pens

DataTiles



- Allows users to manipulate data in form of tangible "tiles"
- Combinations of data streams and functions make it possible to create new applications

WearComp and WearCam

- Mann's experiments with wearable computers started in late 1970s.
- Main application was recording personal visual memories that could be shared with other via the Internet.
- (Photo from http://en.wikipedia.org/wiki/Wearable_computing)

Cyborg 2.0

Electrode array surgically implanted into Warwick's left arm and interlinked into median nerve fibres is being monitored.

Analysis of Early Projects: Distributed Access Support

- Mobile device model design for Tabs and Pads.
- Supported communication & location-awareness for mobile users, commercial mobile ICT devices, widely available wireless networks.
- Late 2000s, mobile devices such as phones and laptops are widely used and wireless networks are widely available that support data communication routing to users wherever they are
- Service discovery of local network resources is weak and the discovery of other local environment resources is still virtually non-existent
- Hence, much of the vision of Cooltown is not routinely available.
  - smart environments not yet mature or widely available.
  - diversity of support needed, cost and secure fixings.

Analysis of Early Projects: context-awareness

- Context-awareness: mainly location awareness
- Early achievements based upon (local not global) location awareness indoors with heavily instrumented environment.
- Legacy: Global Location determinism (via Mobile phone, GPS) but accuracy limited to 10s of M.
- Integrated into some mobile devices, e.g., phones, cameras, cars.
- Location-determinism tends to be supported mainly as stand-alone devices and services that are not readily interoperable.
- Mainly for outdoor use.
- Systems for indoor use are available today based, e.g., based upon trilateration using WLAN but not ubiquitous

Analysis of Early Projects: iHCI

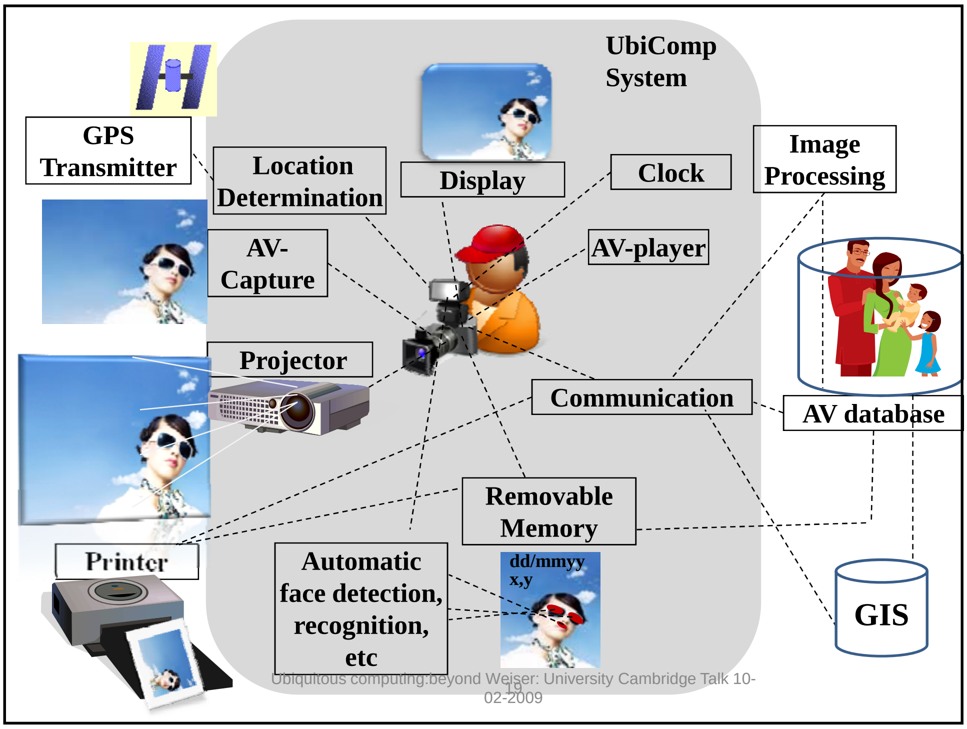
- Electronic boards
  - Allow users to collaboratively edit text and graphics
  - PARC prototype in early 1990s now commercial products.
  - “Classroom 2000” use in 1995-1998 (Abowd) now routinely used in many educational establishments
- Wearable smart devices
  - several products are available but not in pervasive use.
- Robots
  - Heavy use in clean room manufacturing, not in open environments apart from cleaning, mowing robots and robot toys and pets
- iHCI
  - A continuing research initiative.
  - Very many variations
  - Mass market ? But Wii is popular

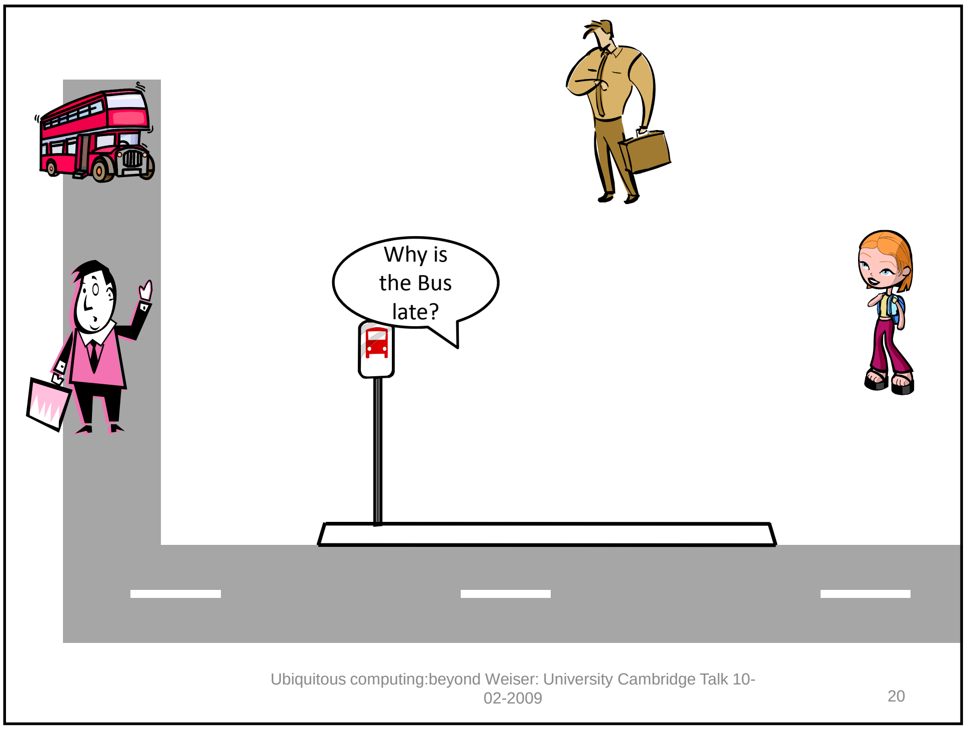
Today: Living in an Increasingly Digital, Interconnected, World

