Ubiquitous Computing

Chapter 1

Ubiquitous Computing: Basics and Vision

Overview

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

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

Ubiquitous Computing

Definition

- The term ‘ubiquitous’, meaning appearing or existing everywhere, combined with computing to form the term Ubiquitous Computing (UbiCom).

- It is used to describe ICT (Information and Communication Technology) systems that enable information and tasks to be made available everywhere, and to support intuitive human usage, appearing invisible to the user.

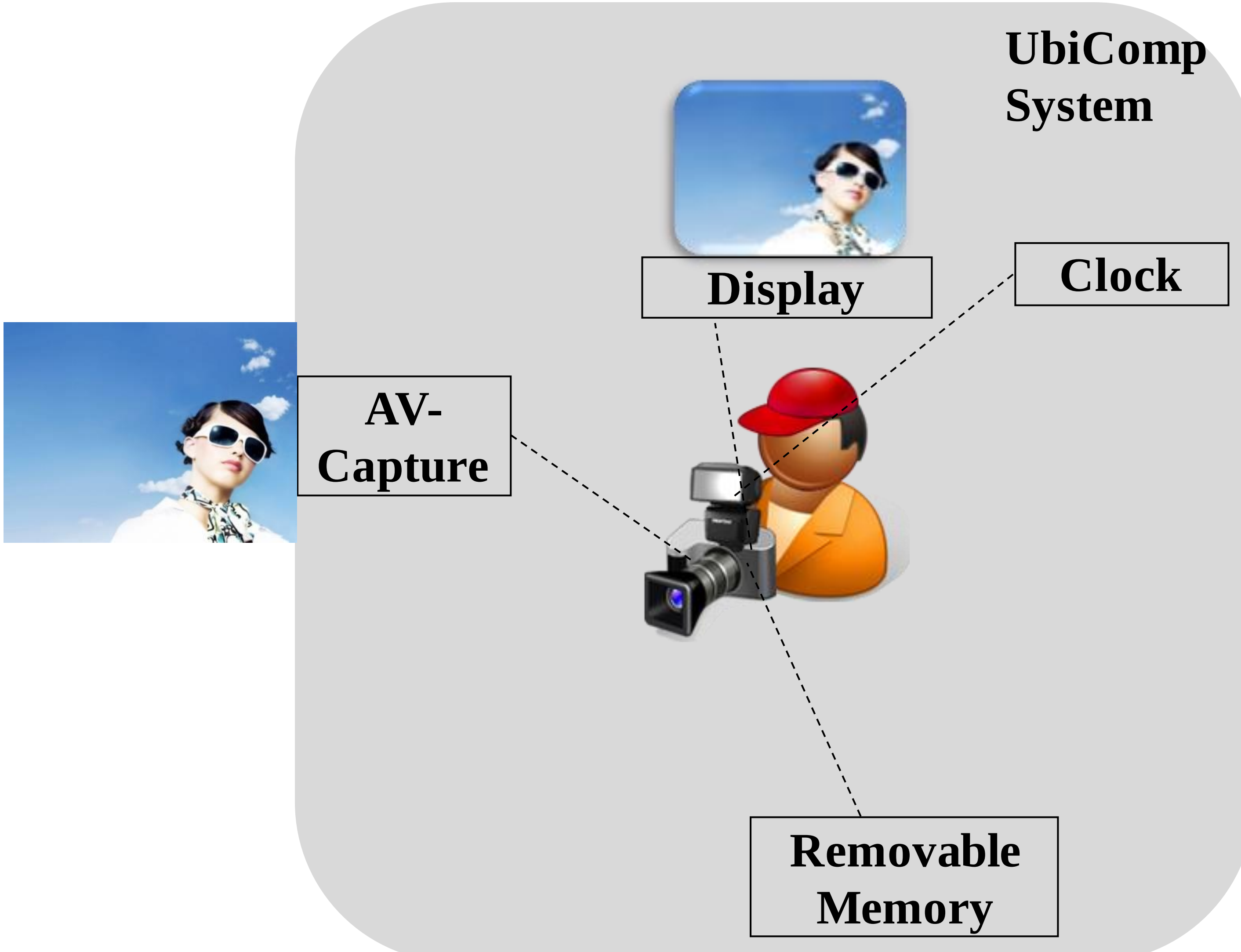
Trend: smaller, higher resource devices

Scenarios

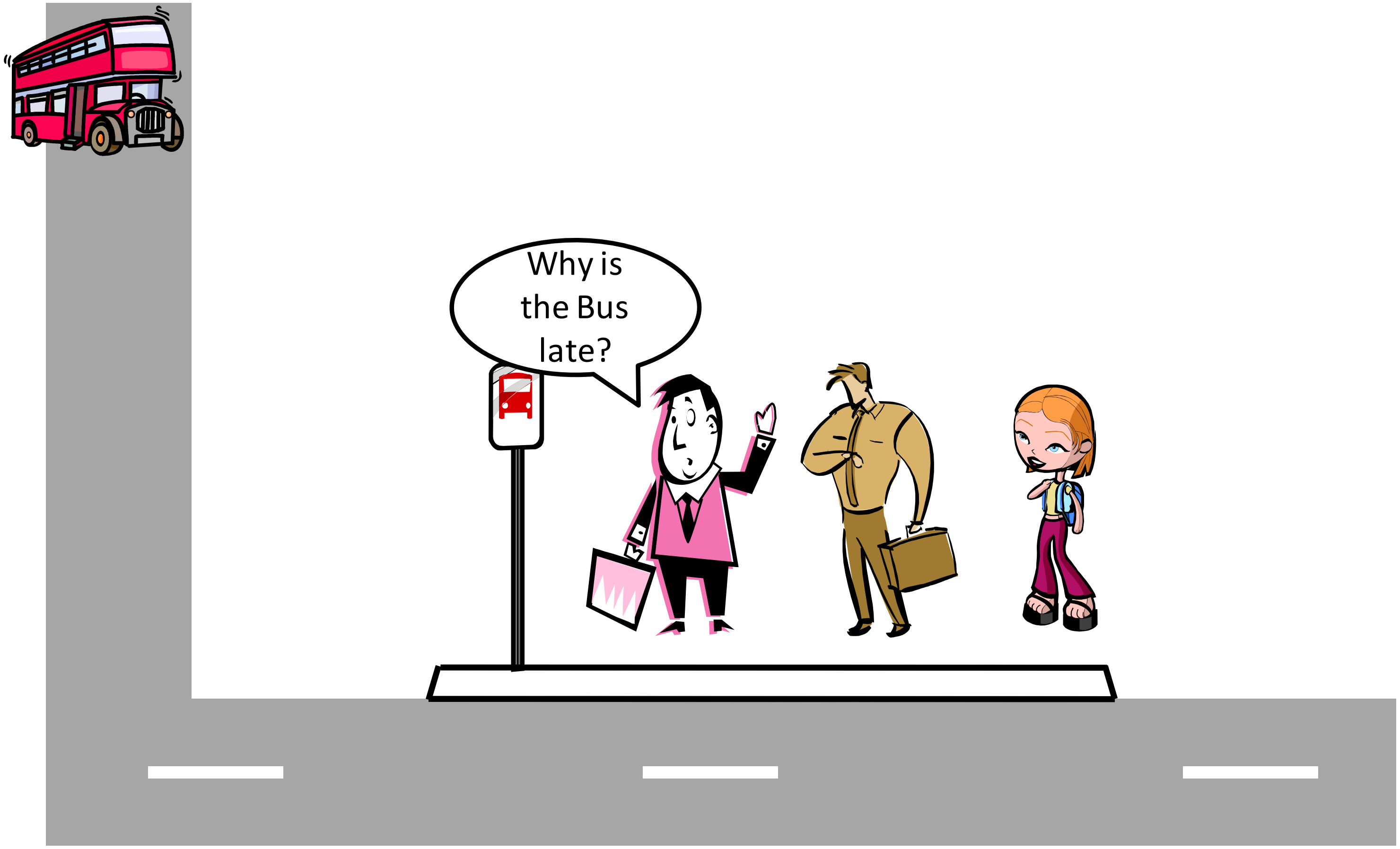
4 scenarios illustrate a range of benefits and challenges of ubiquitous computing:

- Personal memories
- 21st Century Scheduled Transport Service
- Foodstuff management
- Utility regulation

