



Kiel University
Christian-Albrechts-Universität zu Kiel



Internet of Things & Wireless Networks

Introduction

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Who am I?

- Prof. Dr. Olaf Landsiedel
Distributed Systems
HRS 3 – R.507a
www.ds.informatik.uni-kiel.de
- Since October 2018
- Research and teaching focus
 - Networked Systems, Distributed Systems, Security, Internet of Things, Applied AI, ...
- We say “Du”



Team for this Course



Olaf Landsiedel



Valentin Poirot

Course goal, teach you about

- Wireless Networks
 - What is it? What is inside? How does it work?
- Internet of Things
 - What is it? What is inside? How does it work?
- Lectures
 - Knowledge and understanding
- Exercises
 - Practical experience, application

Goal today

- Internet of Things & Wireless Networks
 - Introduction
 - Platforms
- Course organization
 - Corona

Introduction

Internet of Things (IoT)

- What is the Internet of Things?



- Things

- Internet



Internet of Things

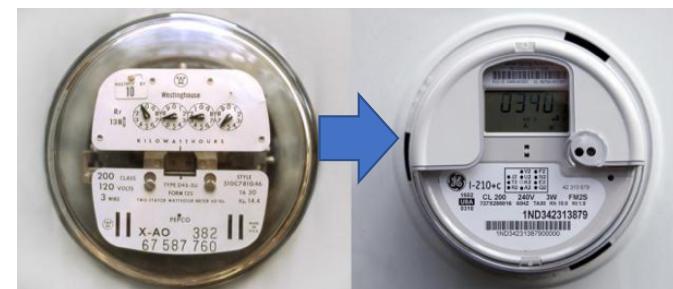
- Computing capabilities
- Interconnected
 - Usually: wireless communication
 - Usually: connected to the Internet
- Interact with the physical environment
 - Sensing
 - Control



Internet of Things (IoT)

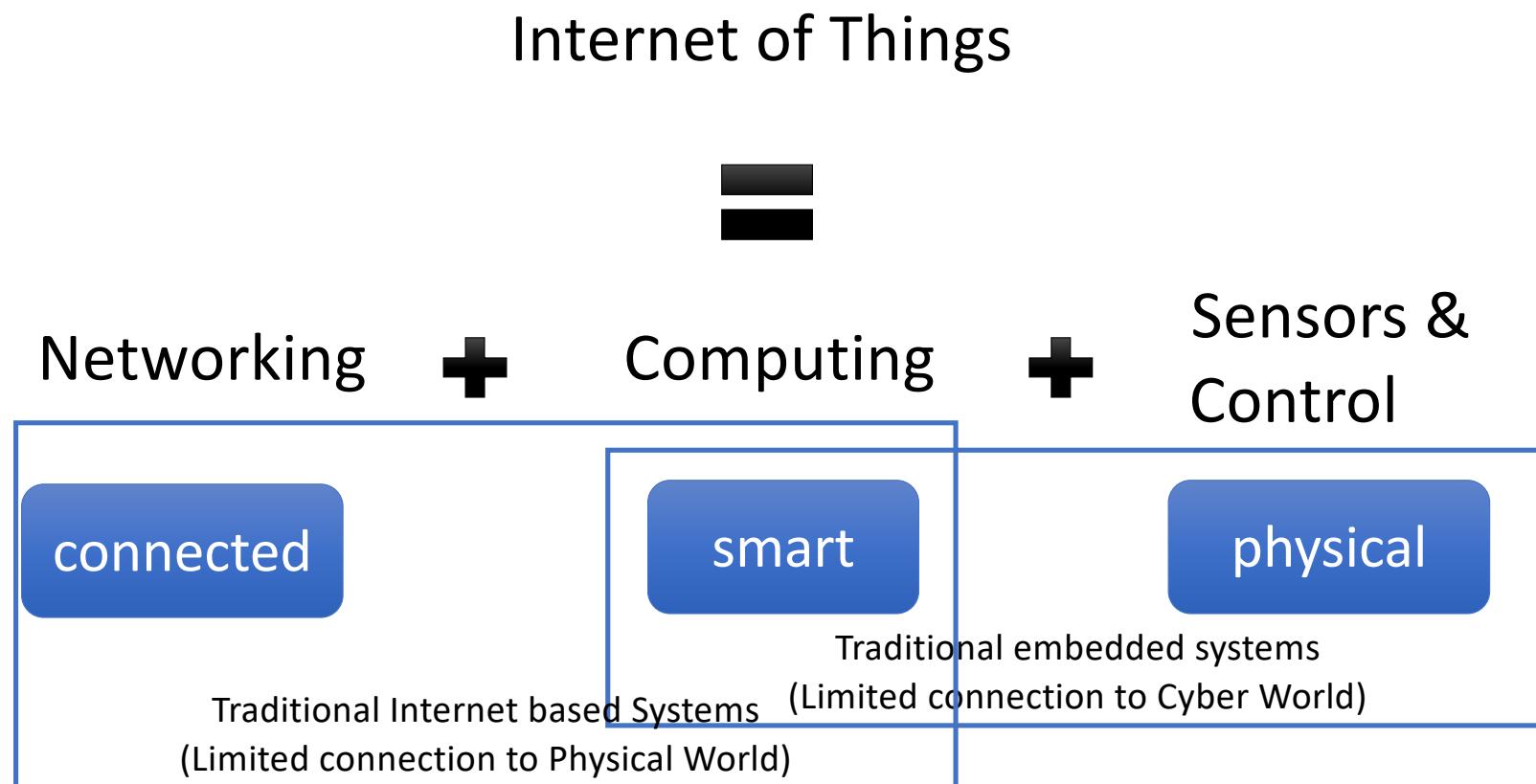
- Have you ever seen / used the
 - the Internet of Things (IoT)?
- Do you own an IoT device?
- TODO: make a quiz here

