Summary for Written Test **Smart Environments** 2020

by THOMAS VAN KLINK

Creative Technology – M2: Smart Environments.

According to guidelines given by lecturer.

Information taken from lectures, papers, and videos.

<u>Introduction</u> Lecture 1

Ubiquitous Computing *A vision for computing in the 21st century.*

- Enable computer-based services to be made available everywhere and anytime.
- Support intuitive human usage.
- Appear to be invisible to the user, very well integrated.

Editors notice: "I will write *UbiCom* as short for *Ubiquitous Computing* as it is a bitch of a term to write fully :)"

Moore's law *Trend behind UbiCom.*

Every 18 months (used to be 12) the number of transistors per square mm will double.

Increasingly more powerful computers → Same power, half the size.

Disappearing Computer *Trend behind UbiCom.*

Computer are becoming more and more integrated into everyday objects, leads to new ways to enhance our lives.

For example: A speaker with Google Assistant integrated or Ikea's desk lamps with smart speakers.

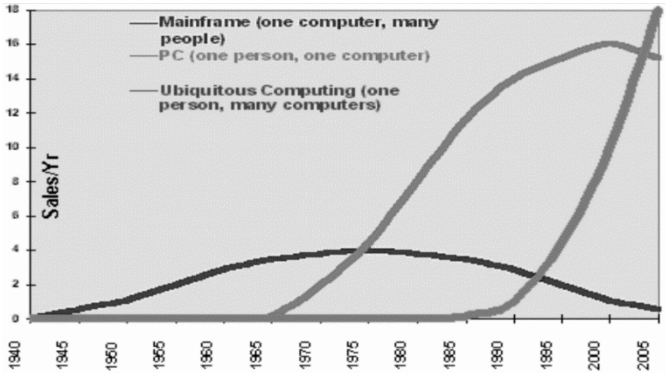
History highlights *Steps in computer development in history*

- *1944* IBM Mark I at Harvard University — First proper computer, very large, 5 tonnes, used in war.
- *1947* IBM Mark II at Harvard University — Second generation, even larger at 25 tonnes.
- *1960s* Batch computing — Mainframe era, one computer – many users, data storage: punch cards or magnetic tape.
- 1980s Personal computing — PC/Desktop era, one computer – one user, system and user eye to eye (both in the same location and nearby).
- 1990s World Wide Web — One user – network of computers, wider data access, data sharing, search engines.
- 2000s Paradigm shift — Rapid change in use and approach to computing.
    - 2001 Ambient intelligence — Small cheap devices, light, wireless, everywhere, anytime.
    - 2008 Peak ubiquitous computing — Since 2008 this trend took off. Moore's law slowed down.
    - 2010 Natural interfaces — A new way to approach computing, more natural to us.
        - 2010 Apple introduces Siri, the first voice-controlled assistant.
        - 2015 Personal robot butlers are introduced.
        - 2018 Amazon opens cashier-less stores.
        - 2018+ Context-aware computing, integration of AR in applications (Google Maps).

One computer, many persons → one person, one computer → one person, many computers

Marc Weiser *Introduced the concept of UbiCom in his papers.*

Prediction made in 1996: three waves of computing.



Mainframes	Gradual increase but fades off
PC's	Rapid increase but now flattens
UbiCom	Rises exponentially and still does

Three main properties for UbiCom systems proposed by Weiser:

1. Computers need to be *networked*, *distributed* and *transparently accessible*.
2. Computer *interaction* with humans needs to be more hidden. No more user interfaces.
3. Computers need to be *aware of environment context*. To optimize operations.

Two additional properties:

4. Computers can operate *autonomously.* No human intervention, self-governed and no configuration.
5. Computers can handle *dynamic actions* and *interactions*, governed by *intelligent decision-making* and *intelligent organisational interaction*. Suggest a form of artificial intelligence.

Five main properties of UbiCom *Main functions which an UbiCom solution should fulfil.*

- Context-aware — Sense, adapt and control environment.

  Takes external and internal factors into account in decision making.
- Intelligent — Handling non-determinism (different results with the same inputs)

  Working goal based. Being a social intelligence (for example assistants).
- Distributed — Networked computers. Transparent access. Openness.
- Autonomous — Automated. Independent. Self-governed.

