DISTRIBUTED & PERVASIVE SYSTEMS

PERVASIVE COMPUTING

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AGENDA

- Introduction to new instructors
- Introduction to the rest of the course
- Introduction to the Poslad book
- Pervasive computing – history
- Pervasive computing key concepts
- Pervasive enabnling technologies

‘Technology is anything that was invented after you were born.’ Alan

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Main research interests:

1. Pervasive computing
2. Pervasive healthcare
3. Ambient assisted living
4. Telemedicine
5. Smartfarming

JORGE MIRANDA, PHD

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Main research interests:

1. Embedded computing
2. IoT & Cloud Edge devices
3. Wireless technologies
4. Distributed systems

THE REST OF THE COURSE

1) Learn something (new) on pervasive systems & related concepts
2) Get inspired to use pervasive computing methods and enabling technologies
3) Have fun doing it

PERVASIVE COMPUTING VS SYSTEMS

We will focus on pervasive systems – which is basically a design paradigm defined as:

"The **systems** that facilitate the human users by **pervasively** providing the computing power, information, and other services specifically tailored to their needs, such as easy living environments for physically and cognitively impaired persons, remotely providing health care services to chronic patients, and adaptive disaster response **systems**, are **pervasive systems**. (Alencar et al. 2012)

Another definition could be:

"**Pervasive systems** are context-aware sensor-based **systems** which are **inspired** by **pervasive computing concepts**, methods and best practices, and which **relies** on **pervasive enabling technologies** to **achieve** a **calm**, **effective**, and **efficient** technology experience for their users." (Wagner 2022)

REST OF THE COURSE IS DIVIDED INTO

1) Pervasive computing introduction (now)

- Introduction to ubiquitous & pervasive computing concepts & history + state of the art
- Distributed systems as a “pervasive enabling technology”
- Specifically – we will use MQTT publish/subscribe framework as an example of how to connect sensors, decision support services, and novel user interface technology

2) Context awareness (next week)

- Introduction to using context
- Context awareness as a means to create a calmer technology UI experience
- Embedded (local/device only) vs Distributed context awareness

3) Intelligent environments (next week++)

- Introduction to the next wave of pervasive systems – intelligent & hybrid environments
- Smart spaces, smart homes, smart cities

4) Project work (next week++)

WHEN & WHERE & WHO

WHEN:

- Mondays 12.15-16: Lectures (and we may start with the tutorials) – PHYSICAL ONLY
- Thursdays 10.15-12: Tutorials – HYBRID (sometimes mixed)

WHERE:

- 5125 – 235 (Edison)

WHO:

- Mondays 12.15-16: Stefan will take all three lectures – and project presentation
- Thursdays 10.15-12: Jorge will be available for tutorials during these two hours
- GROUPS: Keep your present groups for the weekly assignments & project work

MINI PROJECT 2

WHO: You will work in your existing groups

WHAT: You are going to design and implement a distributed pervasive system.

1. I have a “standard” topic you can choose – or you can find one on your own.
2. The only requirements are:
    a) It should be context-aware – using sensors - meaning fetching actual data from sensors + distribution
    b) It should implement a context model for decision support of some kind – also programmed
    c) It should be a pervasive AND distributed system – specifically it must include a server (cloud or physical server or workstation computer) running either MQTT or AQMP or similar (ask Stefan) and one or more sensor nodes for publishing data (e.g. Zigbee) – and a UI device that should be designed as a ”calm technology user interface”

HOW: I will provide you with 1-2 Pi’s per group. And you can use your PC’s or smartphones as clients and/or as sensor nodes. I will also provide you with a Zigbee radio and with sensors. You can decide on either implementing actual sensors – or simulating sensor events. The more ”real” you make it – the less testing you need to do.

CURRICULUM & POSLAD BOOK

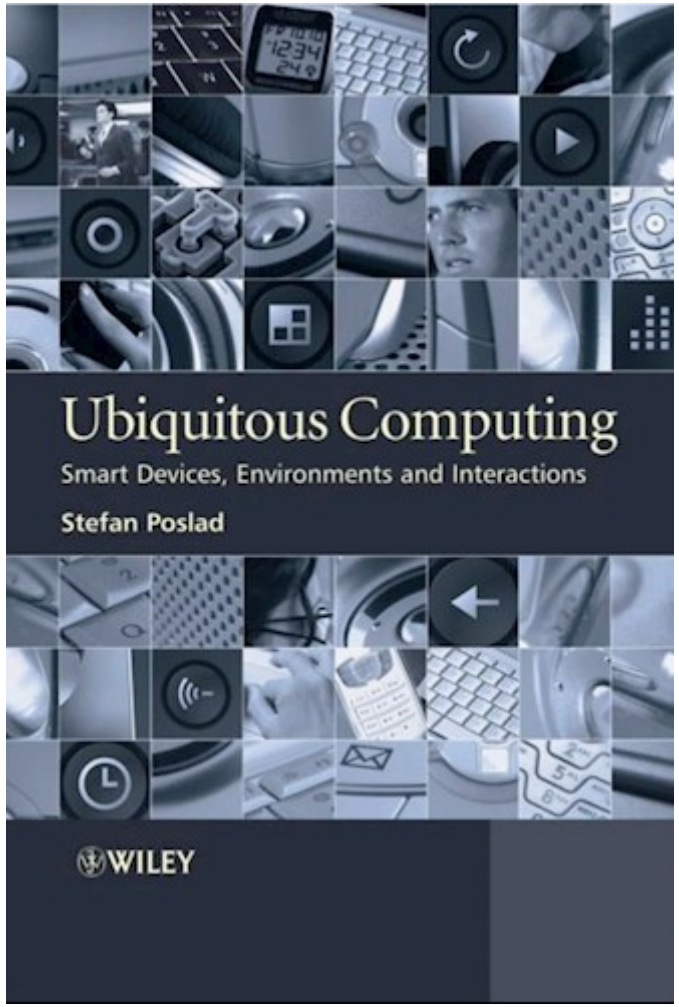
We will use the Poslad book on Ubiquitous computing

