CMPSC 293S
Internet of Things (IoT)

Winter Term 2019
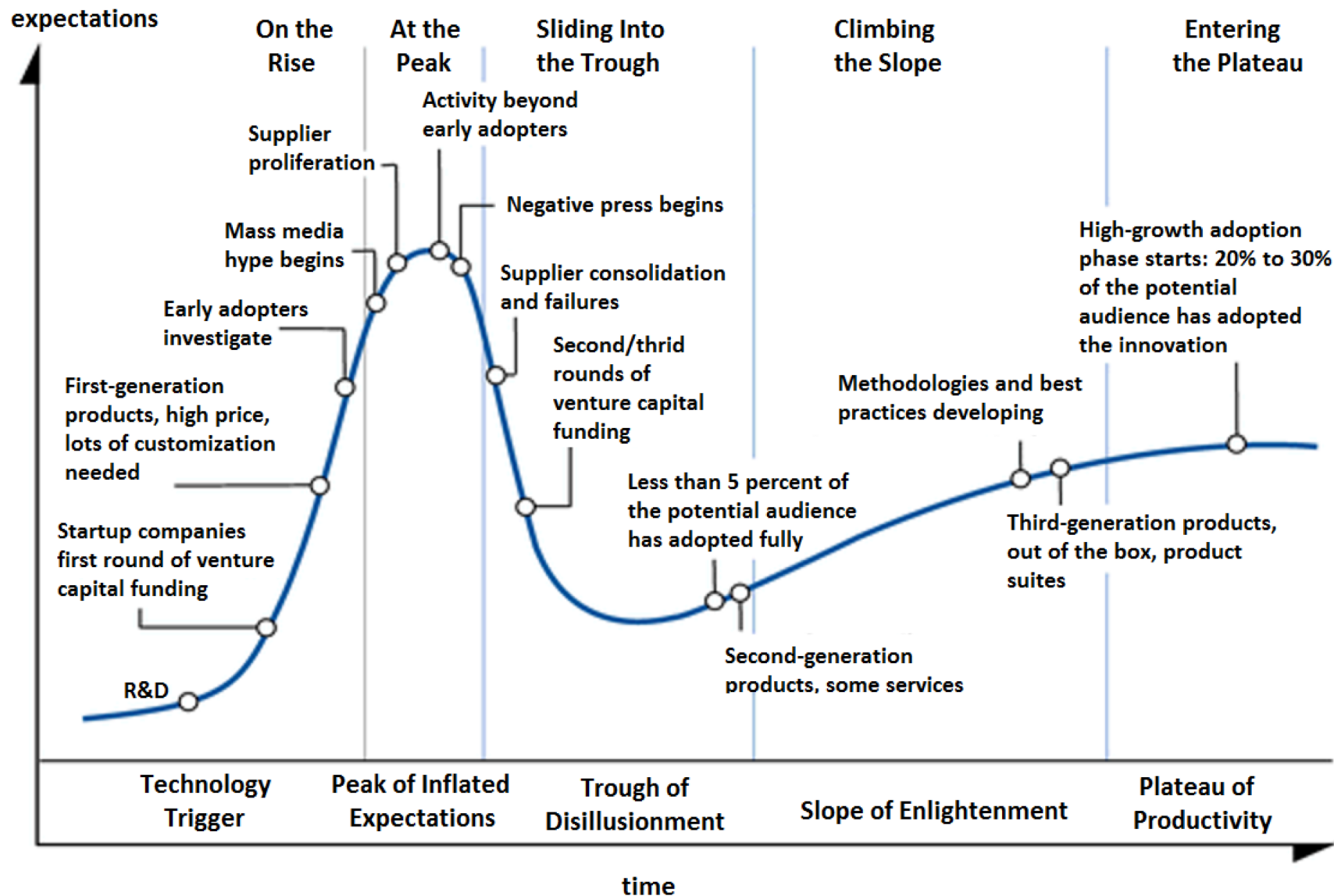
UCSB

Prof. Dr. Markus U. Mock
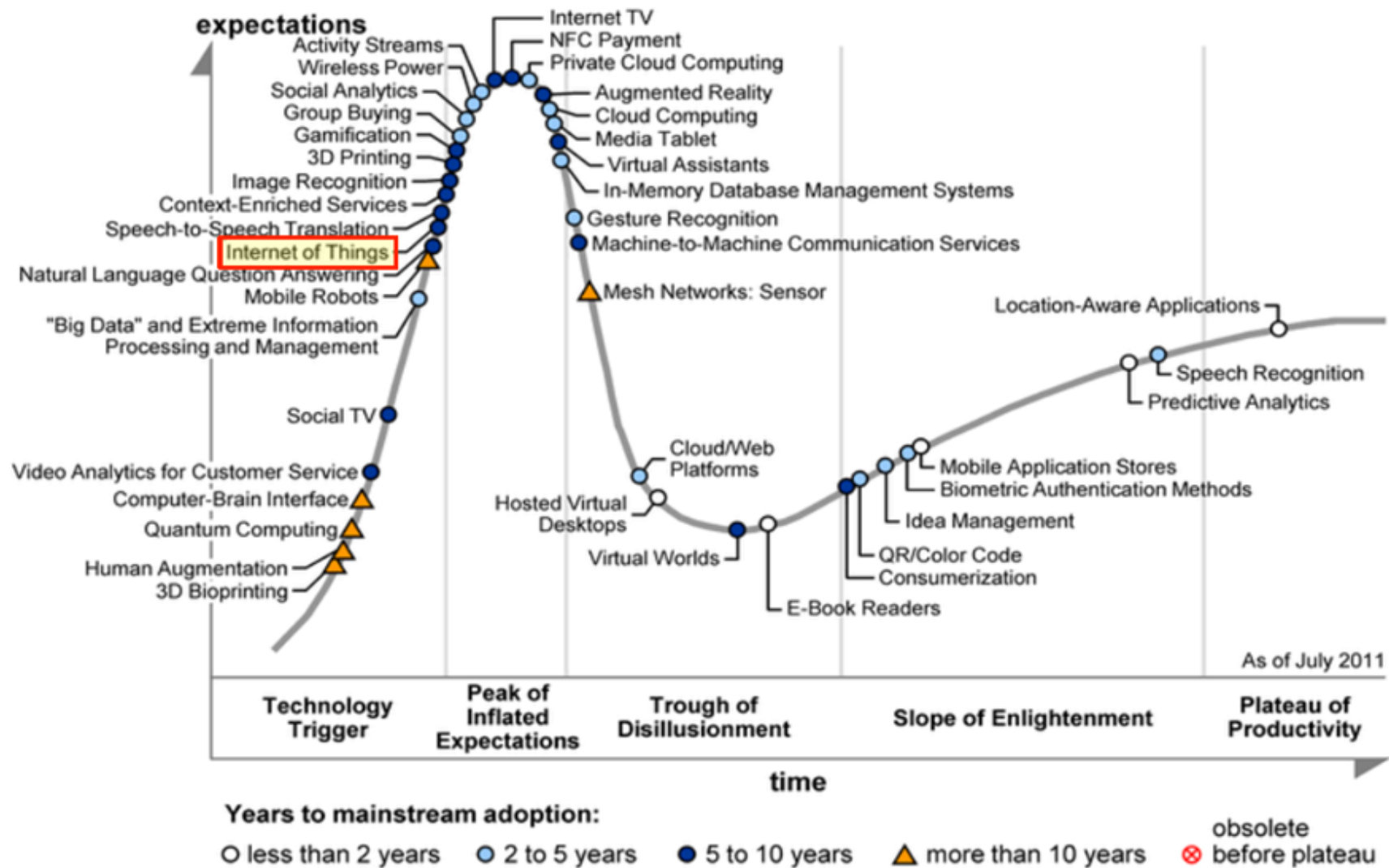
