Telecooperation Lab
Prof. Dr. Max Mühlhäuser

TK3: Ubiquitous / Mobile Computing

Chapter 0: Introduction

Lecturer: Dr. Immanuel Schweizer
Prof. Dr. Max Mühlhäuser

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Basic Information

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- Lectures Monday 14:25–16:05 (14.30–16.00); S2 02/C120
  - Video recordings: http://ccls.rbg.informatik.tu-darmstadt.de:8080/clls /
  - Moodle course (slides, discussion, …)
    - https://moodle.informatik.tu-darmstadt.de/course/view.php?id=429
    - Exercise groups of 4-5 students
  - Appointments: after lectures & via mail

- Exercises
  - Type: 2 programming assignments + project
    - .Net Gadgeteer & uMundo
  - Start: 27.04.2015
    - **No lecture**
    - Introduction to .Net Gadgeteer & 1st session

- Exam: Wed., 22. July 2015 14:00
  - Bonus Points for Exercise -> Details during the exercise

Books

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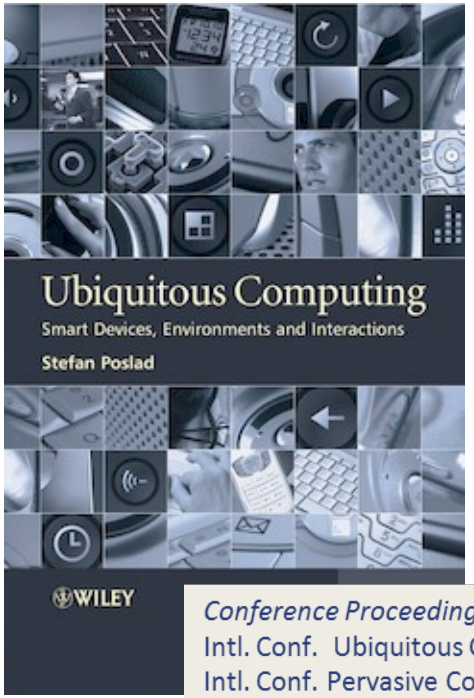
1. Primary Reference:
   Stefan Poslad: Ubiquitous Computing, Wiley 2009, ISBN 978-0-470-03560-3



Additional References:

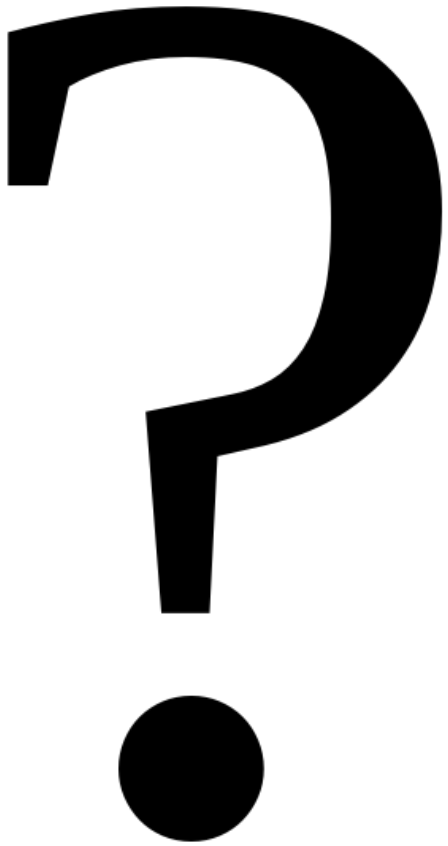
2. F. Adelstein, S. Gupta et al.: Fundamentals of Mobile & Pervasive Computing, McGraw Hill, 2004
3. M. Sauter: Grundkurs Mobile Kommunikationssysteme, Vieweg-Teubner Studium, 2010
4. From GSM to LTE: An Introduction to Mobile Networks and Mobile Broadband, Wiley 2011
5. J. Krumm (Ed.): Ubiquitous Computing Fundamentals, CRC Press 2010
6. D. Cook, S. Das (Ed.): Smart Environments, Wiley 2005

Conference Proceedings of:
Intl. Conf. Ubiquitous Computing (Ubicomp)
Intl. Conf. Pervasive Computing (Pervasive)
IEEE Intl. Conf. Pervasive Computing & Communications (Percom)
Intl. Symposium on Pervasive Computing & Applications (SPCA)

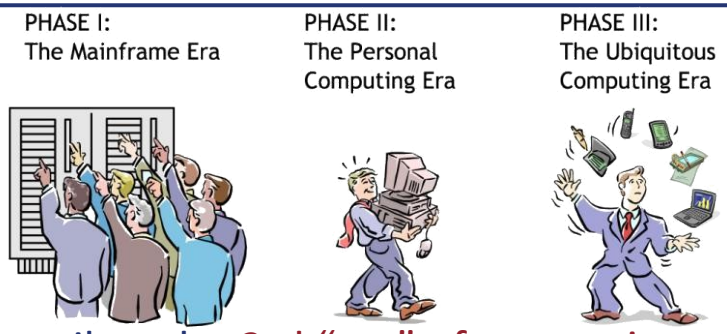
Scientific Journals:
IEEE Pervasive Computing
Springer: Personal & Ubiquitous Comp. (PUC)
Elsevier: Pervasive & Mobile Comp. Jrnl. (PMC)
Emerald: I.J. Pervasivce Comp. & Comm. (IJPCC)

What is UC?

- 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.

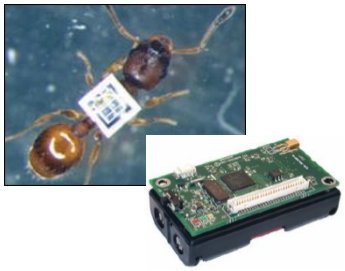


What is UC?

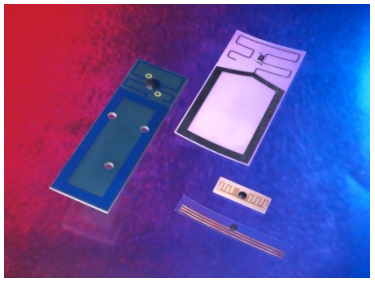


- Ubiquitous Computing describes the 3rd "era" of computing
  - Era 1: Mainframe Computing MC - many users use one computer
  - Era 2: Personal Computing PC - one user uses one computer
  - Era 3: Ubiquitous Computing UC - one user uses many computers
- Note, for Era 3:
  - some computers are *worn* (mobile phone, body sensors, …)
  - other computers are *encountered* on-the-move, more or less consciously (cf. info kiosk / data projection versus badge-reader / surveillance cam)
- UC means "networked computers everywhere"
  - µC's were embedded in VCRs, washing machines etc. since *decades* already!
  - BUT: now, with UC, the embedded computers become
    - networked, i.e., part of a "web" of interacting computers surrounding us
    - "programmable": changing firmware / SW is easier, less noticeable to user (good: cf. bug fixes; bad: cf. undesired functionality, e.g., spying)

Sample Nodes in UC Nets



Tiny, rather general purpose computers acting, e.g., as nodes in **sensor networks** (cf. UC Berkeley's *motes* → *Intel, Crossbow†*)



Wearables and mobile computing devices. cf. handhelds for warehouse picking, washable computer jackets, or companions like the notorious lovegetty: stores user's profile, beeps when a "compatible" person – with lovegetty – appears