  No human intervention should be necessary.
- iHCI — Disappearing computer. Implicit interaction with computers.

  Interfaces should be more natural and less intrusive.

Future trends *What will the future of computing look like?*

- Unobtrusive, pervasive and not always invisible.
- Personalized, adaptive and context aware.
- Smart, intelligent and proactive: in background, gentle (AI).
- Being available and accessible everywhere (mobility and connectivity).
- Mobile phones/accessories will play an important role.
  - Participatory sensing
  - Opportunistic networking
  - Crowd intelligence

  More on these subjects later in the summary.

Wireless Sensor Networks Lecture 2

What is a WSN?

An ad hoc network (a decentralized network with no main computer) of self-powered and self-configuring sensor nodes for collectively sensing and manipulating environmental data and performing actuation functions reliably, efficiently, and accurately.

A node often consists of:

Sensor – Actuator – ADC (Analog Digital Converter) – Microprocessor – Powering unit – Communication Unit (RF Transceiver)

Limitation of Wireless Sensor *Limitations of typical sensor nodes.*

- Modest processing power — Often around 1-300 Mhz.
- Very little storage — A few hundred kilobits.
- Specific communication range — Consumes a lot of power to get a decent range.
- Small form factor — Just several cubic mm (mm^3).
- Minimal energy — Constrains protocols and operations it can perform.
- Batteries — Have a finite lifetime.
- Passive devices provide little energy — For example energy stored in capacitors.

Application domains *Where do we use WSN's?*

The domains where WSN's can be used are nearly endless and is ever expanding.

Some examples: Smart Environments *duhh* Smart Cities Logistics Industrial Control

Typical sensor node features *Features found in many wireless sensor nodes.*

- Sensing material
  - Physical Magnetic fields, light, sound
  - Chemical Gasses, liquids, elements
  - Biological Bacteria, viruses, proteins
- Integrated Circuitry
  - Analog to digital converters
  - SoC, the microprocessor, memory, I/O etc
- Radio and antenna's
- Power supply / Energy harvesting
  - Solar, vibrations
  - Battery power, RF inductance (power from radio waves)
- Packaging for environmental safety
  - Cover for the sensors
  - Water resistant components
  - Shielding from other factors

A significant part of every sensor node is taken by the radio and antenna's, this also consumes the most power.

Modern sensor nodes *Commonly used sensor nodes by multiple brands.*

- Sun Spots *Java powered sensor node.*
    - Embedded development platform
    - Extremely flexible hardware and software package
    - Easy to program because of the implementation of Java
    - Connected by wireless communication
    - Mesh networking
    - Over the air programming
    - Mobile
    - Able to sense and effect surroundings

- ESP32 *The tinkerer's tool.*
    - Very small yet powerful
    - Wi-Fi communication
    - Bluetooth communication
    - Big operating window, -40 °C to 125 °C

- Nordic NRF family *Collection of different powerful nodes.*
    - Some with GPS functionality (9 series)
    - Some with LTE-M (3G-4G) functionality (9 series)
    - Others with Bluetooth Low Energy (53, 52 series)

Characteristics of different WSN's *When does it qualify as WSN or how do you recognize one?*

A special ad hoc network (a decentralized network with no main computer):

Large number of nodes	Scalability and self-configuration
Battery powered	Energy efficiency
Topology and density change	Adaptivity
Nodes for a common task	Fair distribution of load not important
In-network data processing	Message-level latency

Sensor-net applications:

Sensor-triggered burst traffic	Adaptivity	Sensors who only transmits when activated can create a burst in data that is being send.
Can often tolerate some delay	Trade for energy	Timely responses are not that important.

Challenges in WSN's *Problems or issues that need to be addressed when using WSN's.*

- Noisy sensors
  Sensor readings can be inaccurate, protocols need to recognize this.
  Can be solved with calibration/filtering or denoising.
  Calibrating can be done with a very accurate sensor or averaging low noise values.

- Wireless limitations
  Channels are often noisy and interference sensitive by nature.
  It is a broadcast medium; one sender could be received by all receivers in range.

Medium Access Control (MAC) to avoid collisions with multiple nodes transmitting.

- Energy consumption — Maximizing the networks lifetime.
  All the sensing, computation, and transmission costs energy.
  Communication with the radio uses the most energy for the node.
  A sleep state limits all operations to save power, can be forced on scheduled times.