Personal Memories Scenario



21st Century Scheduled Transport Service Scenario



Foodstuff Management Scenario

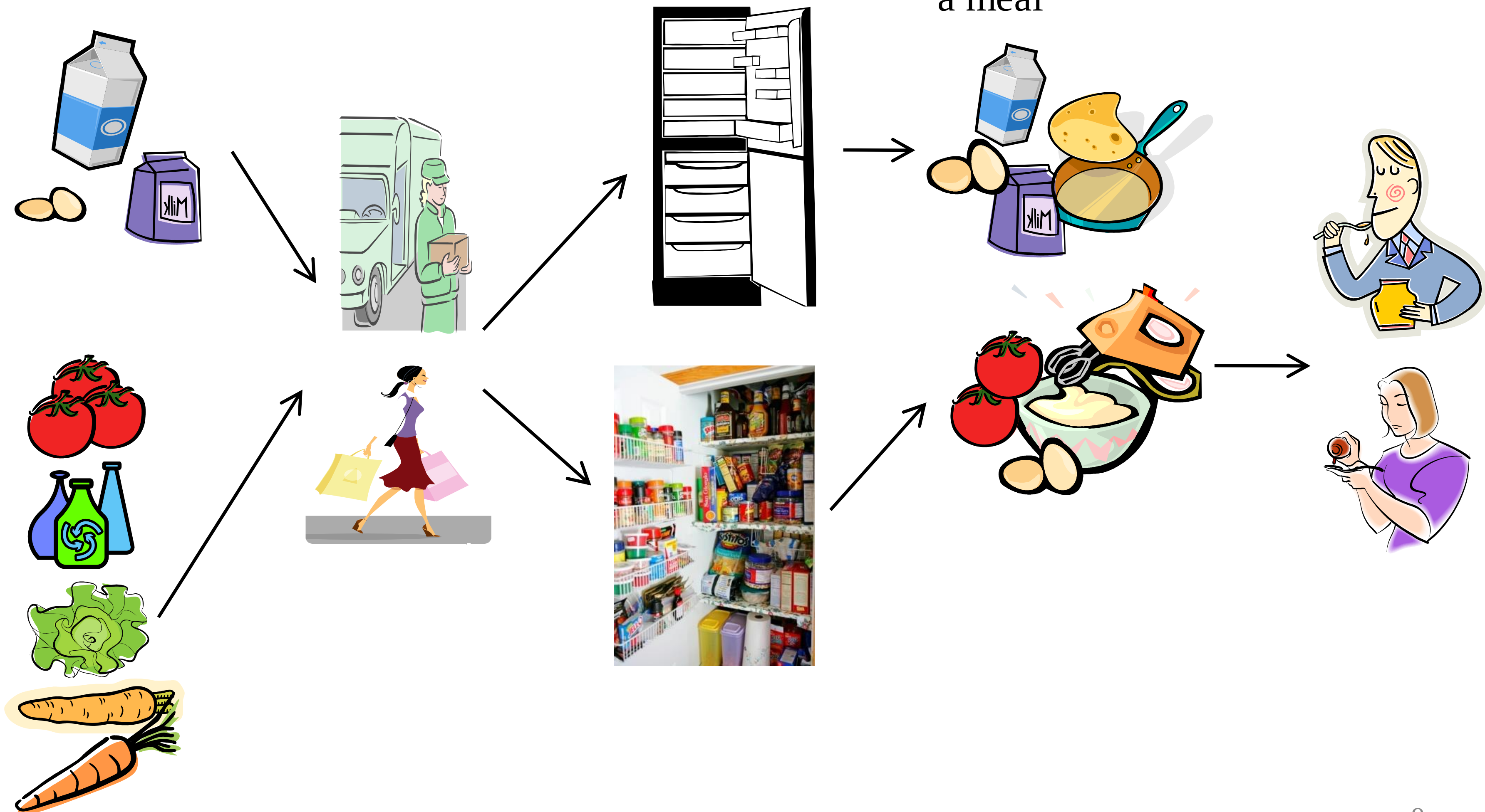
Select & Buy food at physical or virtual market

Transport food to home store

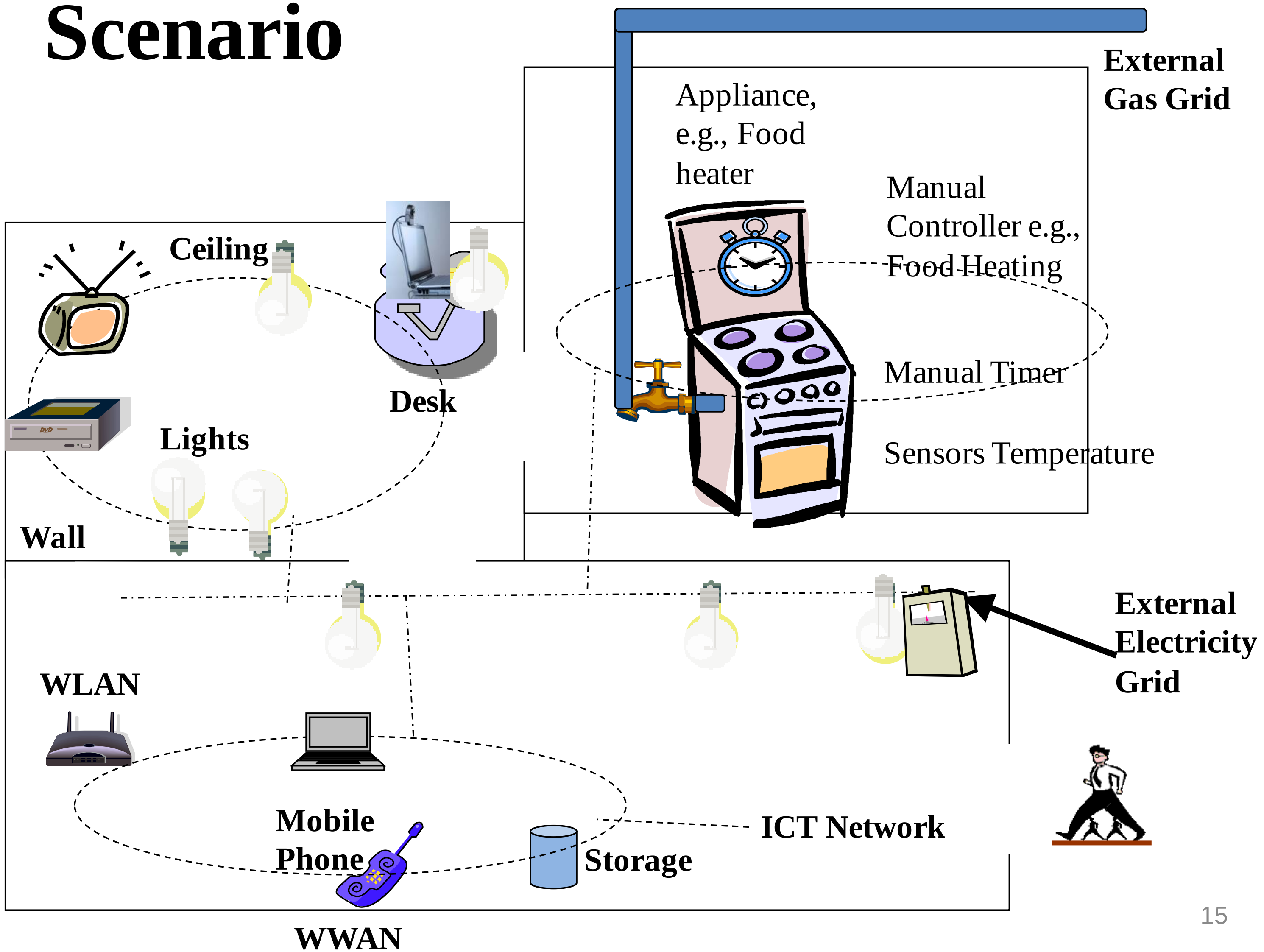
Put in home store

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

Consume food



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.

Framework for UbiCom : Smart DEI

- Design architecture to apply UbiCOm system :

  Smart devices, smart environment and smart interaction.

- Internal model of UbiCom system proterties based upon five fundamental properties:

  distributed, iHCL, context awareness, autonomy, AI

- A model of UbiCom system's interaction with its external environment.