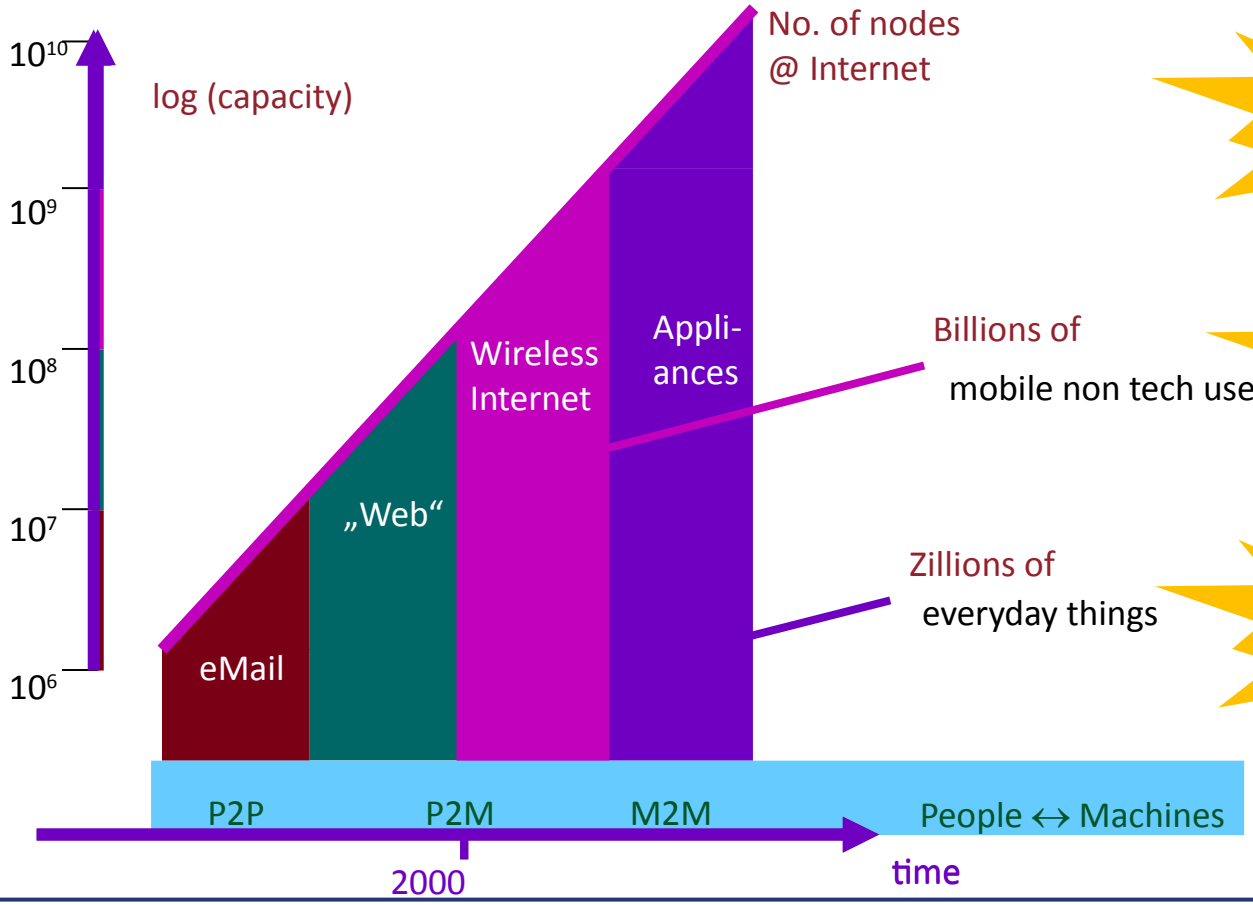
Smart labels such as RFIDs (above) and active badges (below) identify (and optionally, locate, characterize, …) objects, humans, animals; benefits and privacy threats widely discussed

Networked appliances, e.g., "smart vending machines" that transmit fill status, errors etc. to head offices; press rumors about adaptive pricing caused protests

Importance: Exploding # of nodes

issue #1: on the networking side, the exponential growth (# of nodes connected in the Internet) continues way beyond the world's population

consequence: scalability becomes even more crucial

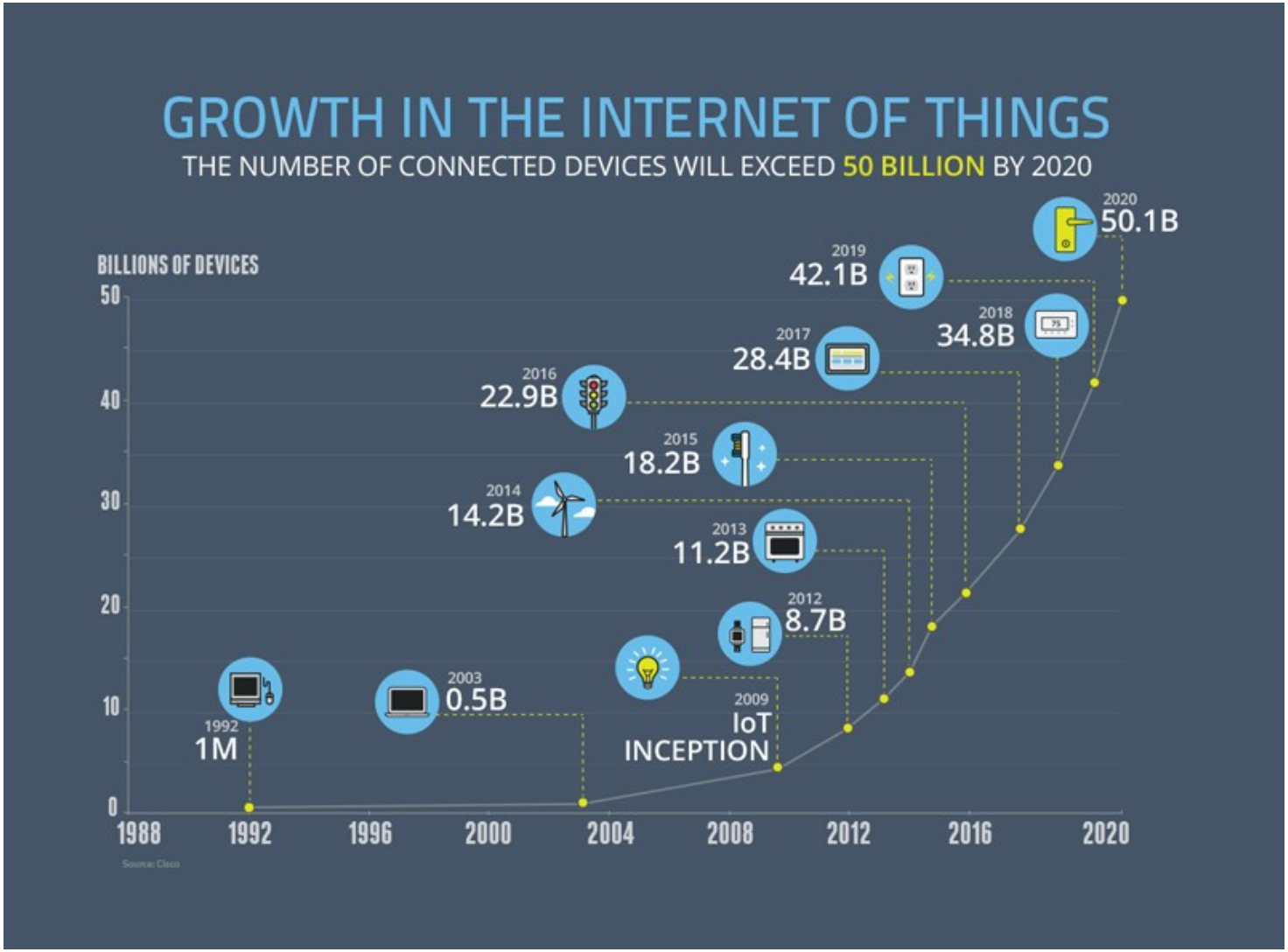


10^{10} by far *not* a limit

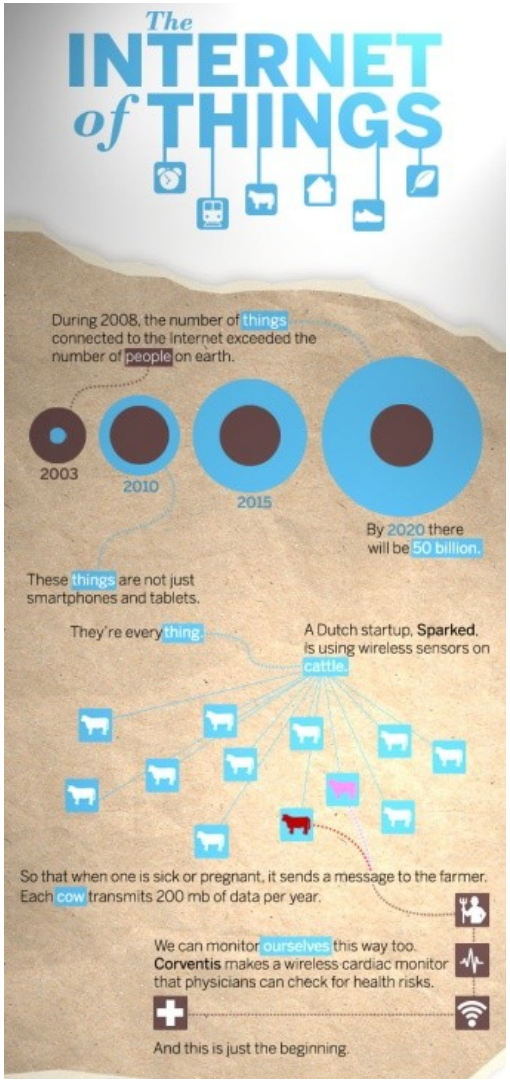
exponential growth , i.e., **explosion**