- Freely available here as a PDF (fully legal)
- It is old (2009) and I have a 2020 book on the same topic for supplement – for interested students

Also, we will use journal and conference papers

Tutorials will not be curriculum – but for your learning

- We have designed some & tutorials for you &
- We will link to external resources



THE ROOTS & SOME RELEVANT CONTEXT

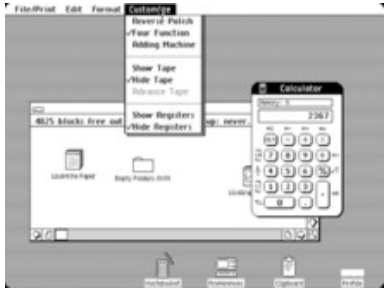
70’s and 80’s:

Industry’s main product development focus was on developing more efficient personal computers – the market for office computing was growing fast

Xerox

Invented the first personal computer the Xerox Alto (1972) and later the Xerox Star (1981) which was the first to feature window-based graphical user interface, icons, folders, mouse, Ethernet networking, file servers, print servers, and e-mail

Xerox Star (1981)



Apple Lisa (1982)

Apple Lisa (1982)

XEROX PARC – THE INCUBATOR

XEROX PARC hired some of the most innovative researchers & engineers fueled by the massive earnings of XEROX and the technology disruption in those years

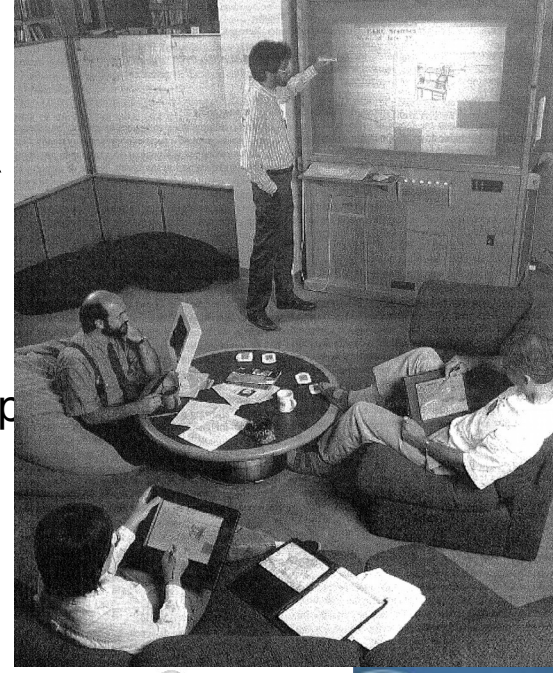
XEROX PARC Director and chief scientist John Seely Brown together with technologist Mark Weiser

formed a research group in 1988

Mission:

Create a computer infrastructure for the 21st century

UBIQUITOUS COMPUTING OR



Next Generation:

Next generation computing for replacing the personal computer and its ”office metap

Implosion:

Computers getting smaller

> “The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.”
>
> *– Mark Weiser (1952 – 1999) XEROX PARC*

Explosion:

Computers will be everywhere and in all things not just PC’s

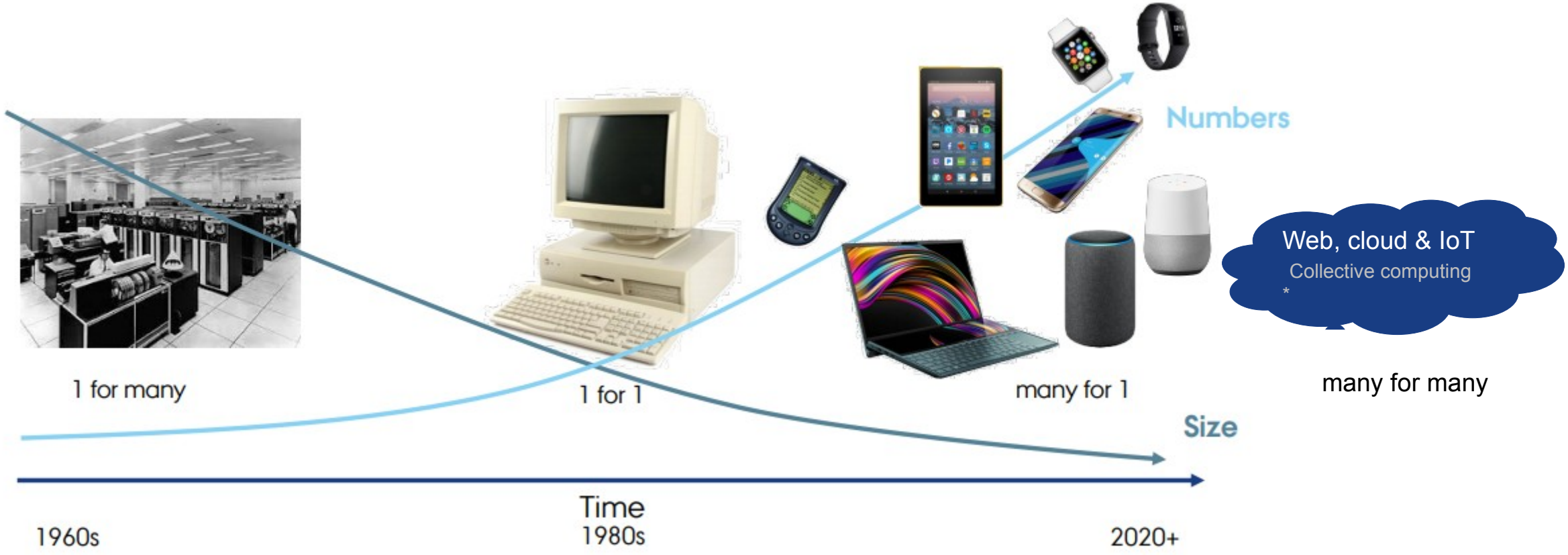
Calm technologies:

Interaction will become intelligent, automated and context-aware - and only occur when actually needed.

This requires added sensor support and AI (in order to put the context into context-aware)

Inspired by “**The Invisible Computer**” (by Donald Norman) and other tech philosophers and thinkers

THE THREE + ONE COMPUTING WAVES



*) Gregory Abowd 2016

NAMES AND CONCEPTS

- Ubiquitous Computing (Mark Weiser, Xerox Parc, 1988)
- Calm Computing (John Brown, Xerox Parc, 1996)
- Universal Computing (James Landay, Berkeley, 1998)
- Invisible Computing (Gaetano Boriello, University of Washington, 1999)
- Pervasive Computing (Academia, IBM, 1999)
- Context-based Computing (Berkeley/IBM, 1999)
- Hidden Computing (Toshiba, 1999)
- Ambient Intelligence (European Commission, FP5)
- Sentient Computing (AT&T, 2002)
- Autonomic Computing (IBM, 2002)
- Amorphous Computing (DARPA, 2002)
- Self-aware Computing (European Commission, FP7)

+ Collective computing (Gregory Abowd, Georgia Tech 2016)

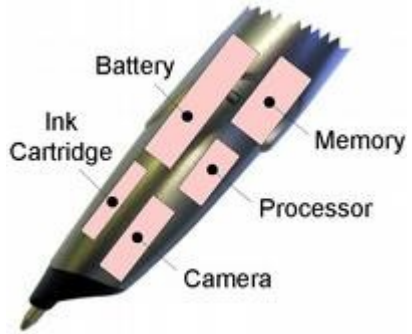
RELATED CONCEPTS

Tangible Computing

- Interacting with the digital world through physical objects

Embodied Virtuality

- Same as Ubiquitous / Pervasive computing
- Opposed to Virtual Reality



Augmented Reality

- Enhancing the ”real world”
- See-through displays with overlay graphics
- Projecting digital images on surfaces
- Digital Pen / Digital Paper