Trend



Dumb devices get connected & smart

Internet of Things



Various Names, One Concept (or very related)

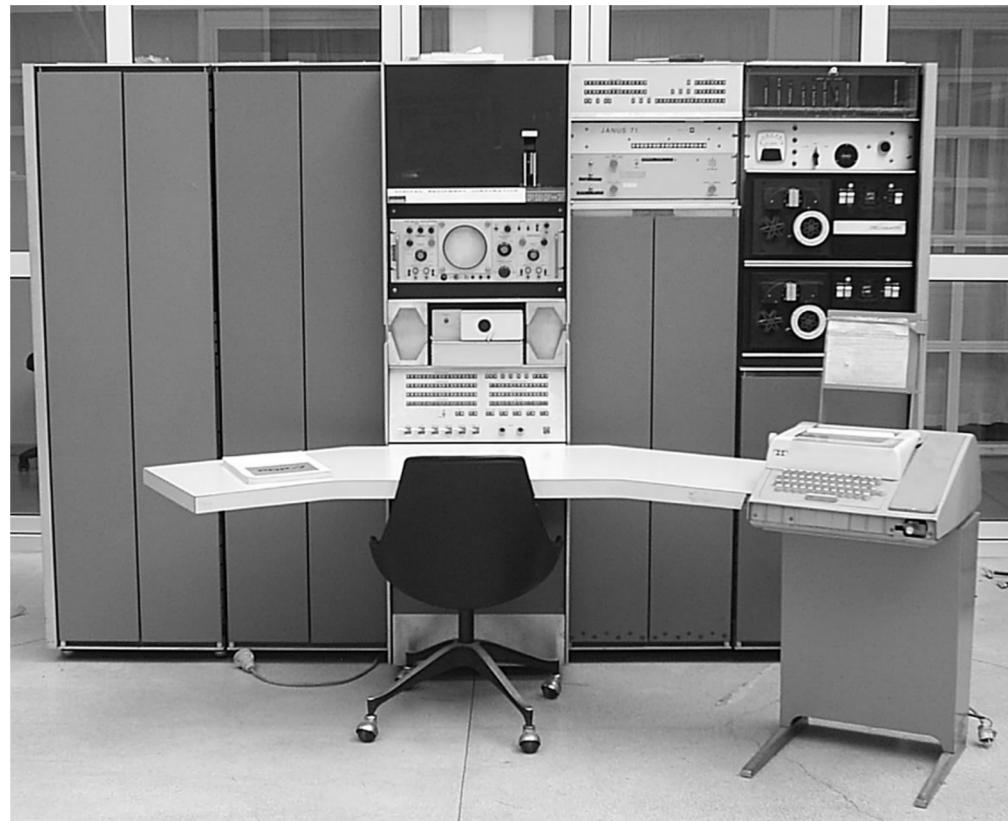
- Internet of Things
- Cyber Physical System
- M2M (Machine to Machine)
- Internet of Everything (Cisco Systems)
- Wireless Sensor Networks
- “World Size Web” (Bruce Schneier)

- “Skynet” (Terminator movie)

A bit I think there is
a world market
for maybe five
computers



Thomas J. Watson, 1943;
Chairman and CEO of
International Business
Machines (IBM)



Key Enabler: Miniaturization



- Apollo 11 Command Module (1965)
 - 64 kilobytes of memory
 - operated at 0.043MHz.
- An iPhone 5s
 - CPU running at speeds of up to 1.3GHz
 - 512MB to 1GB of memory
- Cray-1 (1975) produced 80 million Floating point operations per second (FLOPS)
 - 10 years later, Cray-2 produced 1.9G FLOPS
- An iPhone 5s produces 76.8 GFLOPS – nearly a thousand times more
 - Cray-2 used 200-kilowatt power

Source: Nick T., PhoneArena.com, 2014

A bit of History



Mainframe age (60's & 70's):
One computer for many

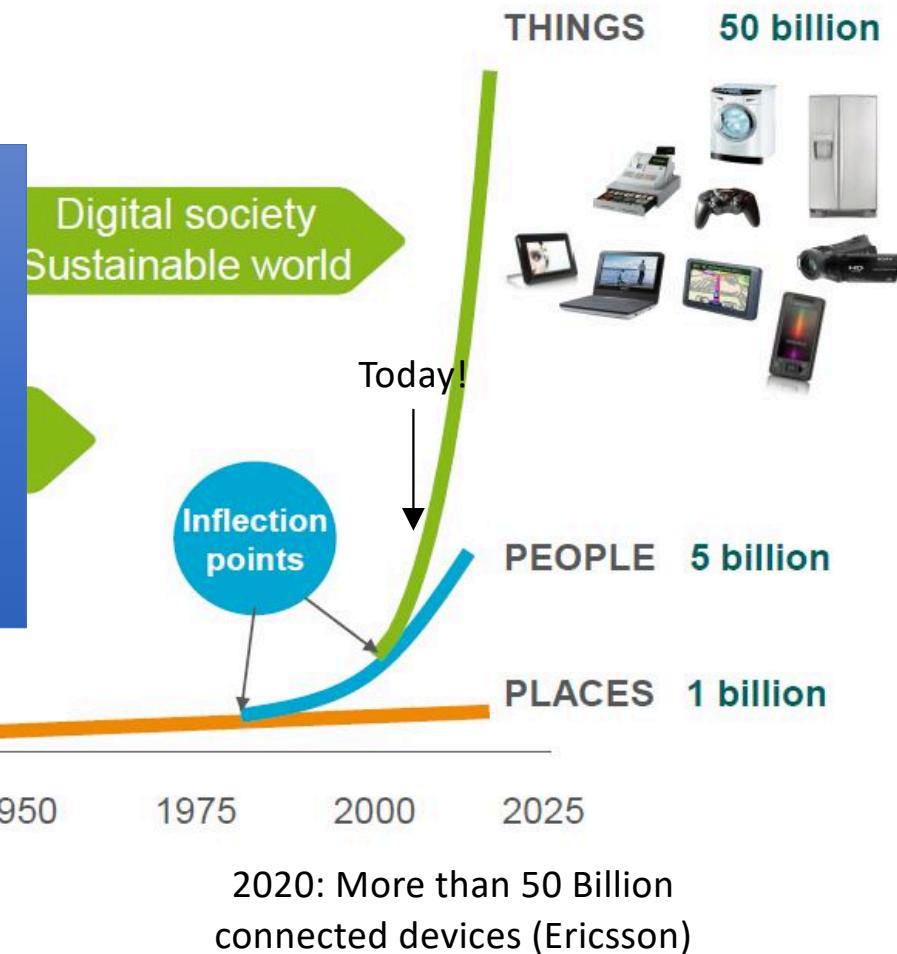
PC age (80's & 90's):
One computer for each,
partially networked