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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?
-

UbiCom: Internal System Properties

3 main properties for UbiCom Systems were

1. Computers need to be networked, ***distributed*** and transparently accessible

2. Computer ***Interaction*** with Humans needs to be more ***hidden***

3. Computers need to be *aware* of ***environment context***

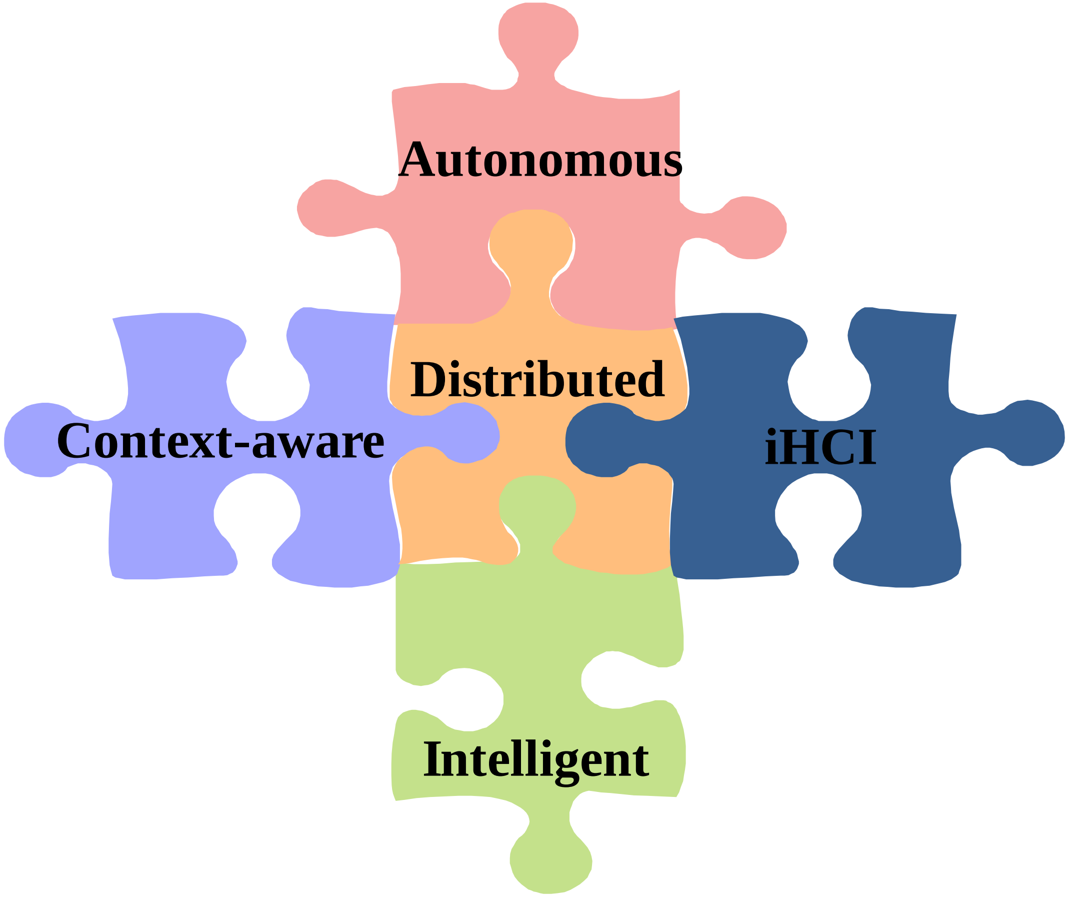
Devices: Extended set of Internal System Properties

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*****.**

Five main properties for UbiCom



UbiCom System Properties: Distributed

- Networked ICT Devices
- Transparency
- Openness

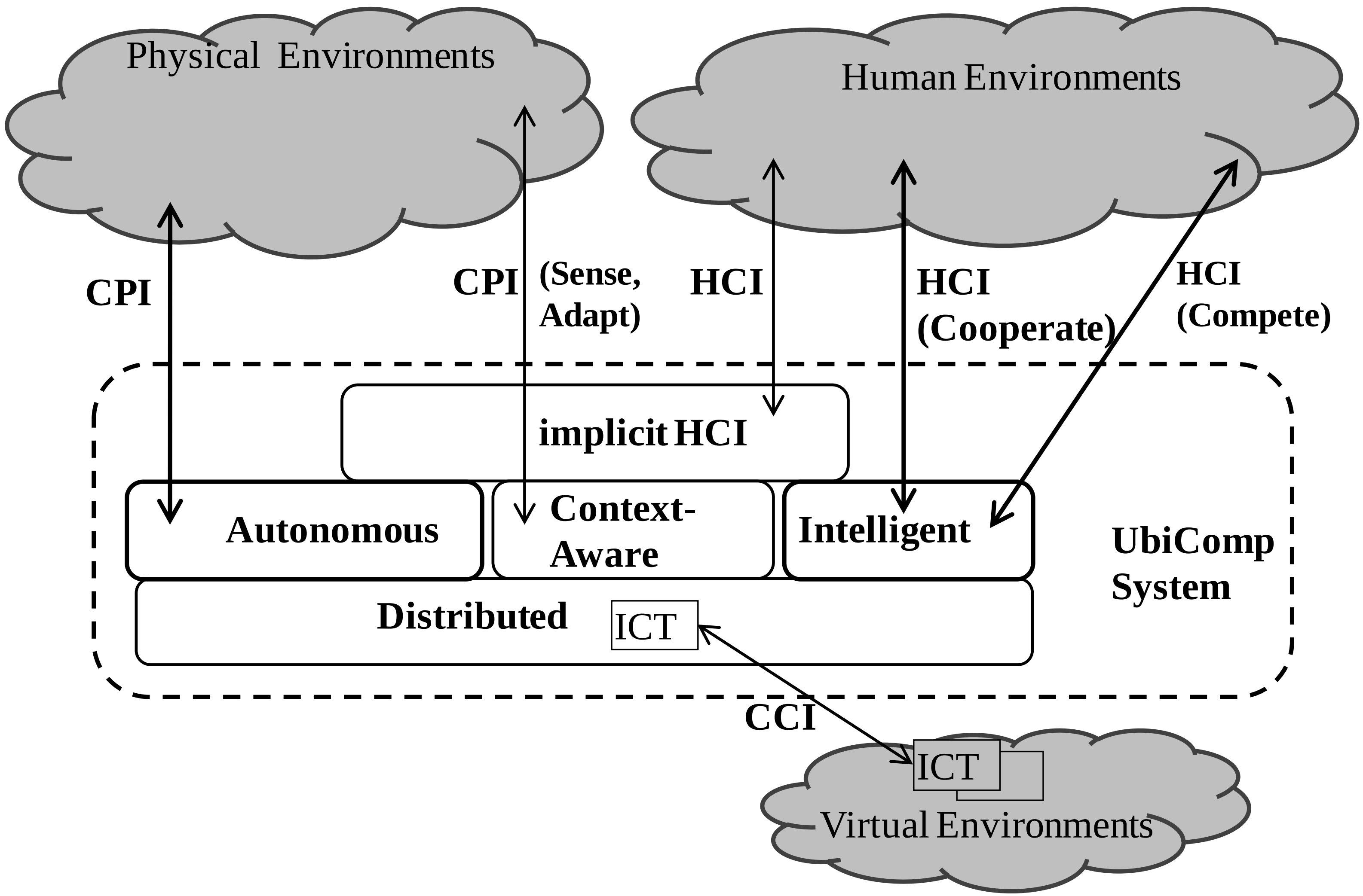
Distributed System: sub-properties

- Often designed middleware, set of generic services
- Universal, Seamless, Heterogeneous
- Networked
- Synchronised, Coordinated
- Open
- Transparent, Virtual
- Mobile, Nomadic

Internal System Properties: iHCI

- Concept of *calm* / *disappearing computer* has several dimensions
- Implicit (iHCI) versus Explicit HCI
- 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

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

Types of environment aware

- Person-aware, User-aware, Personalised, Tailored,
- Environment-aware, Context-aware, Physical context-aware
- ICT infrastructure aware

Internal System Properties: Autonomy

- Autonomy refers to the property of a system that enables a system to control its own actions independently.

- Autonomous systems are defined as systems that are self governing and are capable of their own independent decisions and actions.

- There are several different types of autonomous system. Ex : On the Internet, an autonomous system is a system which is governed by a router policy for one or more networks, controlled by a common network administrator on behalf of a single administrative entity.

Internal System Properties: Autonomy

- Reducing Human Interaction

- Easing System Maintenance Versus Self-Maintaining Systems

Autonomy: Sub-Properties

- Automatic
- Embedded, Encapsulated
- Embodied
- Resource-constrained
- Untethered, Amorphous
- Autonomic, Self-managing, self-star properties
- Emergent, self-organising

Internal System Properties: Intelligence

It is possible for UbiCom systems to be context aware, to be autonomous and for systems to adapt their behaviour in dynamic environments in significant ways, without using any artificial intelli gence in the system.