Hype Cycle

Hype Cycle is a chart that lays out where the hottest technologies are in terms of adoption. Developed by the research and advisory firm Gartner.
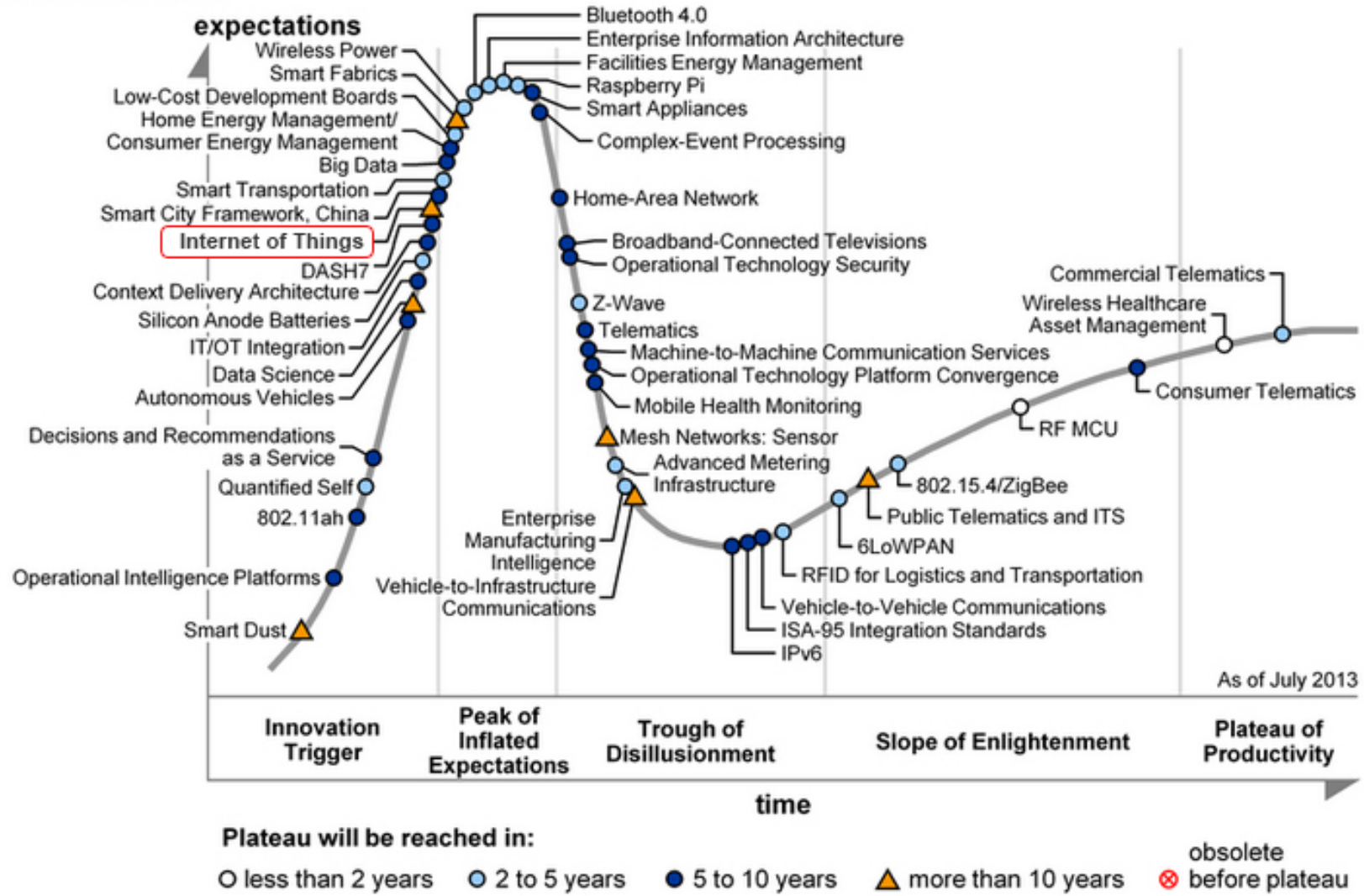
expectations
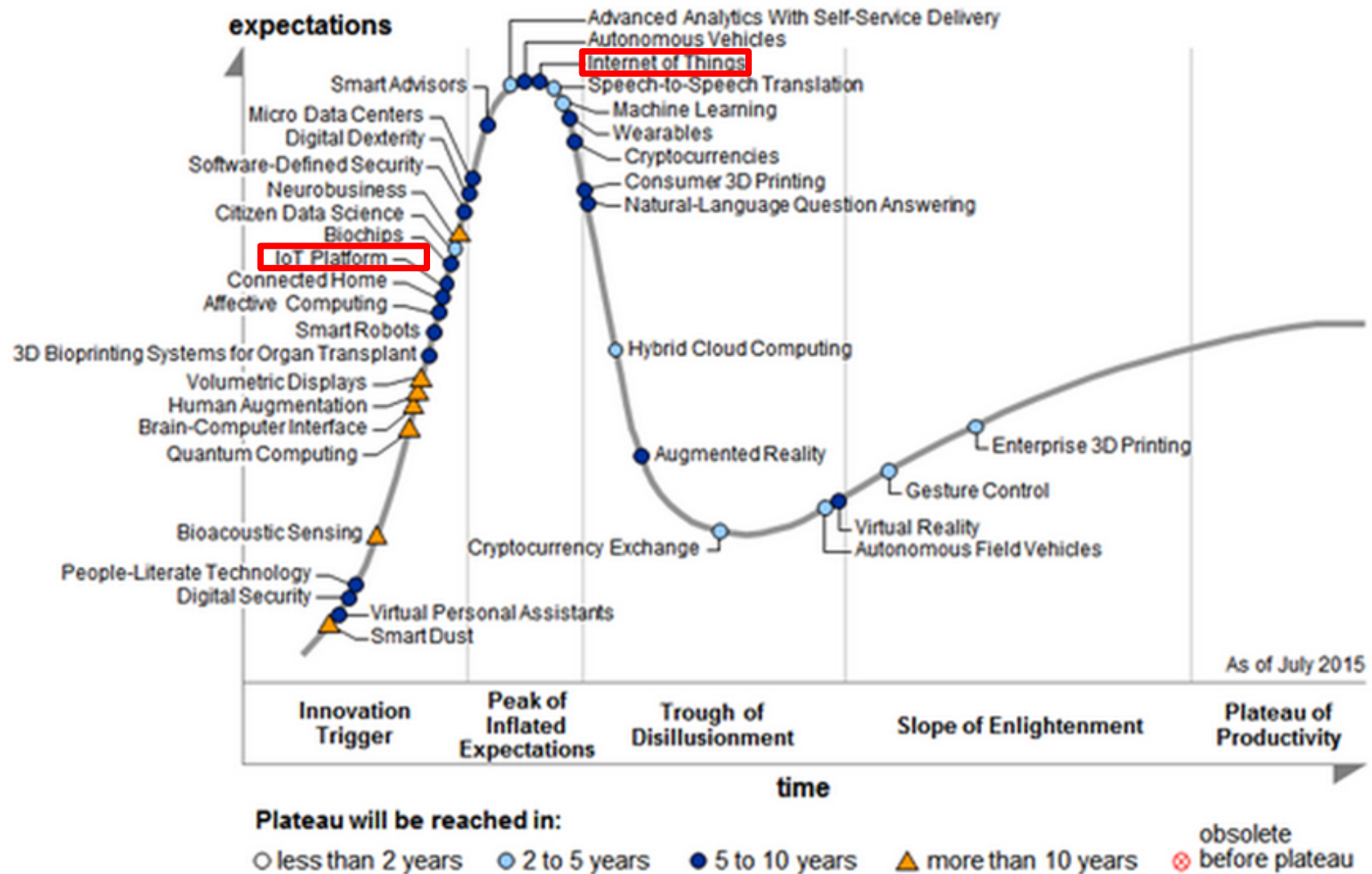
On the Rise | At the Peak | Sliding Into the Trough | Climbing the Slope | Entering the Plateau