- More everyday human activities heavily reliant on computers
- More devices per person, building, transport vehicle, etc
- Greater variety of general purpose vs. task specific computer devices
- Devices smaller/ larger?, cheaper, use less energy, reliability ↑ (or ↓?)
- Profusion of multi-purpose, intelligent, mobile devices can access remote services ... and more local services
- Physical & Human world strewn with embedded sensors & control devices
- More devices can interoperate in ad hoc versus planned ways
- High speed wire(less) networks are pervasive & accessible by all, can be added less disruptively into the physical environment .
- ↑ Energy efficient devices , yet ↑ overall energy consumption

Everyware UbiCom Applications

- Vision: ubiquitous computer systems to support people in their daily activities in the physical world tasks to simplify these and to make these less obtrusive.
- People will live, work, and play in a seamless computer enabled environment that is interleaved into the world.
- Bushnell (1996) coined variations of term *ware* such as deskware, couchware, kitchenware, autoware, bedroomware and bathware to reflect the use of ubiquitous computing for routine tasks.
- Greenfeld (2006) used the term *everyware* to encompass the many different types of ware
- Some Everyware scenarios follow


UbiComp
System
GPS
Transmitter
Location
Determination
Display
Clock
Image
Processing
AV-
Capture
AV-player
Projector
Communication
AV database
Removable
Memory
Printer
Automatic
face detection,
recognition,
etc
dd/mmyy
x,y
GIS
Ubiquitous computing:beyond Weiser: University Cambridge Talk 10-
02-2009
19


Why is
the Bus
late?
Ubiquitous computing:beyond Weiser: University Cambridge Talk 10-
02-2009
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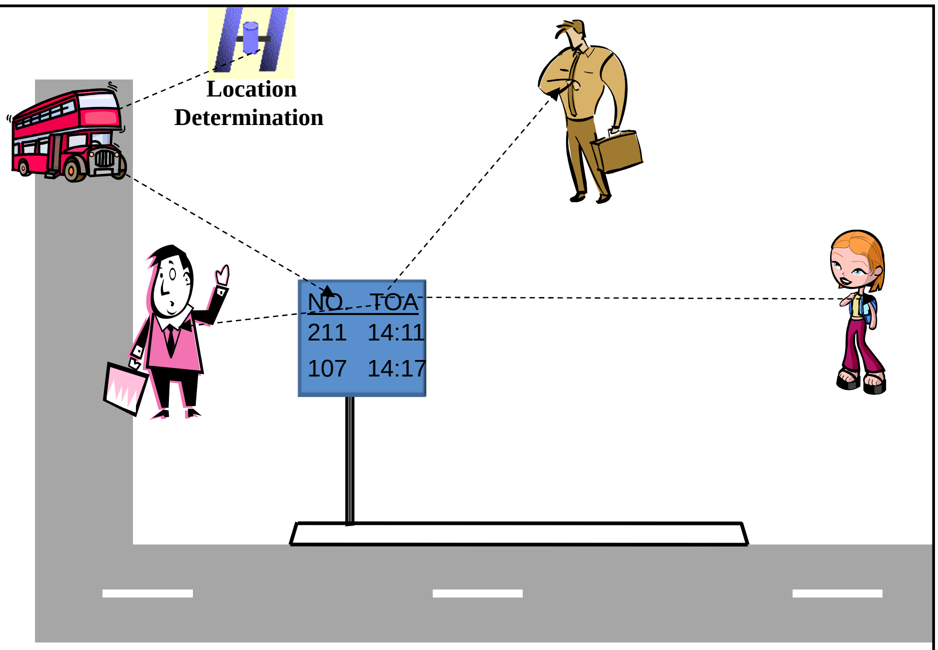
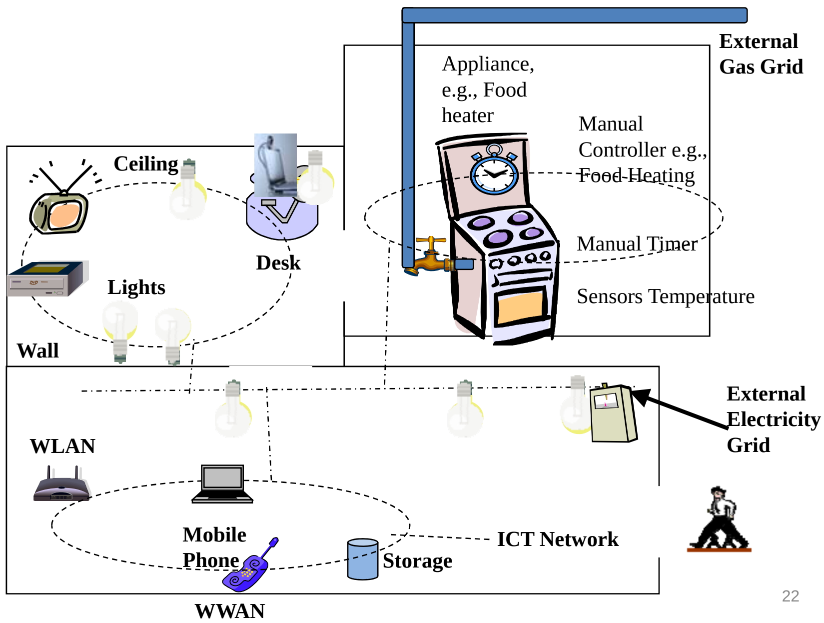
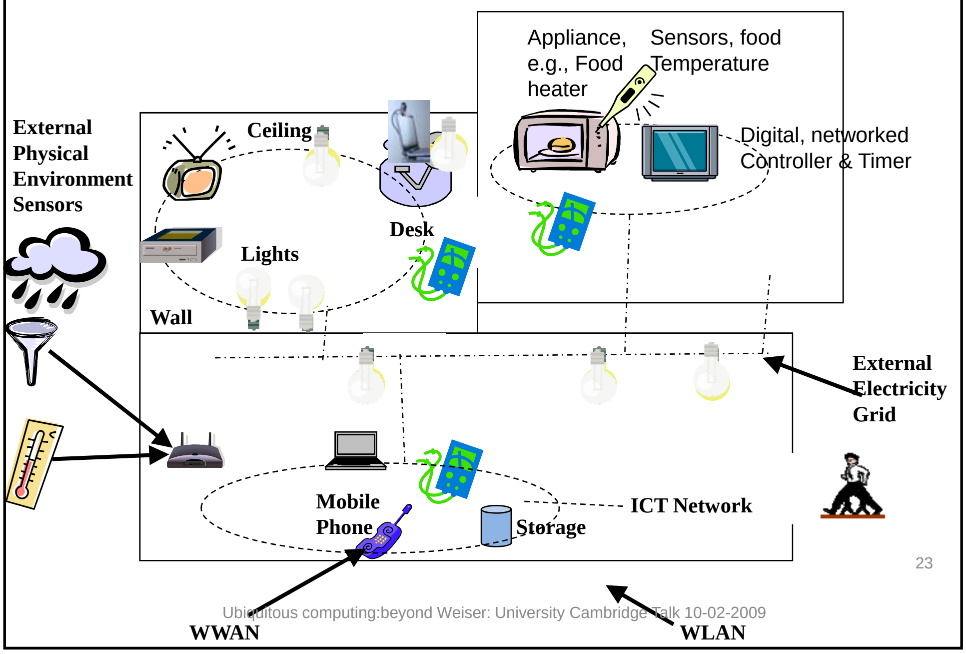


