Emerging Technologies for the Circular Economy

Lecture 4: Introduction to the Internet of Things (IoT)

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- Updated versions of these slides will be available in our Github repository.

TU Clausthal

Institute for Software and Systems Engineering

NEWS/UPDATES

News/Updates

- Mining students <u>final</u> exam date (oral) → 25/26.07.2024
- Everyone else (written exam) → 29.07.2024 from 2 pm – 4 pm

Lectures ETCE – UPDATED

- 15.04.2024 → Organization (L00) + Introduction (L01)
- 22.04.2024 → Circular Economy (L02)
- 29.04.2024 → Lifecycle Assessment – LCA (L03)
- 06.05.2024 → Introduction to the Internet of Things (L04)
- 13.05.2024 → Internet of Things – Communication + Security and Privacy (L05)
- 27.05.2024 → Internet of Things – Data Processing and BigData (L06)
- 03.06.2024 → Industrial Internet of Things (L07)
- 10.06.2024 → Introduction to Blockchain Technology (L08)
- 17.06.2024 → Blockchain Technology – Consensus (L09)
- 24.06.2024 → Blockchain Technology – Ethereum and Smart Contracts (L10)
- 01.07.2024 → Blockchain Technology and Sustainability (L11)
- 08.07.2024 → The Machine-to-Everything Economy – A step towards the CE 2.0? (L12)
- **22.07.2024 → Exam Q&A**

Lectures Mining Students – UPDATE

- 15.04.2024 → Organization (L00) + Introduction (L01)
- 22.04.2024 → Circular Economy (L02)
- 29.04.2024 → Lifecycle Assessment – LCA (L03)
- 06.05.2024 → Introduction to the Internet of Things (L04)
- 13.05.2024 → Internet of Things – Communication + Security and Privacy (L05)
- 27.05.2024 → Internet of Things – Data Processing and BigData (L06)
- 03.06.2024 → Industrial Internet of Things (L07)

- **10.06.2024 → IoT in Mining I (L08)**
- **17.06.2024 → IoT in Mining II (L09)**
- **24.06.2024 → Technologies for Sustainability – MOOC Content (L10)**

- **01.07.2024 → Coding Workshop I (Goslar)**
- **08.07.2024 → Coding Workshop II (Goslar)**

- **15.07.2024 → Exam Q&A**

RECAP

The Nature of Technology

- B. Arthur stipulates that an ***economy is an expression of its technologies***
  - Thus, it can be argued that the current unsatisfying state of <u>the Circular Economy reflects a lack of sufficiently developed technologies</u> that express themselves within the CE.
  - Or, more precisely – difficulties of the stakeholders in combining the technologies that are required to enable the CE.

