SSC0156 – Computação Pervasiva

Chapter 1

Ubiquitous Computing: Basics and Vision

Prof. Jó Ueyama

Overview

- **Living in a Digital World √**
- Modelling the Key Ubiquitous Computing Properties
- Ubiquitous System Environment Interaction
- Architectural Design for UbiCom Systems: Smart DEI Model
- Course Outline

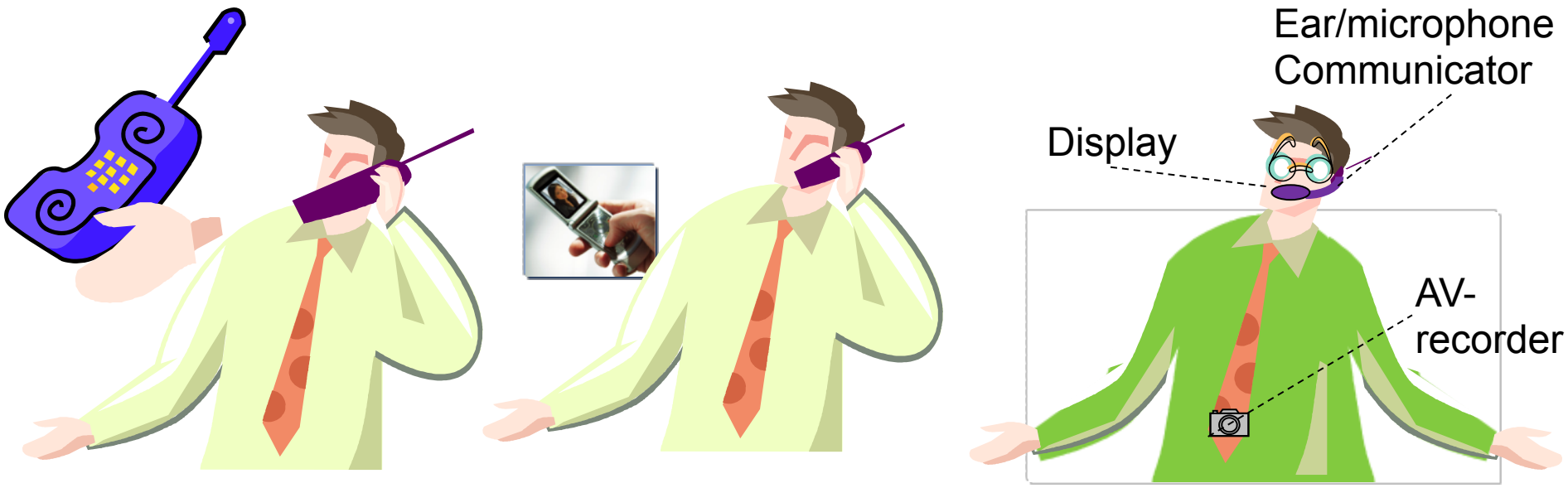
Ubiquitous Computing (UbiCom)

- A vision for computing to:
  - Enable computer-based services to be made available everywhere (Ubiquitous)
  - Support intuitive human usage
  - But yet, appear to be invisible to the user.
  - Also referred to as pervasive computing etc

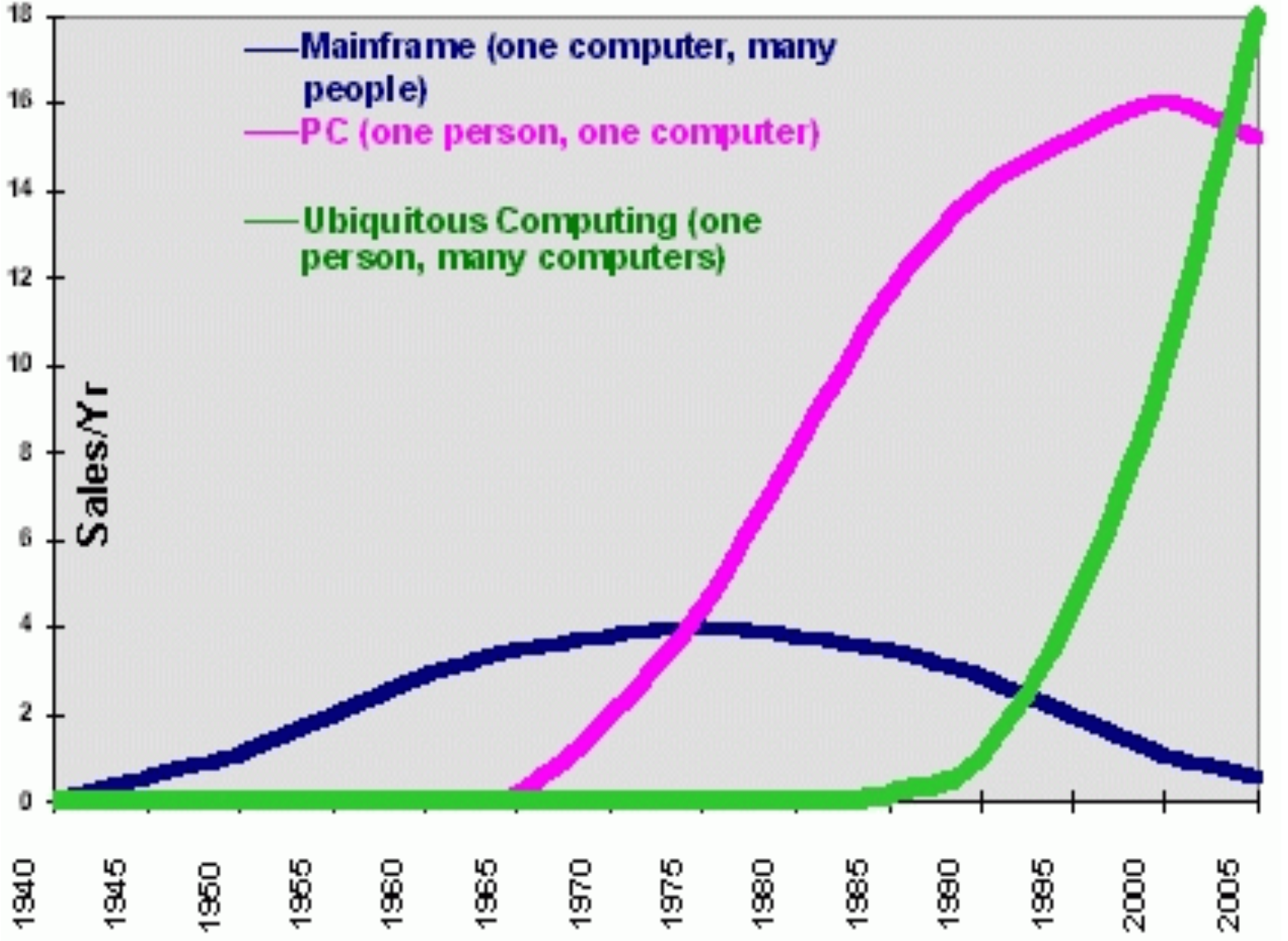
Living in an Increasingly Digital, Interconnected World

- *What are the current technology trends in UbiCom?*

Trend: smaller, higher resource devices



Trend: Weiser's 3 waves of computing



Living in an Increasingly Digital, Interconnected World

- *What will the future be like?*

Scenarios

4 scenarios illustrate a range of benefits and challenges of ubiquitous computing:

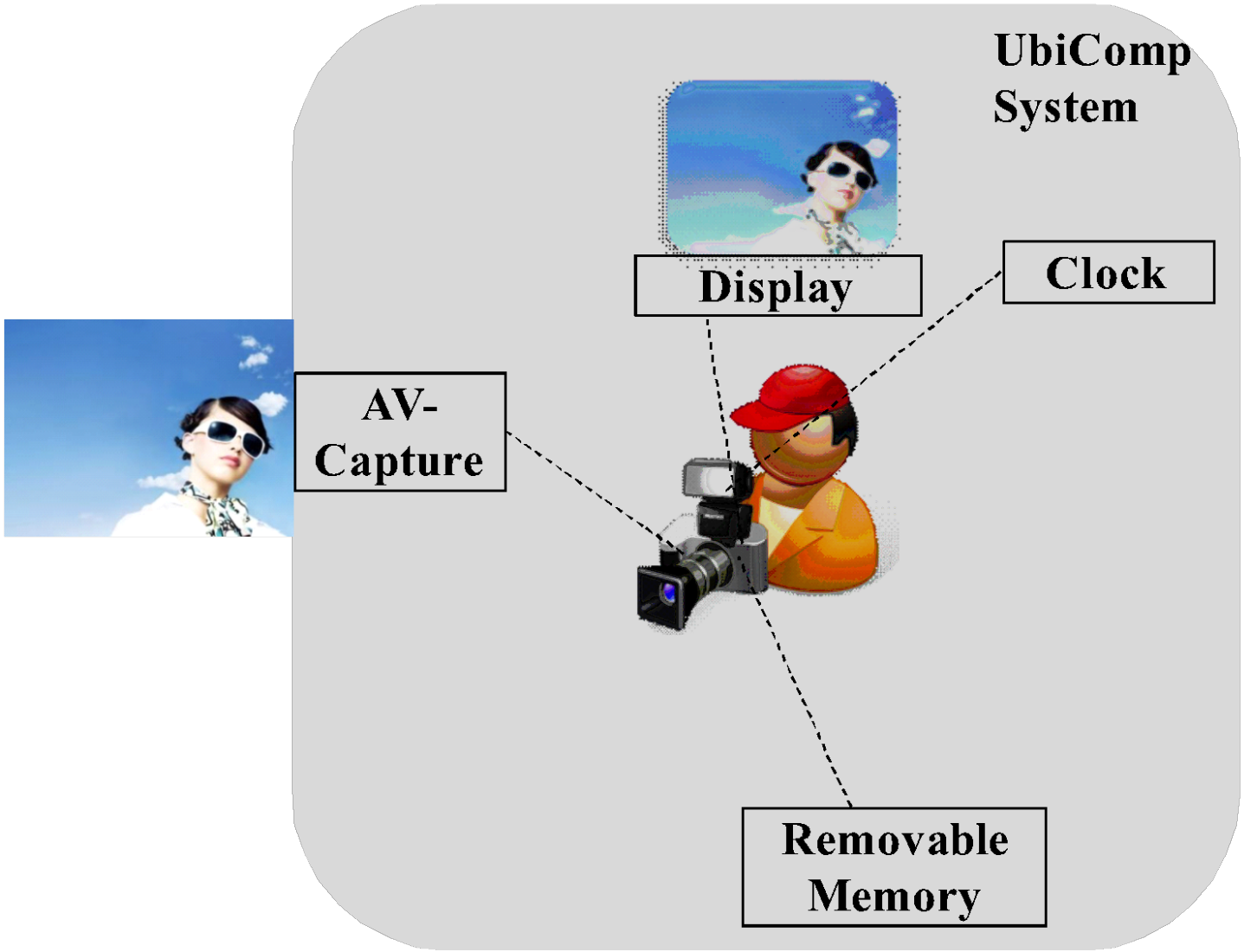
- Personal memories
- 21st Century Scheduled Transport Service

- Foodstuff management
- Utility regulation

N.B. many other scenarios & applications given later

- e.g., Chapter 2 describes some key projects and gives an overview of applications.

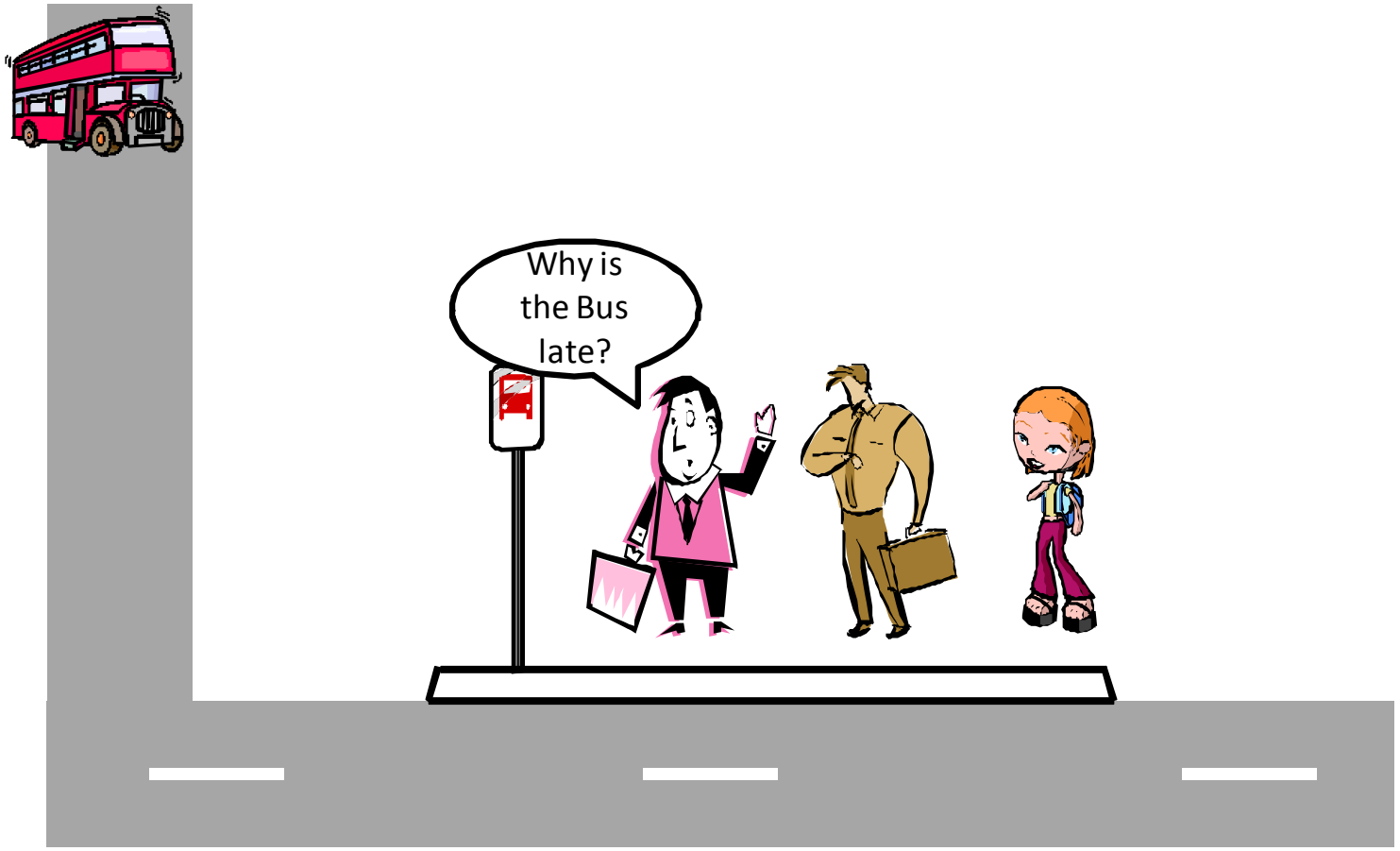
Personal Memories Scenario



Personal Memories Scenario

- How can we enhance the personal memories service using UbiCom?