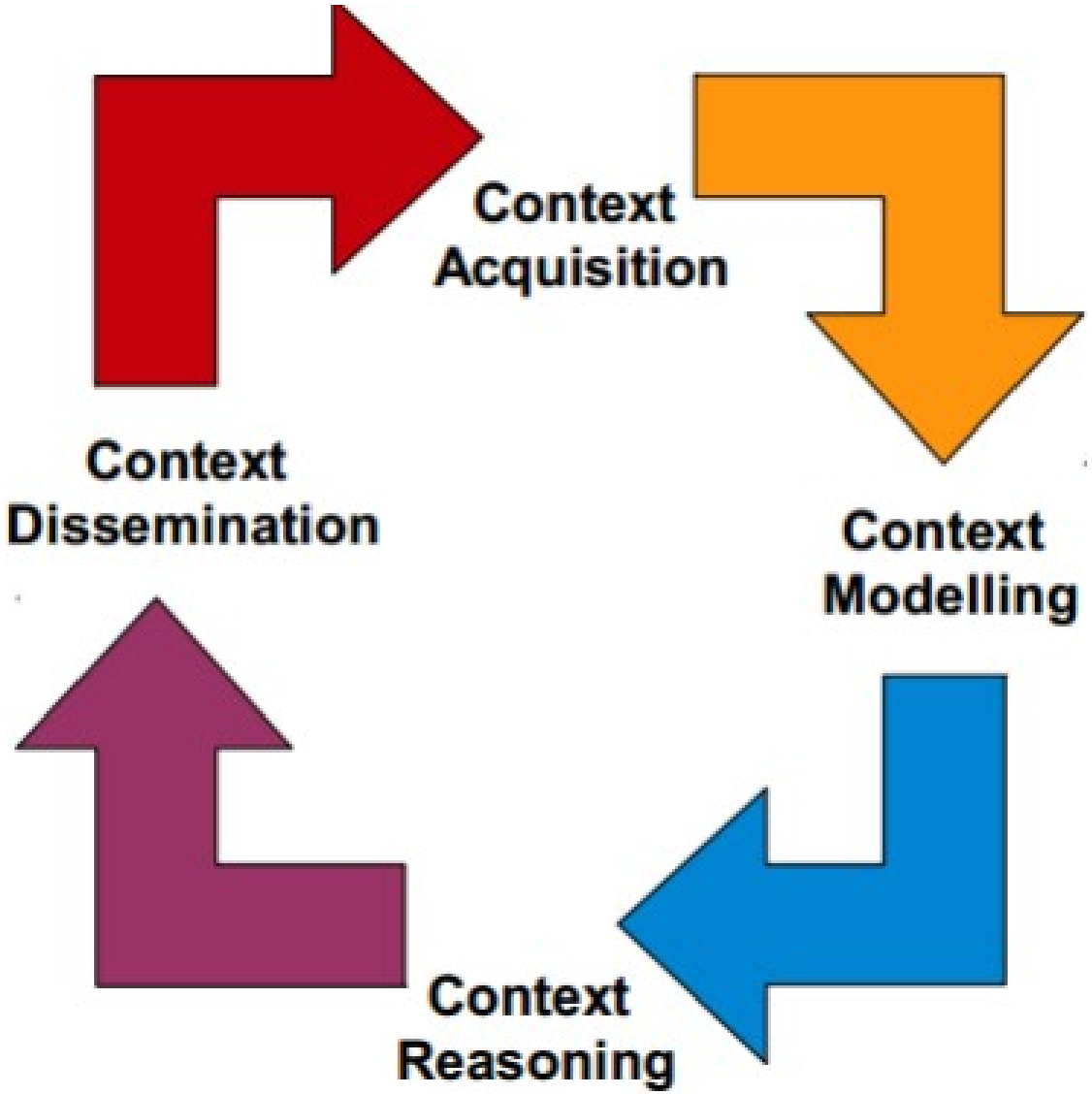
Internet of Things

- All things have a virutal presence
- Popiularized as IoT (original HP Cooltown)

PERVASIVE COMPUTING CONCEPTS

1. Calm technology
2. Invisible computing
3. Implicit HCI
4. Context awareness
5. Location awareness
6. Automated capture & access
7. Activity modelling & recognition
8. Smart dervices, Smart objects & Internet-of-things
9. Smart spaces & Smart / Intelligent Environments
10. Natural interfaces & Continuous interaction

CONTEXT LIFE CYCLE MODEL



PERVASIVE ENABLING TECHNOLOGIES

Distributed systems

Distributed middleware for system inter communication is a key technology

Mobile technologies

Smart phones, tablets, wearables are key technologies to support pervasive access

Sensors

Sentient / context-aware / ambient are key technologies to support context awareness

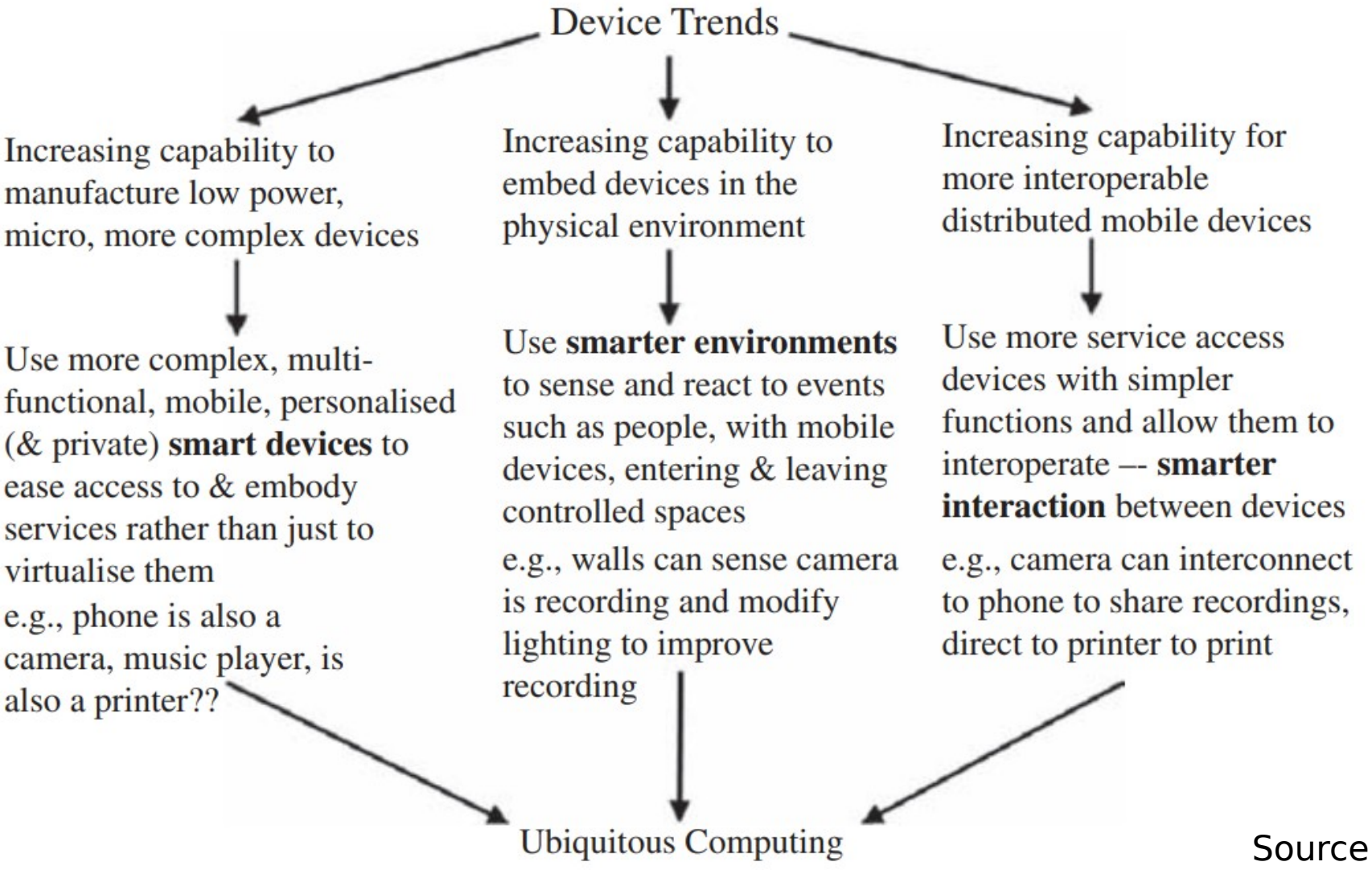
Novel interaction types

Speech, gestures, sound, presence, are relevant technologies for calm & natural interaction