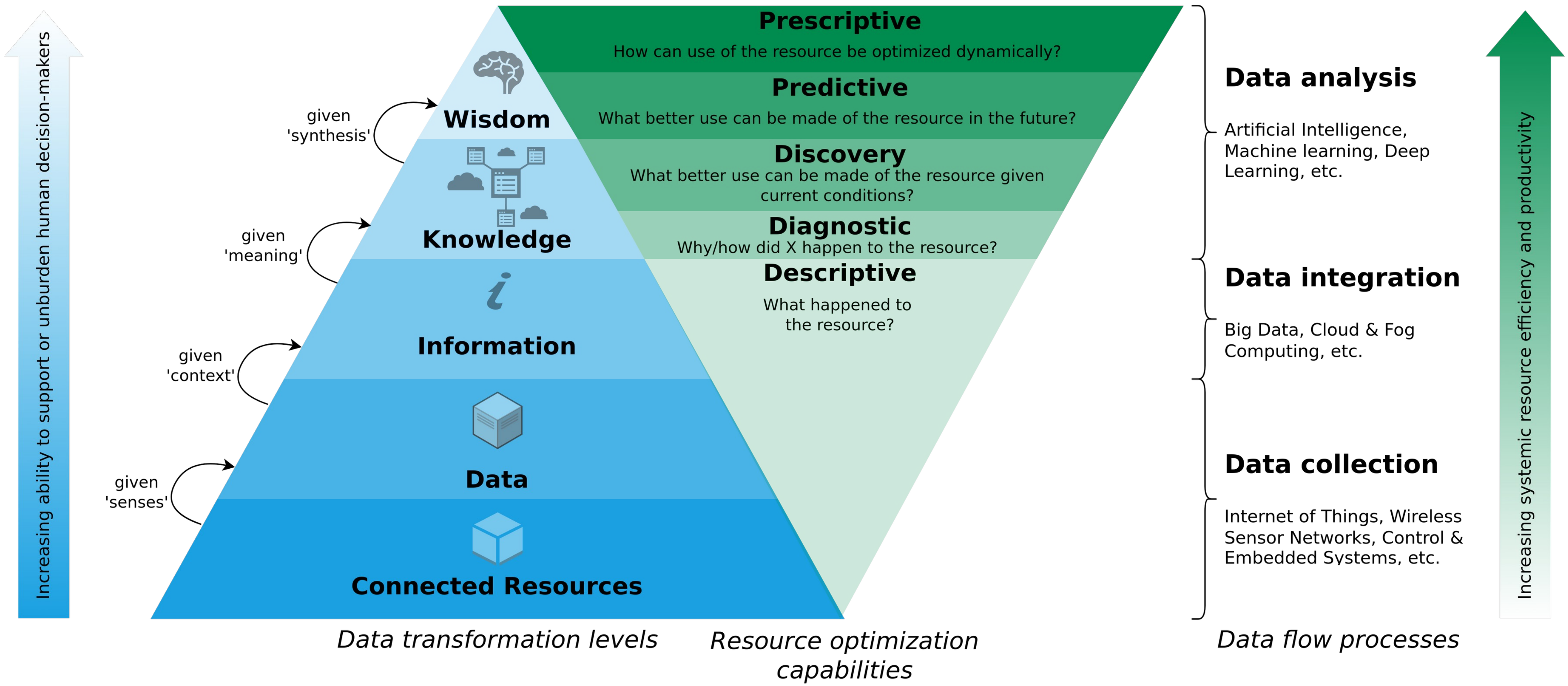
Arthur, Brian (2011) – The Nature of Technology: What It Is and How It Evolves.

Emerging Technologies for the Circular Economy

Lecture 3: Lifecycle Assessment (LCA)

Prof. Dr. Benjamin Leiding
M.Sc. Anant Sujatanagarjuna
M.Sc. Shohreh Kia

A Data-Driven Smart Circular Economy Framework



Kristoffersen et al. (2020) – The smart circular economy: A digital-enabled circular strategies framework for manufacturing companies.

INTRODUCTION AND HISTORY

History

- 1982: Beverage dispenser with an Internet connection (Carnegie Mellon University)
- 1991: Vision of *Ubiquitous Computing*
- 1999: Kevin Ashton → IoT refers to the linking of clearly identifiable physical objects (things) with a virtual representation in an Internet-like structure.