21st Century Scheduled Transport Service Scenario



21st Century Scheduled Transport Service

How can we enhance the transport service using UbiCom?

- GPS,
- integration with a traffic management system

Foodstuff Management Scenario

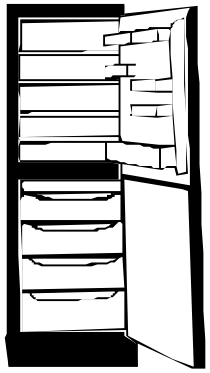
Select & Buy food at physical or virtual market

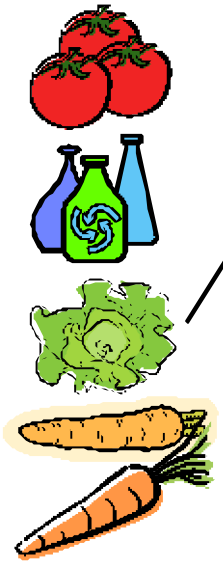
Transport food to home store

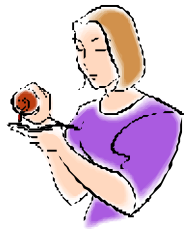
Put in home store

Select food from store, get & transform food into a meal

Consume food





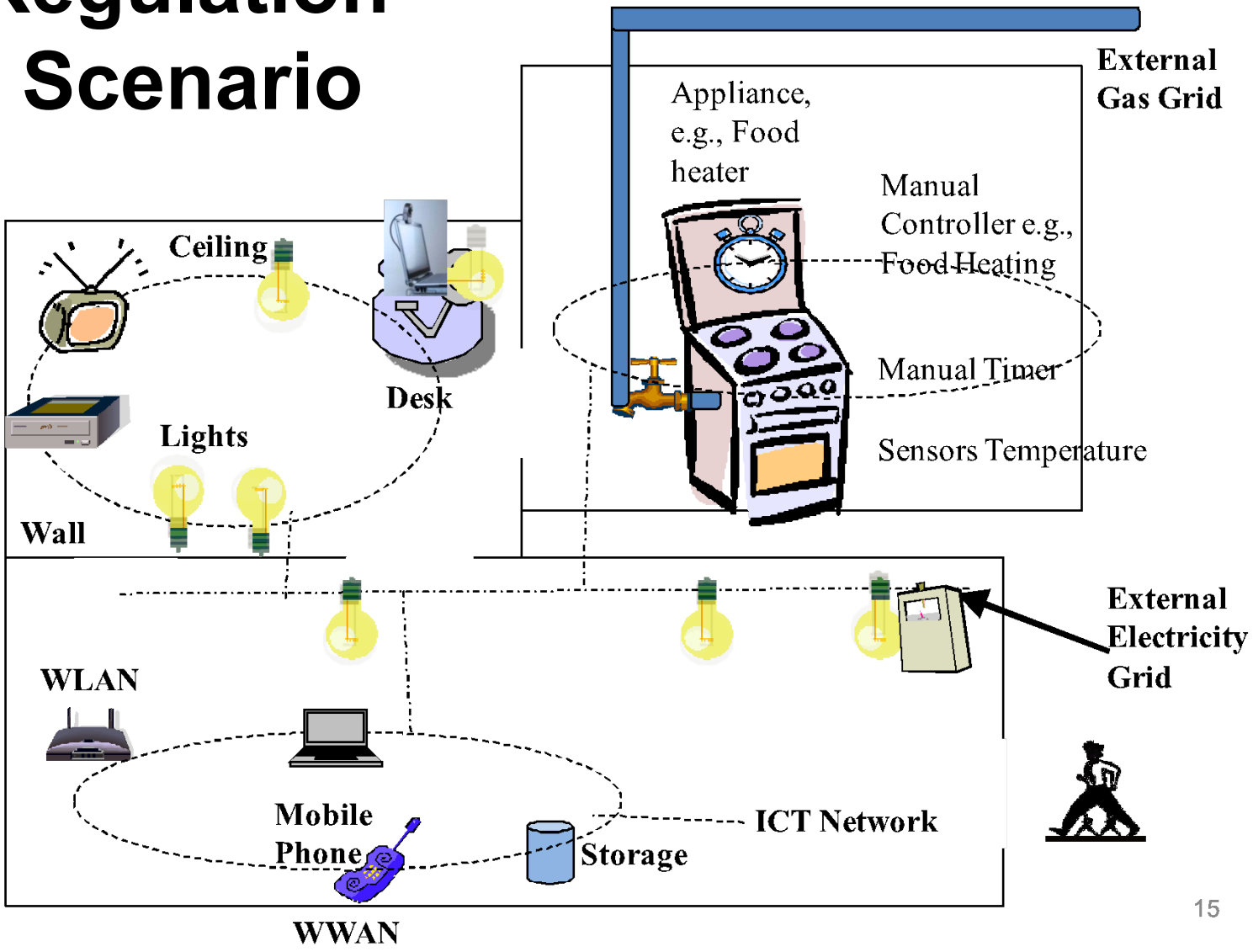


Foodstuff Management Scenario

How can UbiCom enhance the foodstuff management scenario?

- Eating a balanced diet
- Food in and out
- Weight of food
- Expiry dates

Utility Regulation Scenario



Utility Regulation Scenario

- Utility regulation concerns energy, water, waste regulation by end-users.
  - Natural light and heating suffices?
  - Novelty detection
  - Use energy according to tariffs (e.g. washing machine, etc.)

How can UbiCom enhance the Utility Regulation scenario?

UbiCom System Design

For these scenarios

- Which system designs should be used for:
  - comms., data storage, processing, sensing, control etc
- How to model system - physical world interaction?
- How to model human computer system interaction?
- These are covered later in this course.

Overview

- Living in a Digital World
- **Modelling the Key Ubiquitous Computing Properties √**
- Ubiquitous System Environment Interaction
- Architectural Design for UbiCom Systems: Smart DEI Model
- Course Outline

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
- What core system properties would you propose to define ubiquitous computing?
- Three main types of design for UbiCom systems
  - Smart device
  - Smart environment
  - Smart interaction

.

UbiCom: Weiser's 3 Internal System Requirements

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.