Mobile, ubiquitous computing
(Today, > 2000):
Many computers for each,
networked

Tomorrow?

Why should I study IoT?

1. They will impact our daily life (even more than the Internet)
2. Employment opportunities ;-)



Sensor devices are becoming widely available

- Programmable devices
- Off-the-shelf gadgets/tools



Linker Intel Group



Image Sensor Device



More “Things” are being connected

Home/daily-life devices
Business and
Public infrastructure
Health-care

...



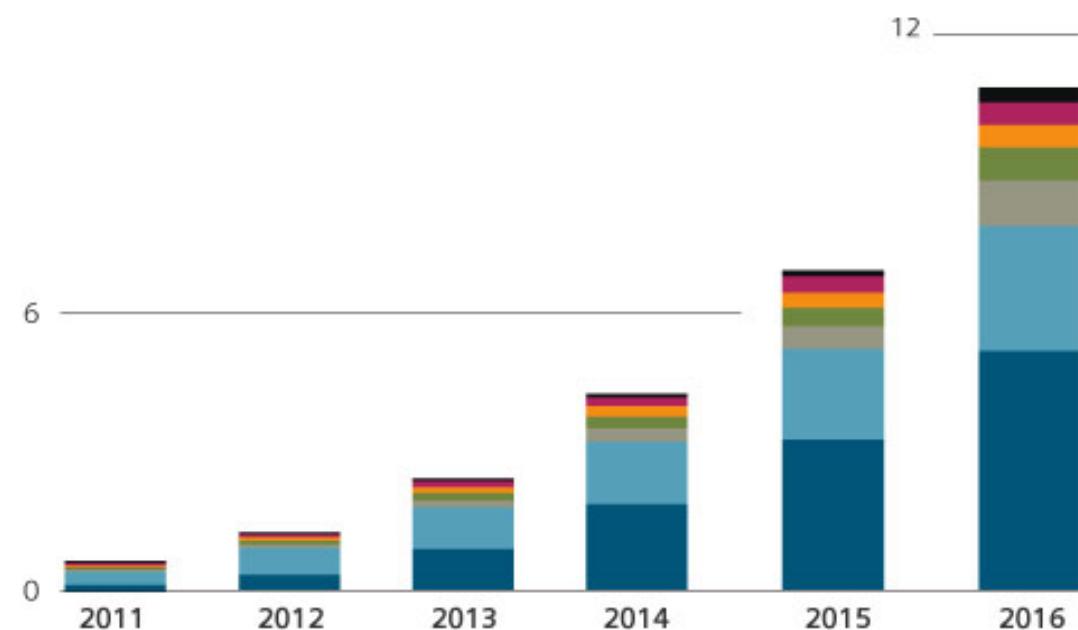
Global Data Generation

- Everyday around 20 quintillion (10^{18}) bytes of data are produced (Source: <http://www-01.ibm.com/software/data/bigdata/>).
- This data includes textual content (unstructured, semi-structured, structured) to multimedia content (images, video and audio), on a variety of platforms (enterprise, social media, and sensors).