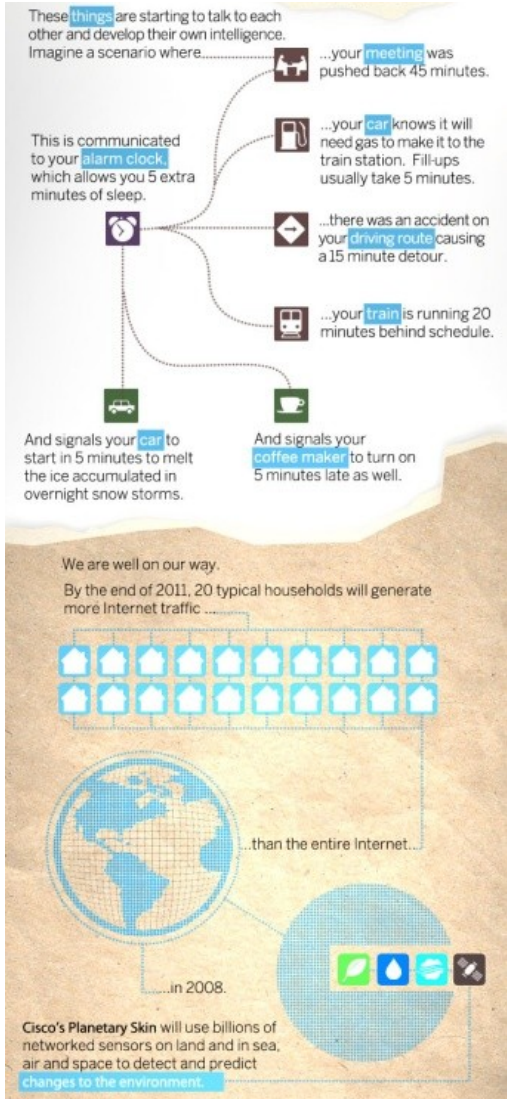
M2M: no humans in loop → ‚no limits'

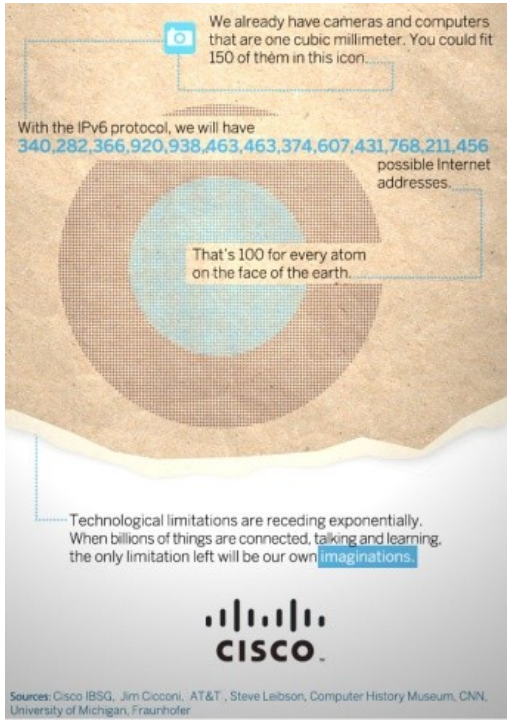
Exploding # of nodes



IoT 'Sales Pitch' by Cisco







Google

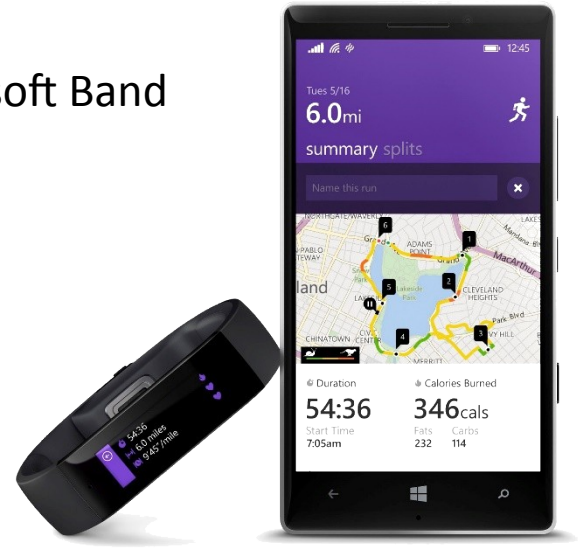
Motorola Moto 360 (AndoidWear)

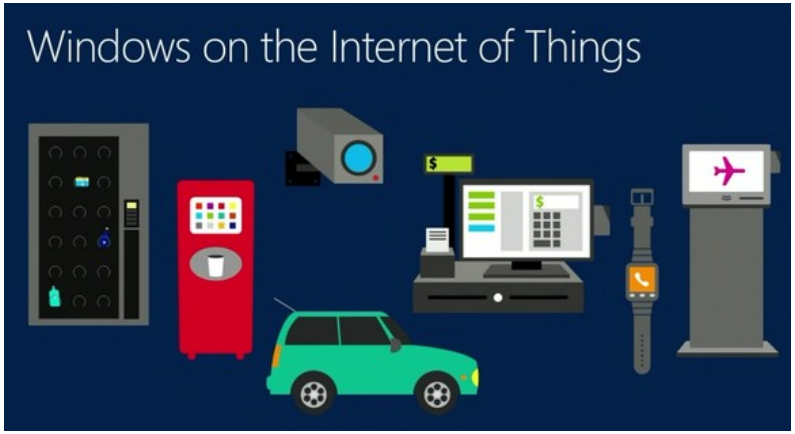
Google Glass

Nest thermostat

Microsoft

Microsoft Band





Windows4IoT

Microsoft Surface Hub

…osoft Hololens

Others

Samsung GearFit

Oculus Rift

Apple Watch

HTC Vive

Fitbit Flex

Conclusion

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At the 30,000 ft. level, UC is "the next key technology to change our society" for 3 reasons:

1. UC describes *the* third era of computing
   - therefore, all of computer science / IT is potentially impacted
   - … it will be difficult to be selective in designing this course/book (but we will see that a course / book on UC still makes a lot of sense)
2. UC has potential impact on every facet of our lives
   - computing is no more "what we do when we sit at the computer" + "what is embedded, i.e., encapsulated/hidden deep inside VCRs etc."
   - see the more / less comparison on next slide
3. UC is impossible and inevitable at the same time
   - components ("gadgets") are developed and deployed
   - more and more UC scenarios become profitable → industry will push
   - many issues of "the whole", i.e., integrated UC systems still unresolved

Challenges

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A first glance (not yet structured, non exclusive) at challenges…

Anytime/anywhere presence of networked computers means:

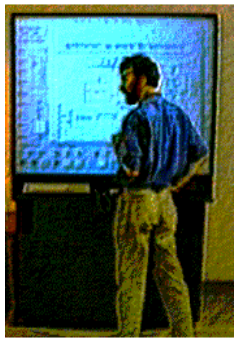
- more sensitivity ↔ less protection (cf. security)
- more dependence ↔ less perfection (cf. reliability)
- more obtrusion ↔ less attention (cf. HCI)
- more overhead ↔ less throughput (cf. networking)

In other words: as computers become ubiquitous …

- There is a risk that "the whole may be way *less* than the sum of the parts", i.e., the desired integral functionality may lack way behind
- Some known problems aggravate considerably – we've got to care!
- In short, UC is a problem of complex integrated systems, not of gadgets
  compare to: new Airbus, Space Shuttle, not to: better rocket-fuel, headlights

History: Mark Weiser

- *1952, †1999 (died before UC really took off)
- Coined the term, spread the vision of UC
- Most famous: article in *Scientific American:*
  The Computer of the 21st Century (1991)
  Web pre-version cf. http://www.ubiq.com/hypertext/weiser/SciAmDraft3.html
- Worked at Xerox PARC (now: PARC)
  - Was *the* (?) world leading center of research combining computing with humanities (≈ "birthplace" of mouse, windows-based UIs, desktop metaphor, laser printer, many CSCW contributions and much more)
- Co-Developed prototype UC devices, in particular three:
  - Pad, a prototype PDA
  - Tab, a prototype TabletPC
  - Liveboard, cf. Smartboards™ --- all in the late 80es!!