Introduction

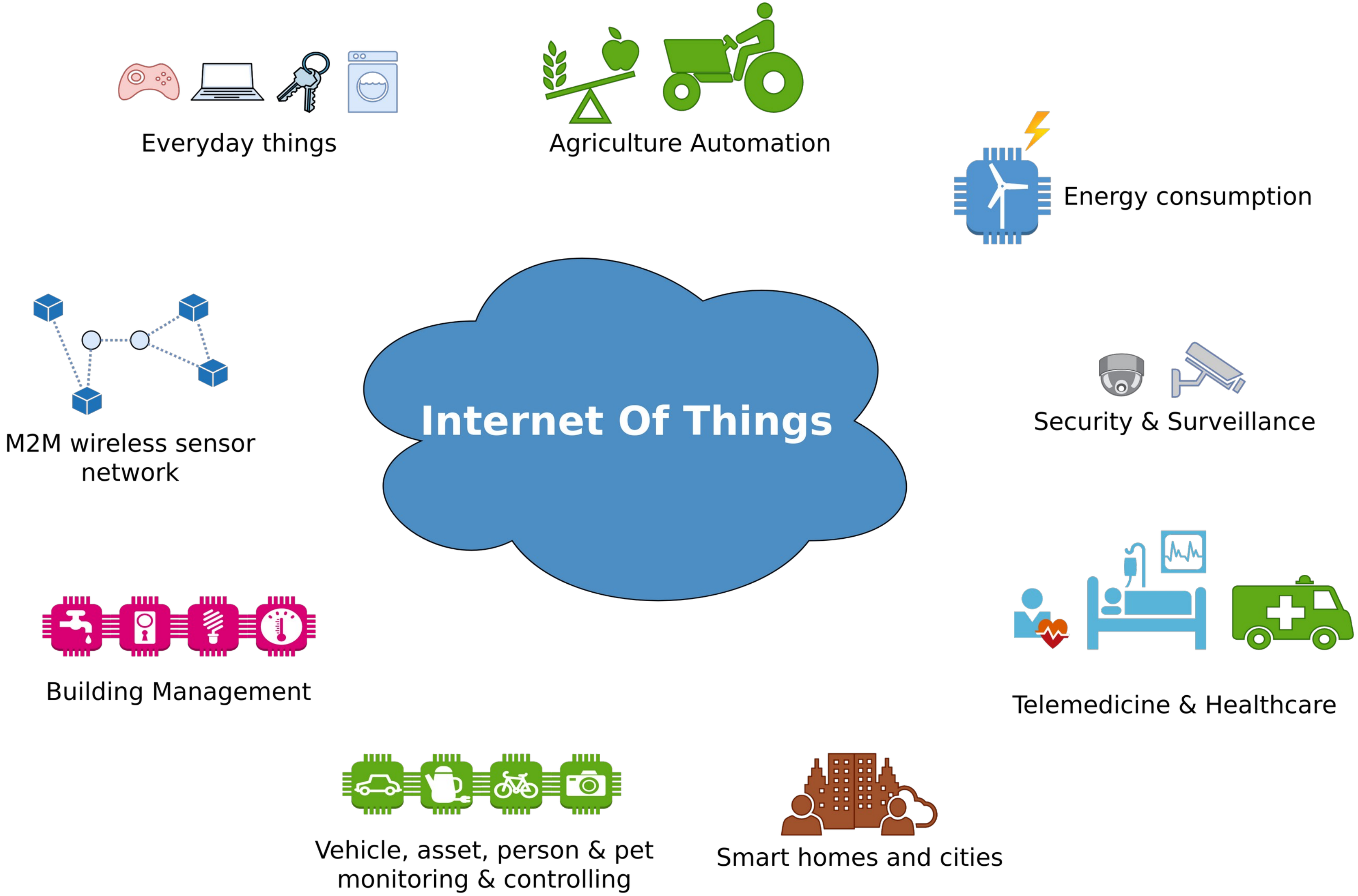
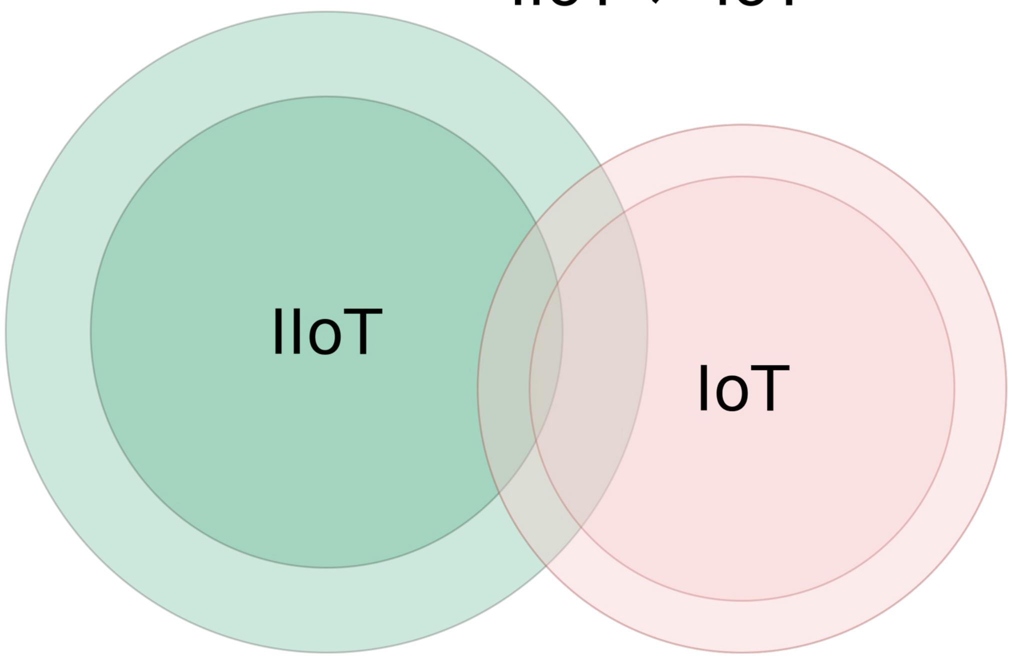