Data Generation

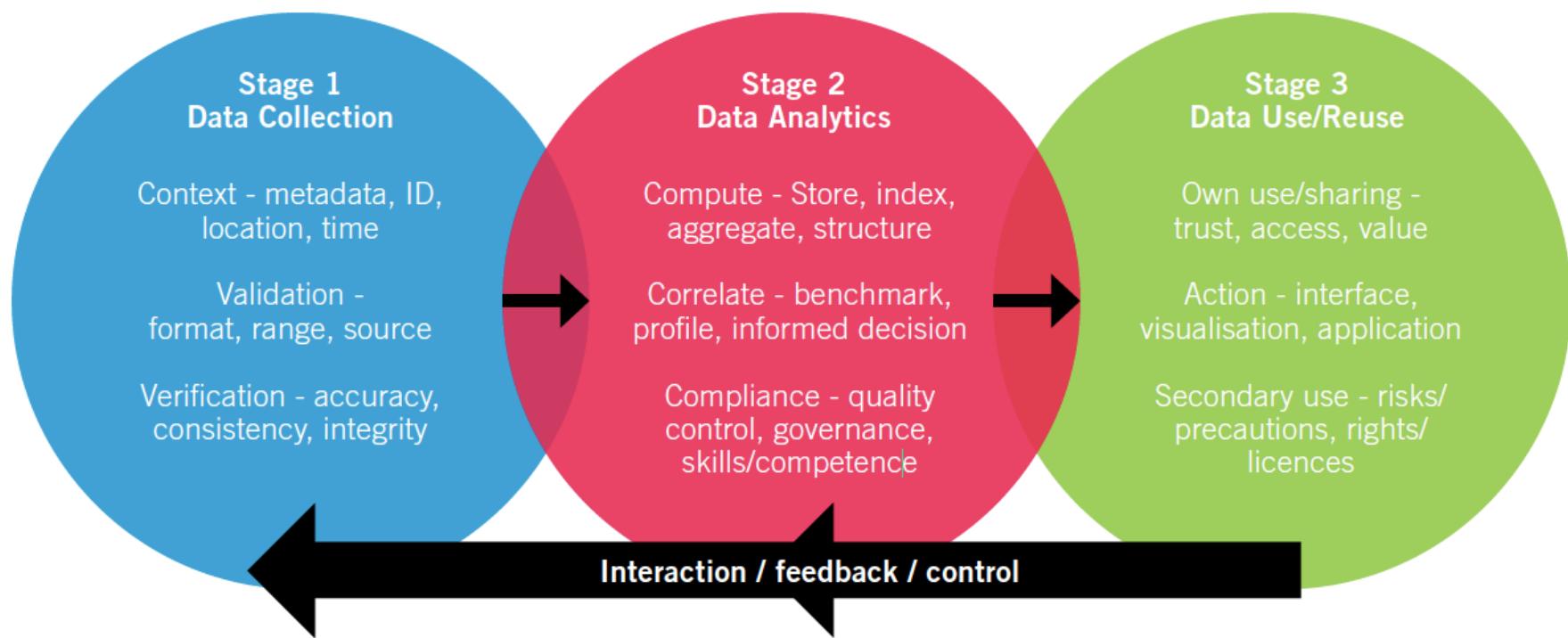
Global Data Generation

Exabytes (quintillion bytes) per month



| Source: Cisco VNI Mobile, 2012

Data Lifecycle



Source: **The IET Technical Report**, Digital Technology Adoption in the Smart Built Environment: Challenges and opportunities of data driven systems for building, community and city-scale applications,
<http://www.theiet.org/sectors/built-environment/resources/digital-technology.cfm>

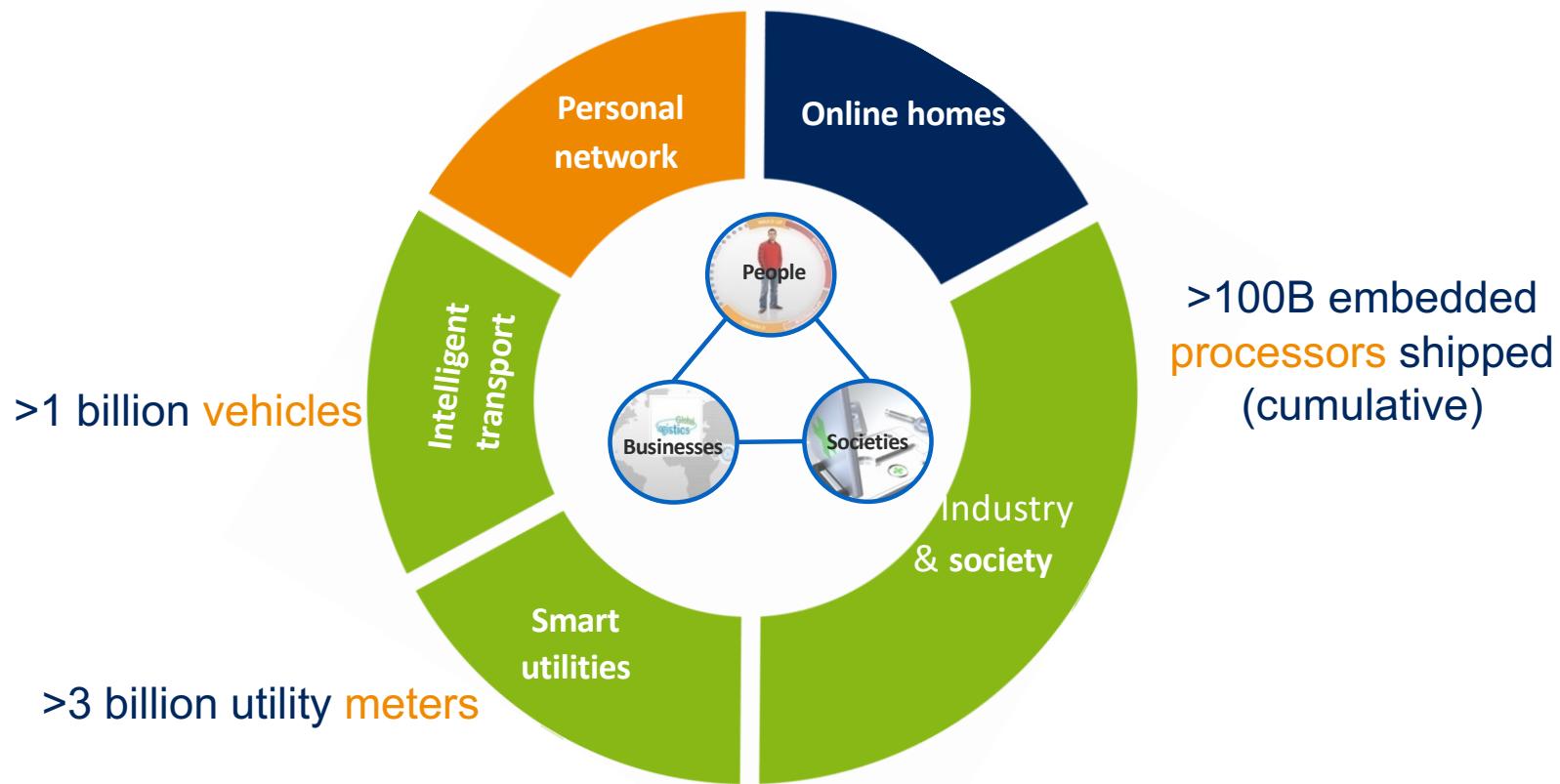
“The ultimate goal is transforming the raw data to insights and actionable knowledge and/or creating effective representation forms for machines and also human users and creating automation.”