Intelligent environments

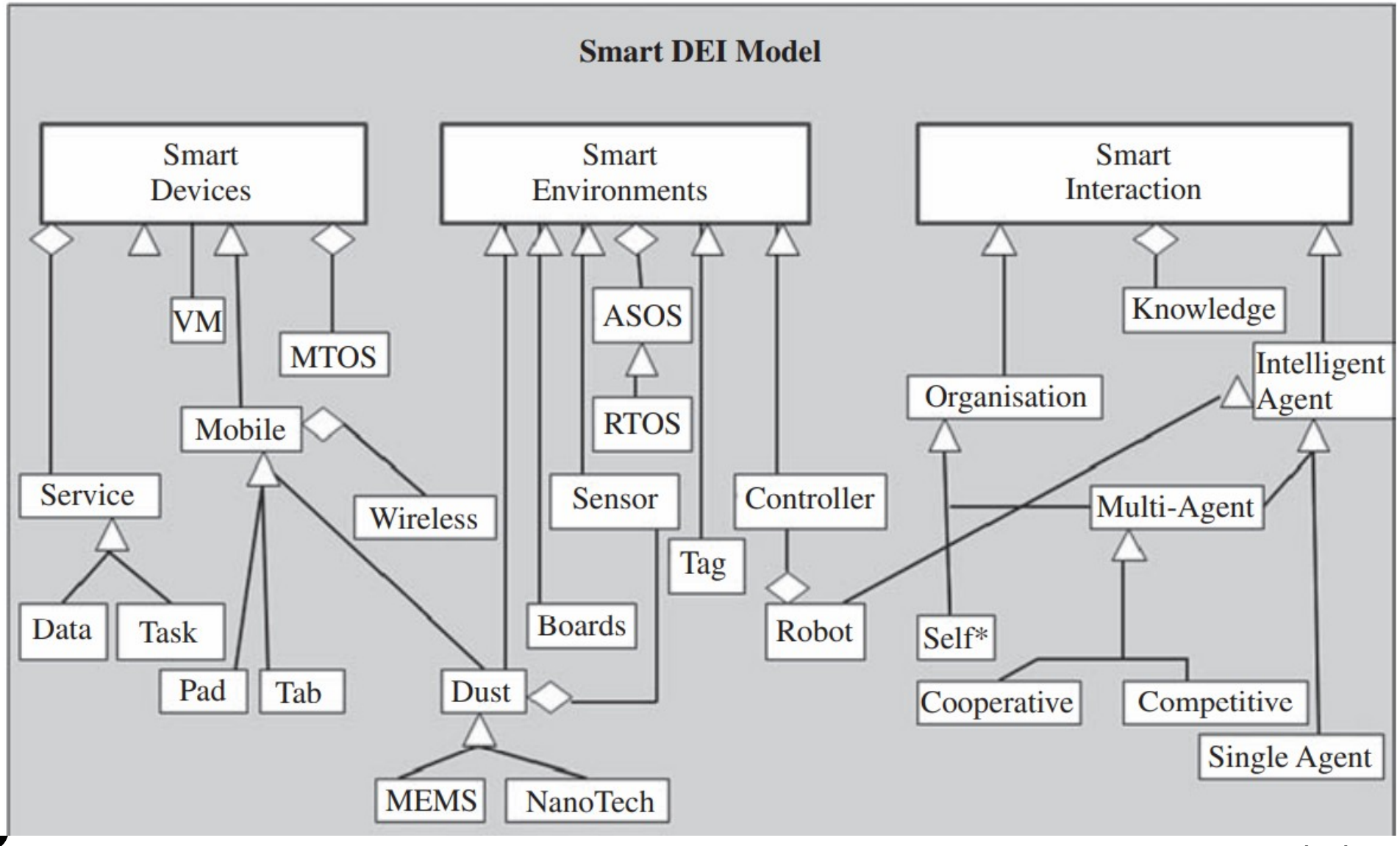
Smart spaces, smart environments, are the next technologies that will create added value

DEVICE TRENDS TOWARDS SMART



Source: Poslad 2009

SMART DEI MODEL



Source: Poslad 2009

GROUP EXERCISE – 10 MINUTES

Discuss in your groups and make an “association” diagram:

1. How is Pervasive computing related to the bachelor & masters courses you already had?
2. How is Pervasive computing dependent on Distributed systems technology ?
3. Which specifc distributed systems technologies do you see as enablers?
4. Stefan will collect your feedback in plenum?