- Energy sources — Small batteries are used in most cases, but they have a limited run time.

  - Energy Harvesting — Energy can also be harvested by ambient energy (pressure, solar, heat). This energy is sporadic, transmission and reception are only possible when enough is available.
  - Remote powering — SWIPT: Simultaneous Wireless Information and Power Transfer
    The node is powered by RF waves and transmits only while it receives this power by the waves being send.

- Environmental Factors — Wireless sensors need to operate in conditions that are not encountered by typical computing devices. Rain, sleet, snow, hail, wide temperature variations, may require separating sensors from electronics.

Why use WSN's today? *Reasons why WSN's are used more and more in current day.*

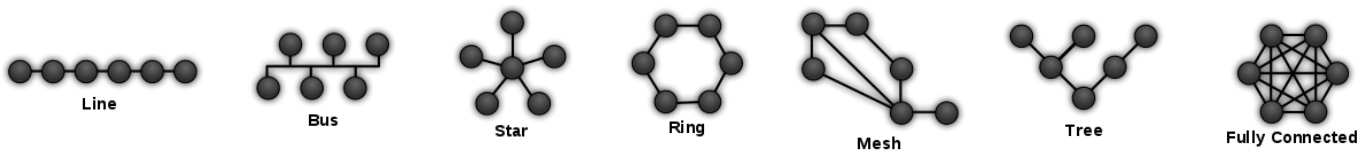
- Moore's Law is making sufficient CPU performance available with low power requirements in a small size.
- Research has resulted in new sensing materials for many chemical, biological, and physical sensing tasks.
- Transceivers for wireless devices are becoming smaller, less expensive, and less power hungry.
- Power source improvements, better batteries, and better passive power sources.
- Miniaturization has enabled the combination of multiple technologies on the same SoC.

Organization in WSN's *Organising nodes within a network to optimize their use.*

Induvial sensors are quite limited in their operation, full potential is only reached using many sensor nodes.

They are then organized into networks which can be of different types:

- Line — Point-to-point connecting from device to device.
- Bus — Every device is connected to one cable, data flows in one direction.
- Star — Every device is connected to a hub which can connect to others.
- Ring — Every device forms a link with two neighbouring devices, unidirectional.
- Mesh — Every device is connected to another device via a particular channel.
- Tree — Hierarchical flow of data, uses hubs to distribute data down the hierarchy of devices.
- Fully — Every device has a dedicated connection to another device.



You need efficient protocols to route and manage data in such a network.

The future of WSN's *Where will WSN's evolve to?*

- Mobile sensors
    - Micromachines with sensors (for example sensors at millimetre level).
    - Low-power motors that will support mobility for sensors.
    - Insects with sensors (cyborg beetles, cyborg cockroaches lovely).
- General purpose sensors
    - Sensors that can adapt to changing objectives.
    - More memory and CPU will allow more complex applications.
    - Sensors are becoming more flexible and more useful.
- Synthetic sensing Using many sensors to function as a certain specific sensor.

Conclusions *Finally…*

- Wireless Sensor Networks are here to stay.
- Enable a new way for engineers to design human-computer interactions.
- Availability of sensors will lead to new and exciting applications.
- Sensors networks are essential building blocks for smart environments (but are *not* one themselves).

Urban Sensing Opportunistic Ubiquitous Systems Lecture 3

Understanding the city around us *Sensing in urban environments.*

There are many ways to integrate technology in daily urban living.

We embed sensors in everyday objects (for example streetlights) to try and sense the city.

Technologies helpful to achieve this goal: Wireless Sensor Networks ofcourse

WSN's for Smart Cities *Characteristics for wireless sensor networks in urban areas.*

- Usually a small scale Otherwise connectivity or energy might be a problem.
- (Often) static idem
- Application specific Every vendor has their solution.
- Not scalable with city usage Expensive to move, repair or recharge.
- Focus on monitoring How do the users interact?

Using smartphones for sensing *Possibilities for using already available devices for sensing.*

- Exploiting the sensing capabilities in modern smartphones for large scale opportunistic sensing.
- People will not only be consuming data, but they will become producers as well.
- Provides a basis for human-centric applications.