This usually requires data from multiple sources, (near-) real time analytics and visualisation and/or semantic representations.

Connected Devices

3B middle class consumers x 10 connected devices

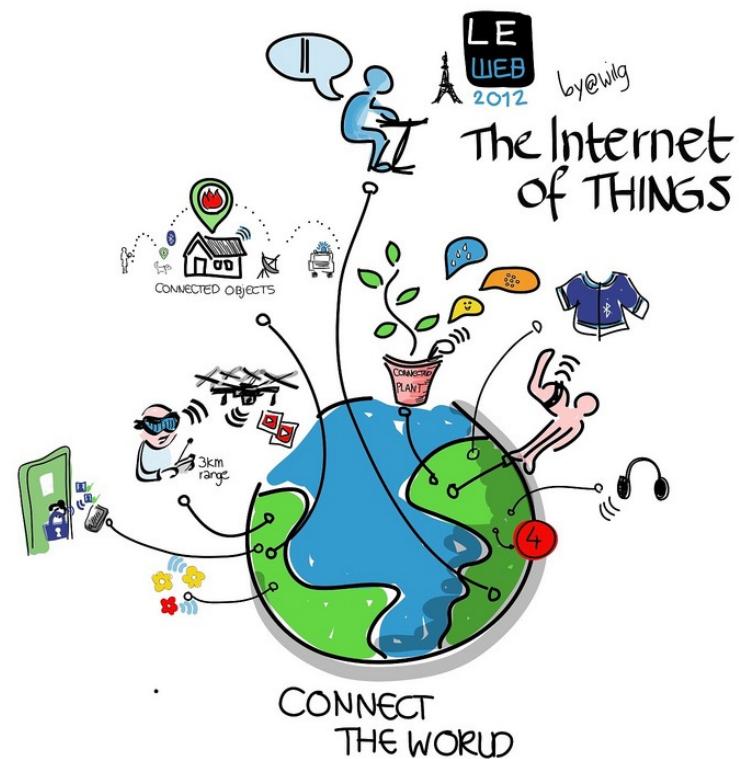
30B **connected consumer devices**



Source: Ericsson

Let's zoom out

- What does this vision mean...
 - ... for our society?
 - Networked society, digital natives
 - Deep connection of physical and cyber world
 - Everything depends on computers
 - Hardware and software
 - Digital divide
 - ... for you?



Quiz: Pause here and answer these questions

- What is the Internet of Things?
- What are the IoT enablers?
- What about data?

Quiz: Pause here and answer these questions

- What is the Internet of Things?
 - Things (sensors, actuators, ...) connected to the Internet
- What are the IoT enablers?
 - Miniaturization
- What about data?
 - The Internet itself combined with IoT will lead to a data “explosion”

Platforms

Internet of Things



Computing



Networking



Sensors &
Control

What components should a IoT device have?

Internet of Things



Computing



Networking



Sensors &
Control

Some
embedded
MCU

Wireless communication:

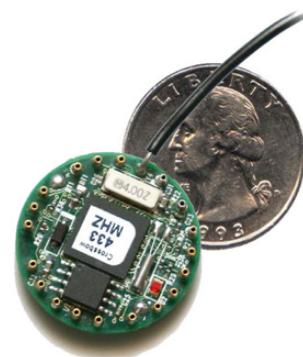
MAC: 802.15.4 (ZigBee) or
Bluetooth or cellular...

Routing etc.

Sensors and actuators

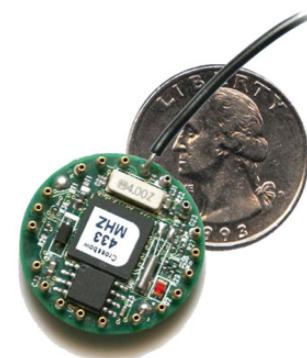
Platforms

- Embedded nodes
 - Limited computing capabilities
 - Low bandwidth communication
 - Usually: low cost
 - Often: Limited energy
- Sensing and actuation