Image adapted from: https://www.scientechworld.com/blog/telephone-network-computer-network-mobile-network-network-things-internet-things-iot/

IIot vs. IoT

IIoT ≠ IoT

Connected
Industrial
High-cost
Assets



Connected
Low-cost
End-point
Devices

Image adapted from: https://web.stanford.edu/class/archive/ee/ee392b/ee392b.1186/lecture/apr3/ee392b_2018_Lecture1_Overview.pdf

IT and OT in IIoT

OT (Operational Technology): Hardware and software that detects or causes a change through the direct monitoring and/or control of physical devices, process and events in the enterprise.

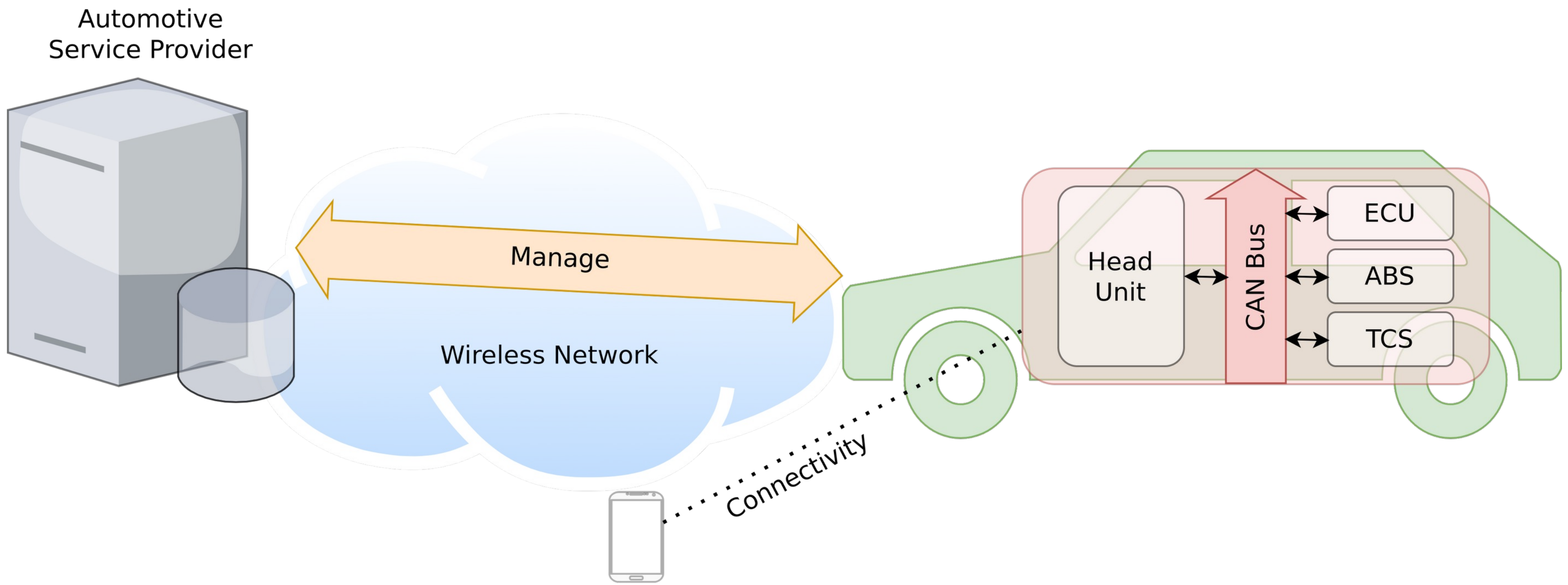
IT (Information Technology): This is the common term for the entire spectrum of technologies for information processing, including software, hardware, communications technologies and related services.