Activity beyond early adopters

Supplier proliferation

Negative press begins

Mass media hype begins

Supplier consolidation and failures

High-growth adoption phase starts: 20% to 30% of the potential audience has adopted the innovation

Early adopters investigate

Second/thrid rounds of venture capital funding

Methodologies and best practices developing

First-generation products, high price, lots of customization needed

Less than 5 percent of the potential audience has adopted fully

Startup companies first round of venture capital funding

Third-generation products, out of the box, product suites

Second-generation products, some services

R&D

Technology Trigger | **Peak of Inflated Expectations** | **Trough of Disillusionment** | **Slope of Enlightenment** | **Plateau of Productivity**

time

2

Hype Cycle 2011

Hype Cycle 2013

Hype Cycle for 2013

Hype Cycle 2015

expectations

Advanced Analytics With Self-Service Delivery
Autonomous Vehicles
Internet of Things
Smart Advisors
Speech-to-Speech Translation
Micro Data Centers
Machine Learning
Digital Dexterity
Wearables
Software-Defined Security
Cryptocurrencies
Neurobusiness
Consumer 3D Printing
Citizen Data Science
Natural-Language Question Answering
Biochips
IoT Platform
Connected Home
Affective Computing
Smart Robots
Hybrid Cloud Computing
3D Bioprinting Systems for Organ Transplant
Volumetric Displays
Human Augmentation
Brain-Computer Interface
Enterprise 3D Printing
Quantum Computing
Augmented Reality
Gesture Control
Bioacoustic Sensing
Virtual Reality
Cryptocurrency Exchange
Autonomous Field Vehicles
People-Literate Technology
Digital Security
Virtual Personal Assistants
Smart Dust

| Innovation Trigger | Peak of Inflated Expectations | Trough of Disillusionment | Slope of Enlightenment | Plateau of Productivity |

As of July 2015

time

Plateau will be reached in:

○ less than 2 years   ○ 2 to 5 years   ● 5 to 10 years   △ more than 10 years   ⊗ obsolete before plateau

Hype Cycle 2016

expectations

- Internet of Things
- Cloud Service Brokerage
- Smart City Framework
- Bimodal IT Operations
- MOOC Platforms
- Platform Business Models
- Open-Source Banking Systems
- Advanced Underserved Area Comms
- Mobile Commerce
- Cloud Office
- Wristbands
- LTE-A
- Social Media
- Student Retention CRM
- Payer Self-Service
- Mobile Apps
- On-Site Photovoltaic
- Solar Power for Data Centers
- Direct CSP Billing
- Digital Wallets
- Crowdfunding
- Heterogeneous Networks
- Mobile Health Monitoring
- IT PMO
- Humanitarian Disaster Relief
- Cellular to Wi-Fi Authentication
- Super Wi-Fi
- Video Visits
- Public Cloud Storage
- Mobile Money
- Mobile Learning Smartphones
- 3D Printing Service Bureaus

As of July 2016

| Innovation Trigger | Peak of Inflated Expectations | Trough of Disillusionment | Slope of Enlightenment | Plateau of Productivity |

time

Years to mainstream adoption:

○ less than 2 years   ◐ 2 to 5 years   ● 5 to 10 years   △ more than 10 years   ⊗ obsolete before plateau

6

Number of connected devices worldwide

Connected devices in billions

Year	Devices
2020*	50.1
2019*	42.1
2018*	34.8
2017*	28.4
2016*	22.9
2015*	18.2
2014	14.4
2013	11.2
2012	8.7

2012

IoT Landscape: Huge Career Opportunities

Internet of Things Landscape 2016

© Matt Turck (@mattturck), David Rogg (@davidjrogg) & FirstMark Capital (@firstmarkcap)

A few words about myself

- Ph.D. in Computer Science, University of Washington, Seattle, 2002, on "Automating Selective Dynamic Compilation", (Advisors, Susan Eggers and Craig Chambers)

- 2002 – 2005 Assistant Professor of Computer Science, University of Pittsburgh

  ◦ Research and Teaching in Compilers, Programming Languages, Computer Architecture

- 2005-2010: Google, Mountain View, Advertising and Google Docs Backend

- 2010-2014: VMware, Consulting, Nutanix, Amazon Kindle Division

  ◦ Worked on the Kindle Fire and Amazon Echo

Organizational Issues (1)