Location
Determination
NO. TOA
211 14:11
107 14:17



External
Gas Grid
Appliance,
e.g., Food
heater
Manual
Controller e.g.,
Food-Heating
Manual Timer
Sensors Temperature
Ceiling
Desk
Lights
Wall
External
Electricity
Grid
WLAN
Mobile
Phone
Storage
ICT Network
WWAN



Overview

- Ubiquitous Computing: achievements
- **Beyond Weiser's model: Smart DEI model of Ubiquitous Computing √**
- Research Examples

UbiCom: Weiser's 3 Internal System Properties

3 main properties for UbiCom Systems were proposed by Weiser (1991)

1. Computers need to be networked, *distributed* and transparently accessible
   – In1991, little wireless computing, Internet far less pervasive
2. Computer *Interaction* with Humans needs to be more *hidden*
   – Because much HCI is overly intrusive
3. Computers need to be *aware* of *environment context*
   – In order to optimise their operation in their physical & human environment.

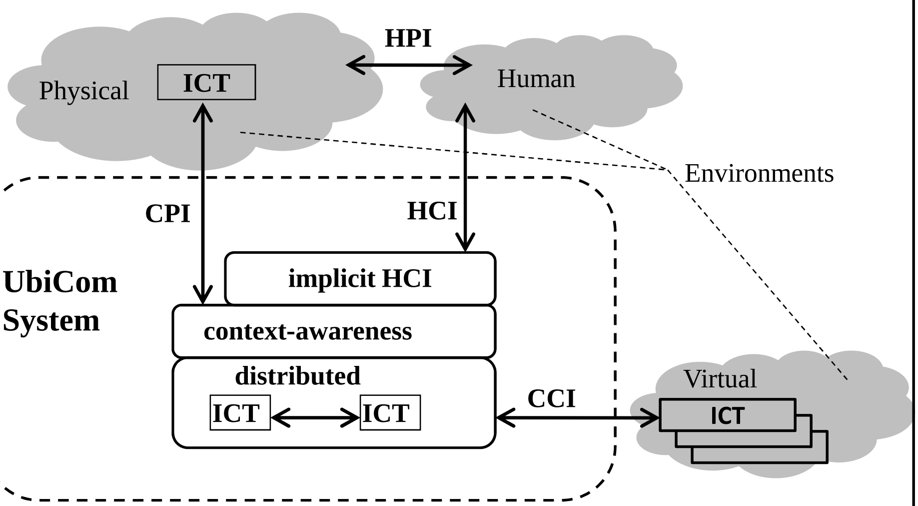
Internal System Properties: iHCI

- Concept of calm or disappearing computer model:
  – Device too small to be visible, embedded,
  – Devices visible, not noticeable, part of peripheral senses
- Implicit (iHCI) versus Explicit HCI
  – Much HCI is explicit, low-level, more devices -> human overload
  – More natural, less conscious interaction
  – Systems anticipate use -> explicit interaction ↓
  – Calm Computing
  – If explicit HCI ↓, -> careful balance between several factors
- Embodied Reality as opposite of VR (people in virtual world)
  – Devices as embodied, env. aware, service access & execute entities
  – Devices aware of, & bounded by, physical, not just virtual env.