Intelligence can enable systems to act more proactively and dynamically in order to support the following behaviours:

- Modelling of its physical environment
- Modelling its human environment
- Handling incompleteness
- Handling non deterministic behaviour

Individual Intelligence: Sub-Properties

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

Sub-Properties (sub-types of individual intelligence)

- Reactive, Reflex
- Model-based,
- Rule/Policy-based
- Logic/Reasoning
- Goal-oriented, Planned, Proactive
- Utility-based, Game theoretic
- Learning, Adaptive

Multiple Intelligence: Sub-Properties

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

Sub-Properties

- Cooperative , Collaborative, Benevolent
- Competitive, self-interested, antagonistic, adversarial
- Orchestrated, Choreographed, Mediated
- Task-sharing
- Communal, shared meaning
- Shared knowledge
- Speech-act based , Intentional, Mentalistic

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- **Ubiquitous System Environment Interaction √**
- Architectural Design for UbiCom Systems: Smart DEI Model
- Course Outline

Ubiquitous System Environment Interaction

Three types of system environment

- UbiCom systems which form the ICT infrastructure, supporting services and act as middleware for that particular ICT system applications (virtual worlds)
- Human individuals and human organisations
- Physical world

Together, the virtual (computer) environment humans and the physical world can be considered as forming an external environment for UbiCom systems.

UbiCom system is organised as a layered information system stack

- Bottom layer of information resources
- Middle layer of processing
- Top layer of user information abstractions to view and interact with the information

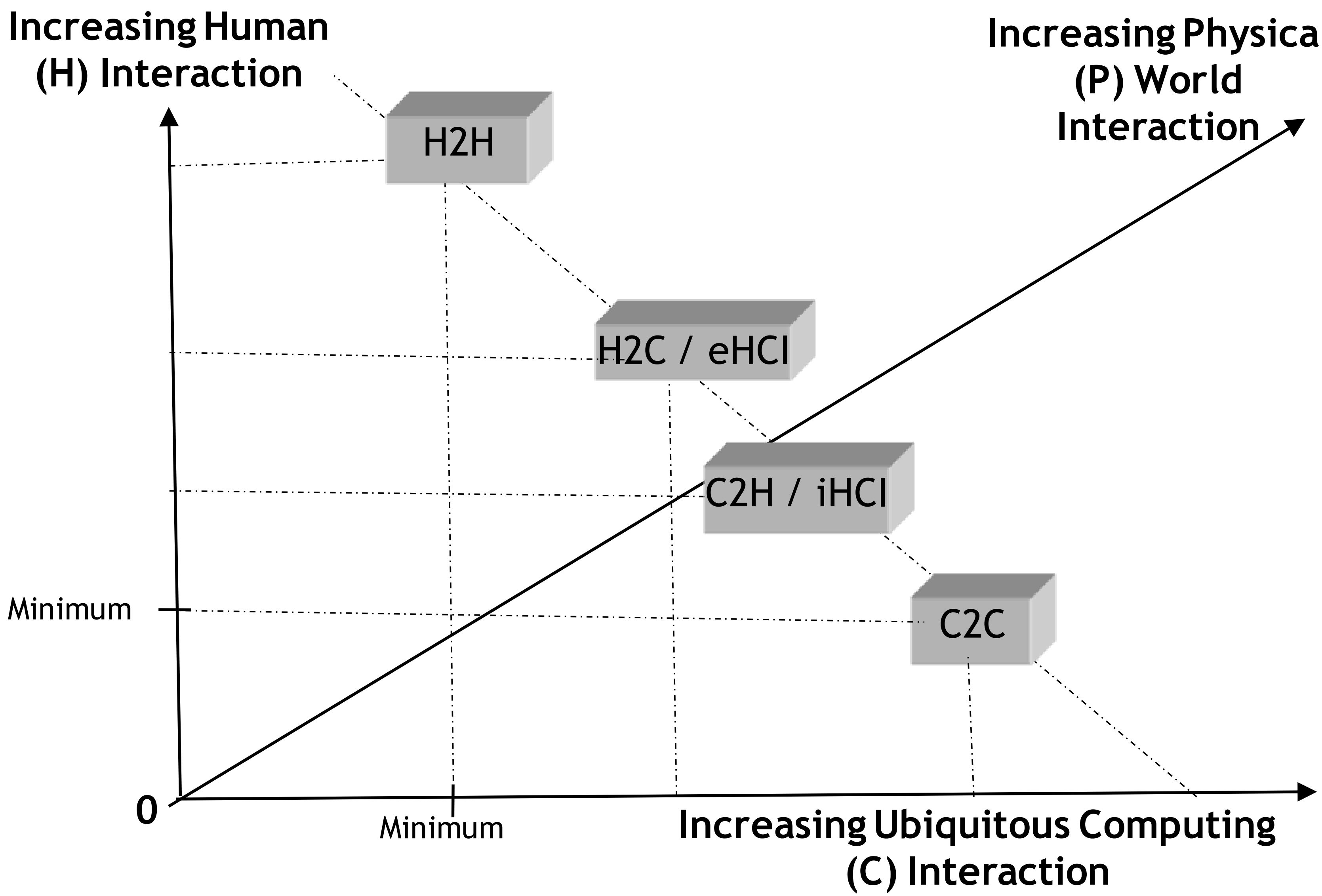
The physical environment can be represented using multiple models.

- local physical control model, e.g., lighting controls can sense the existing natural lighting and switch on artificial lighting when the natural light is below a certain threshold.
- A second type of physical world model is an ecology system.

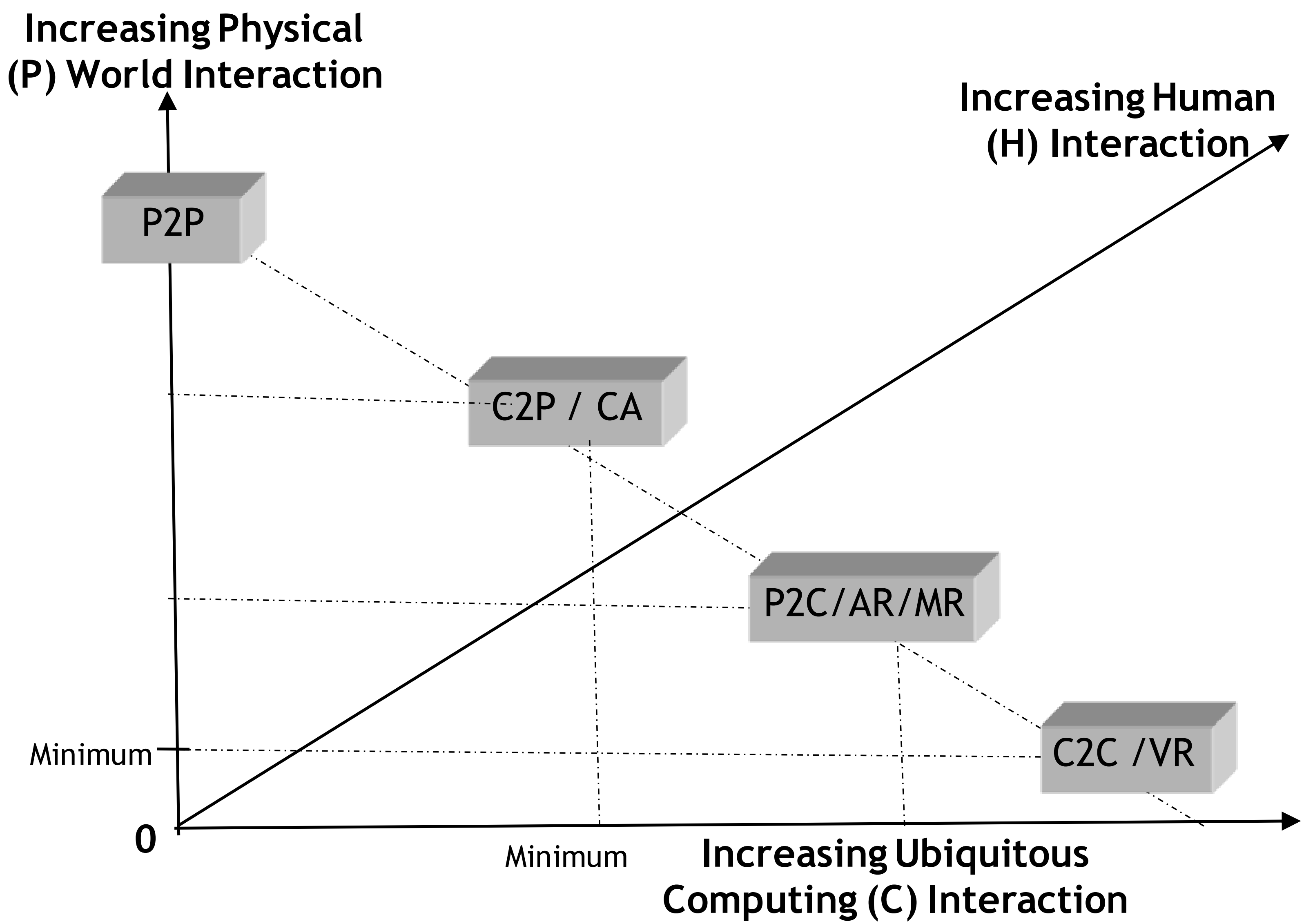
The system environment interaction occurs between