IT

OT

Image and definitions adapted from: https://www.coolfiresolutions.com/wp-content/uploads/2020/09/difference-it-ot.gif and https://web.stanford.edu/class/archive/ee/ee392b/ee392b.1186/lecture/apr3/ee392b_2018_Lecture1_Overview.pdf respectively

IoT Example – Connected Cars



IT
1. Fleet Management 2. Telematics

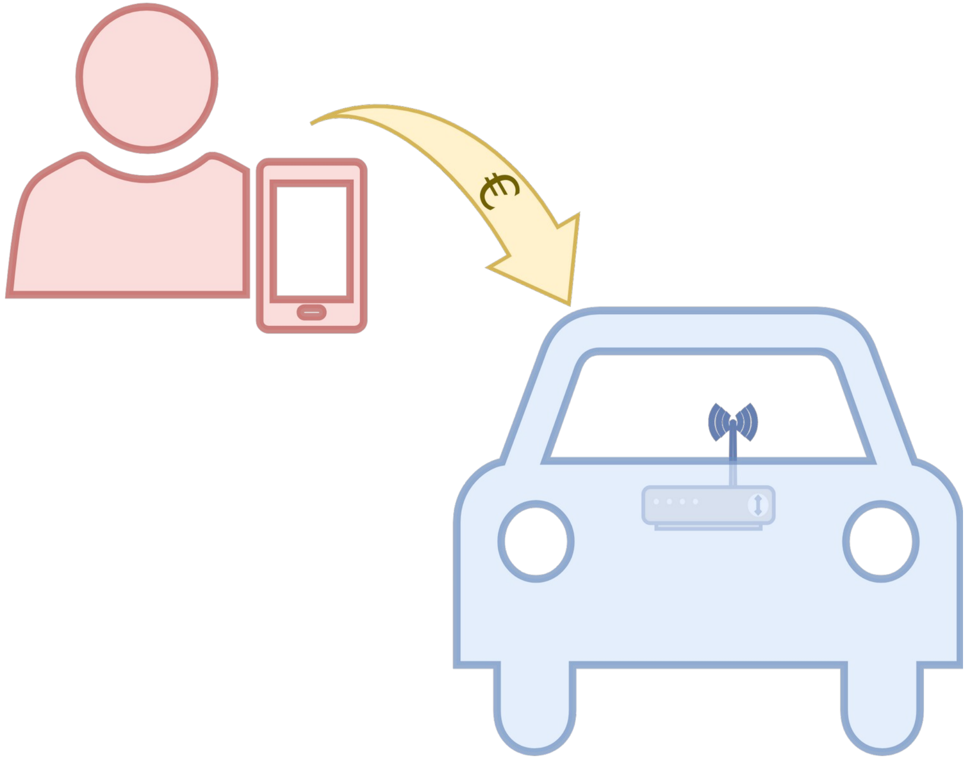
OT
1. Integrated info system (head unit) 2. CAN bus functions

Embedded
1. ECU 2. ABS 3. TCS

Image adapted from https://web.stanford.edu/class/archive/ee/ee392b/ee392b.1186/lecture/apr3/ee392b_2018_Lecture1_Overview.pdf

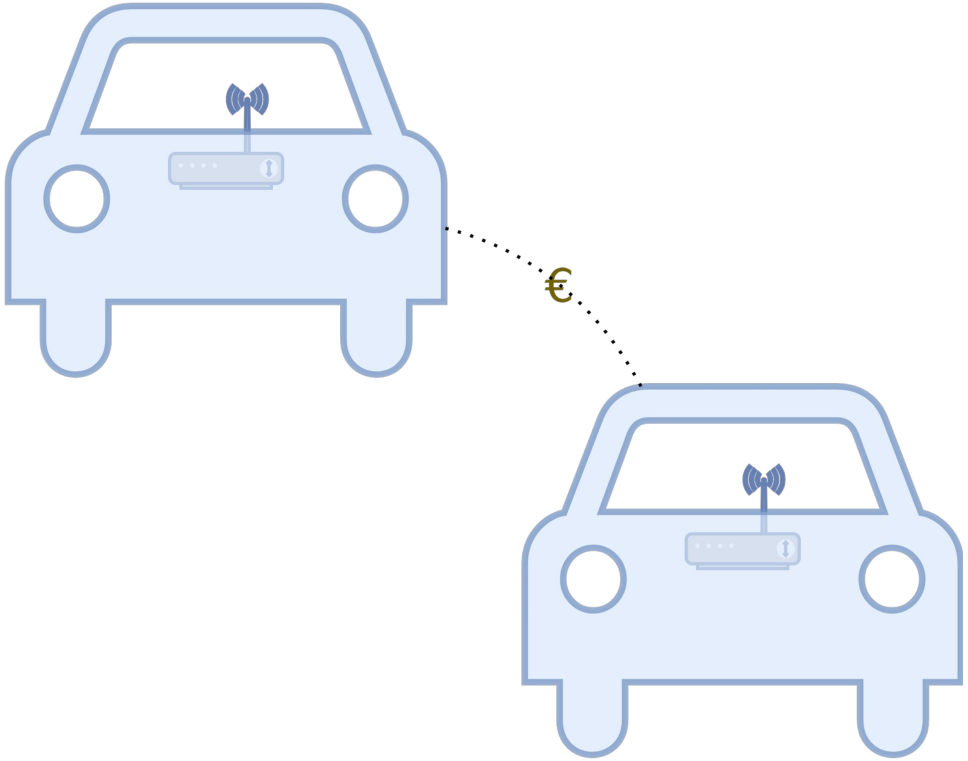
IoT Example – Machine-to-Everything (M2X) Applications