PERVASIVE = MOBILE COMPU G

Xerox Tab (1992)

- Since the beginning – smart phones have been the main driver
- Smart watches and other smart wearable devices extends this **mobile computing** trend – **wearable computing – Poslad calls them “Smart devices”**
- **Most state-of-the-art apps relies on the Android and iOS platforms – including sensor platform, com & UI components**
- **One of the remaining barriers – is how to create hybrid systems – which can rely on both ambient and mobile systems – in a volatile environment with sensors, services and UI’s appearing and dissaparing**

Apple Newton (1993)

Palm 1000 (1996)

Microsoft Pocket PC (2000)

Apple iPhone (2007)

HTC Dream Android (2008)

WEARABLES ARE NOT ALWAYS ENOUGH

Wearables include smart phones, smart watches, clothes, hearing aids, pacemakers …

They are great for many things – especially mobility - but have several shortcomings:

1. You have to actually wear them for them to them work
2. They need sufficient power to work effectively (both processing power and battery)
3. They have limited user interfaces – limited by their form factor and power
4. They have limited sensing capabilities – limited by their physical sensors – and connectivity

In the **web of technologies*** – we can enhance & replace wearable functionality through:

5. Ambient sensors in the environment that the users occupy (GPS, WiFI, occupancy, and more)
6. Connected calm interaction devices (screens, surfaces, visual, audial, tactile)
7. Collective technologies (cloud & other users' devices nearby or far away)

*) Nielsen & Søndergaard, 2000

Thus enters the concept of the **Intelligent (or "smart") environment** and **zero-conf**

NOVEL INTERACTION TYPE

Present day user interfaces inadequate

fixed computers with keyboards and mouse

phones and tablets also have their limitations

Do you always carry your phone or tablet?

in the shower? … or to the toilet?

in the kitchen while cooking? To the pig pen?

while driving, eating, training, sleeping, relaxing?

New class of alternative UI devices needed

smart watches, voice recognition, intelligent surfaces (walls, doors, tables)

face/eye tracking, hand gestures

implicit interaction (getti f the couch or the bed will turn on the lig floor,

m sensors

NOVEL USER INTERFACE TYP






Tangible User Interfaces (TUI)

- Interact with physical objects, input and output

Surface User Interface (SUI)

- Utilizes a surface to act as a display and/or input,
- Usually a screen or a projected image

Ambient User Interfaces (AUI)

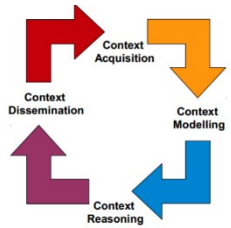
- Ambient technologies are ignorable or glanceable, speech, lig
- They are in the periphery of our attention (peripheral vision)

Context-aware User Interfaces (CUI)

- Interfaces that reacts on context but are otherwise invisible
- Implicit interaction, medication cabinet auto opens when relevant

Artificial Reality Interfaces (ARI)

- Produces an overlay of information on real objects
- Google glasses, projected image on milk with expiry date, laser dot on pig that needs medication or needs other treatment

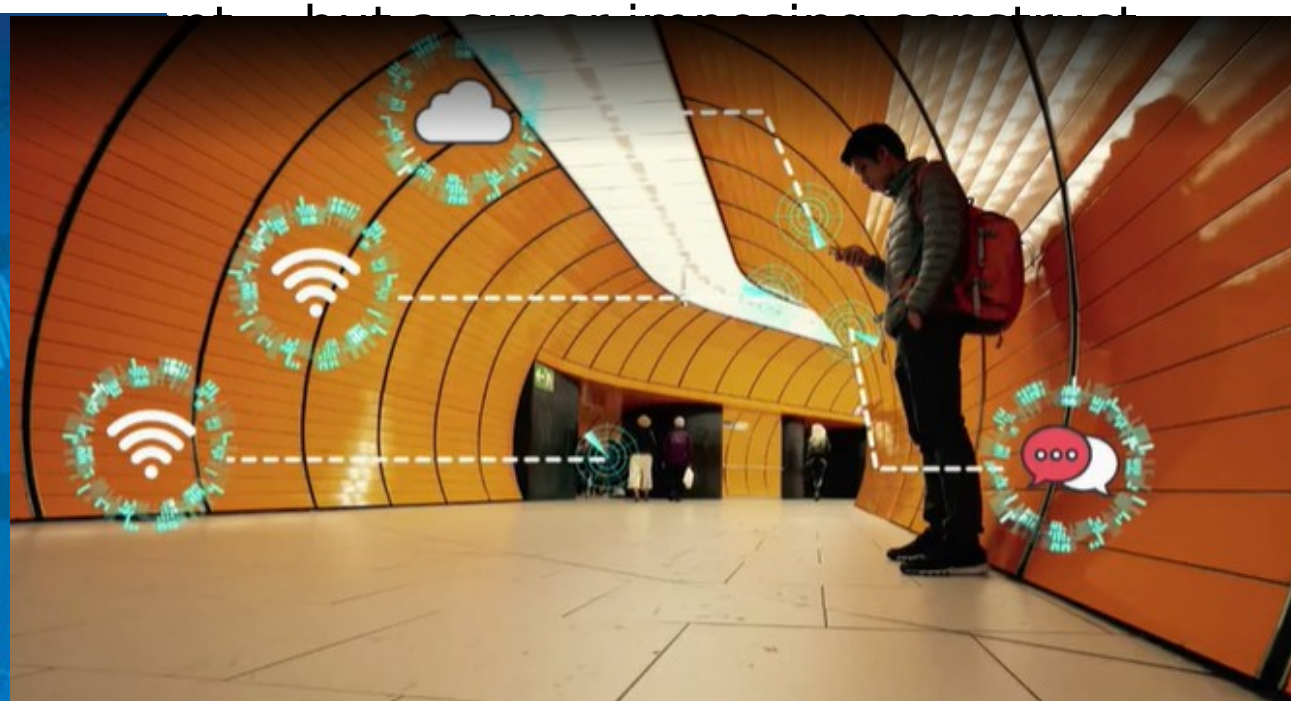


Krumm 2010

INTERNET OF THINGS (IOT)