- Human and ICT system(HCI)
- ICT system and physical world (CPI)
- Between ICT system(C2C or CCI)

Different Degrees of HCI



Different Degrees of CPI



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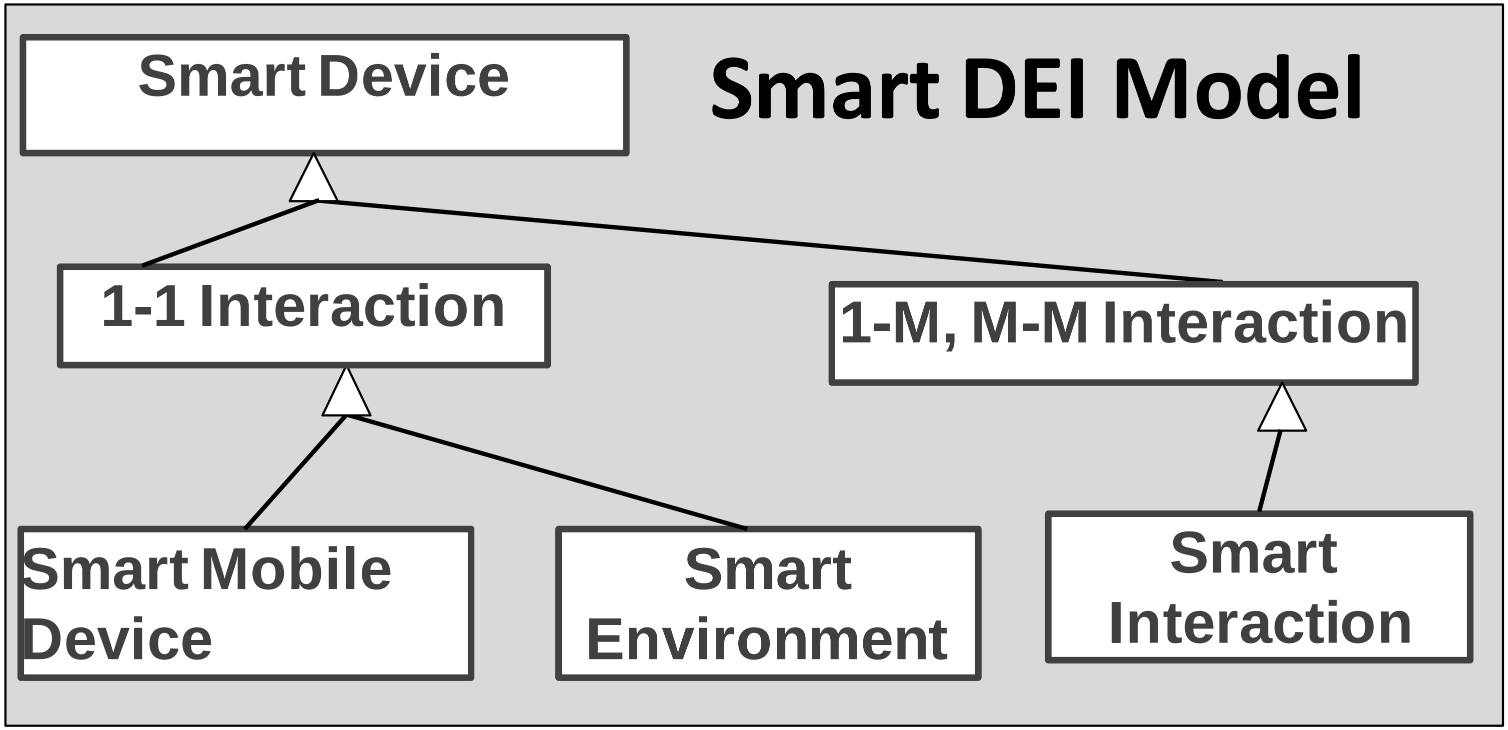
UbiCom System Model: Smart DEI

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


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

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

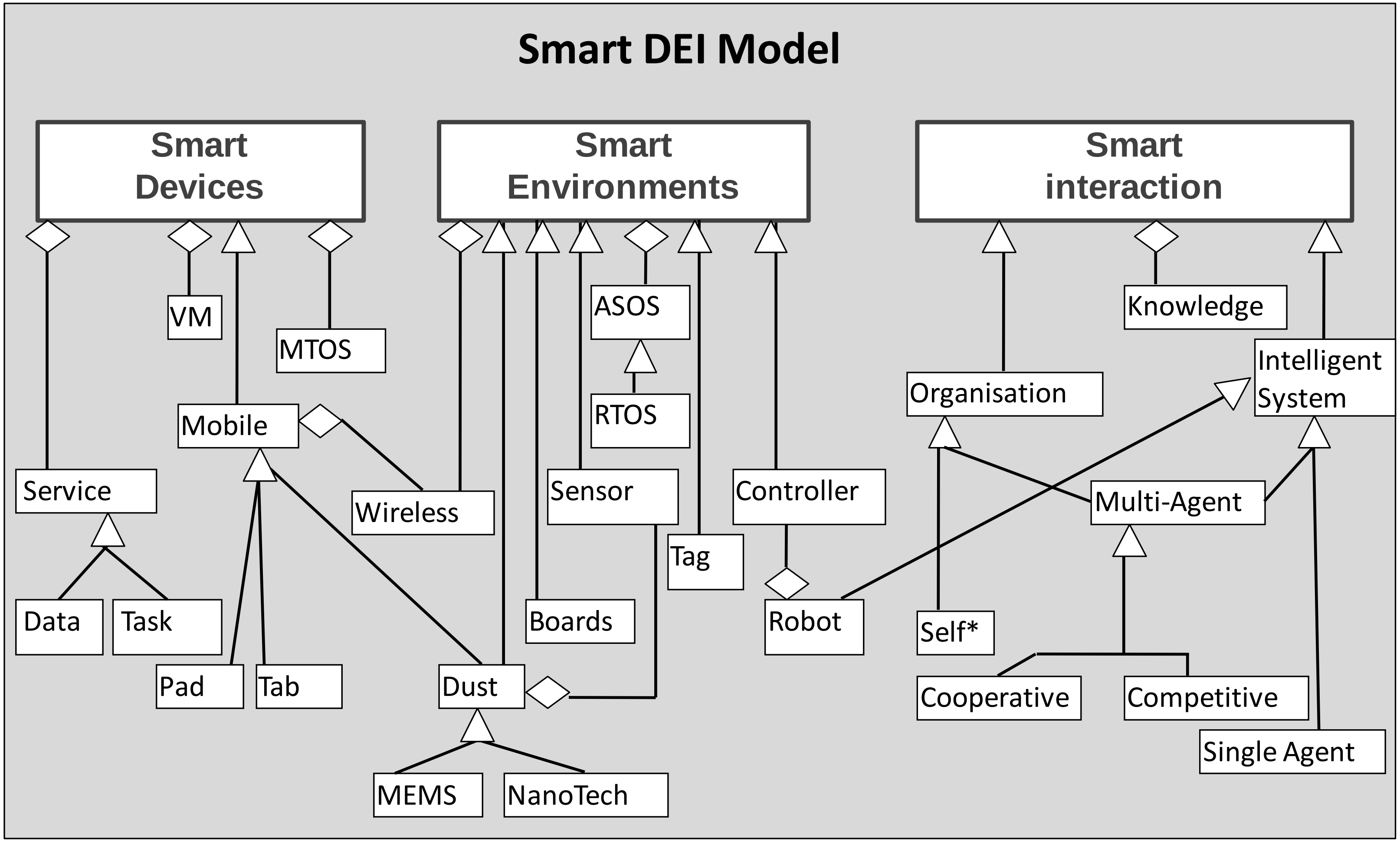
e.g., camera can interconnect to phone to share recordings, direct to printer to print

Ubiquitous Computing

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



Smart Devices

- The main characteristics of smart devices are as follows: mobility, dynamic service discovery and intermittent resource access (concurrency, upgrading, etc.).