- Machine-to-Human (M2H)
- For example → Transportation-as-a-Service



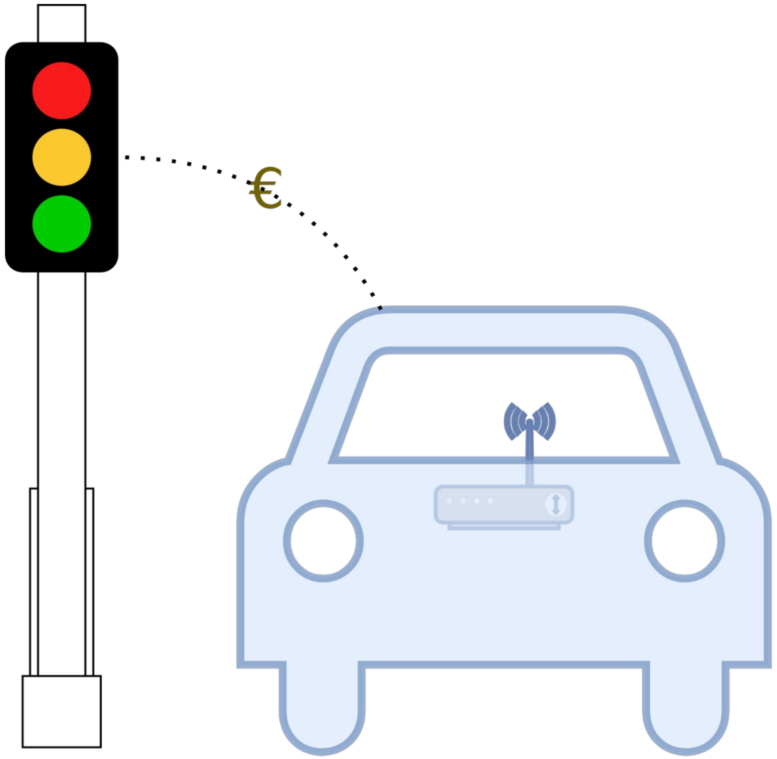
IoT Example – Machine-to-Everything (M2X) Applications

- Machine-to-Machine (M2M)
- For example → Road space negotiations



IoT Example – Machine-to-Everything (M2X) Applications

- Machine-to-Infrastructure (M2I)
- For example → Smart parking, battery charging or traffic information



IoT Example – Machine-to-Everything (M2X) Applications

Machine-to-Human (M2H)
+
Machine-to-Machine (M2M)
+
Machine-to-Infrastructure (M2I)
=
Machine-to-Everything (M2X)

IoT Example – Machine-to-Everything (M2X) Applications

Machine-to-Human (M2H)
+
Machine-to-Machine (M2M)
+
Machine-to-Infrastructure (M2I)
=
Machine-to-Everything (M2X)

M2X Economy → Is the result of business interactions, transactions and collaborations among entities of the M2X ecosystem.

IoT Example – Machine-to-Everything (M2X) Applications

Transforming Urban Mobility

MOBI Grand Challenge Submission Video

https://chorus.mobi

IoT Example – Agriculture

FUTURE FARMS
small and smart

Farming Data

The farm generates vast quantities of rich and varied data. This is stored in the cloud. Data can be used as digital evidence reducing time spent completing grant applications or carrying out farm inspections saving on average £5,500 per farm per year.

Survey Drones

Aerial drones survey the fields, mapping weeds, yield and soil variation. This enables precise application of inputs, mapping spread of pernicious weed blackgrass, increasing yields by 2-5%.