- **Lecture**
  - Mondays & Wednesdays, 3pm - 4:50pm, Phelps 2510
- **Documents**
  - Syllabus online at http://cs.ucsb.edu/~mock/cs293S/index.html
  - Using Gouchospace for lecture notes etc.
  - Piazza sign up at: piazza.com/ucsb/winter2019/cmpsc283S
- **Exams**
  - Midterm planned for 2/4, no final
- **Lecturer**
  - Prof. Dr. Markus U. Mock
  - Office: HFH 5112
  - Contact: Via Piazza for questions etc.
  - Office hours: Wednesdays from 13:30 – 14:30 (subject to change) and after class

Organizational Issues (2)

- **Books & Articles**
  - There is no textbook for the class
  - Articles will be provided in Gouchospace as needed
- **Project**
  - Group Project 2-3 people in one group, form a group this week
  - Focus is Data Analysis, statistical and / or machine learning techniques
  - You will work with sensor data and do analysis for them
    - More details Wednesday

SYLLABUS

- Available on http://cs.ucsb.edu/~mock/cs283S/index.html

Will probably be updates as we move along

Content

Planning

Chapter 1

Introduction

Chapter 2

Smart Objects

Chapter 3

Connectivity

Chapter 4

Application protocols

Chapter 5

Backend

Last Chapter

Q&A
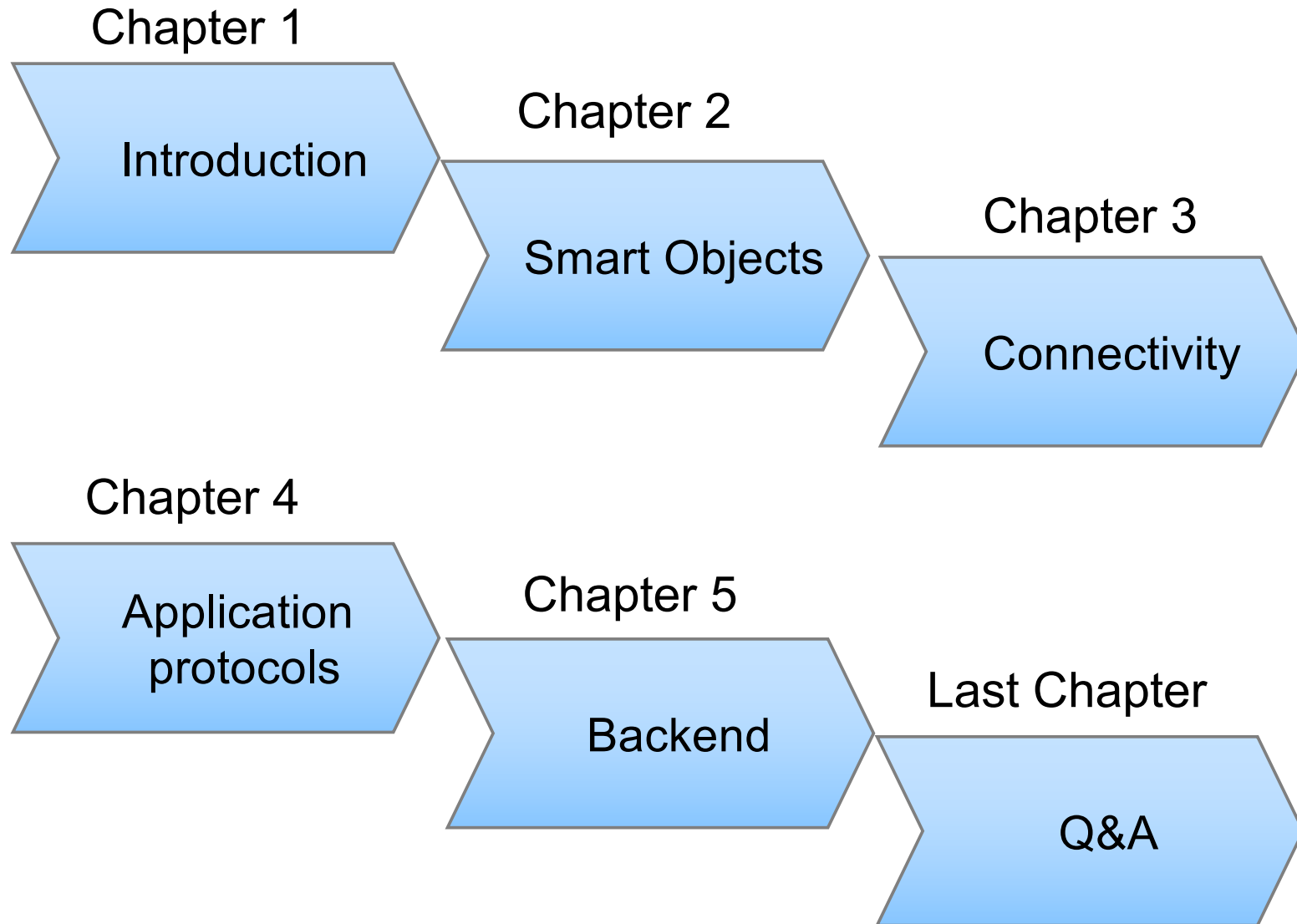
Overview – Lecture Topics

- Introduction

- Smart Objects

- Raspberry-PI and Arduino Platforms

- Connectivity for IoT

- IoT App Protocols: MQTT & CoAP

- IoT Cloud Backends

- IoT Device Management: OMA LWM2M

- Application Development: NodeRED

- 11: IoT Misc.: Cloud / Energy-Efficiency / Security / OS

- Anomaly Detection methods

- Not necessarily all of these topics are covered

Group Exercise: Interviews

- Counting exercise

- Find an interviewee (listen for instructions)

  - Get to know your interviewee (1 minute)

    - Why are they taking the class?