Devices: Extended set of Internal System Requirements

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

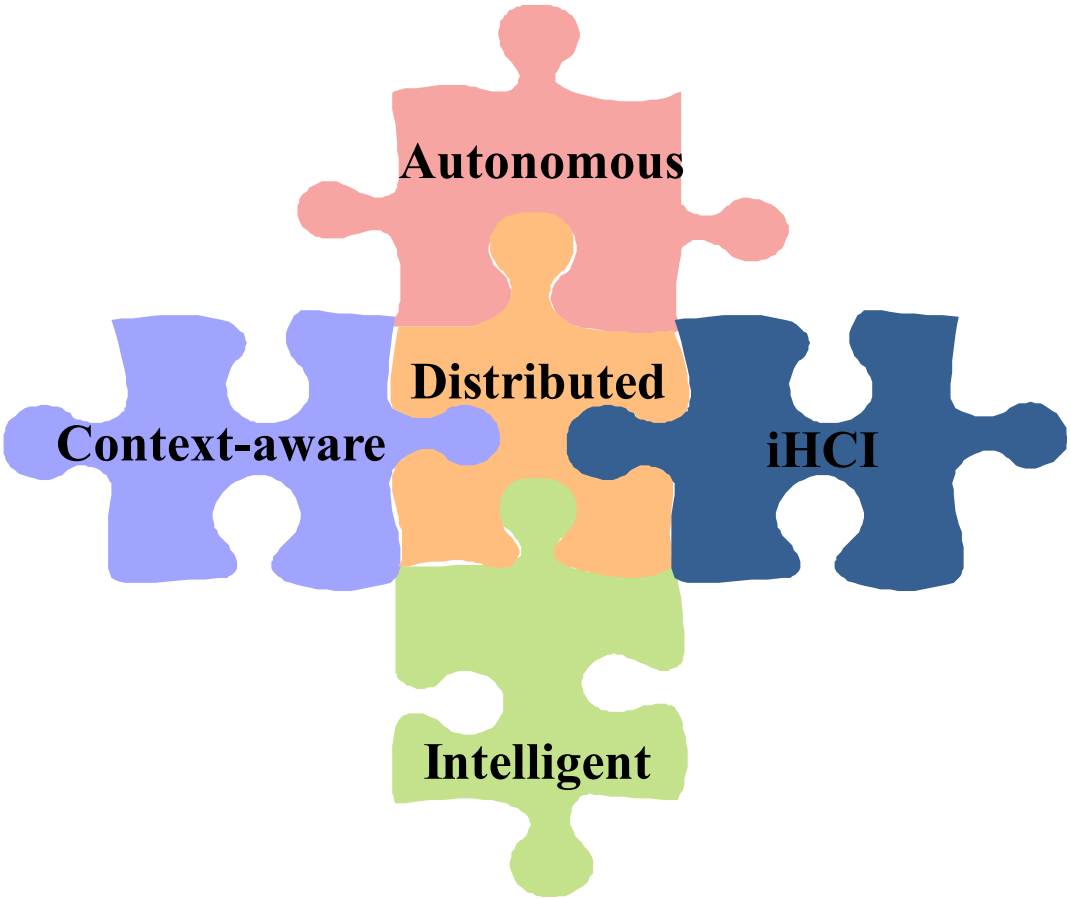
Here are some examples proposed by others

- 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.

Exercise: Do your own survey of UbiCom definitions and highlight the properties they define.

.

Five main properties for UbiCom



UbiCom System Properties: Distributed

- Networked ICT Devices
  - Offer services that are locally and remotely accessed.
- Transparency
  - Embedded or hidden
  - Transmit via BT and/or Wi-Fi?
- Openness
  - Often it brings complexity and availability
  - Open implementation, not closed, i.e., interoperable
  - UbiCom camera may discover printing services and send photos; they can be sent thereafter

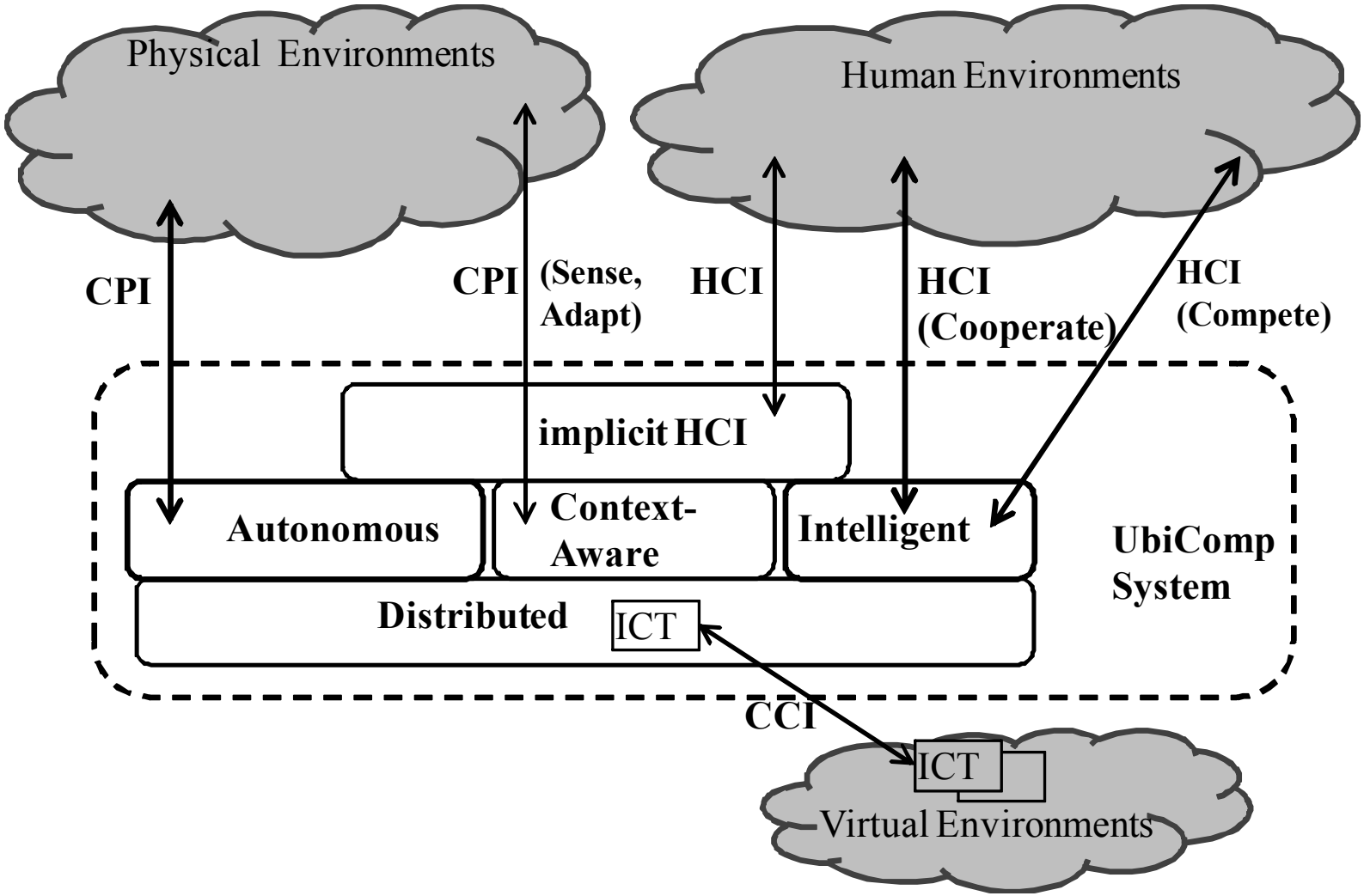
Distributed System: sub-properties

- Often designed middleware, set of generic services
- Universal, Seamless, Heterogeneous
  - Generic tool is better or worse? Why?
- Networked
- Synchronised, Coordinated
- Open
- Transparent, Virtual
- Mobile, Nomadic (solved forwarding packets to foreign network)

Internal System Properties: iHCI

- Concept of *calm* / *disappearing computer* has several dimensions
- Implicit (iHCI) versus Explicit HCI
  - Detect user and usage context
- Embodied Virtuality as opposite of VR (people in virtual world)

Devices: Extended set of Internal System Properties



iHCI: Sub-Properties

Implicit Human Device Interaction (iHCI)

- Non-intrusive, Hidden, Invisible, Calm, computing
- Tangible, Natural
- Anticipatory, Speculative, Proactive
- Affective, Emotive
- User-aware
- PostHuman
- Sense of Presence
- Immersed, Virtual , Mediated reality

Internal System Properties: context-aware

- Often *Context-based ubiquity* rather than global ubiquity
  - Why?