Texting Cows

Sensors attached to livestock allowing monitoring of animal health and wellbeing. They can send texts to alert farmers when a cow goes into labour or develops infection increasing hard survival and increasing milk yields by 10%.

Fleet of Agribots

A herd of specialized agribots tend to crops, weeding, fertilizing and harvesting. Robots capable of microdot application of fertiliser reduce fertiliser cost by 99.9%

Smart Tractors

GPS controlled steering and optimised route planning reduces soil erosion, saving fuel costs by 10%

https://www.nesta.org.uk/blog/precision-agriculture-almost-20-increase-in-income-possible-from-smart-farming/

IoT Example – Healthcare

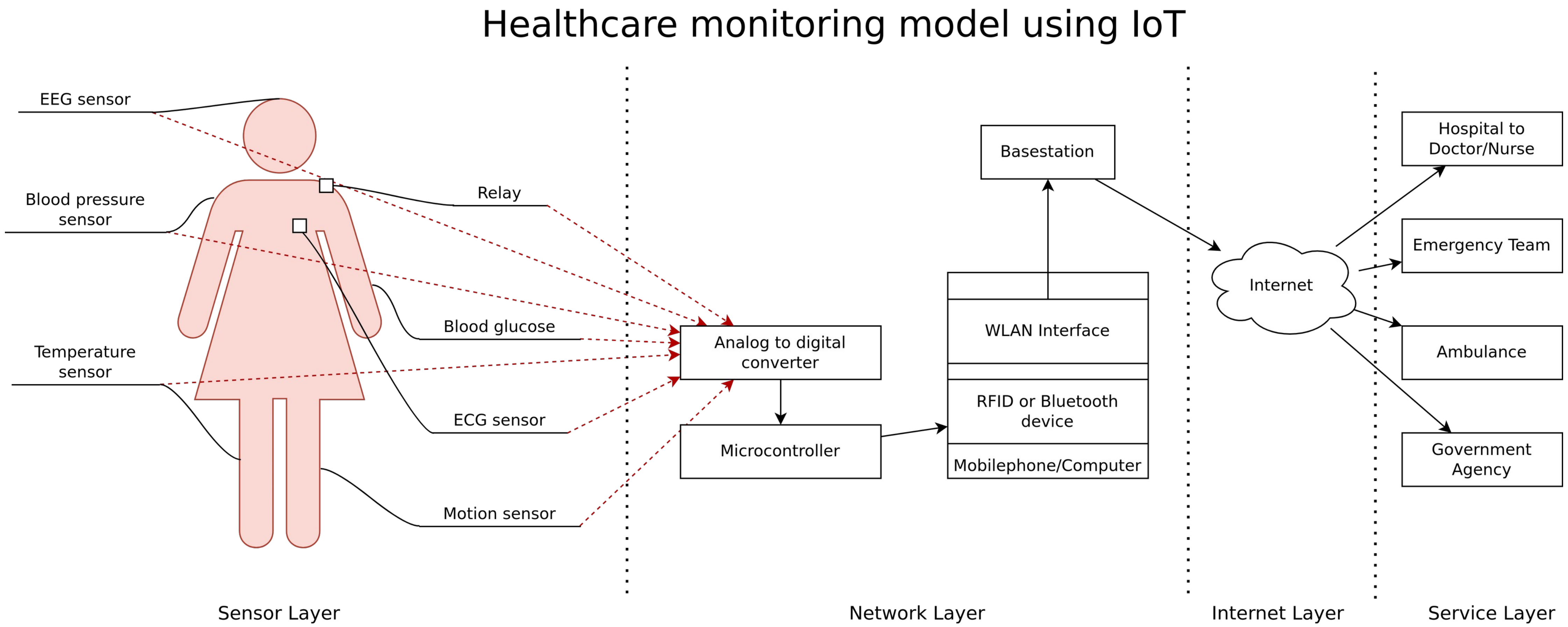


Image adapted from: Khan, Sarfraz Fayaz. "Health care monitoring system in Internet of Things (IoT) by using RFID." 2017 6th International Conference on Industrial Technology and Management (ICITM). IEEE, 2017.

IoT Example – Smart Retail

Smart Inventory

Shelf sensors alert staff (and the warehouse) of impending inventory issues, solving the negative "out of stock" experience.

Mobile self-checkout

Scan items with your personal device and simply exit with them: anti-theft RFID technology disarms immediately as payment is confirmed.

Engaged entry

Your device is recognized and coupons are sent to you based on buying history.