    - What experience do they have in IoT?

    - What do they study? Which year?

    - Unique factoid: what do they think is something unique that no one else in the class has? (e.g.,10 siblings, married 15 times, born on an airplane etc.)

  - Take turns

    - Now the interviewer becomes the interviewee (1 minute)

- If you have a bad short-term memory: take notes

  - You will introduce your interviewee to the class (1 minute)

Introduction to IoT

Contents

- Illustration of Smart Objects

- IoT Definition

- IoT Applications/Verticals

- IoT Technology Roadmap

- IoT Market

What IoT Devices Do You Know?

●

Smart Things at Consumer Electronics Show (CES 2013)

- Parrot: "Flower Power" with humidity & light sensors [to monitor health of the plant]

- Withings: "Smart Body Analyzer"
  [to monitor weight, heart rate, temperature and air quality]

- Belkin: "Smart WeMo Light Switch"
  [to remote or automatic control light]

- Dacor: "Android Smart Oven"
  [to install apps and download recipes]

- .. And many others
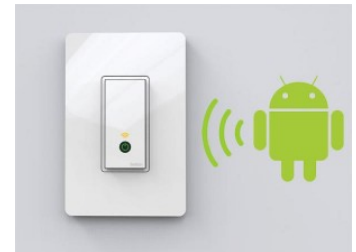
Smart Things at CES'2015

- Sony Smartwatch

- Alcatel Smartwatch

- Withings Smartwatch with the HealthMate app

- Connected Pacifier

- Mini Drones

- .. And many others

https://www.pastemagazine.com/blogs/lists/2015/01/the-10-best-gadgets-from-ces-2015.html

Smart Things at CES'2016

- The WiFi-enabled, Airmega smart air purifier

- WowWee's CHiP robot dog

- The Bluetooth-enabled Chipolo is a wireless tracker

- Digisole smart shoes are controlled by a smartphone app (runprofiler, heated, etc)

- .. And many others

https://www.thestar.com/business/2016/01/05/10-of-the-best-gadgets-at-ces-2016.html
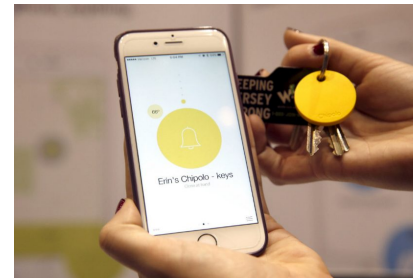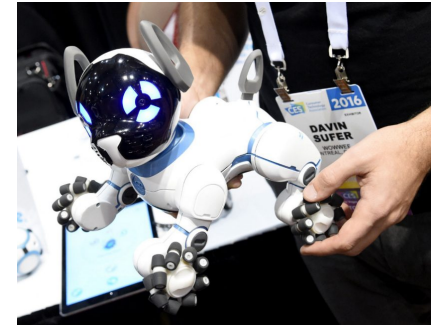
Smart Things at CES'2017

- Plume is a wearable device that tracks pollution around you

- The Griffin Connected Toaster

- Checking your blood alcohol content with a breathalyzer

- Kuri is an adorable little robot designed for the home

- Motiv's fitness/sleep tracking ring

- Intel's Compute Card, which is a mini-computer about the size of a credit card.

- .. And many others

https://techcrunch.com/2017/01/09/10-of-the-coolest-gadgets-we-saw-at-ces-2017/
http://time.com/4626654/ces-2017-best-gadgets/
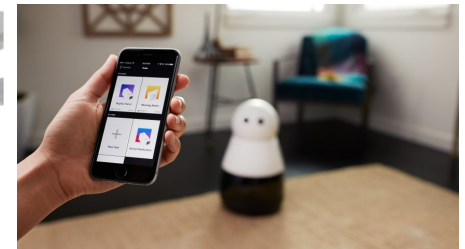
Smart Cars

"The vehicle is actually the third-fastest growing connected device behind smart phones and tablets" IHS Automotive

- FORD: EV charging app
- NISSAN: Kan-Kan-Kyo house

- TOYOTA: Smart Center
- CHEVROLET Volt: OnStar app

- DAIMLER BENZ: Smart Car2Go
- BMW-TENDRIL: BMW ActiveE

- ..