Urban sensing

Sensing in urban environments. Often uses smartphones for sensing as networks are more difficult.

Opportunistic sensing *Grab the data when you can, but with some consent.*

- Owners may not be aware of active applications.
- Executes automatically at certain locations.
- States change automatically, device is context aware.
- Privacy and transparency must meet the user requirements. Limiting and dangerous factor.

Participatory sensing *Ask for the data, kindly.*

- Owner consciously participates because of interest or other factors.
- The owner (should) decides what data is shared.
- Accompanying application assists people to publish, share, interpret or verify data collected by the owner.

Recent example: The CoronaMelder app from the Dutch government.

Advantages of urban sensing *Sounds good man.*

- Very large scale, over very large areas.
- Exploit people's mobility. One sensor can cover large areas as it will be moving.
- Application diverse. Personal, public, social etc.
- Focus on human-centric applications. Often, but not necessarily.
- Societal relevance.
- Infrastructure is already in place. No need to pay for more.
- Ubiquitous, very large install base.
- No performance problems.
- No energy problems. At least none that you need to worry about.
- Development tools available. Android Studio, Swift.
- Deployment through app stores. Google Play, App Store.
- Variety of data sets. GPS, Microphone, Accelerometer, 4G/5G etc

Challenges of urban sensing *But.*

- Processing massive amounts of data collected.
- Finding higher level meaning out of sensor data. What does it actually mean?
- Determining the devices sampling context. Activity, behaviour, places/locations, social context.
- Changing coalitions of sensors asks for adaptation. Group which sensors are bond within changes often.
- Security and privacy.
- Convincing people to participate. Like current issues with CoronaMelder.

Application areas of urban sensing *For what can urban sensing be implemented?*

- Measuring city stress Safety, traffic, air quality, noise, road conditions.
- Wellbeing Health and sports.
- Social networking
- Transportation
- Green applications
- Recreation Games etc.

Conclusion *This was better.*

What is the best option for sensing in urban environments? Depends on your application / research needs.

- Wireless Sensor Network Static and specific
- Opportunistic sensing Dynamic and invisible
- Participatory sensing Dynamic and active

Ubiquitous Computing Context Awareness Lecture 4

Context in a smart environment *Data tells the story.*

A smart environment combines many technologies together to reduce the need of user involvement and provide intelligent assistance to the user.

To accomplish this the system needs to be context aware.

- Context *Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.*
  - Human factors Who
  - Physical context Where
  - Computational context What
  - User context What
  - Time When

Keep in mind: context information is:

Temporal, imperfect and highly interconnected.

- Context Awareness *A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task.*

  Lifecycle: Capture physical context → Capture User Context → Context Processing →

  Adapt to Context → Manage Context

Capturing context *How to capture the required data for gathering context?*

- Generation
  - Explicitly User gives input based on context (for example: put phone in airplane mode).
  - Implicitly Monitoring user and computer-based activities (for example: switching off screen).
- Sensing the context
  - Raw contextual information Location, time, light level, sound, vision (camera), calendar.
  - High-level contextual information User's current activity.
- How to sense
  - One powerful sensor Collects lots of information with one device, understanding the data is more difficult.
  - Lots of (smaller) sensors Each sensor only collects part of the data, need to be in sync, possibly cheaper than one sensor.
- Sensor fusion Adapting to situations rather than fixed physical states, combine sensor data to obtain context awareness.

- Sensing context changes
    - Acting — Most contextual information changes over time. These changes are triggers for action.
    - Detecting — Changes can be sensed by different methods.
        - Polling — Request information update periodically.
        - Advertising — Interrupts.

Processing context *How do you process the gathered date into context?*

All the gathered data together with other available data can be used to gather the state of the context.