Xerox Liveboard

History: Mark Weiser

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

History: Mark Weiser

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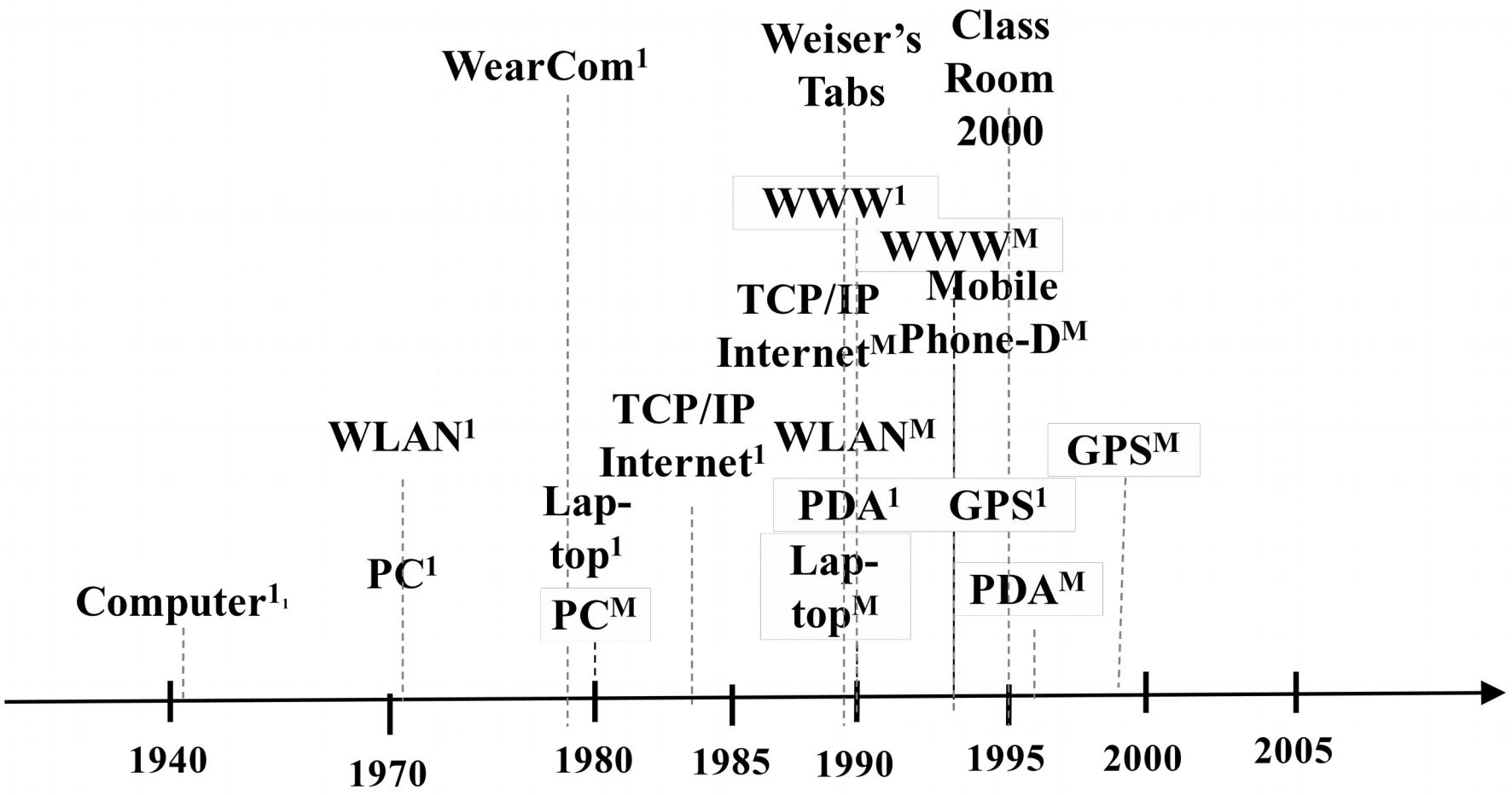
- But MW's vision comprised more
- We will try to recall Mark's view on three conflicting issues:
  - UC vs. VR (virtual reality)
  - UC vs. AI (artificial intelligence)
  - UC vs. UA (user agents)
- Thereby, we imagine Mark at panel discussions, as a UC advocate trying to argue why VR, AI, and UA are "dead end" research roads, while UC is the open road
- Compare them to today and take a less dramatic standpoint

What ICT Environments Were Like

- Late 1980s, when much of the early work on UbiComp started
- A distinction has been made in the history between the availability of the first prototypes or ICT product (1) and the first widespread commercial uptake of an ICT product (M).
  - Difference between the (1) and (M) phases seems to be averaging about 10 years give or take a few years.
- Today, it is hard to imagine such a world, where people were often unreachable if away from a fixed phone point and computing was only available at a desk computer, attached to the wired Internet.

Short History of ICT Technology



PARC Tab, MPad, LiveBoard

- 3 main intertwined devices and applications known as *Boards, Pads and Tabs developed at PARC*
  - Large wall-display program called LiveBoard
  - Smaller computers Book-sized MPad
  - Palm-sized ParcTab computer
- Marc Weiser investigated their *integration* in group work (Computer-Supported Cooperative Work - CSCW) scenarios
  - Imagined the ubiquitous availability of Tabs (laying around in meeting rooms, personalized as users grab them), …

ClassRoom 2000

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- 1995, *Classroom 2000* (led by Abowd, Georgia Institute of Technology)
  - Most research focussed on development of multimedia-enhanced materials
- Classroom 2000 researched content generation by instrumenting a room with the capabilities to automatically record a lecture
- Capture the live experiences of the occupants and to provide that record to users for later access and review.

EasyLiving & SPOT

- EasyLiving project (Microsoft, 1997-2003) developed intelligent environments to support dynamic aggregation of diverse I/O devices into a single coherent user experience.
- SPOT devices (Microsoft, 2003) designed to listen for digitally encoded data such as news stories, weather forecasts, personal messages, traffic updates, and retail directories transmitted on frequency sidebands leased from commercial FM radio stations

Ambient Intelligence (AmI)

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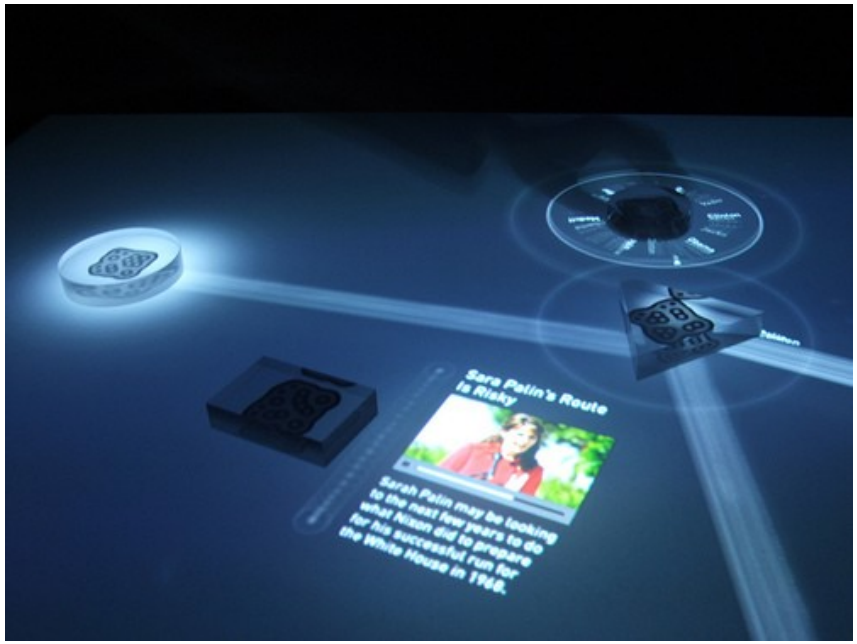
- Proposed by Philips in late 1990s as a novel paradigm for consumer electronics that is responsive to the presence of people
- & became part of a EU Research Framework (FP6 IST)
- Key properties of AmI systems are:
  - User-aware / iHCI:
  - Intelligence?:
  - Embedded:

Smart Dust

- Micro fabrication and integration of low-cost sensors, actuators and computer controllers, MEMS (Micro Electro-Mechanical Systems)
- Can be sprayed & embedded throughout the digital environment
- Creating a digital skin that senses physical & chemical phenomena

iHCI: Tangible Bits & Things That Think (TTT)

- In 1997, and still to a large extent 10 years later, GUI-based HCI displayed its information as "painted bits" on rectangular screens in the foreground
- In contrast, Tangible Bits project (led by Ishii, MIT, 1997) aimed to change "painted bits", into "tangible bits" by leveraging multiple senses & multimodal human interactions within the physical world
- "Tangible User Interfaces" emphasize both visually intensive, hands-on foreground interactions, and background perception of ambient light, sound, airflow, and water flow at the periphery of our senses.



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.