3 Main Types of Context

- *Physical Environment Context*
- *Human Context* (or *User context* or person context)
- *ICT Context* or *Virtual Environment Context*:

Context-aware: sub-properties

- Also referred to as Sentient, Unique, Localised, Situated
- Presupposes sensing of environment to be aware of its context
- Adaptive: active versus passive context-aware (vehicles break - active; GPS positioning – passive)

Types of environment aware

- Person-aware, User-aware, Personalised, Tailored,
- Environment-aware, Context-aware, Physical context-aware
- ICT infrastructure aware
- (See Chapter 7)

Internal System Properties: Autonomy

- Autonomy property – it enables a system to control its own actions independently.
- Challenge 1: increasing computer systems can overload humans – humans become a bottleneck
- What can be done?

Internal System Properties: Autonomy

- Challenge 2: automated system can become too complex to maintain
  - must reduce maintenance of ↑ complex systems
- What can be done?

Autonomy: Sub-Properties

- Automatic
- Embedded, Encapsulated
- Embodied
- Resource-constrained
- Untethered (not tied), Amorphous (no specified shape)
- Autonomic, Self-managing, self-star properties
- Emergent, self-organising

Internal System Properties: Intelligence

Intelligent UbiCom systems (IS) can:

- Act more proactively, dynamically & humanely through:
- Model how their environment changes when deciding how it acts.
- Discover local resources such as the nearest printer
- Goal-based / planning
- Reasoning for re-planning (in case something goes wrong)
- Handle uncertainty, incompleteness
- Semantic and knowledge based behaviour
  - to be able to interoperate between heterogeneous systems and their components

Individual Intelligence: Sub-Properties

- Referred to as Intelligent Systems, AI, agent-based system etc.

Sub-Properties (sub-types of individual intelligence)

- Reactive, Reflex (environment is sensed and actions are taken)
- Model-based
  - system use a model of how it operates; models can be the below ones
  - Rule/Policy-based
  - Logic/Reasoning
  - Goal-oriented, Planned, Proactive
  - Utility-based, Game theoretic (can handle multiple common goals)
  - Learning, Adaptive (improve their own performance)

Multiple Intelligence: Sub-Properties

- Referred to as Distributed AI, Multi-Agent Systems, Collective or Social Intelligence

Sub-Properties

- Cooperative , Collaborative, Benevolent (multiple agents can cooperate towards shared goals)
- Competitive, self-interested, antagonistic, adversarial (single agent can compete towards its own goal)
- Orchestrated, Choreographed, Mediated (multiple interactions are coordinated by one elected leader)
- Task-sharing (multiple agents share a task between a limited domain)
- Communal, shared meaning
- Shared knowledge

Multiple Intelligence: Sub-Properties

- Speech-act based , Intentional, Mentalistic
  - Multiple agents interact upon attitudes
    - Relationships based upon
      - Benefits
      - Desires
      - Wants
      - intentions

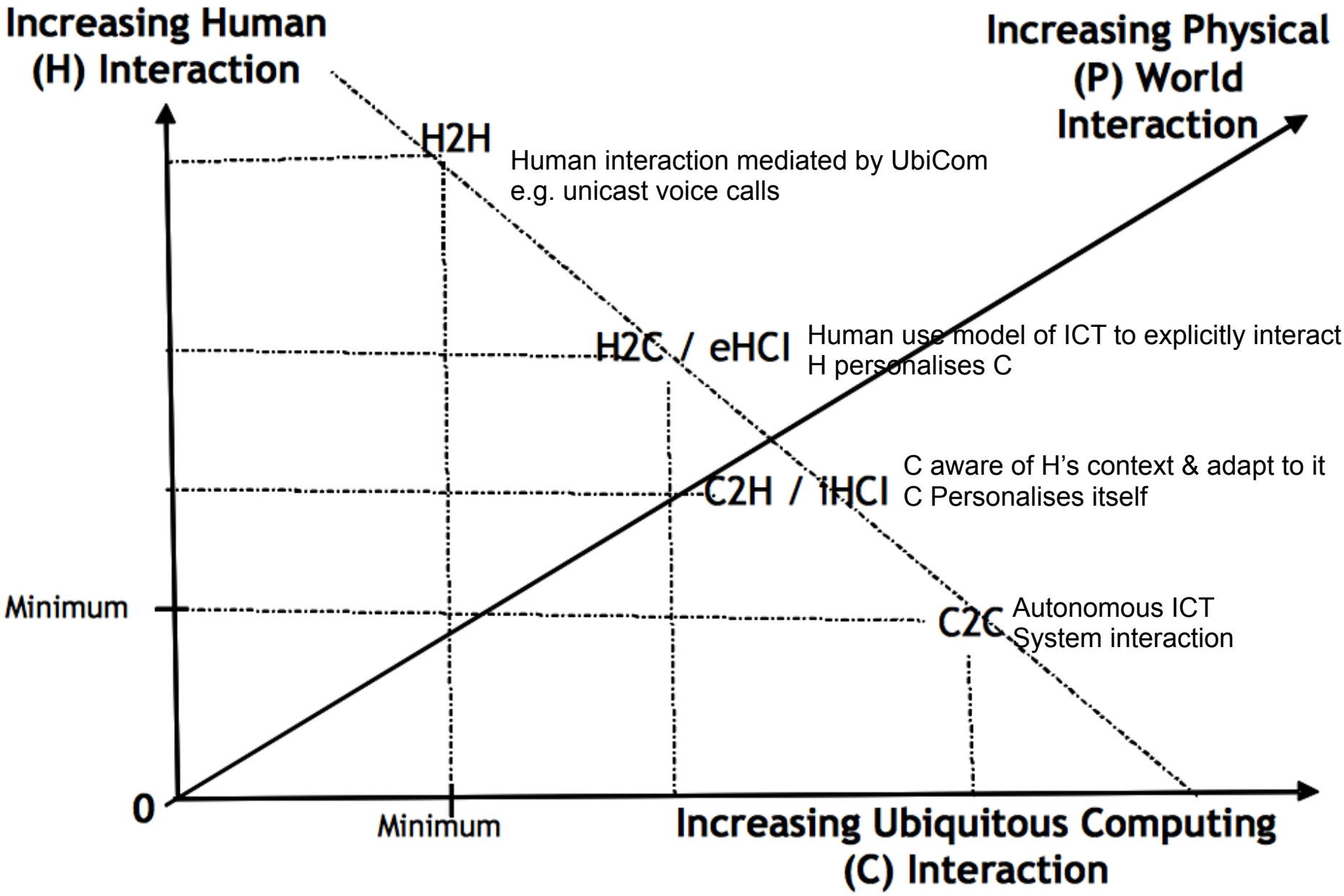
Overview

- Living in a Digital World
- Modelling the Key Ubiquitous Computing Properties
- **Ubiquitous System Environment Interaction √**
- Architectural Design for UbiCom Systems: Smart DEI Model
- Course Outline

UbiCom System versus ICT System focus

- Conventional focus on ICT systems
- Systems situated in a virtual world, in an environment of other ICT systems -> a system of ICT systems
- Conventional use a restrict view of physical environment interaction:
- Conventional ICT systems often require humans in the loop
- UbiCom represents a powerful shift in computation:

Different Degrees of HCI



Different Degrees of HCI

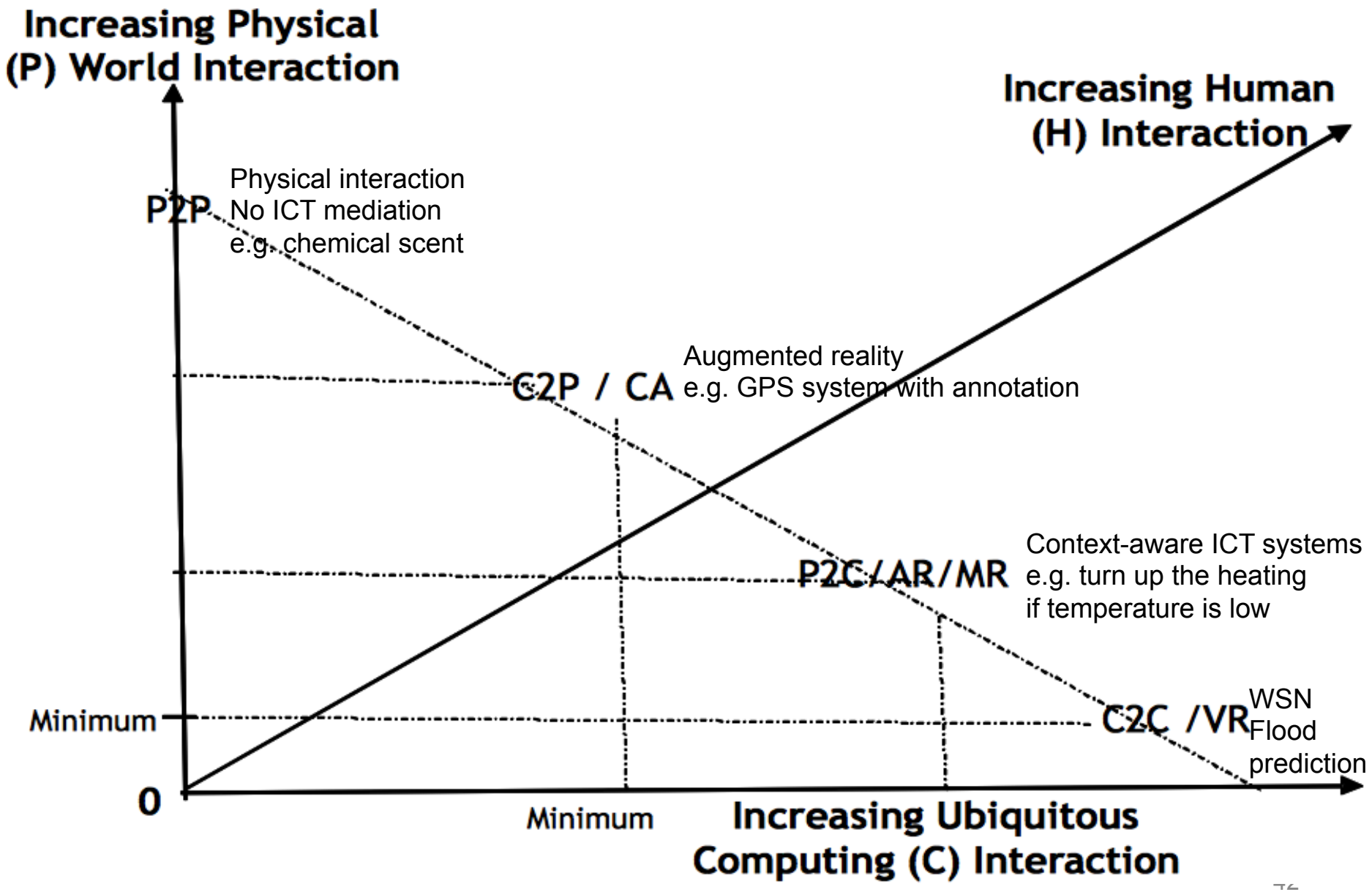
- From less to more C Interaction with H
- H2H: human interaction

- H2C or explicit (e)HCI:

- C2H or implicit (i)HCI:

- C2C:

Different Degrees of CPI



Different Degrees of CPI

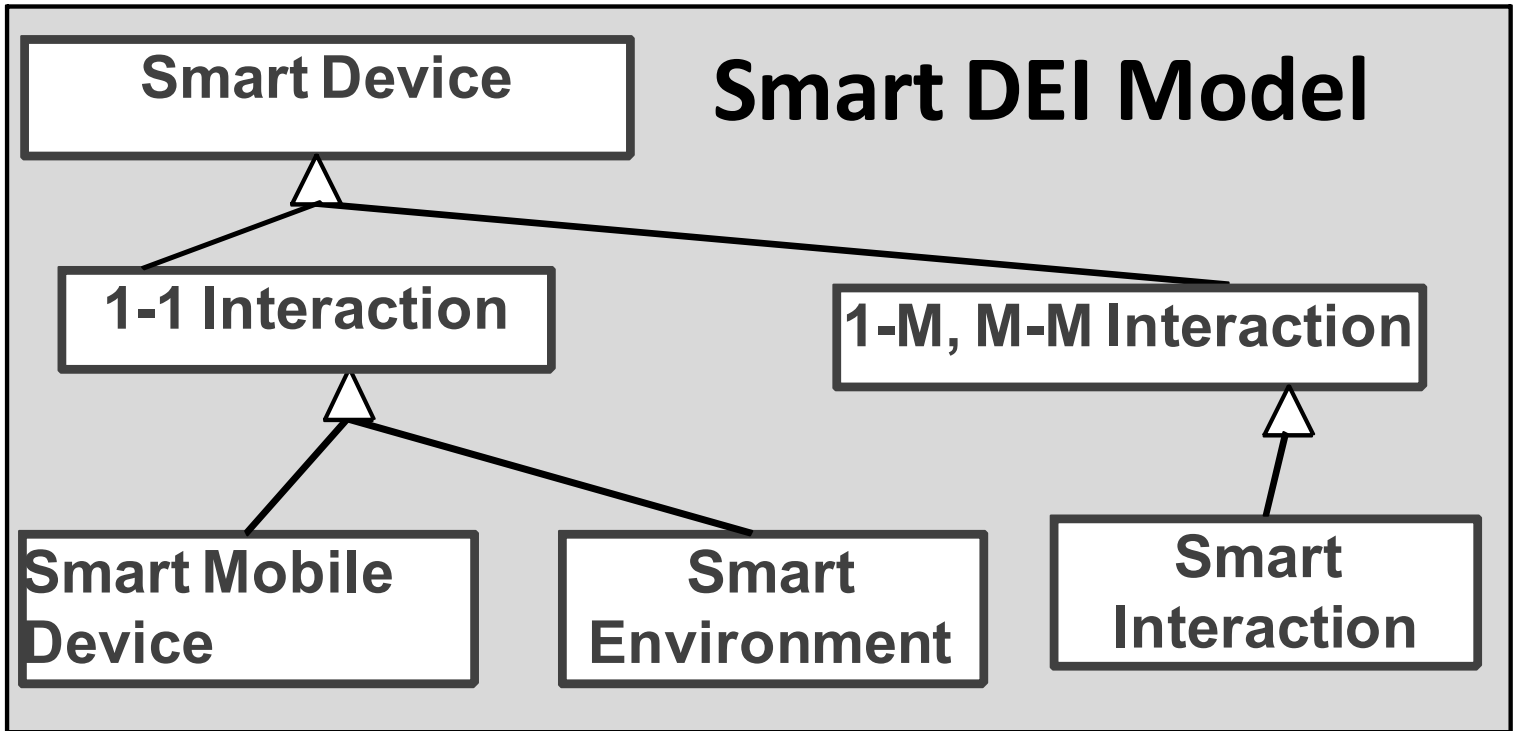
- From less to more C Interaction with P
- P2P
  - Physical interaction (No ICT mediation)
- C2P / CA (Physical Env. Context-aware)
  - C Senses P. C Aware of P's Context
- P2C/AR/MR
  - C augments or mediates P's reality.
  - C actively adapts to P's context
- C2C /VR
  - Virtualisation of reality facilitated by C