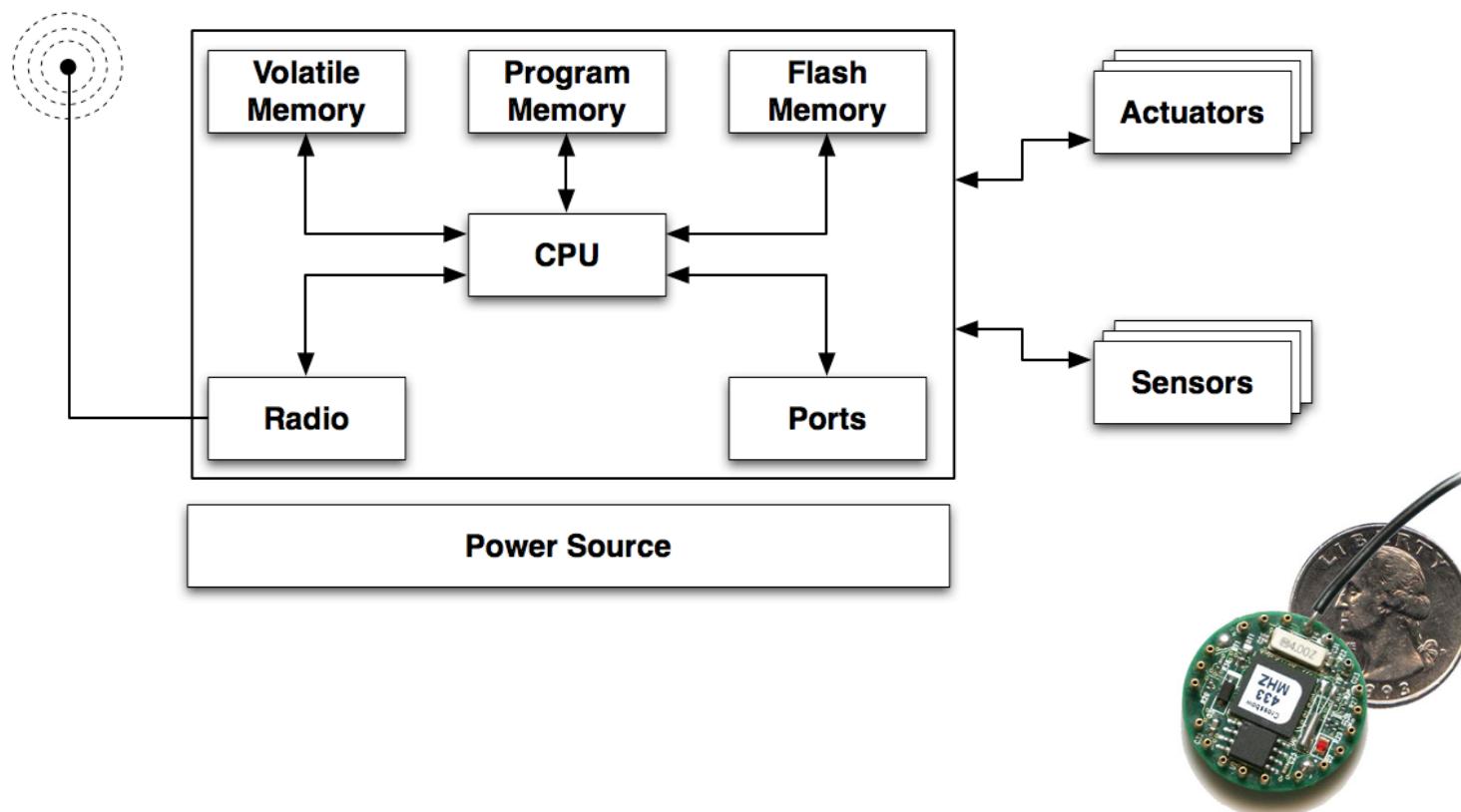


Platforms

- Computing: Microcontroller based
 - Commonly: no Memory Management Unit (MMU)
 - -> No segmentation faults
 - -> You can write to any memory address
 - Even into the interrupt information
 - You should know what you are doing when
 - Using pointers, casts, etc.
 - Bring C-Programming Skills



Example



Programming IoT

- What do we need to write software for a IoT System?
(or: for any system, like your laptop, cell phone?)

- Programming language
 - With compiler, etc.
- OS / runtime libraries
 - Access to system resources
 - APIs: Communication, sensors, etc.

- Put Windows 10 on a sensor node?

- Or Linux, Android, ...
- Use Java, Python, ... as programming languages?
- CPS devices are embedded systems
 - Resource constraints
 - Need custom solutions



CPU	16bit, 8 MHz
RAM	10kB
ROM	48kB
Flash	1MB
Batteries	2xAA

IoT devices vs. your laptop, smart phone etc.



TelosB Sky (MSP430)

CPU 16bit, 8 MHz

RAM 10kB

ROM 48kB

Batteries 2xAA

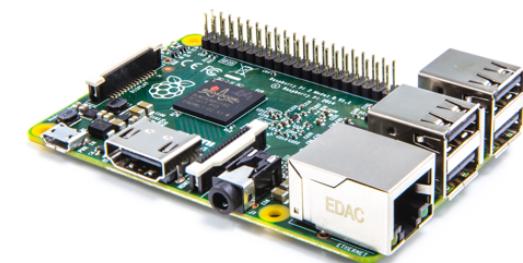
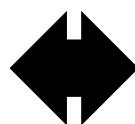
OpenMote (ARM-M3)

CPU 32bit, 32 MHz

RAM 32kB

ROM 256kB

Batteries 2xAA



Raspberry Pi 2 (ARM-A7)