Mark Weiser – UC vs. VR

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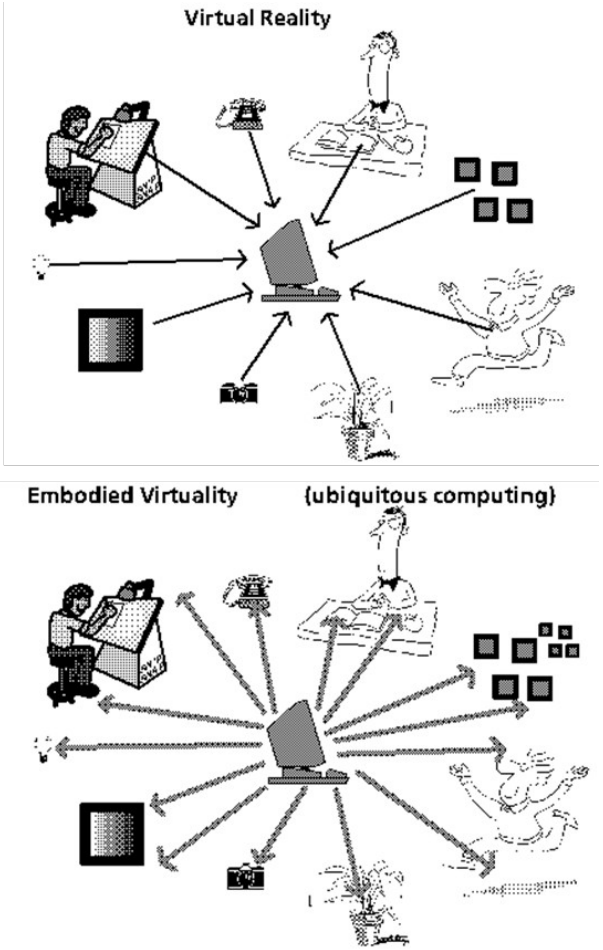
- VR is based on (3D *and* semantic) models of the real world
  - (ever larger, ever more detailed) cut-out of the world is modeled in the computer
- Put to an extreme: the world is moved into the computer
  - … and even the user becomes a computer peripheral (hmd, data glove)
- With UC, in contrast, the computer is moved into the world!!

→not one "big boss" computer, but many small ones with dedicated task & responsibility

→networking for making sense of the small parts

→*not the computer is in the center, but the human!*



cartoons by Mark Weiser

History: Mark Weiser – UC vs. AI

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- Around 1980, AI had been over-hyped
- Around 1990, frustration reigned: AI had not lived up to its promise
- Mark's argument: analogy computer = brain is exaggerated
  - Terms "intelligent" and "knowledge" raise too many expectations
  - The AI vision of intelligence concentrated in a computer is wrong
- With UC, in contrast, we aim at *smart* components
  - They figure out a tiny cut-out of the world only (just temperature or just presence of object, at just a small location, …)
  - Smart computers compare to intelligent computers like neurons to brains
  - Higher-level "sense" comes from networking smart components

History: Mark Weiser – UC vs. UA

- UAs were thought as intelligent intermediaries between the user and the computer world, thus, an approach towards ease-of-use / HCI
- Mark challenged five requirements for UA as “dead end roads”:
  1. UAs should give advise --- why don’t they do the job themselves?
  2. UAs should obey (like a butler) --- why aren’t they more proactive?
  3. UAs should work at the interface --- why interact and not *do* things
  4. UAs should listen to the user --- with immature natural language processing technology, speech recognition etc., how should they understand?
  5. UAs should learn the user’s preferences, wishes etc. by observing --- with immature machine learning technology, how should they do the right thing
- note: wrt. 1-3, UAs are “too little”, wrt. 4+5 they are “too much”
- UC, in contrast, according to Mark, should aim at “agents” which
  - carry out actions and not just mediate
  - do that largely autonomously such as not to bother the user
  - … and therefore have not much of an interface at all

History: Past vs. Present (VR-vs.-UC)

VR-vs.-UC dispute – today, we would say:

- 2014: Year of VR
  - Oculus Rift bought for $2 billion
  - Sony announces project Morpheus VR Headset
- But: VR as natural extension of real world
  - Not computer in the center
  - VR extends into the real world as Augmented Reality (AR)

- Conclusion
  - We need „the computer in the world“
  - But also: „The world (model, distributed) in the computers“ if the cooperating whole shall make sense of the „smart“ parts

90 year old immobile grandma „walking outside“

History: Past vs. Present (AI-vs.-UC)

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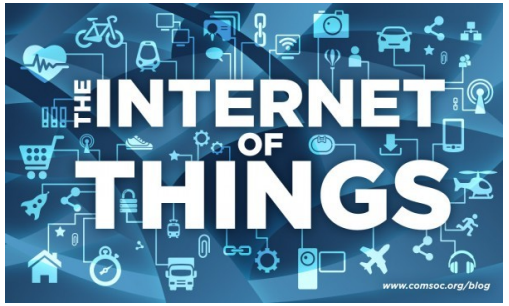
Describes without errors	Describes with minor errors	Somewhat related to the image	Unrelated to the image
 A person riding a motorcycle on a dirt road.	 Two dogs play in the grass.	 A skateboarder does a trick on a ramp.	 A dog is jumping to catch a frisbee.
 A group of young people playing a game of frisbee.	 Two hockey players are fighting over the puck.	 A little girl in a pink hat is blowing bubbles.	 A refrigerator filled with lots of food and drinks.
 A herd of elephants walking across a dry grass field.	 A close up of a cat laying on a couch.	 A red motorcycle parked on the side of the road.	 A yellow school bus parked in a parking lot.

History: Past vs. Present (AI-vs.-UC)

AI-vs.-UC dispute:

- AI was indeed overhyped …
  - Today: Still far away from real brains
    - IBM Watson, Deep Believe Networks
    - Facebook, Google, MS have big AI research labs
  - EU: Human Brain Project (1.190 billion € total funding)
  - USA: BRAIN ($100 Million per year [$200 Million proposed])
- How to combine „smart computers“ like neurons into a „brain“ that makes sense
  - Remember: UC = computers (=sensors?) everywhere
    - Big Data, Machine learning, etc.
    - We need the methods developed by the AI community

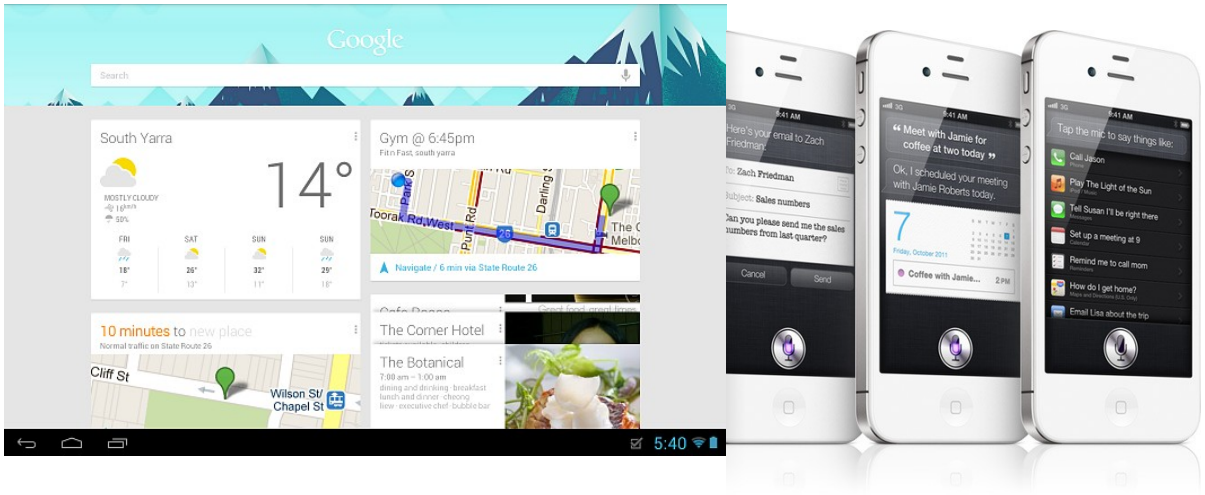


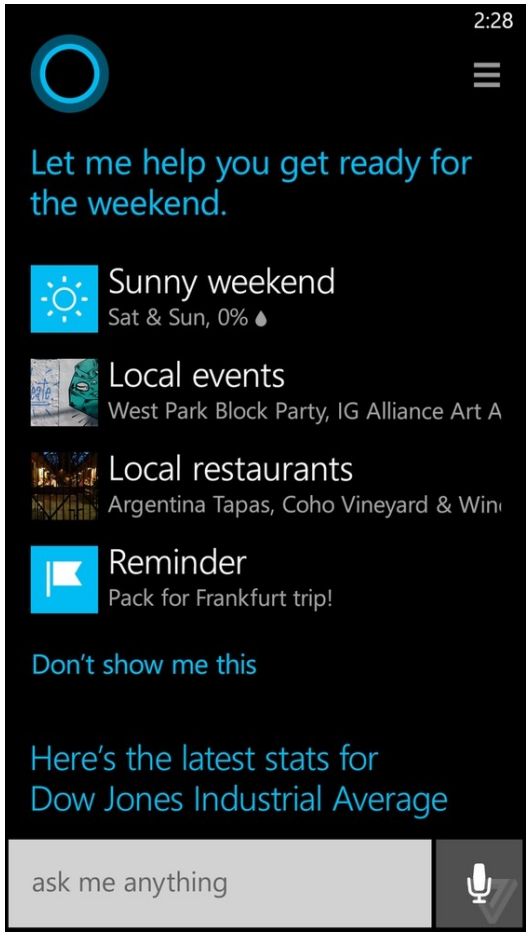
- Conclusion: *Integration is key*

History: Past vs. Present (UA-vs.-UC)