- Autonomous cars

Src: https://secure.myvolt.com/

Src: http://social.ford.com

Src: http://www.toyota-global.com/innovation/smart_grid/

https://secure.myvolt.com/
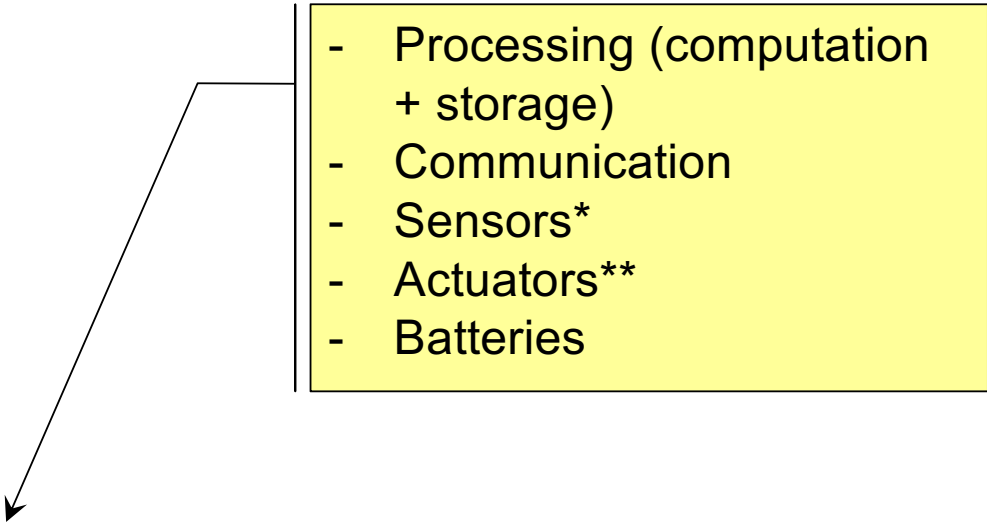
What is Common to All / Most IoT Devices?

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Prof. Elgar Fleisch:

-	Processing (computation + storage)
-	Communication
-	Sensors*
-	Actuators**
-	Batteries

Thing + IT = Function + Service

*Sensors** are active devices that **measure** some variable of the natural or man-made environment (e.g., a building, an assembly line, an industrial assemblage supporting a process).

An **actuator is a **mechanized device** of various sizes (from ultra-small to very large) that accomplishes a specified **physical action**, for example, controlling a mechanism or system, opening or closing a valve, starting some kind or rotary or linear motion, or initiating physical locomotion. An actuator is the mechanism by which an entity acts upon an environment.
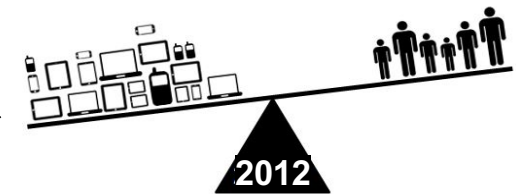
Metcalfe's Law (1980)

- Robert M. Metcalfe is the inventor of Ethernet

- The value of a network grows **quadratically—proportionately** with the number of connections you can make.

- Metcalfe's Law: **value = n^2 – n**

# participants (n)	Value
3	6
10	90
100	9.900
7×10^9 (Internet of People)	$\sim 7^2 \times 10^{18}$
M*7×10^9 (Internet of Things)	$\sim M^2 * 7^2 \times 10^{18}$

2012

In 2020: 50×10^9 connected devices

"Everything that can be networked, should be networked!"

- But scaling is challenging!

Further important laws

- **Nielsen's law(1998):** The bandwidth doubles every 24 months (updated 2018: 50% per year)

→ „Everything that can be networked is also networked!"

- **Moore's law (1965):** the integration density (or the computing power of computer chips) doubles approximately every 18 months .

→ „Everything that can be digitized is also digitized" Karl-Heinz Land

Src: nngroup

Src: Intel
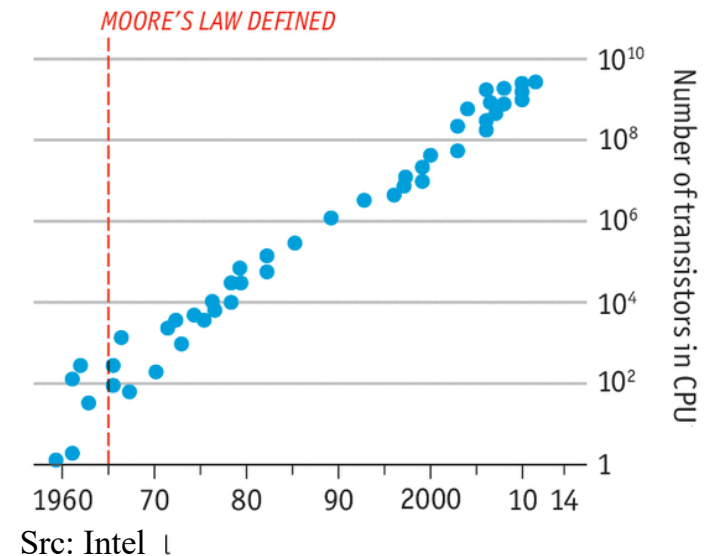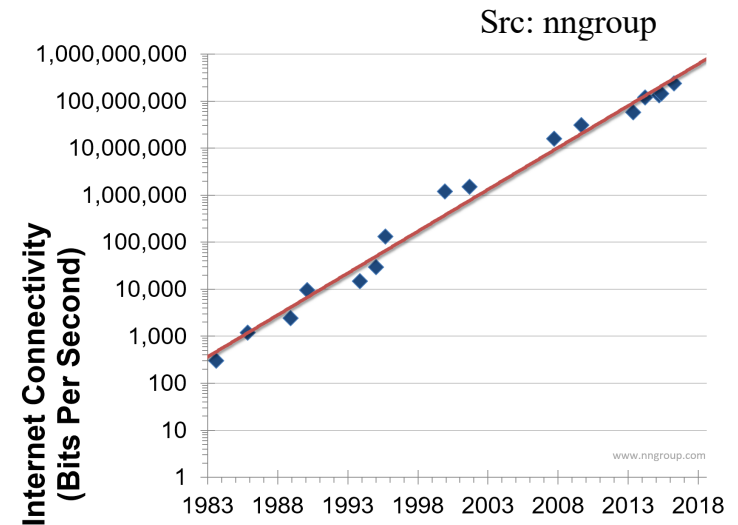
IoT Definition(s)