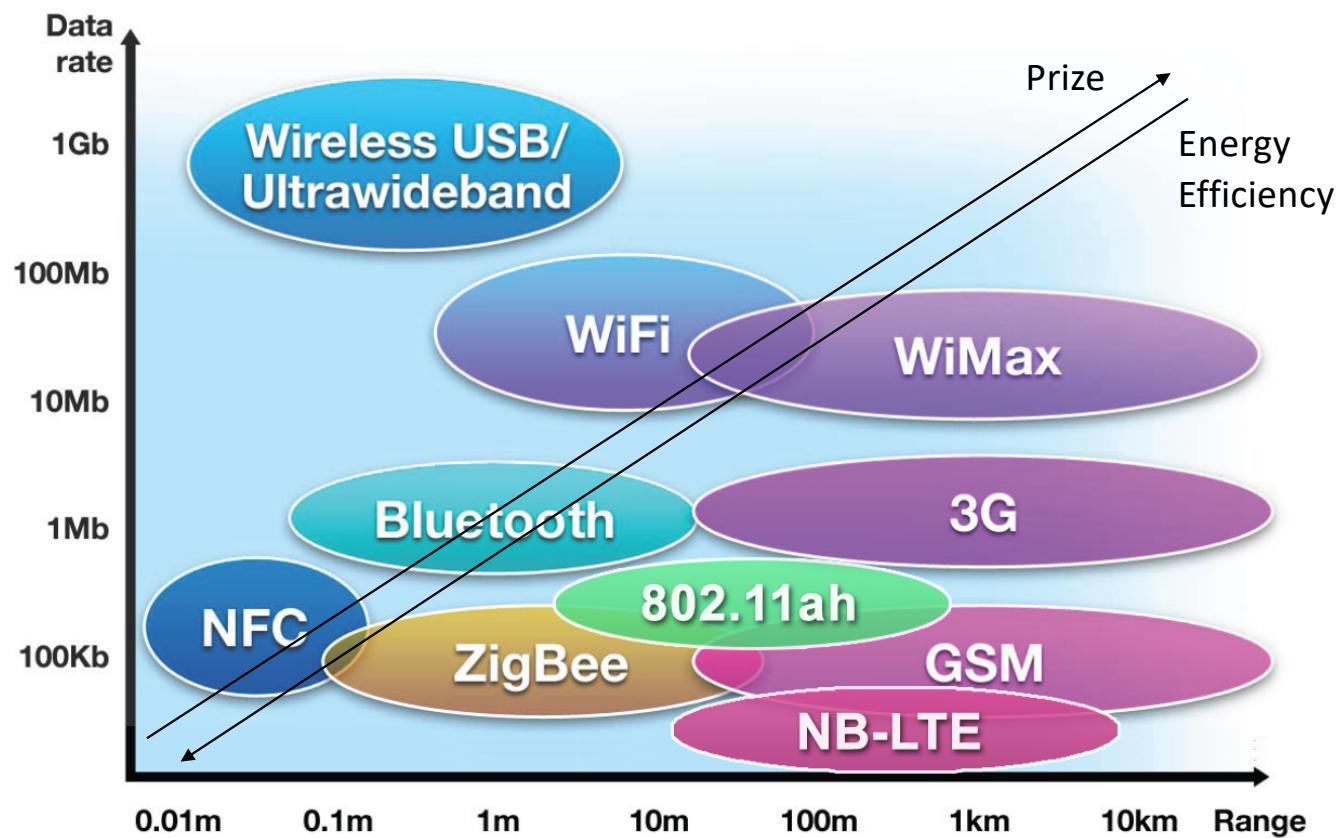
CPU 32bit, 900 MHz

RAM 1GB

ROM SD/Flash

Batteries ?

Connectivity



Quiz: Pause here and answer these questions

- Key components of an IoT device
- Microcontroller Programming: Challenge?
- Compute power compared to a Laptop

Quiz: Pause here and answer these questions

- Key components of an IoT device
 - Microcontroller for computing
 - Radio for Communication
 - Battery
 - Sensors, Actuators
- Microcontroller Programming: Challenge?
 - No memory protection
 - Can basically write anywhere in the address space
- Compute power compared to a Laptop
 - Roughly factor 1000 less powerful

Course Organization

Contents, Orga

Course Content

- Wireless Networking
- Internet of Things

Corona Edition

- Online version: Goals and Content stay the same
 - But we do things a bit differently this term
 - As long as needed. If needed, the whole semester
- Schedule
 - The schedule stays as if we were at the university
 - Two lectures per week, one exercise session per week
 - But you can also watch the videos earlier

Course Structure: V3, Ü2, P1

- Lectures: V3
 - 3 hours of lectures per week
- Exercise: Ü2
 - 2 hours of exercise per week
- Project: P1
 - 1 hour of project per week

Schedule

Date	Day	Lecture	Date	Day	Lecture
06.04.20	Monday	Introduction	25.05.20	Monday	IoT 2
10.04.20	Friday	<i>Good Friday</i>	29.05.20	Friday	Project
13.04.20	Monday	<i>Easter Monday</i>	01.06.20	Monday	<i>Whit Monday</i>
17.04.20	Friday	Contiki	05.06.20	Friday	<i>Project</i>
20.04.20	Monday	Introduction Mobile	08.06.20	Monday	IoT 3
24.04.20	Friday	Wireless	12.06.20	Friday	<i>Project</i>
27.04.20	Monday	Medium Access Control	15.06.20	Monday	IoT 4
01.05.20	Friday	<i>May 1st</i>	20.06.20	Friday	<i>Project</i>
04.05.20	Monday	Cellular I	22.06.20	Monday	Recap
08.05.20	Friday	Cellular II	26.06.20	Friday	<i>Project</i>
11.05.20	Monday	WIFI I	29.06.20	Monday	Project Presentations
15.05.20	Friday	WIFI II	03.07.20	Friday	AMA
18.05.20	Monday	Network Protocols			
22.05.20	Friday	<i>Project</i>			

Note: tentative schedule!

Your Background

- Suggested
 - Course on Computer Networks
 - TCP, UDP, IP, ...
 - Most of you had such a course in their BS or MS programs
 - Course on Operating Systems or Concurrent Programming
 - Threads, locks, ...
 - Most of you had such a course in their BS program
 - **C programming experience for the labs and project**
 - Do not be scared of structs, casts, and pointers
 - Kiel: BSKS plus IT-security should provide you with these C-skills
 - If you do not bring this... this course is not the right one for you
 - You have been warned
 - Some Linux experience
 - Most of you have this from their BS, too
 - Kiel: BSKS plus IT-security should be enough

What does this code do? Problem?

```
struct foo {  
    int a;  
    int b;  
};  
  
struct foo *f;  
void *vp;  
  
void main() {  
    f = (struct foo *)vp;  
    f->a = 5;  
}
```

Components in this Course

- Lectures
 - Usually Mondays, Fridays,
 - Lecture notes uploaded (after class or before) to iLearn
- Labs
 - Usually Mondays
- Project
 - Projects and labs are mandatory
- Written Exam
 - Date?

Lectures – Corona Edition

- Lectures will be pre-recorded
 - Delivered as Video
 - Recorded (not as live stream)
 - You can download and watch on your own
 - Available in iLearn
- Note: about 50% are recordings from Jochen Schiller of FU Berlin
- Note
 - Watching a 90 minute video can be very boring
 - So, please take a break each 20 to 30 minutes

Some notes...