- The term "Internet of things" was coined by Kevin Ashton of Procter & Gamble in1999(ref)

- It represents a move from an internet of devices – controlled by users –to autonomous things



SENSORS AND ACTUATC

Comes in many price ranges

Cost benefit analysis needed

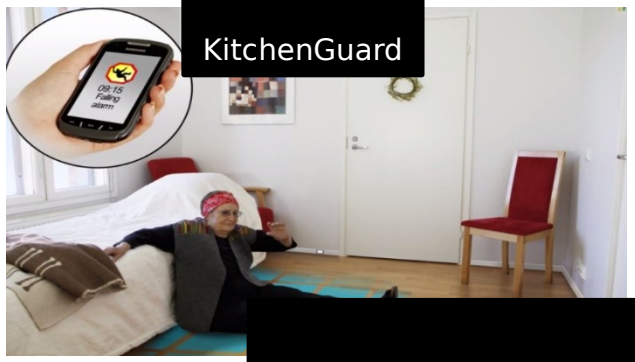
price

DKK 100

DKK 500

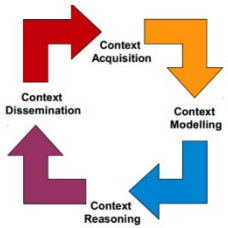
DKK 2,000

DKK 10,000



DKK 75,000

DKK 200,000



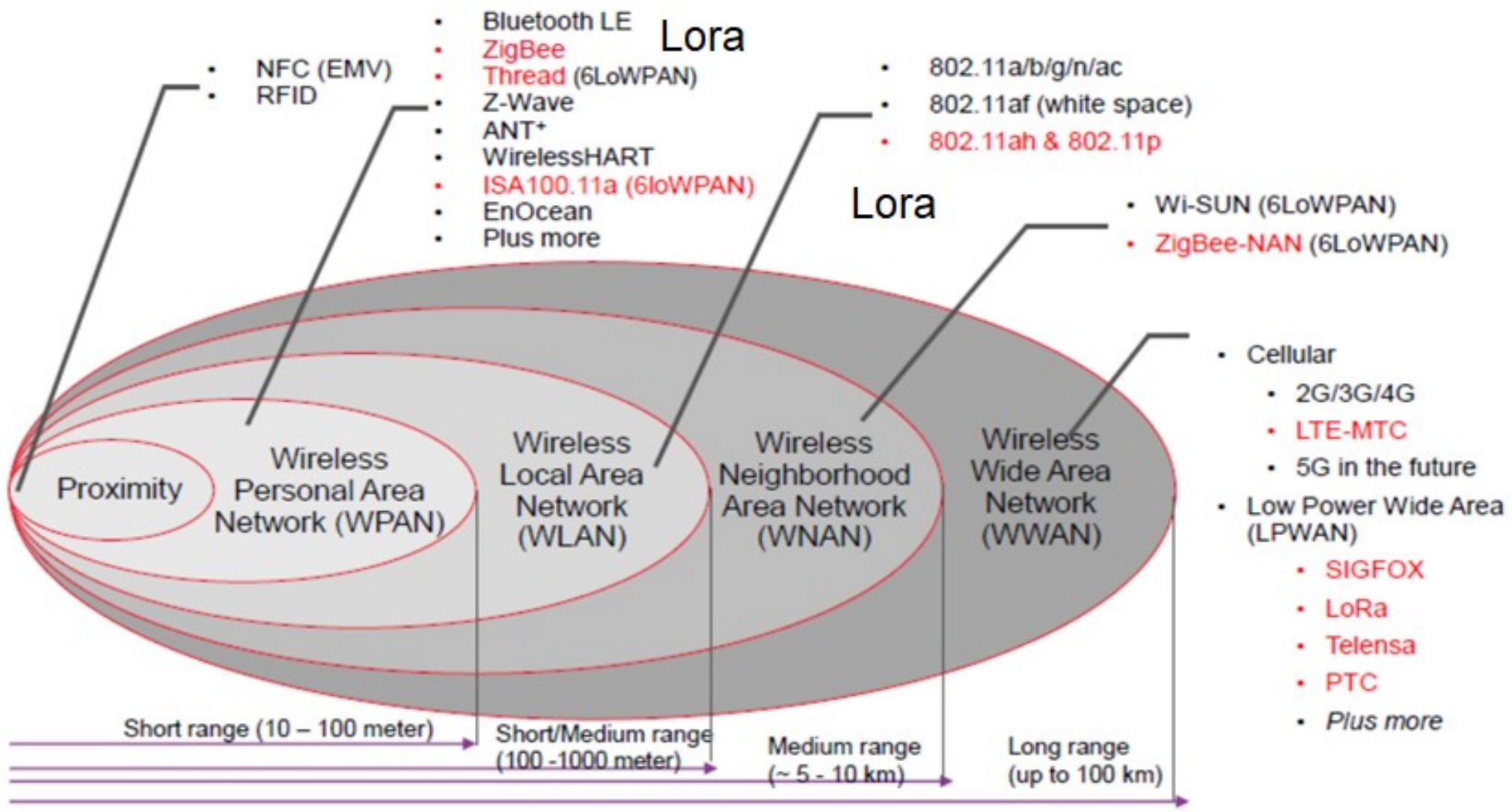
EXERCISE – GROUPS OF 2-3

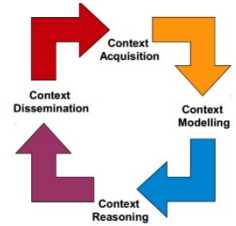
CONSIDER THE FOLLOWING SCENARIO

“Ruth – is an elderly woman. She has fallen many times, and once broke her arm. She could not get up when it happened, and it took 14 hours before she was found, resulting in a 19 days hospital stay. Since then, she is very afraid of even walking in her own home, which is not healthy – an affliction knowns as ‘fear of falling’. To help her feel safer and become more active again her children bought her an Apple Watch with a fall detection algorithm and an ‘SOS’ button. However, Ruth keeps forgetting to wear it, and she keeps forgetting to recharge it. “

CHALLENGE: What can we do to help Ruth and her family? Can we use distributed technology and ubiquitous ambient sensors to make the surveillance more reliable and effective? Please make a UML deployment diagram of the technologies you would suggest to add – consider costs not rising exponentially (there is a limit to what we will pay for granny’s safety)– and explain in ½ A4 the pro’s and con’s of your suggested solution(s)

NETWORK TECHNOLOGIES





DISTRIBUTION MIDDLEWAR

AMQP:

- **Advanced Message Queuing** Protocol
- International publish/subscribe standard protocol for interoperability between messaging middleware

MQTT:

- **Message Queue Telemetry Transport**
- a publish/subscribe, lightweight messaging protocol, designed for constrained devices and low-bandwidth, high-latency or unreliable networks for IoT devices, but not actually for BLE, ZigBee, Lora, & Zwave

Web services (HTTP, SOAP, REST):

- Simple, effective and firewall friendly

DDS, Java RMI, .NET Remoting, CORBA, ICE:

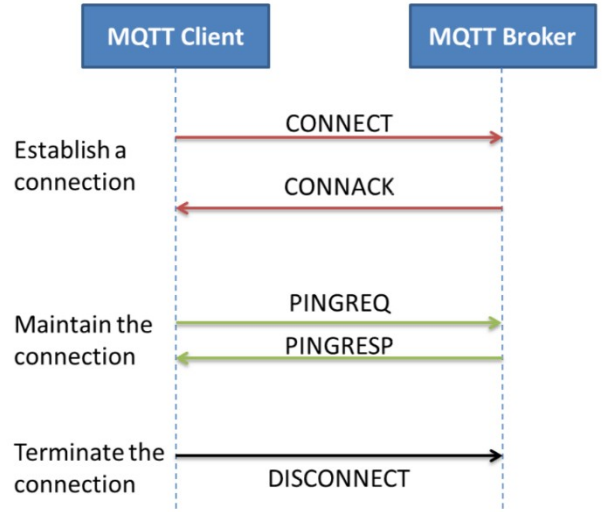


Fig. 1. Establishing, maintaining and terminating MQTT connection

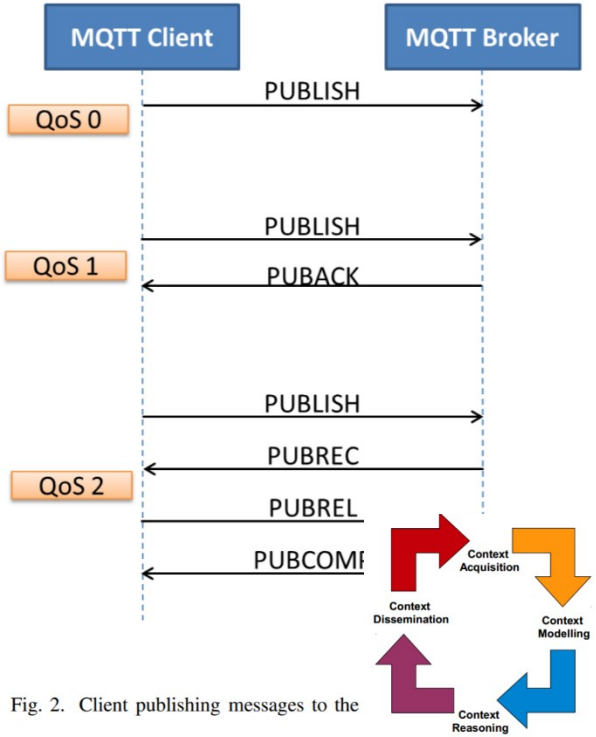


Fig. 2. Client publishing messages to the

DISTRIBUTED TUTORIALS(T1-T2)

For your mini projects – you need a distribution middleware and some gateways.

You can choose which ever you want (WEB API, AQMP) but we provide supervised tutorials and support for MQTT only - either on a Windows PC and/or Raspberry Pi (RPI).

Tutorial 1 focuses on installing an RPI while Tutorial 2 is about installing the Mosquito MQTT server

You can either follow the tutorials 1+2 - or if you feel confident – take the quick route

1. Install Mosquito MQTT broker on PC and/or PI – use standard settings (see Tutorial 1+2)
2. Install MQTTExplorer
3. Can you emulate the fall detection sensor of Ruth and the relatives alerting app using MQTT publish / subscribe?
4. Try using different types of programming languages to connect via MQTT (e.g. Python and C#)
5. Remember – Eduroam is not suited for distributed systems – you can use a

QUESTIONS?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