Internal System Properties: context-aware

- Context-based ubiquity rather than global ubiquity
- Physical Environment Context: location, time, temperature, rainfall, light level etc.
- Human Context (or User context or person context): interaction is usefully constrained by users' identity; preferences; task requirements, etc.
- ICT Context or Virtual Environment Context: UbiCom system is aware of the services available that are available internally and externally, locally and remotely
- Active (by system) versus passive context adaptation (by user)

Devices: Weiser's 3 Internal System Properties



Devices: Extended set of Internal System Properties

3 main properties for UbiCom Systems were proposed by Weiser

1. Computers need to be networked, *distributed* and transparently accessible.
2. Computer *Interaction* with Humans needs to be *hidden* more
   – Because much HCI is overly intrusive
3. Computers need to be *aware* of *environment context*
   – In order to optimise their operation in their physical & human environment.

To which two additional properties are added:

4. Computers can operate *autonomously*, without human intervention, be self-governed
5. Computers can handle a multiplicity of dynamic actions and interactions, governed by intelligent decision-making and intelligent organisational interaction. This entails some form of *artificial intelligence*.

UbiCom: Different Combinations of Core Properties versus a Single Definition

- No single, absolute definition for ubiquitous computing.
- Instead propose many different kinds of UbiCom based upon combining different sets of core properties

Here are some examples proposed by others

- Weiser (1991): distributed, iHCI, physical environment context aware
- Ambient Intelligence (AmI), similar to UbiCom - intelligence everywhere?
  - Arts and Marzano (2003) define 5 key features for AmI to be embedded, context-aware, personalised, adaptive and anticipatory.
- Buxton (1995): ubiquity and transparency
- Endres et al. (2005): distributed mobile, intelligence, augmented reality
- Millner (2006): autonomy, IHCI etc

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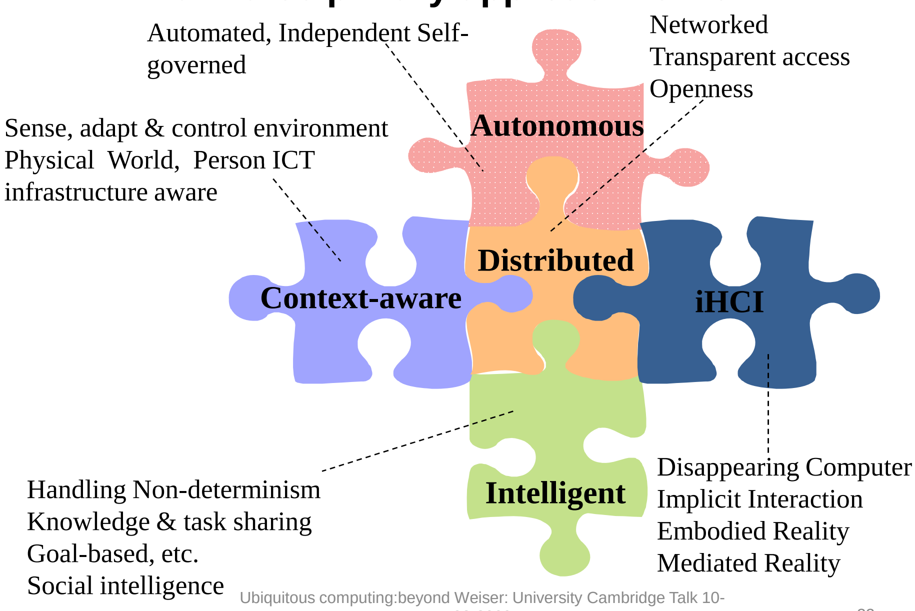
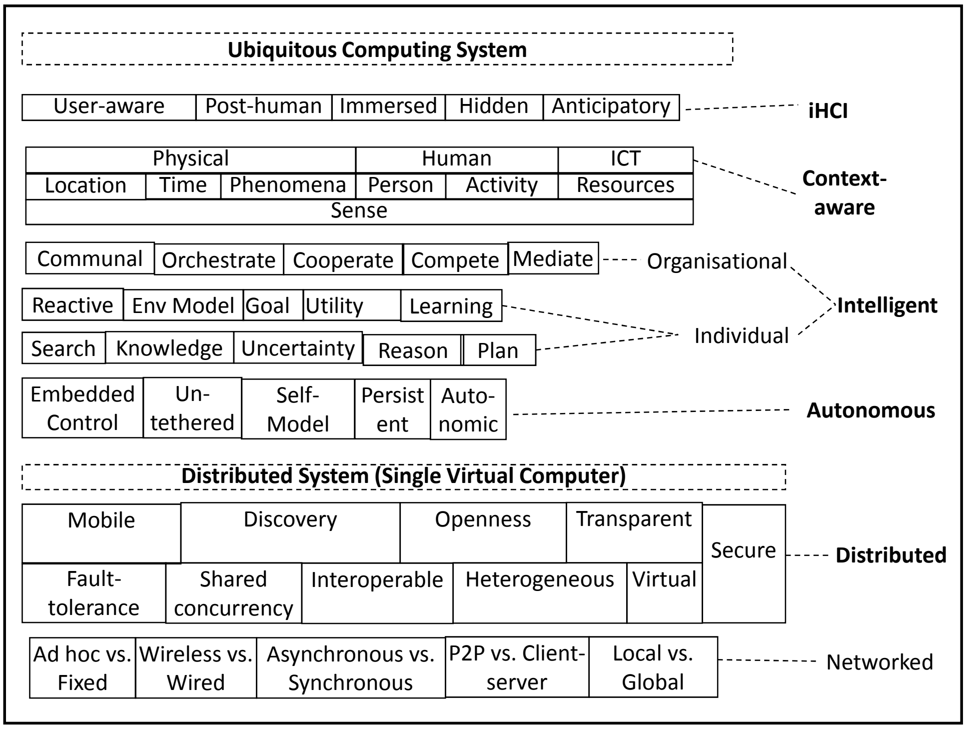
UbiCom System Model: Smart DEI