- We are recording the teachers voice
 - To create screencasts for you
 - Let us know if this leads to privacy concerns
- Please interrupt me if you have questions
 - If you have a question, it is likely that others have a similar one...
 - Help yourself and your classmates and ask it

Some more notes...

- I am asking questions, too ;-)
- *Feedback & suggestions: very welcome!*
 - Talk to me after class, send me an email, ...
 - Anonymous course evaluation

Even more notes...

- This is a master level course
 - In terms of speed, workload, general knowledge...
 - But advanced bachelor students are very welcome

To Pass

- Exercises (graded with points)
 - 3 labs
 - Plus a small project in part two of the course
- Pre-Lab:
 - To get you started with Contiki-NG
 - Need to pass, but does not give points
- Pass written exam, graded
 - Admission to exam: **50% of exercise points and 50% of the project points**
 - Final grade: the better one of
 - exam grade or
 - 80% of the exam grade + 20% of the exercise and project grade

Exam – Corona Edition

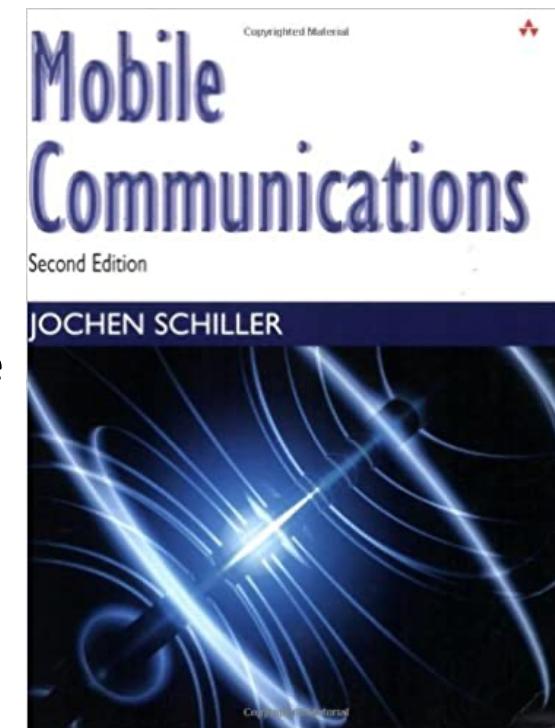
- No information yet
- But for now
 - Let's assume that things are better at the end of the term

Lectures: Please Come to Class

- Lectures deepen and discuss
 - Difficult to do from just slides or book: This is key!
 - Ask questions: Do not be shy
- In general (statistically shown)
 - People who come to class have
 - Better grades
 - A higher probability of passing

Lectures: Book

- Mobile Communications
 - Jochen Schiller
- Nice book, well written
 - Matches the wireless network parts of the course
 - No book (or video) can replace coming to class



Exercises & Project

- Wireless IoT Communication
 - Improve it each lab
 - In C
- Run & Test: Cooja
 - “Internet of Things on your Laptop”
 - Experience
 - Run a distributed IoT system on your laptop
 - ...

Exercises & Project – Corona Edition

- We are still working on the details
 - Most likely we will use slidedecks and maybe videos to explain the tasks
 - Likely: you submit your results as screencast
 - Maybe video conferences
- For now, please
 - Enroll to the exercise (Übungsgruppe) in iLearn
 - And find a partner (teams of two)
- Details will be posted in iLearn

What is where? TODOs!

- iLearn (**Please register to course**)
 - Slides, exercise groups, videos, ...
- Studi DB (**Please register to course**)
 - Official enrollment to the course, required for exam
- Module DB
 - Syllabus
- Univis
 - Rooms and dates
- www.ds.informatik.uni-kiel.de
 - Website of the research group
 - Email address etc. of us

How to prepare

- We will open the videos in the next days in iLearn
 - So you can get started
- Install Contiki-NG,
 - <https://github.com/contiki-ng/contiki-ng/wiki>
 - Suggested: Docker
- Do the tutorial Contiki-NG (see the Cooja one)
 - <https://github.com/contiki-ng/contiki-ng/wiki#tutorials>
- Kickstart your C-skills

You should have - Corona Edition

- Access to a computer
 - On which you can install Contiki-NG
- Be able to record screencast / video-podcasts on your computer
 - Show some slides and demonstrate your results
 - And your voice to comment on it
- Access to the Internet
 - For Videos, iLearn, Video conferences
 - Some of this might require a high-bandwidth connection
 - Video conference: webcam, microphone

Notes – Corona Edition

- We try to make this work stable
 - And be two weeks ahead
 - So that the course can continue when / if one of us get sick
- This is new to us and we do not have much time to prepare
 - Expect hiccups, problems, challenges, ...
 - Expect me and others to get ill during the course
 - And that worst case events might have to be paused for some time
- But we promise to give our best to make this work
 - Please give us feedback!
 - In the exercises or contact me directly

Quiz: Pause here and answer these questions

- What are your todos for now?
- Where are the videos and slides?
- Admission criteria for the exam

Quiz: Pause here and answer these questions

- What are your todos for now?
 - Enroll in Studi DB and iLearn.
 - Find partner and form team in iLearn
 - If you have time: boost your C skills, see videos, installs software (next video)
- Where are the videos and slides?
 - iLearn
- Admission criteria for the exam
 - 50% of exercise points and 50% of project points

Next time

- Next time
 - Programming IoT with Contiki-NG

Questions?

In part, inspired from / based on slides from

Beshr Al Nahas, Jochen Schiller, Holger Karl, Klaus Wehrle, Kyoung-Don Kang, Leonardo Leiria Fernandes, Joe Polastre, Chenyang Lu, Leif Kobbelt, Leo Selavo, Ericsson, Phil Levis, David Gay, David Culler, Hongwei Zhang, Luca Mottola, Dr Payam Barnaghi, Dr Chuan H Foh, Cisco and many others