But still:

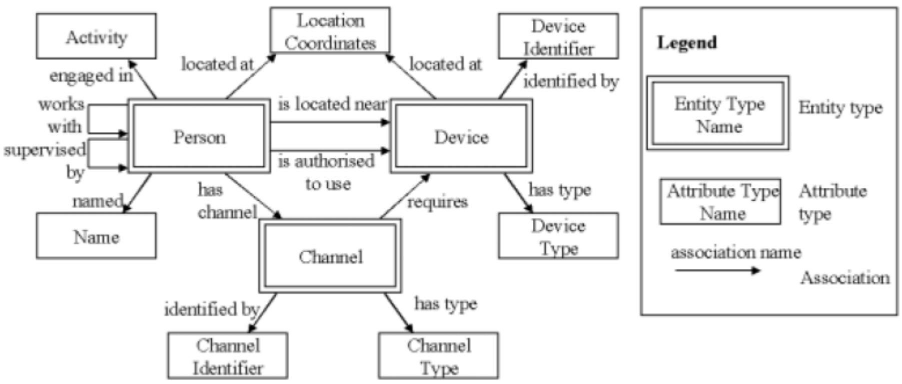
- Applications may require more than just low-level context, can be achieved by using more sources.
- Handling the possible errors or inaccurate measurements by sensors is still required.

To gather the context of an environment you model it using a:

Object based approach

- Entities — A physical or conceptual object.
- Attributes — Properties of entities.
- Associations — Linking an entity, its attributes, and other entities (uni-directional)
    - Owner of an association has assertions (*beweringen*) about the owning entity.
    - Context description is a set of such assertions.

Example scenario with three entities:



Where do we analyse the context out of all the gathered data?

- Local — Faster, lower network traffic, only partial access to information, limited power.
- Central — Needs all data, high network traffic, takes all information into account, more power.

Using context *What do you do with the context gathered?*

- When a certain situation is recognized by the system it can take a certain action.
- Action to be taken is application specific and might just trigger further sensing.
- After every action, the context should be reconsidered as it has changed.

Considerations:

- Performance of the system — Action should be performed in time.

- Control User must be able to retain (or regain) control at any time.

Challenges:

- Are all sensors capturing the same event?
- Context must be abstracted to make sense for an application.
- How to convert data into knowledge?
- Context is always dynamic.
- The need to detect changes in real time and adapt to constant changes, history information is valuable.

Designing for people:

- Avoiding embarrassment The system should not do the wrong things.
  - Location aware notifications (know where the user is and act on that)
- Avoiding danger What is the cost of a system mistake or malfunction?
  - Getting locked in or out of your smart home.
  - Malfunctioning smart smoke detectors.
- Including privacy As with all smart systems this is a big factor.
  - What is collected and by whom?
  - Is the data shared by others?

Security and privacy:

- Protecting the gather information
  - Each user should have control over their own contextual information.
  - Each user should have control over the distribution of contextual information.
- Not letting the system gather information on its own
  - Each user should approve and consent the data being collected.
- Interconnected systems are dangerous
  - Your system is only as strong as your weakest link.

Applications with the use of context *Context-awareness in practise.*

- Triggering useful information
  - Car navigation systems.
  - The f**king Google Maps "Do you know this place?" notification.
  - Reminder at certain times or locations.
  - Gmail: reminding you to actually attach a file after you mentioned it in the text you wrote.
- Memory retrieval Save contexts of events and retrieve them later (prosthetic memory).
  - Who was the girls with Tom at the theatre later yesterday?
  - What was the note I made at a meeting last July in this conference room?
- Sharing experience
  - Refer to other people's context For example reviews on Google about restaurants.
  - Broadcasting context Realtime reviews. For example, information about gas prices which you share after you went to a pump.

Conclusion *Only one lecture to go.*

Context-awareness is a necessity in Smart Environments. Almost all projects require a form of context-awareness.

<u>Applications and some history</u> Lecture 5

Active Badge *forerunner of ParcTab, developed at Cambridge University*

Small badge which can determine your location inside a building/office.

- First context-aware computing application.
- Designed as an aid for telephone receptionist.
- Periodically sends infrared signals to sensors embed in rooms throughout the building.
- Limited accuracy.

Active Bat

Active Badge concept but with greater accuracy.

- Uses ultrasound, accurate to 3cm.
- Base station used for determining position.

Active Floor

Indoor location determination concept like the Active Badge and Bat.

- Identification by a person's gait (walk).
- Special floor design with embedded sensors in tiles.

PARCTab, MPad and LiveBoard *From ya boi Marc Weiser*

Three main intertwined devices and applications developed at PARC (research facility).

- Palm-sized PARCTab computer (mobile phone like).
- Smaller book-sized computers, MPad.
- Large wall-display program called LiveBoard.