UA-vs.-UC dispute:

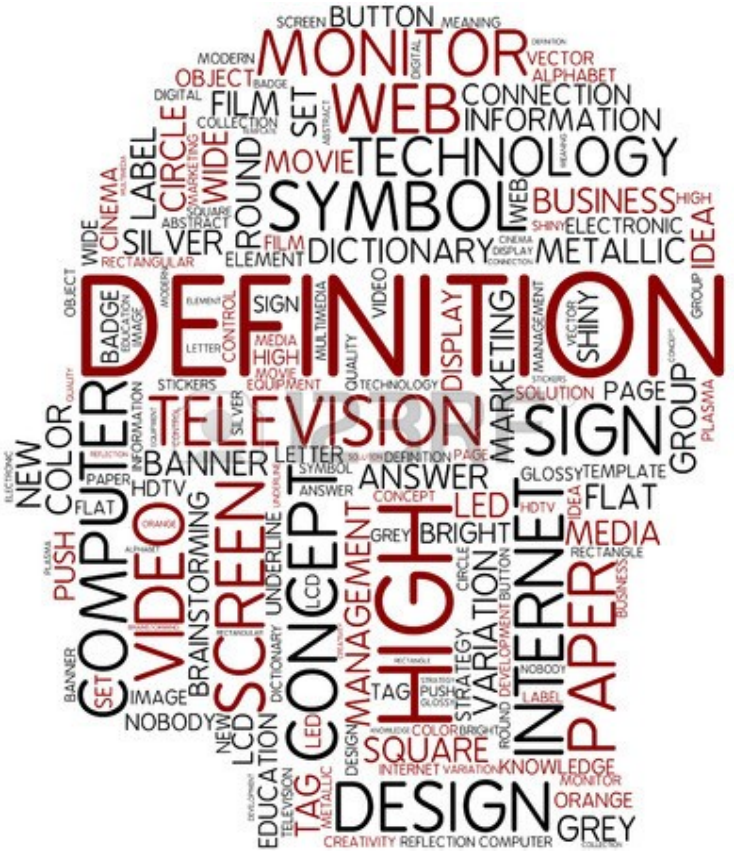
- „Listen to user and learn“ was (over?) ambitious, but:
  - (1) autonomous-actions instead of „obey/advice“: even more ambitious
  - (2) machine learning made progress → „learn->advice“ becomes feasible





Defintion

- No single, absolute definition for ubiquitous computing.
- Instead propose many different kinds of UbiCom systems based upon combining different sets of core properties
- What core system properties would you propose to define ubiquitous computing?



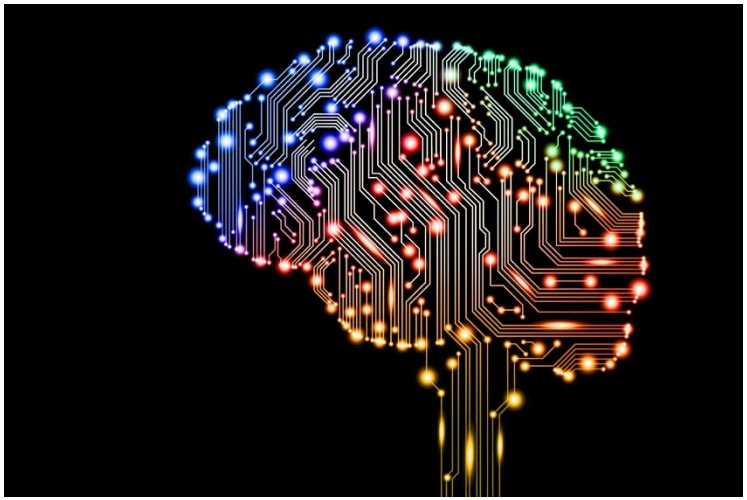
Weiser's 3 Internal System Properties

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.

Extended set of Internal System Properties

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.



Weiser's 3 Internal System Properties

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   - Components ("gadgets") are developed and deployed
   - More and more UC scenarios become profitable → industry will push
   - Many issues of "the whole", i.e., integrated UC systems still unresolved

S.C.A.L.E.: Scheme

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Major UC challenges, on a very high level:

- S – SCALABILITY
  - how to support cooperation of “zillions” of components?
  - how to support nomadic users around the globe?
- C – CONNECTIVITY
  - how to “easily” connect these zillions?
  - wireless networks – a blessing and a curse (unreliable!); important but…
  - most issues *above* wired/wireless net: how to find/understand peers, enable zero configuration, design huge networks w/o server/bottleneck (overlaps w/ ‘S’)
- A – ADAPTABILITY
  - usage during daily work, surrounded by 100s of components: need *minimal* interaction
  - major approach: context-aware computing – use it to automate tasks & reduce options
  - adapting-to-user (user *modeling)* must be focused beyond context-awareness
- L- LIABILITY
  - term indicates: we must go beyond today’s IT security solutions (not goals)
  - today’s solutions do not scale (root PKI?), are not “humane”
  - & don’t flexibly consider conflicting (privacy, traceability) / related goals (dependability…)
- E – EASE-OF-USE
  - adaptability permits “minimal” …, ease-of-use means “optimal” interaction (related!)
  - issue: optimal use & combination of modalities, advancement of specific modalities
  - issue: “understanding” natural input: a) xxx-to-text; b) text-to-meaning; “intelligence”?

Taxonomy: Buzzwords

UC has many names (sigh! hinders establishment as wide-spread discipline!)

Warning: follows a boring myriad of terms but: needed for 'UC literacy'

- **Pervasive Computing:** more common in industry
  (coined by IBM?); emphasizes computers „penetrating" the world
- **Ubiquitous Computing:** more common in academia
  emphasizes the „final" state of penetration: computers everywhere

- **Disappearing Computers:** less common, like…
- **Calm Computing:** also less common, says basically the same:
  should be hardly noticed by user, should not „disturb"
- **Invisible Computers:** same as above, but *very* demanding
  (disappearing / calm is less demanding)
- **Post-PC era:** not a good term, only says what it is *not* (PCs)
  refers to relation users:computers N:1 (1960-80) → 1:1 (1980-2000) → 1:N

Taxonomy: Buzzwords (2)

- **Ambient Intelligence:** „invented“ for EU research framework programs (FP 5, **6, 7**);
  „ambient“ refers to Weiser‘s quote, „disappearing in the environment“;
  „intelligent“ is revival of over-hyped term → Amb.I. is *only* common in Europe
- **Realtime Enterprise:** common in business world, see next slides

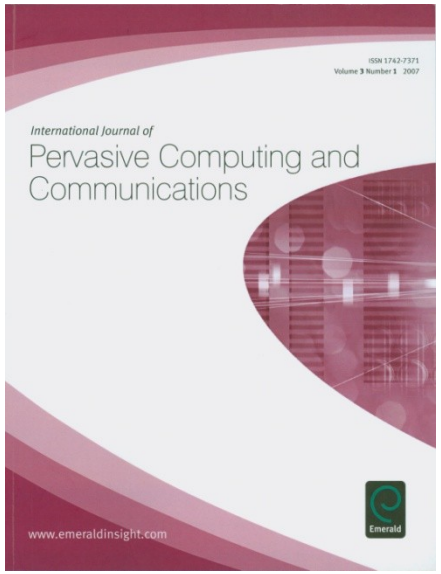
- **Mixed-Mode Systems:** not very common either, but pops up every now and then
  refers to „resource heterogeneity“ in the range RFID – Sensor – PDA – PC – Cluster etc.
- **Tangible Bits:** rather uncommon (1 book?), seen in NL/JP
  means: computers in appliances, Smart Paper (see below) etc. →
  „bits“ i.e. Computing become part of physical world
- Some people argue that the major terms represent subsequent steps, e.g.:
  pervasive → ubiquitous → disappearing → invisible → ambient …
  but this should *not* be tried:
  - The terms are synonymous; „proof“: research labs with either of these names work on the same issues!