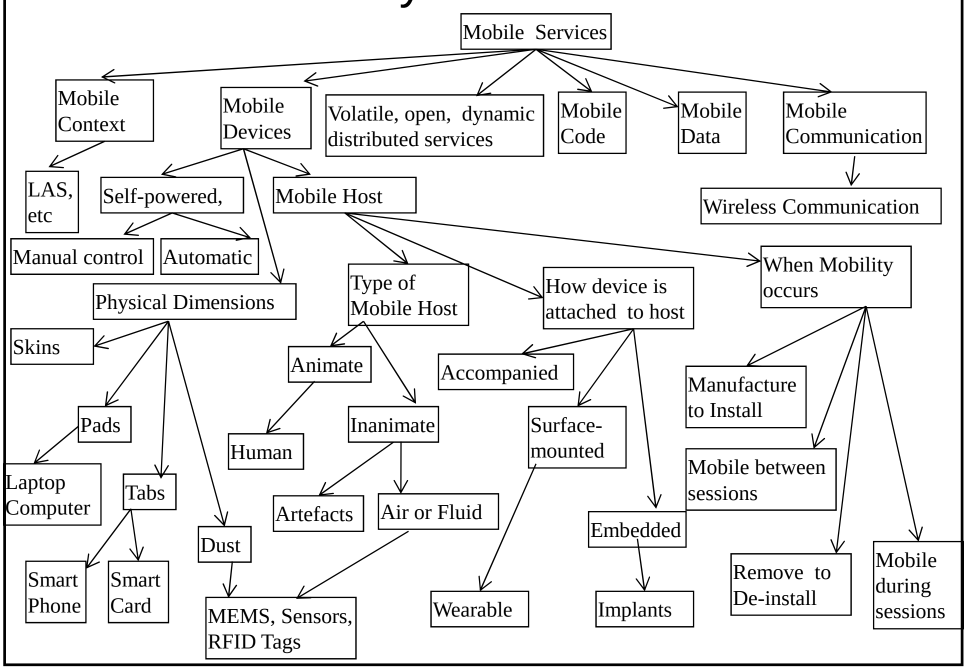
- No single type of UbiCom system
- Different UbiCom systems applications support:
  - Internal properties (distributed, iHCI etc) to different degrees
  - Different types (phys. virtual, human) of external environment interaction to different degrees
  - Different form-factors (six basic forms) for devices
  - Multiple systems can combine to form interacting systems of systems
- 3 basic architectural design patterns for UbiCom:
  - smart **D**evices, smart **E**nvironments, smart Interaction
- ‘Smart’ means systems are:
  - active, digital, networked, autonomous, reconfigurable, local control of its own resources, e.g., energy, data storage etc.