ClassRoom 2000

Similar to modern day facilities at the UT, it pioneered a high-tech classroom which captures live experiences of the occupants and records it for other users to later access and review.

- Most research was focused on development of multimedia-enhanced materials.

Smart space projects

- NIST (1998-2003) Used pervasive devices, sensors and networks for context-aware smart meeting rooms that sense ongoing human activities and respond to them.
    - Meeting room design When people talk, system takes dictation, records a transcript of the meeting, tracks individual speakers, follow what the conversation is about, and triggers associated services from the Internet.

Interactive workspaces project *Stanford University, 1999*

Investigated design of rooms (iRooms) to create applications integrating the use of multiple types of devices of varying form factors.

Cooltown *HP project, 2000-2003*

Build to develop a vision of ubiquitous computing.

- Each physical and virtual world resource in Cooltown has a web presence (URL).
- Benefits for mobile users in the physical world
  - Ubiquitous access.
  - Enough middleware (software that provides common services and capabilities to applications).
  - Local actually means local in this case.

Microsoft EasyLiving *Project from Microsoft 1997-2003*

Intelligent environments that support dynamic aggregation of diverse I/O devices into a single user experience.

It had some critical issues:

- Privacy
  - Others intervening even if you did not want to.
  - Access to recorded videos.
  - Possibility to turn tracking off.
- Robustness
  - People working close together was difficult for the systems.
  - Maintaining object mapping in the scene.
  - Handling breakdowns.
- Flexibility Too restricted model, little options.
- Accuracy Is it capable enough to anticipate intentions correctly?
- Scaling to new possibilities

Microsoft Future Vision 2040 *You can probably skip this one.*

Lots of screens everywhere, on every possible surface. Remember the very happy school children connected to each other by drawing the dog on the screen, very wholesome.

WearComp and WearCam

Steve Mann's experiments in the late 1970s.

Main application was recording personal visual memories that you could share with others via the internet.

Cyborg 1.0 and 2.0

Implanted devices into human mobile hosts are a form of embedded device.

- Cyborg 1.0 A silicon chip implanted in a forearm for nine days.

- Cyborg 2.0   A sensor in the lower arm which could send signals back and forth the nervous system and a computer.

Analysis of early projects

Focus on the three basic UbiComp properties:

- Distributed Access Support
  - Work at PARC and by Olivetti was focused on basic smart mobile device design (Tabs and Pads)
  - Proprietary communication and location awareness for mobile users.
    No commercial ICT networks or wireless network were available back then.
  - Late 2000s, mobile devices and wireless networks are widely available.
- Context Awareness
  - Early achievements based upon (local not global) location awareness indoors with heavily instrumented environment.
  - Location determining indoors proves to still be a problem today, possible but not ubiquitous.
  - GPS is now widely used for outdoor location services.
- Implicit Human Computer Interaction (iHCI)
  - The inventions developed at PARC were the first which allowed users to collaboratively edit text and graphics. This was the foundation where eventually Word was built on.
  - Wearable smart devices were a novelty then but normal now be it not fully pervasive
  - Many different variations of iHCI are possible and its not clear which type will catch on
    For example, will the trend of the use of voice-controlled applications continue.

Why does it take so long? to read the damn summary.

There is an enormous gap between the dream of comfortable, informed, and effortless living and the accomplishments of IoT/ UbiComp research.

A fundamental stumbling block has been harnessing the huge variability in what people do, their motives for doing it, when they do it and how they do it.

The very idea of calm computing has also raised several ethical and social concerns.

Even if it were possible for Weiser's dream to be fulfilled, would we want to live in such a world?

<u>The Computer for the 21st Century</u>   Paper by *Marc Weiser*

Scales for defining computers:

- Inch-scale   Mobile phone size devices   "Active Post-It notes"
- Foot-scale   Tablet to laptop sized devices   "That behaves like a book or magazine"
- Yard-scale   Interactive schoolboard sizes   "Blackboard or bulletins boards"

"Look around, how many tabs, pads and board-size objects to you see in a typical room?"

"This would be the amount of similar sized computers will become the standard later"

Editors notice: "These are just small things that seemed imported in the paper to me, but you should read and learn it yourself too but be aware that it is quite lengthy. It can be found on Canvas."