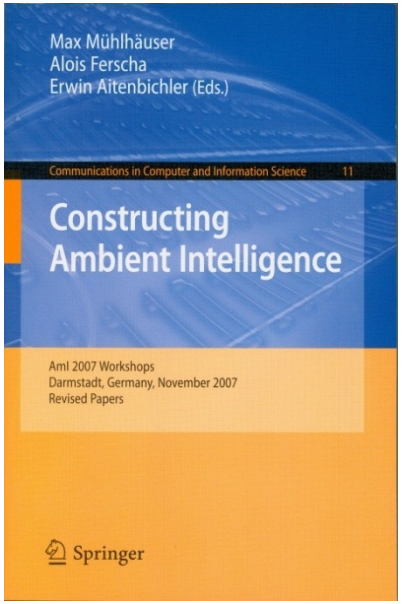
Taxonomy: 3 Major Buzzwords

„Hypothesis“:

Ubiquitous Computing = Pervasive Computing = Ambient Intelligence

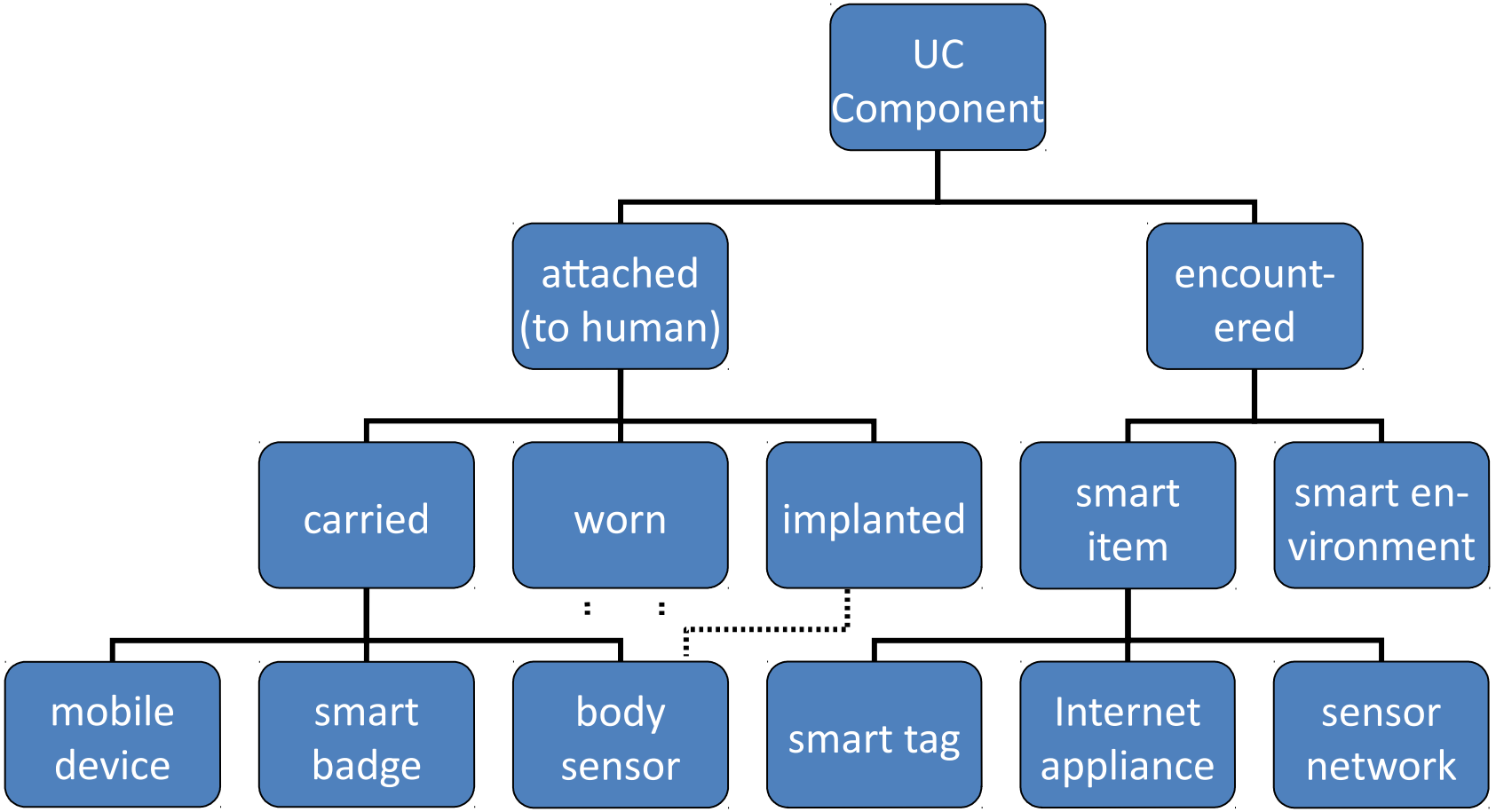
Google-Hits: 2,370 k 2,460 k 2,370 k (2014, circa)





Taxonomy: An Attempt

We may start to organize UC components in a real taxonomy:



Reference Architecture: Motivation

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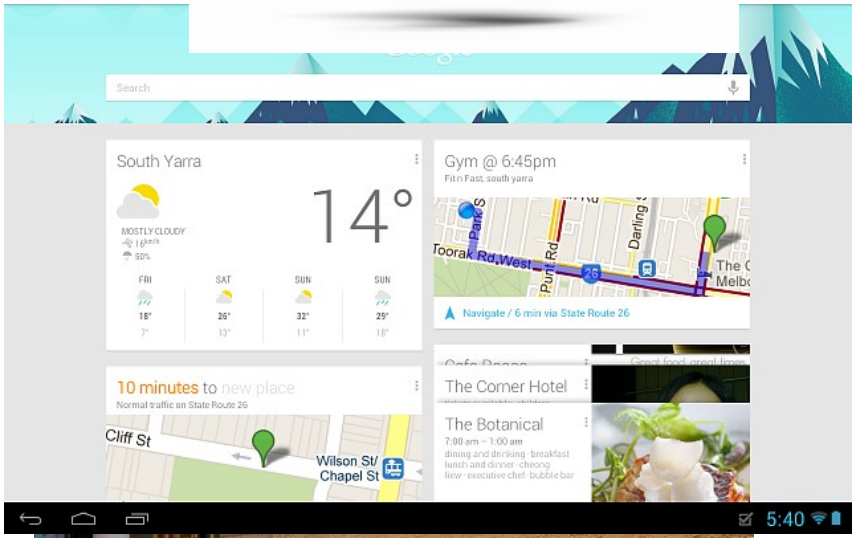
Why a reference architecture?

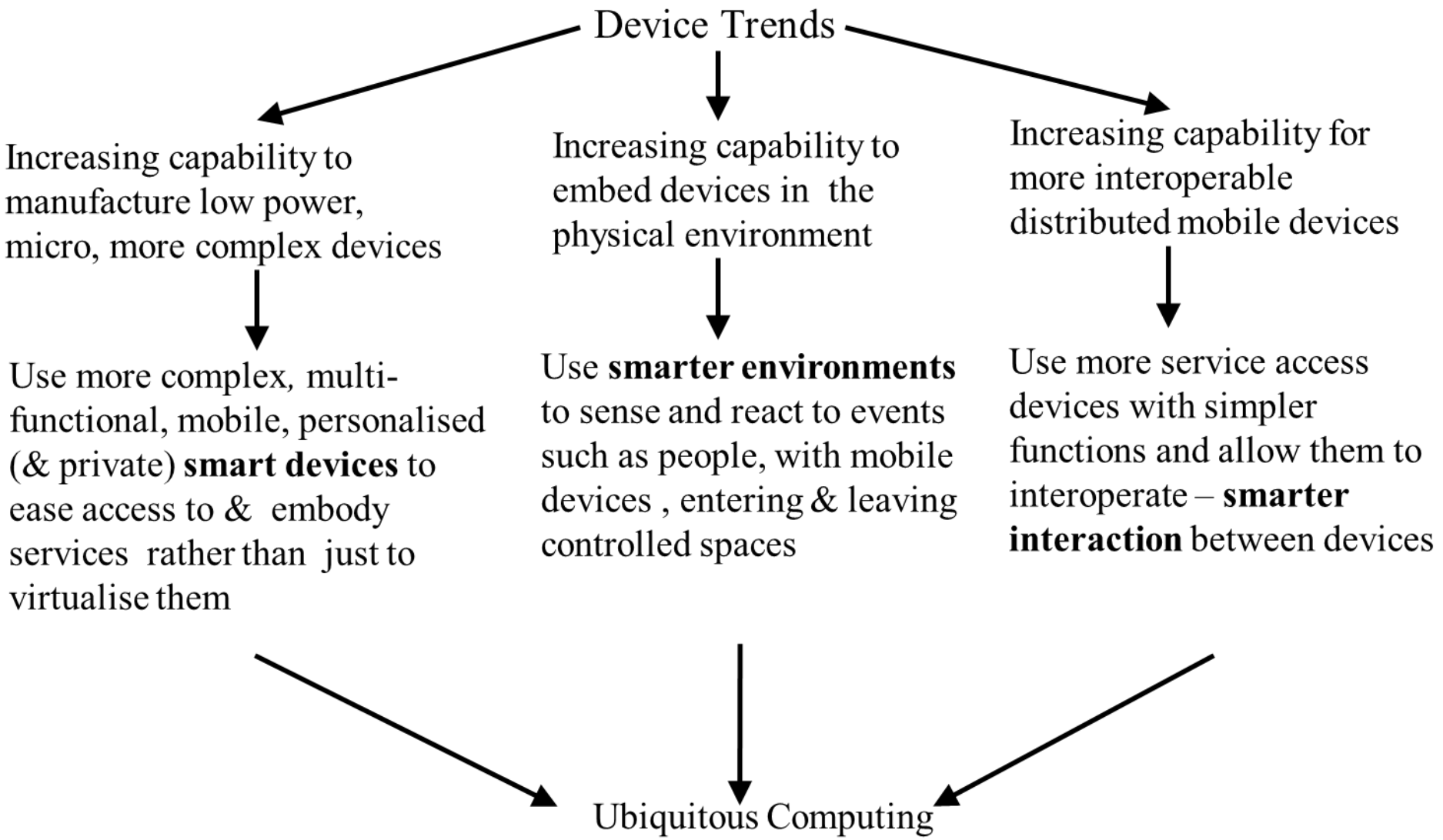
- "Old definition" of Distributed Systems not appropriate
  - OLD: "a distributed system is a collection of autonomous systems AS, interconnected through a communication subsystem CSS": DS :== {AS} ∪ CSS …
  - … where communication happens via message exchange only
    - (note 1: an AS may be a multi processor with shared memory i.e. shared mem not entirely "forbidden")
    - note 2: AS defined to consist of: 1. processor, 2. memory, 3. communication, 4. identity (e.g., IP address)
  - *NEW:* nothing but (half) "3" required: *passive communication; rest optional !*
- Futher "old" views:
  - client-server world: two kinds of nodes exist (clients, servers), maybe blurred
  - peer2peer world: deliberately no distinction between nodes
  - for both views: all nodes are created equal
- However, in UC world, there are 2 main reasons to introduce distinctions:
  - resource heterogeneity: special-purpose inappropriate for general-purpose tasks
  - role heterogeneity: very personal nodes should not be treated like very public ones?