Five main properties for UbiCom require a multi-disciplinary approach to R&D

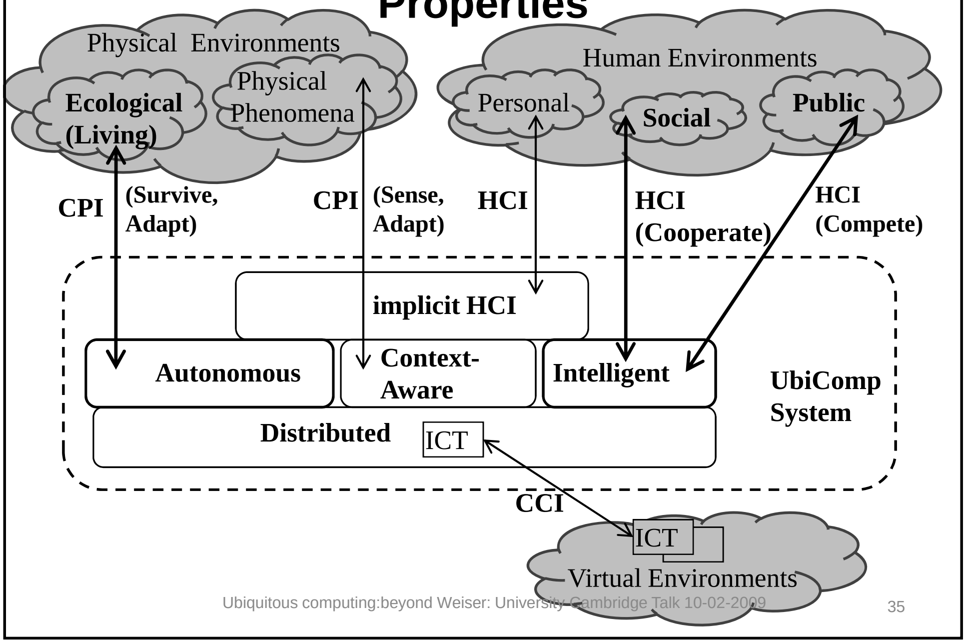




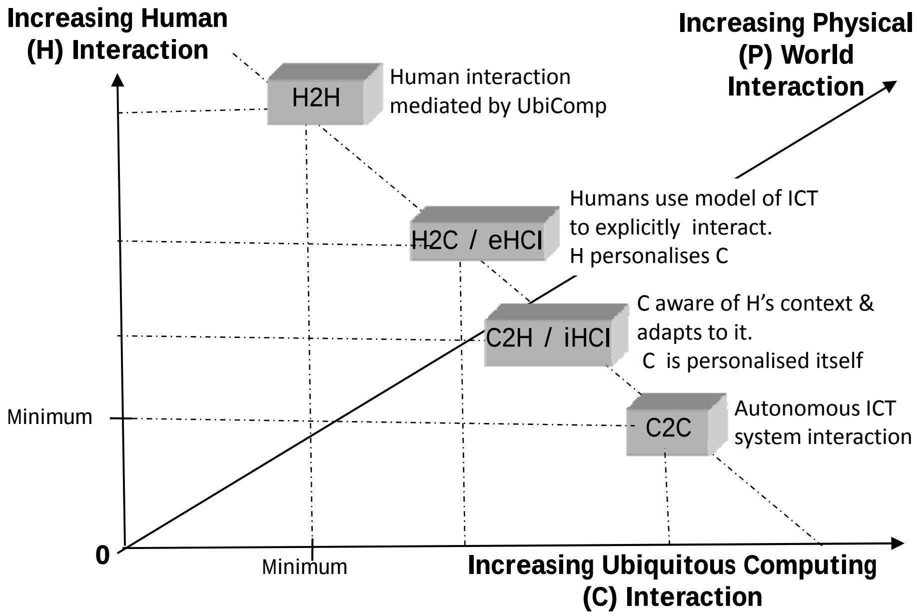
Mobility: Dimensions



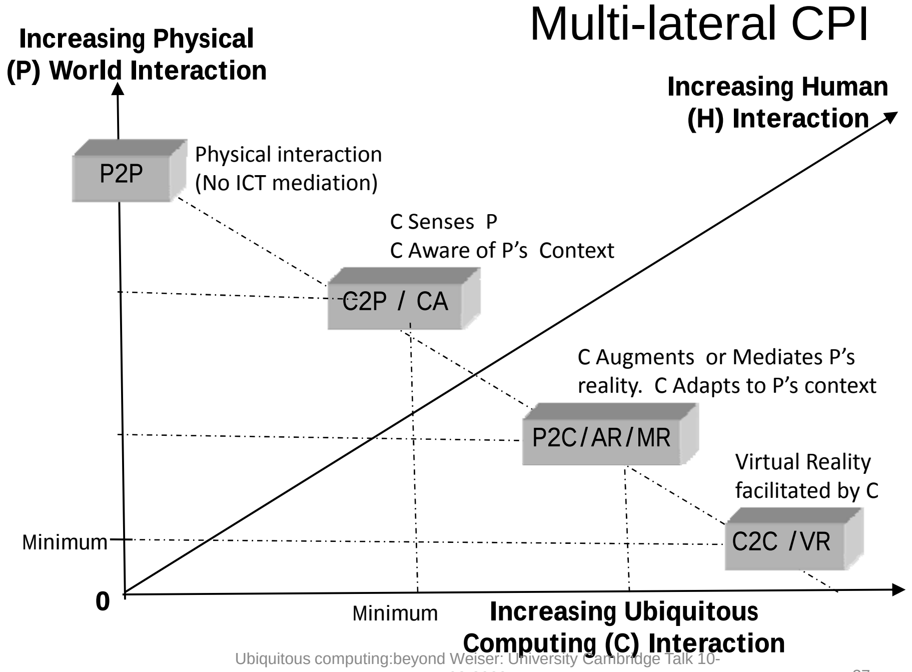
Devices: Extended set of Internal System Properties



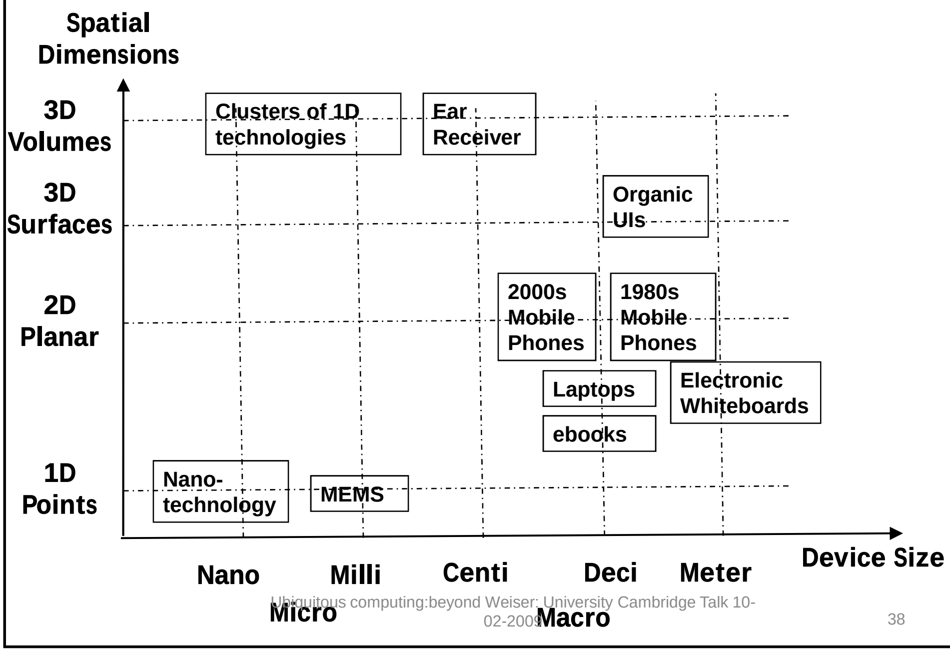
Multi-lateral HCI



Multi-lateral CPI



Form Factors for Smart Devices



UbiCom System Model: Smart DEI

Device Trends

Increasing capability to manufacture low power, micro, more complex devices

Use more complex, multi-functional, mobile, personalised (& private) **smart devices** to ease access to & embody services rather than just to virtualise them

e.g., phone is also a camera, music player, is also a printer??