- There are various different forms for smart devices:
  - ICT Device Forms: Tabs, Pads and Boards
  - Extended Forms for ICT Devices: Dust, Skin and Clay
  - Mobility

ICT Device Forms: Tabs, Pads and Boards

- Devices tend to become smaller and lighter in weight, cheaper to produce.
- Devices can become prevalent, made more portable and can appear less obtrusive.

Weiser proposed a range of device sizes

1. *Smart Tabs*
2. *Smart Pads*:
3. *Smart Boards*:

Extended Forms for ICT Devices: Dust, Skin and Clay

Form Factors can be extended to support

1. **Smart Dust** : ICT devices can be miniaturised without visual output displays, e.g., Micro Electro Mechanical Systems (MEMS), ranging from nanometres through micrometres to millimetres. This form is called Smart Dust.

2. **Smart Skins :** Second, fabrics based upon light emitting and conductive polymers, organic computer devices, can be formed into more flexible non planar display surfaces and products such as clothes and curtains. This form is called Smart Skins.

3. **Smart Clay :** ensembles of MEMS can be formed into arbitrary three dimensional shapes as artefacts resembling many different kinds of physical object. This form is called Smart Clay

Mobility

Mobile devices usually refer to communicators, multimedia entertainment and business processing devices designed to be transported by their human owners, e.g., mobile phone, games consoles, etc.

There is a range of different types of mobiles as follows:

- Accompanied
- Portable
- Hand held
- Wearable
- Implanted or embedded

Smart Environment (Devices)

- In a smart environment, computation is seamlessly used to enhance ordinary activities.

- smart environment is ‘one that is able to acquire and apply knowledge about the environment and its inhabitants in order to improve their experience in that environment’.

- A smart environment consists of a set of networked devices that have some connection to the physical world.

Types of Smart Environment Device Interaction

- Tagging and Annotating
- Sensing & monitoring
- Filtering
- Adapting
- Controlling
  - Assembling
  - Regulating

Smart Interaction

- Smart interaction is needed to promote a unified and continuous interaction model between UbiCom applications and their UbiCom infrastructure, physical world and human environments.

- Smart interaction design model, system components dynamically organise and interact to achieve shared goals.

- A range of levels of interaction between UbiCom system components exists from basic to smart.

- Basic interaction that uses fixed interaction protocols between two statically linked dependent parties, whereas smart interaction that uses richer interaction protocols between multiple dynamic independent parties or entities.

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
- Cooperative versus competitive interaction
- Policy and Convention based Interaction
- Dynamic Organisational Interaction
- Semantic and Linguistic Interaction

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

Smart devices and services

Smart devices and service characteristics

- Smart devices are characterised by the
  - ✓ ability to execute multiple,
  - ✓ possibly concurrent,
  - ✓ applications,
  - ✓ mobility and customisation
  - ✓ remote service access
  - ✓ operating according to local resource constraints.

Service architecture model

it consists of

- partitioning and distribution of service components.
- Multi-tier client server models.
- Middleware
- Service oriented computing
- Grid computing
- Peer to Peer system

Partitioning and distribution of service components

- Range of designs for dividing and distributing services that depend on:

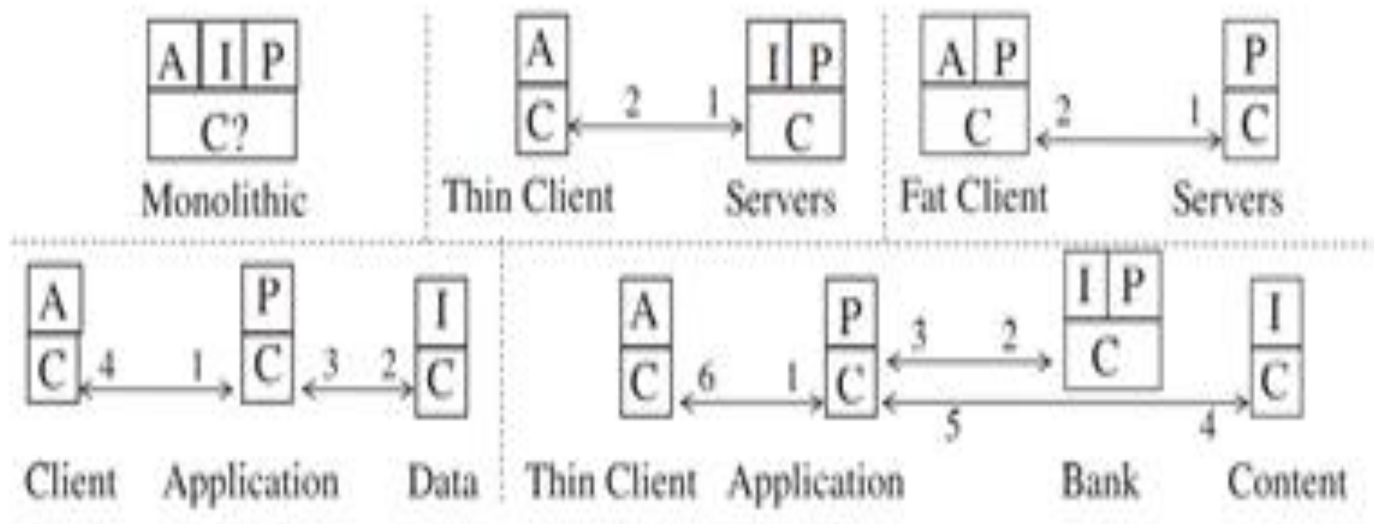
(1) the application

(2) the type of communication service

(3) the type of access device used.

- There are two types of resource devices high source devices and low resource devices.
- Consider the example of chess application, two different ways in which a chess application can be designed to run on smart devices.
- If we consider the example of chess application In a high resource device and in low resource devices.

Multi-tier client service models



- **In a single tier**

The whole application service resides locally, when it is operating. The system may be networked so that under special conditions it can go online to seek help when its operation is interrupted or because of local failures.

- **In a two tier**

Thin client server, the access device (or client device or terminal) supports data access or presentation, service processes execute remotely and the information associated with these services is stored remotely.

- **In multi-tier (3, 4 ... N tier) systems**

Rather than access devices being directly connected to the end service nodes, different numbers of intermediate nodes can be used.

It includes three parts

- **Distributed data storage**

  It includes : Transition monitor

  Centralised analysis of centrally stored data subset

  Mapping of a database

- **Distributed processing**

Divide the processing, distribute it among multiple remote processors, each executive part of the processing in parallel and then reassemble the result from the individual pieces to form the whole

- **Client server design**

The client server model has the advantage of more centralised control of distribution. The client server model is an asymmetric distributed computing model with respect to the resources and the direction of the interaction.