Overview

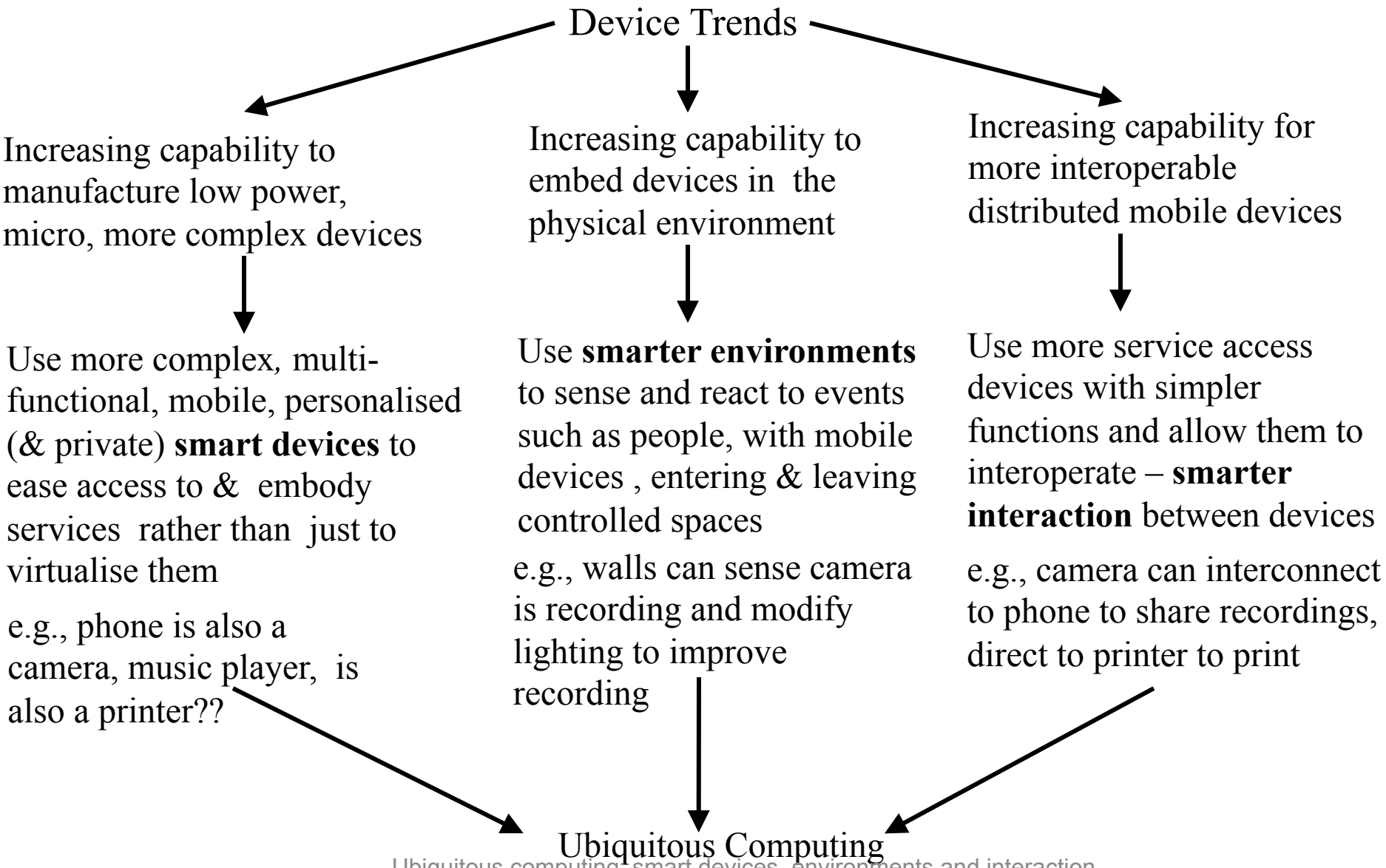
- Living in a Digital World
- Modelling the Key Ubiquitous Computing Properties
- Ubiquitous System Environment Interaction
- **Architectural Design for UbiCom Systems: √**
- Course Outline

UbiCom System Model: Smart DEI

- No single type of UbiCom system
- Different UbiCom systems support:
- 3 basic architectural design patterns for UbiCom:
  - smart **D**evices, smart **E**nvironments, smart **I**nteraction
- ‘Smart’ means systems are:
  - active, digital, networked, autonomous, reconfigurable, local control of its own resources, e.g., energy, data storage etc.


Smart Device
Smart DEI Model
1-1 Interaction
1-M, M-M Interaction
Smart Mobile Device
Smart Environment
Smart Interaction