Increasing capability to embed devices in the physical environment

Use **smarter environments** to sense and react to events such as people, with mobile devices , entering & leaving controlled spaces

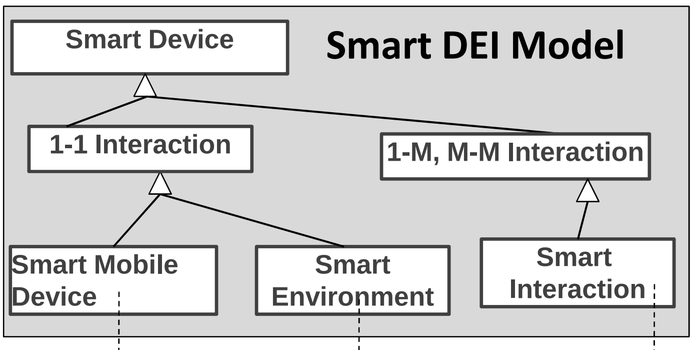
e.g., walls can sense camera is recording and modify lighting to improve recording

Increasing capability for more interoperable distributed mobile devices

Use more service access devices with simpler functions and allow them to interoperate – **smarter interaction** between devices

e.g., camera can interconnect to phone to share recordings, direct to printer to print

Ubiquitous Computing



Mobile, Personalised, MTOS, Remote 1-1 interaction

Design: Fat-client-proxy-server ?

Fixed vs. Untethered, ASOS, sense-control, local 1-1 interaction

Design: Autonomous Peer-to-Peer interaction?

1-M, M-M, richer (coop, compete, semantic, etc), P2P interaction

Design: Appliance Model, Service Pool, Remote Service Access Point, Service Contract, on-demand, autonomic?

Design Thin-client-proxy-server interaction?

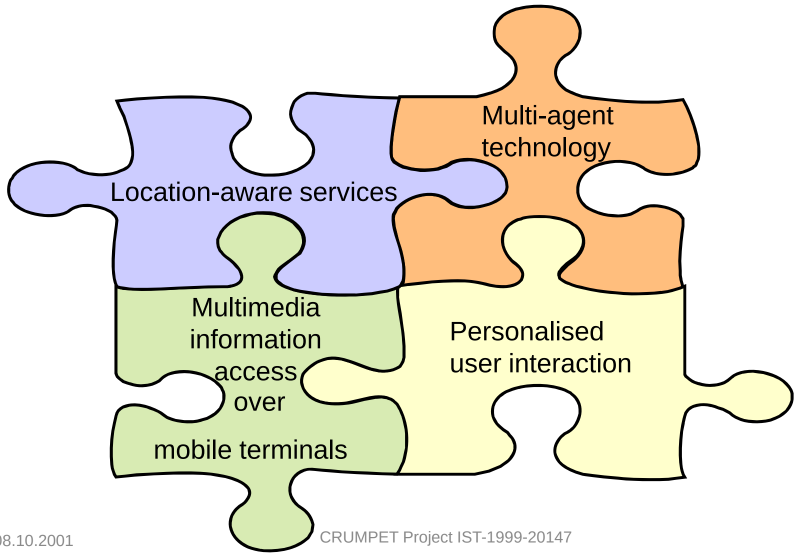
Overview

- Ubiquitous Computing: achievements
- Beyond Weiser's model: Smart DEI model of Ubiquitous Computing
- **Research Examples √**

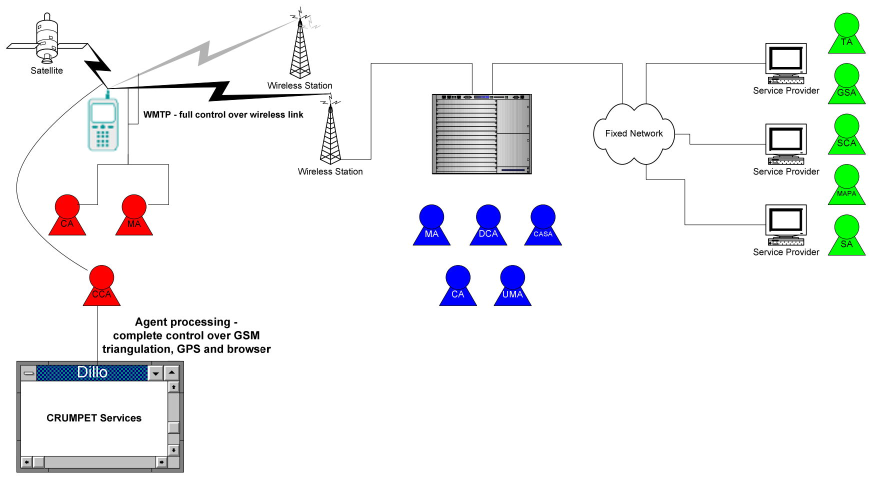
CRUMPET, CReation of User-friendly Mobile Personalised for Tourism Project

- The main objectives of the CRUMPET project was to:
  - Implement and trial tourism- related value-added services for nomadic users:
  - Evaluate the use of agent technology as a suitable approach for the fast creation & composition of such services.
- Hence based upon a Multi-Agent System (MAS design), to
  - ACL to factor out common service actions to ease interoperability across services
  - Semantic approach to service mediation to integrate multi-service content
  - Content adaptation for mobile use & heterogeneous ICT, wireless network, terminals
  - Location-aware map service
  - Personalisation
- Two designs
  - Active intelligent mobile client (micro agent platform) aids content adaptation
  - Passive mobile client (micro-browser)