UbiCom System Model: Smart DEI

- No single type of UbiCom system
- 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.



UbiCom System Model: Smart DEI



Smart DEI Model Summary

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- 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

Big Picture

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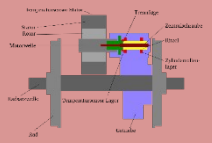
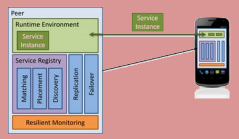
Things [People]



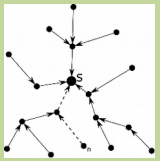
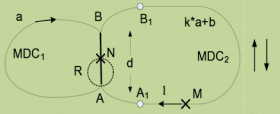
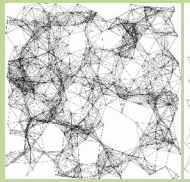


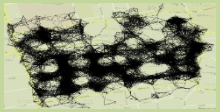
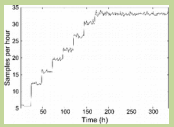




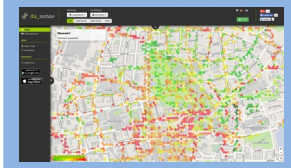

Connect

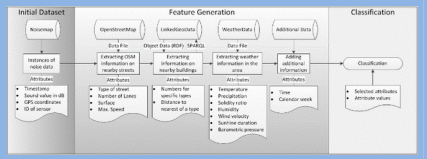
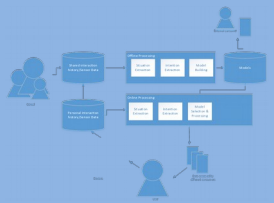
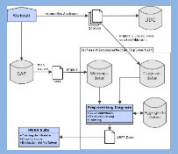


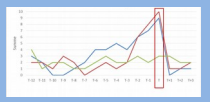




Smart Services

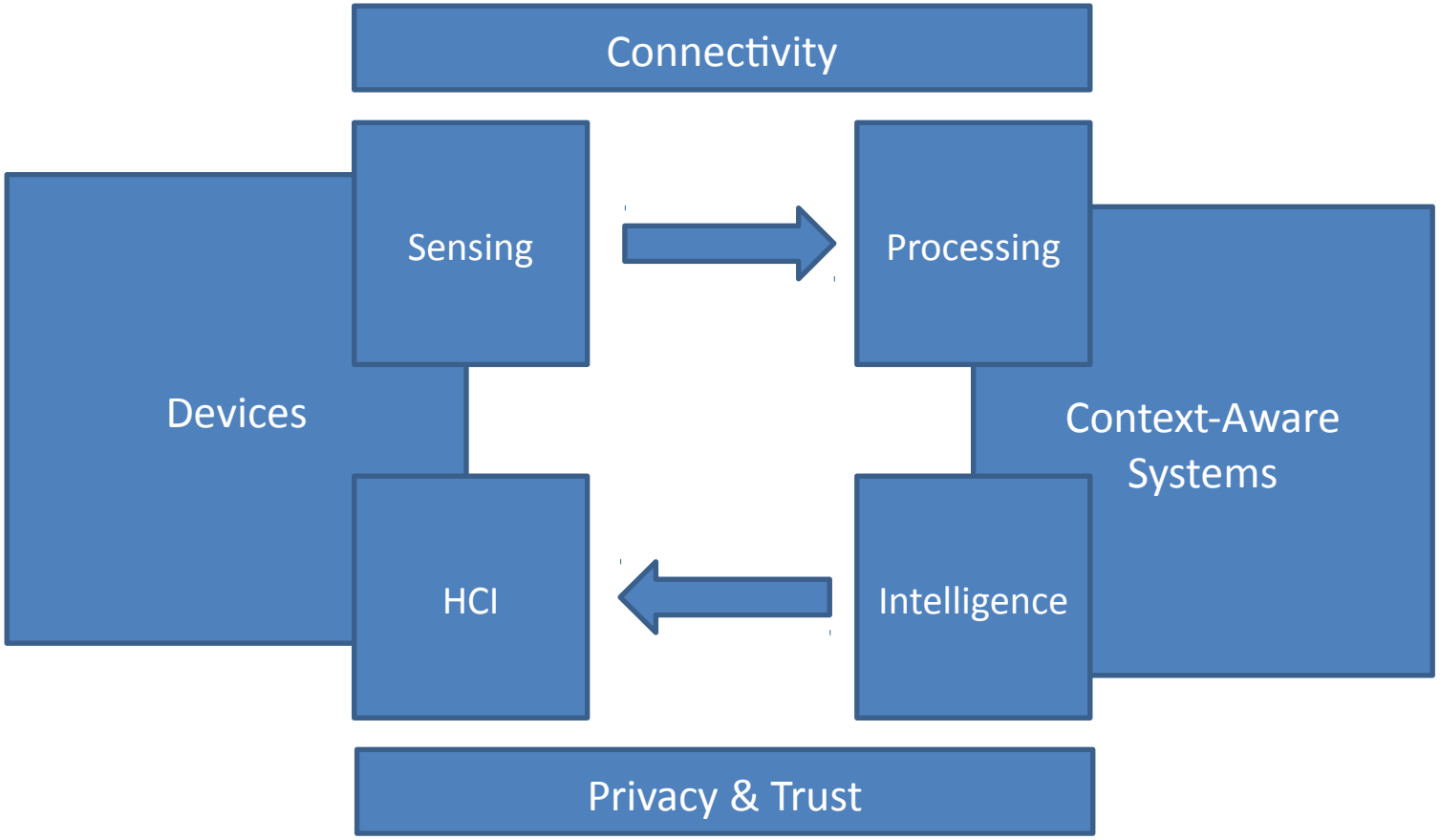




People [Things]

Simple Architecture



Contents of TK3

1. Introduction to Ubiquitous Computing
2. Devices & Sensing
   a. Mobile Sensing
   b. Wireless Sensor Networks
   c. Smart Items & RFID
3. Connectivity
   a. Wireless Networks
   b. Service Discovery
4. Context-Awareness
   a. Processing
   b. Context / Activity Recognition
   c. User modeling
5. Applications
   a. Interaction
   b. Privacy & Trust

- Slides contributed by lecturers and TK researchers;
- Some illustrative slides from external sources
  → for internal use & TK3 students only

Common Myths of Ubiquitous Computing

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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

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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

For Your Long Term Memory

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Ubiquitous Computing:

- Smart devices, roaming users, zillions of nodes
- Inevitable, even reality today…
  - … but integration remains a grand challenge
- Challenge as five large research issues: S.C.A.L.E.
  - scalability
  - connectivity
  - adaptability
  - liability
  - ease-of-use
- What else to remember:
  - the many terms & buzzwords ☹
  - reference architecture and “ideas behind” visions, organizations