- "The **Internet of things** (**IoT**) is the <u>inter-networking</u> of <u>physical devices,</u> vehicles (also referred to as "connected devices" and "smart devices"), buildings, and other items—embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to <u>collect and exchange data</u>" Wikipedia

- "The **Internet of Things (IoT)** is the <u>network</u> of <u>physical objects</u> that contain embedded technology to communicate and sense or interact with their internal states or the external environment" Gartner

- "The Internet of things <u>links</u> the objects of the <u>real world</u> with the <u>virtual world,</u> thus enabling anytime, anyplace connectivity for anything and not only for anyone. It refers to a world where physical objects and beings, as well as virtual data and environments, all interact with each other in the same space and time" Cluster of European Research Projects on the Internet of Things, "Vision and Challenges for Realizing the Internet of Things", March 2010

IoT Definition(s)

- "The IoT refers to as <u>ubiquitous networking or pervasive computing environments</u>, is a vision where <u>all manufactured things</u> can be network enabled, that is connected to each other via wireless or wired communication networks" European Network and Information Security Agency (ENISA)

- "The IoT <u>is a world</u> where <u>physical objects</u> are seamlessly integrated into the <u>information network</u>, and where the physical objects can become <u>active participants in business processes</u>. Services are available to interact with these "smart objects" <u>over the Internet</u>, query and change their state and any information associated with them, <u>taking into account security and privacy issues</u>. RFID, sensor networks, and so on are just enabling technologies " SAS

- "The **Internet of things** (**IoT**) <u>is the infrastructure</u> of the <u>information society</u>" Global Standards Initiative on Internet of Things: IoT-GSI, 2013

IoT: Espousing Cyber & Physical Worlds

Physical World - Continuous Digitalization:

- Pervasive sensing/embedded computing
- Low-cost wireless connectivity for things (RFID, ZigBee, NFC, dongles ..)
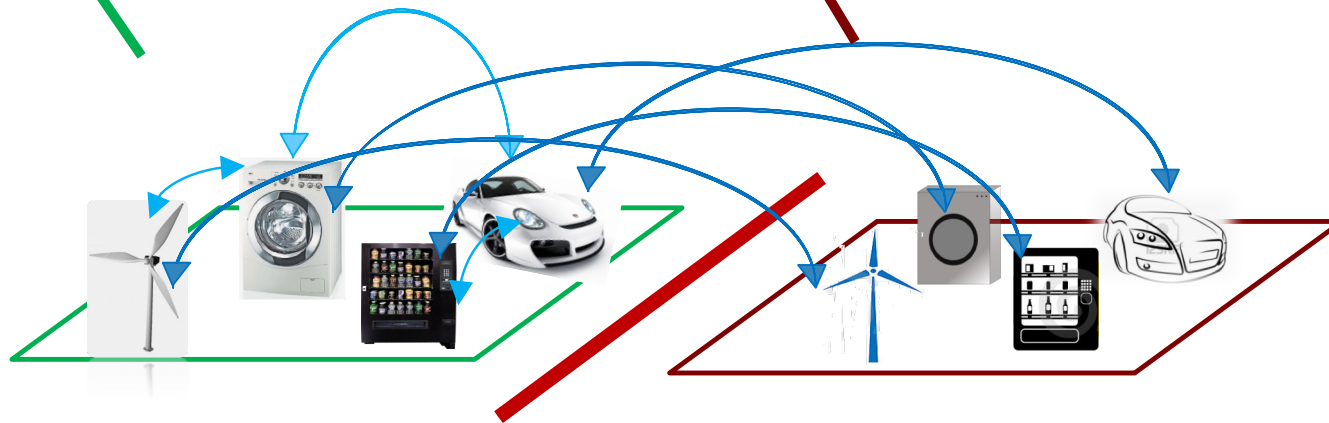
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Cyber World - Web of Things:

- Powerful computation, sensing cloud (quality-aware, intelligent, predictive Big Data analytics)
- (Semantic) Web 3.0
- Information-centric networks

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IoT - Cyber Physical World:

- Fully automated processes based on rules/predicates
- Social networking for things
- (Virtual) Things, augmented reality

Ubiquitous access of trustworthy services

Real Life of Things (Physical World)

Second Life (shadows) of Things (Cyber World)