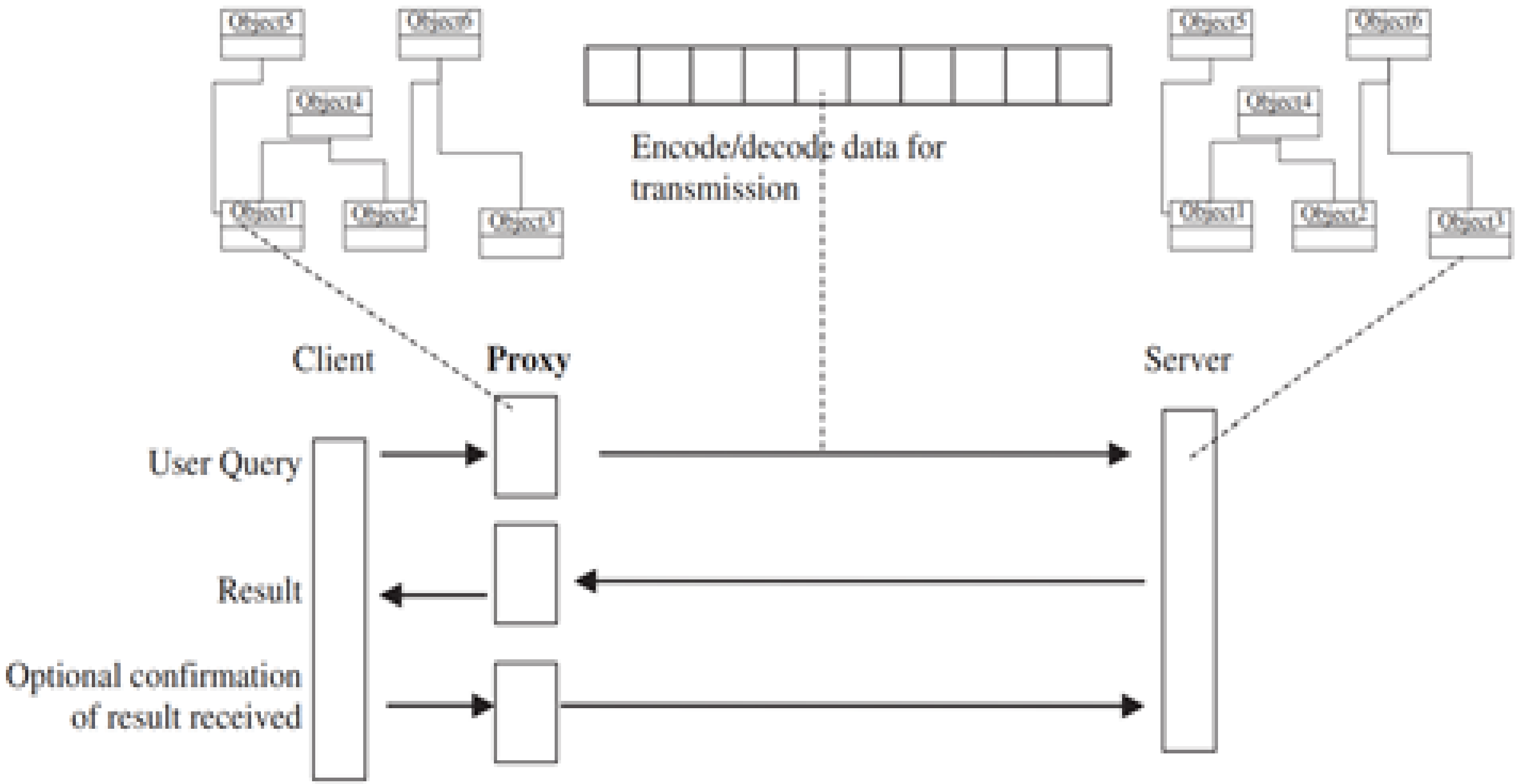
- **Proxy based service access**

Some applications, in order to mask the complexity of communication from being supported in client access process, use a client proxy.

Proxy based service access can:

- ➢ offload presentation processing and network processing
- ➢ hide the heterogeneity
- ➢ simplify and compose access to multiple service providers.
- ➢ reduce the complexity of communication used in access devices
- ➢ enable devices to operate intermittently in a disconnected state.
- ➢ shield network based applications from the mobility of the access devices

- **Proxy based service access**



Middleware

- Middleware was introduced in between applications and the operating system, to enable applications to hide and simplify access to the heterogeneous and distributed resources of multiple networked computing systems.

- Middleware essentially factors out a set of generic services, e.g., database access, file system access, messaging, time service, directory service, etc., out of the application services and out of the operating so that they can be application and operating system independent.

Service Oriented Computing (SOC)

- SOA is ‘a paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains’.

- service can be characterised in terms of:

    Descriptions

    Outcomes

    Offers

    Competency

    Execution

    Composition

    Constraints or policies

Services in a SOA can be separated into three layers of functions:

- Basic (lower)
- Composition (middle)
- Management (higher layer).

These functions are described as follows:

- Service discovery (Basic function)
- Enterprise service bus (Basic function)
- Service invocation (Basic function)
- Service composition
- Service management

Grid Computing

- Grid computing refers to distributed systems that enable use and sharing of distributed resources.
- Three main types of grid system occur in practice:

(1) Computational grids

(2) Data grids

(3) Service grids :

Demand

Collaborative

Multimedia grid systems

- Grids focus on providing a single virtual computer view of distributed systems made up of heavyweight servers and fat client computers that communicate on high bandwidth highly available fixed networks.

Peer-to-Peer Systems

- They can be defined as distributed systems consisting of interconnected nodes able to self organise into network topologies with the purpose of sharing resources.

- A P2P computing model offers several important benefits:

➢ Lower cost of ownership for content sharing

➢ Performance enhancements

➢ Resource utilisation and sharing

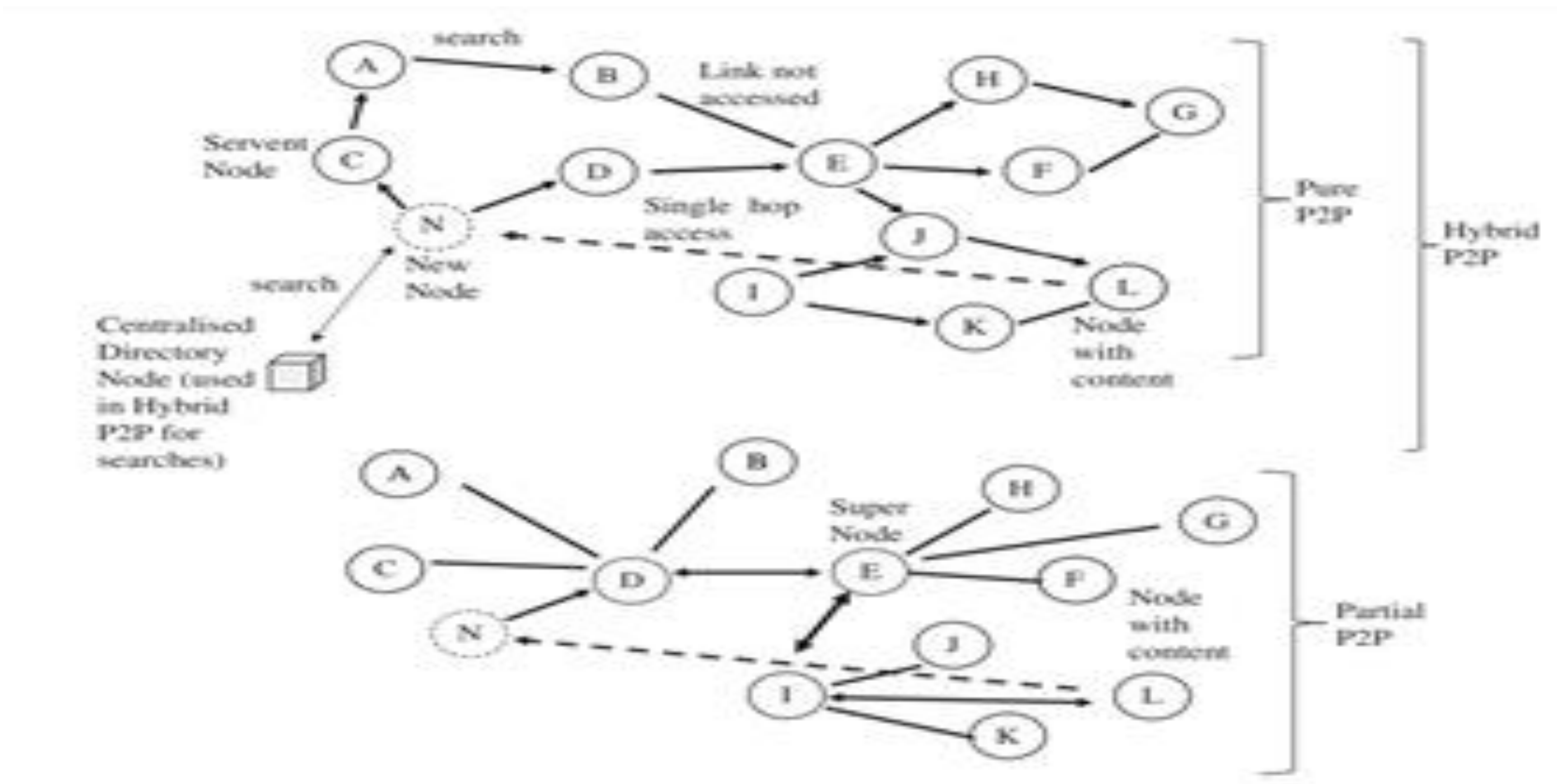
➢ Fault tolerance

- There are three main variations of P2P system depending on the types of computer nodes:

➢ Pure, decentralised, P2P

➢ Partially decentralised (SuperNode) P2P

➢ Hybrid decentralised P2P



Service Provision Life-Cycle

- The design of service provision must contend with intermittent service access and handovers between different service instances, e.g., wireless communication handovers.

- There are two separate aspects to this:

First, defining a generic life cycle model for service provision

Second , to manage this life cycle.