UbiCom System Model: Smart DEI

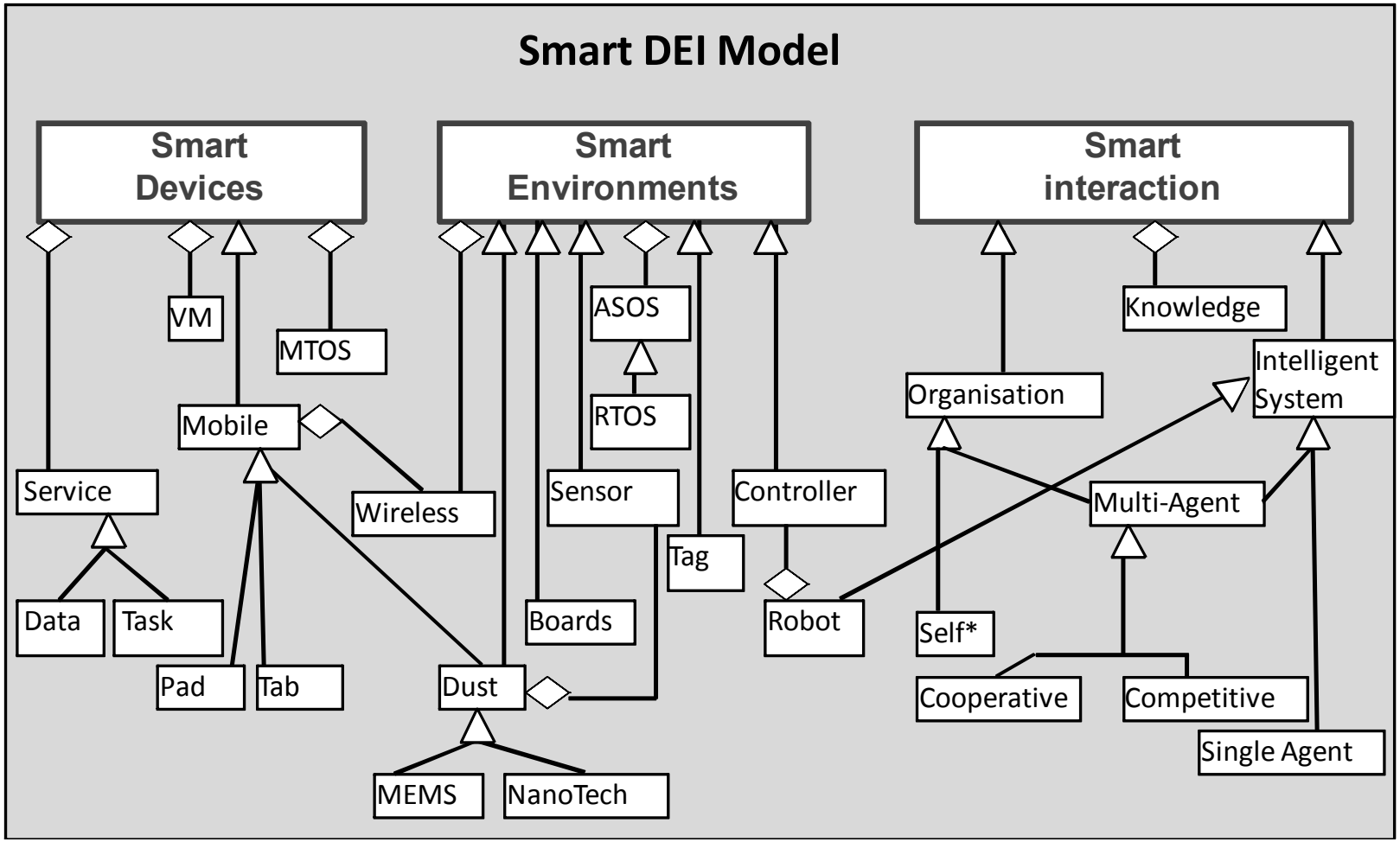


Smart DEI Model: types of smart device

- 3 main types of UbiCom system may themselves contain smart sub-systems at a lower level of granularity
  - e.g., a smart environment device may consist of smart sensors and smart controllers

UbiCom System: Smart Sub-Systems or Components

Arrows indicate subtype Diamonds mean “contain”



Smart Device Form Factors

- Devices tend to become smaller and lighter in weight, cheaper to produce.
- Devices can become prevalent, made more portable and can appear less obtrusive.
- Devices often consists of service discovery services

Weiser proposed a range of device sizes

1. *Smart Tabs* (wearable centimetre sized devices)
2. *Smart Pads* (handheld decimetre-sized devices)
3. *Smart Boards* (e.g. metre sized displays)

Smart Device Form Factors (2)

Form Factors can be extended to support

4. *Smart Dust* (nanometre devices with MEMS –Micro-electronic mechanical systems -> accelerometers)
5. *Smart Skins* (clothes and curtains may have fabrics with so-called organic computer devices
6. *Smart Clay (*3D objects consisting of intelligence)

(See Chapters 5,6)

Design challenges in Using Varying Form Factors

- What are the design Challenges?

Smart Device: Variations

- Many variations or sub-types of smart devices,
  - e.g. *smart mobile device*, smart environment device
  - Use different combinations of sub-components
  - Support different combinations of UbiCom properties
  - Interact in different types of environment
  - Take different form factors

Smart Device Variations: Smart Mobile Device

- Many flavours or variants of these basic designs
- One of the most important variants of the smart device is the *smart mobile device*
- Combines several main types of UbiCom property:
- Note mobile devices are sometimes taken to be synonymous with wireless devices but these are different (see Chapter 11)

Smart Mobile Devices

- Multi-purpose ICT devices, operating as a single portal to multiple services
- eases access & interoperability versus decreased openness
- Usually personalised devices, specified owner.
- Locus of control and user interface resides in the smart device.
- Main characteristics: mobility, open service discovery, intermittent resource access.

Smart Devices: Mobility

- Many dimensions for mobility
- *Static*:
- *Accompanied*:
- *Wearable*:
- *Embedded* (into objects):
- *Implanted* (into humans):
- *Untethered* or unanchored:
- Division between statics and mobiles can be more finely grained and multi-dimensional (see Chapter 4)

Volatile Service Access

- Devices access software services and hardware intermittently. Why?
- Devices can dynamically discover services available.
- Context-aware discovery can improve basic discovery.
- Asymmetric remote service access, more downloads than uploads, tends to occur. Why? Limited power capacity?

Smart Mobile Devices: Context-Aware

- Can use contexts to filter information & service access.
- Often designed to work with a reference location in physical environment called a *home location*
- Direct and indirect routing
- The problem of triangular routing
- Mobile devices are ICT *resource constrained*.
- Mobile devices tend to use a finite internal energy cache.
- Devices' configuration, operation tends to be personalised

Smart Environment (Devices)

- Definitions – acquire info and apply knowledge (environments and their inhabitants)
- Consists of a set of smart devices specialised to interact with their (virtual, phys., human) environments.
- Typically, embedded single task devices; not MTOS devices
- Can automatically respond to or anticipate users, using iHCI
- E.g. doors open automatically as one walks towards the door
- Smart environments support bounded, local user context
- Smart environment devices may also be:
  - fixed versus anchored mobile versus unanchored mobile devices
  - macro to micro to nano

Types of Smart Environment Device Interaction

- Tagging and Annotating (using RFID?)
- Sensing & monitoring
- Filtering (it reduces views and help to focus on the features of interest)
- Adapting (adapting routes according to current congestion)
- Controlling (e.g. heating or cooling according to temperature sensor?)
  - Assembling
  - Regulating

Smart Interaction

- Additional type of design is needed to knit together many individual system components and interactions.
- Smart interaction promotes unified & continuous interaction model between UbiCom applications & their UbiCom infrastructure, physical world & human environments.
- Internal self-organising system vs. externally driven system
- Components can interact cooperatively versus competitively
- Several benefits to designs based upon set of interacting components:
- A range of levels of interaction between UbiCom System components
- Distinguish between (basic) interaction and (smart) interaction

Basic Interaction

- Typically involves two interlinked parties, a sender and a receiver.
- Sender knows things in advance:
- Two main types of basic interaction synchronous versus asynchronous

Smart Interaction

Smart Interaction extends basic interactions as follows.

- Coordinated interactions
- Orchestrations vs. Choreography
- Cooperative versus competitive interaction
- Policy and Convention based Interaction
- Dynamic Organisational Interaction
- Semantic and Linguistic Interaction (share common language/knowledge)

Smart DEI Model Summary

- Basic Smart Device has many variations
  - 6 different physical form factors
  - 5 different groups of internal properties & over 70 sub-properties
- Multiple flavours of smart device,
  - e.g., Smart Mobile type of Smart device
  - e.g., Smart Environment type of Smart Device
- UbiCom System interact across 3 main types of environment: physical, virtual & human
- System of systems models in terms of multiple device combinations and interactions

Common Myths of Ubiquitous Computing

1. There is a single definition which will accurately characterises Ubiquitous Computing
2. The ideal type of Ubiquitous computing is where all the properties of ubiquitous must be fully supported
3. Ubiquitous computing means making computing services accessible everywhere.
4. Ubiquitous computing is boundless computing
5. Ubiquitous computing is just about HCI
6. Calm Computing should be used as a model for all HCI.
7. Ubiquitous computing is just about augmenting reality

Common Myths of Ubiquitous Computing 2

8. Ubiquitous computing is just distributed or virtual computing
9. Ubiquitous computing is just mobile wireless computing
10. Ubiquitous computing is just about smart environments
11. Ubiquitous computing need to be highly autonomous systems
12. Ubiquitous computing is just about physical world context-awareness
13. Ubiquitous computing is just distributed intelligence
14. Ubiquitous computing systems can operate effectively in all kinds of environments:

Overview

- Living in a Digital World
- Modelling the Key Ubiquitous Computing Properties
- Ubiquitous System Environment Interaction
- Architectural Design for UbiCom Systems: Smart DEI Model
- **Course Outline √**