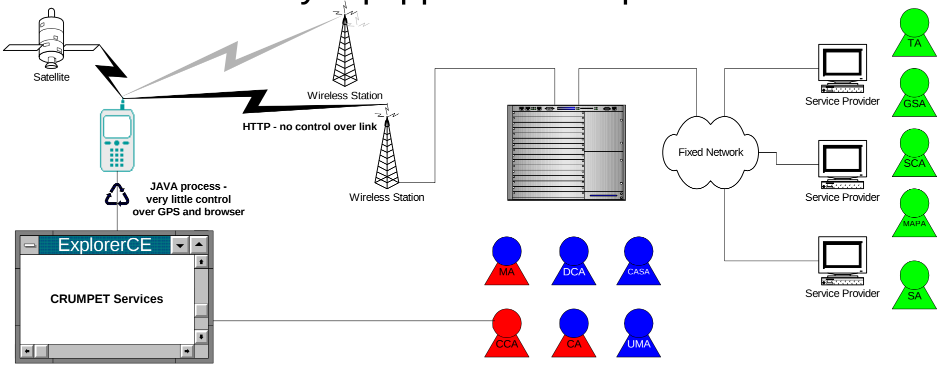
CRUMPET Project integrates 4 key technologies



Architecture Variation A: This deployment architecture has a larger client-side footprint and is suitable for deploying in high end PDAs and PCs

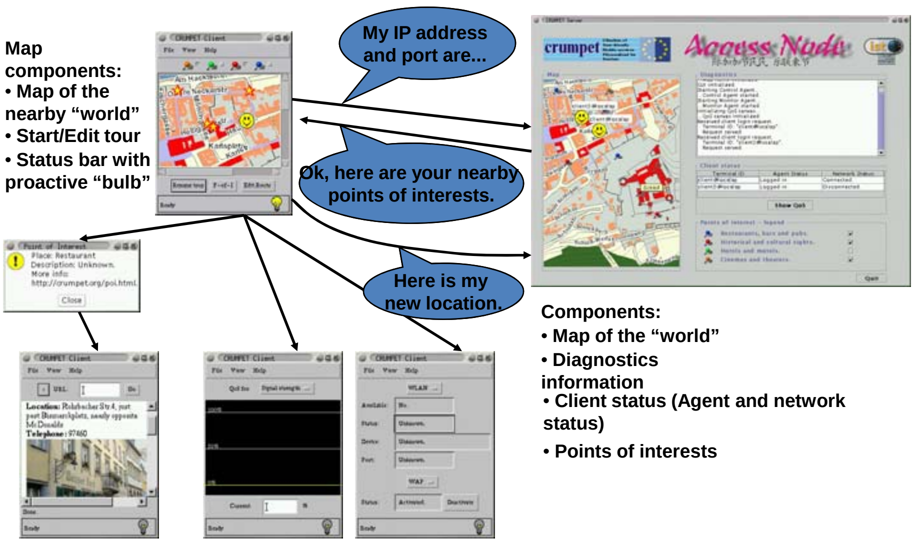


Architecture Variation B: This deployment architecture has a very small client-side footprint and is suitable for deploying in low end PDAs and suitably equipped mobile 'phones



CRUMPET ICT Adaptation

Map components:
- **Map of the nearby "world"**
- **Start/Edit tour**
- **Status bar with proactive "bulb"**



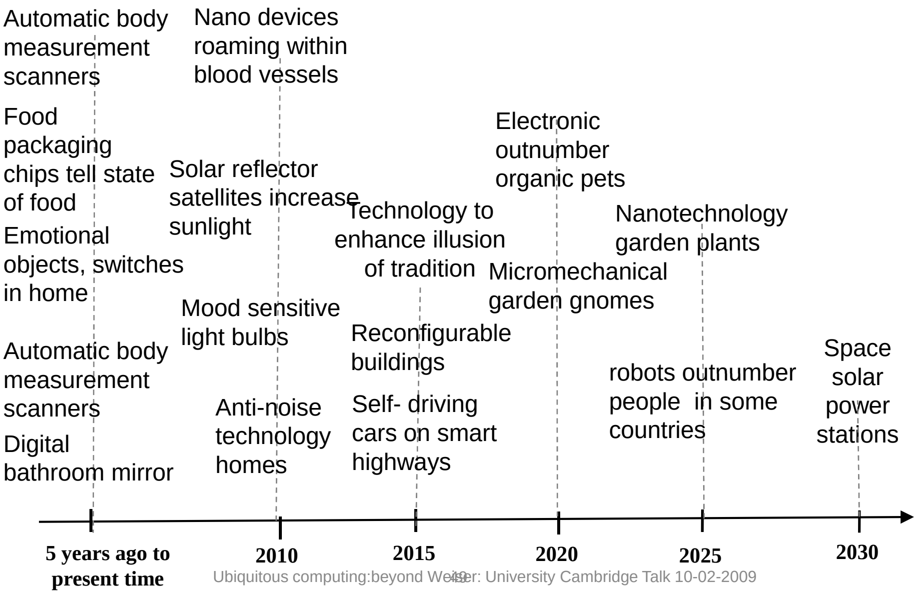
Components:
- **Map of the "world"**
- **Diagnostics information**
  - **Client status (Agent and network status)**
  - **Points of interests**

CRUMPET System

Crumpet System: conclusions

- Low resource terminals find it challenging to parse rich semantic messages
- Multi-lateral approach to adapt content:
  - E.g., variable image compression, text headings vs. whole body, etc
- Context acquisition & composition design:
  - What is an event: user stopping? Etc?
  - Ordering: location -> personalisation -> terminal or different
  - Generic versus specific adaptation e.g., personalisation
- Agent design
  - Simple reactive and proactive
  - ACL need?

Pearson (2000) Predictions for Smart Environments



Conclusions

- Good opportunities for mass use of smart devices and context-ware devices began relatively recently – these opportunities are expanding.

- References

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