Service Provision Life-Cycle

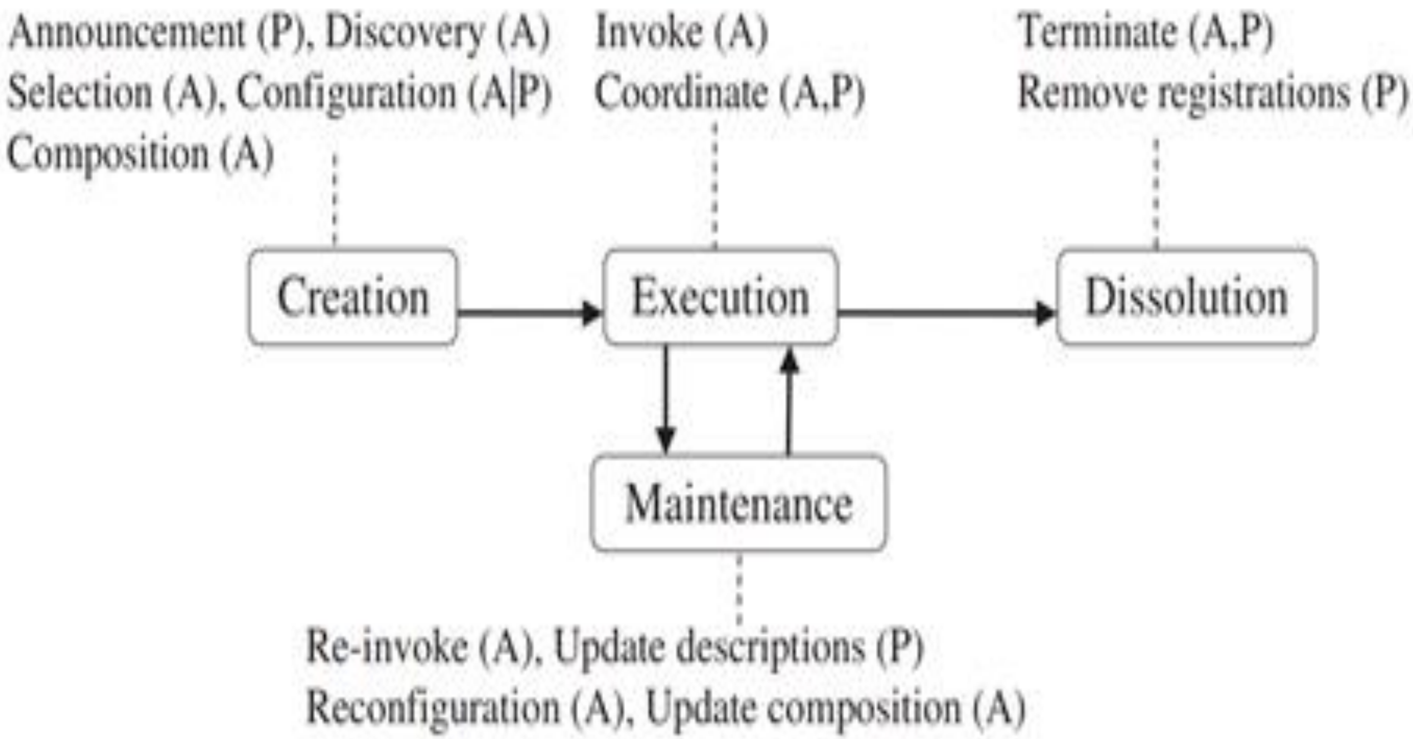


Figure 3.9 The service life cycle: smart services entail operation and management throughout the whole life cycle. P and A indicate that service processes and service access are active during each phase

- In a simple service provision lifecycle model, only two of the five service model components are active, the processing services or service provision and service access or clients, the other three components, communication, stored information and information sources, are treated as passive components.

- We have a we use different phases in the service provision life cycle:

✓ service creation phase

✓ operational or service execution phase

✓ service maintenance phase

✓ service dissolution phase

- Different things have been explained for service provision life cycle:

- Network Discovery

- Service Announcement, Discovery, Selection and Configuration

- Service Invocation

- Service Composition

Network Discovery

- Network discovery must precede service registration and service discovery.

- Dynamic network discovery is used by mobile nodes and when new nodes are introduced into a network.

- A Domain Name Service or DNS is used to map an IP address to a name of some network node and vice versa.

- A common approach to discover the network is to use DHCP (Dynamic Host Control Protocol) to ask a DHCP server for an IP address that is leased for a given time.

Service Announcement, Discovery, Selection and Configuration

- If service providers and requesters are static, then there is little need for dynamic service discovery.

- Dynamic service discovery is needed to allow

➢ service requester to change provider when requester or provider are mobile.

➢ When network exists is intermittent.

➢ When requestor or provider fails.

There are two main approaches for dynamic service announcement and discovery

- Pull
- Push

Pull

pull use is broadcast or multicast the available service request or service capabilities to all the unknown parties example Bluetooth.

Push

Push uses look up to search or browse list of request or capabilities previously announced two or discovery held by some known third party.

Service selection

There are several dimensions for service selection

- Request base versus capability based versus gold based.
- Exact versus inexact.
- Syntactical versus semantic.

Service invocation

Two possibilities are there

- Requester need to know how to invoke the service.

- Requester may not know in which order to invoke service action or how to handle message sequence in a process without terminating service process

The mean service invocation design include

- Distributed processes
- Asynchronous versus synchronous communication model
- Reliable versus unreliable communication
- On demand service access
- Event driven architecture
- Shared data repository
- Enterprise service bus model
- Volatile service invocation

Service composition

- Composition is concerned with synthesising new services and assembling more complex (composite) services from simple (atomic) services to achieve a user or application goal, and then collectively executing them as composite service processes.

- Service processes are sequences of individual service actions that are scheduled for execution.

- Service processes may involve one or more entities, one or more actions and involve one or more processes.

Applications and requirements

Smart Devices: CCI

- **Smart Boards, Pads and Tabs**

A large wall display program called LiveBoard which migrated from amorphous silicon to rear screen projection; smaller computers, the book sized MPad and the palm sized ParcTab computer.

- **Active Badge, Bat and Floor**

First context aware computing application, designed to enhance user mobility and to support location awareness.

Active Bat, based on ultrasound4 that could locate people up to an accuracy of 3 cm.

The active floor or smart floor did not require someone to explicitly carry some identifying token. Instead, this type of device is designed to identify people indirectly, e.g., in this case by their type of walk or gait

Smart Environments: CPI and CCI

- **Classroom 2000**

➢ Classroom 2000 in an attempt to support both teaching and learning.

➢ Microphones and video cameras were embedded in the ceiling and the signals from the microphones and cameras were stored. The electronic whiteboard was used again but this time networked. Two ceiling mounted projectors attached to networked computers were also for display.

- **Smart Space and Meeting Room**

- Smart Space and Meeting Room Projects, focused on the use of pervasive devices, sensors, and networks to provide an infrastructure for context aware smart meeting rooms that sense ongoing human activities and respond to them.

- The Meeting Room digitised signals from two hundred microphones, five video cameras, i.e. direct sensor data, and had a smart whiteboard.

- **Interactive Workspaces and iRoom**

➢ Interactive rooms called iRooms that contained one or more large displays, with the ability to integrate portable devices and to create applications integrating the use of multiple devices in the user space.

➢ The second version of the iRoom contained three touch sensitive whiteboard sized displays along the side wall, a large display supporting pen interaction called the interactive mural built into the front wall and a custom designed display to look like a standard conference room table.

➢ The room also had cameras, microphones, wireless LAN support, and a variety of wireless buttons and other interaction devices. The room supported three main interactive tasks: moving data, moving control and dynamic coordination of multiple applications.

- **Cooltown**

- Support mobile users providing access to information via wireless hand held devices based upon Web technology and linking the virtual ICT world to the physical world.

- A key feature of the Cooltown approach is that a physical world resource can have a Web presence.

- Physical resources are associated with a simple standard resource identifier, a URL or Universal Resource Locator.

- **EasyLiving and SPOT**

- The focus of the EasyLiving was on developing intelligent environ ments which allow the dynamic aggregation of diverse I/O devices into a single coherent user experience.

- In order to allow content created in one device to be output to a different device and controlled by yet another device, or because the input control device is not conveniently collocated with a remote display device, such as when remotely controlling a large screen display.

- EasyLiving enables this kind of flexible interac tion by providing abstract descriptions of their capabilities, geometric modelling of the location of devices in relation to other devices and through sensing capabilities.

- In the SPOT initiative, SPOT devices were designed to listen for digitally encoded data such as news stories, weather forecasts, personal messages, traffic updates, and retail directories trans mitted on frequency sidebands leased from commercial FM radio stations