Connected Parking Lot

IR sensors identify prime, empty parking spaces and send alerts to your connected vehicle.

Virtual Fitting Room

Augmented reality enables you to swipe through clothes: virtually fitted to your body in mirror-like screens

Virtual jewelry counter

Browse jewelry that isn't really there (to reduce theft and staff): tap an item to have it brought to you.

IoT Example – Tsunami Early Warning System

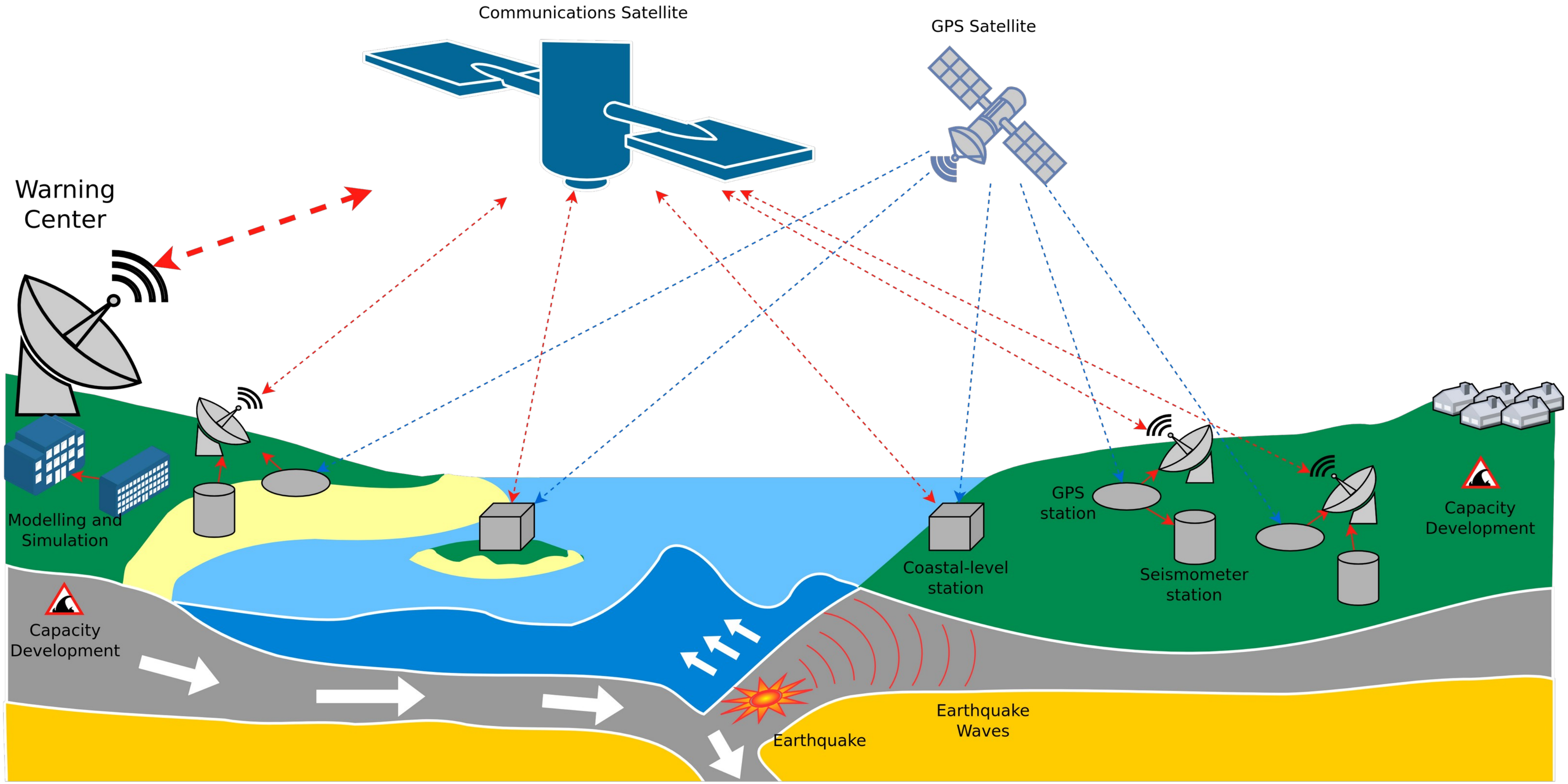
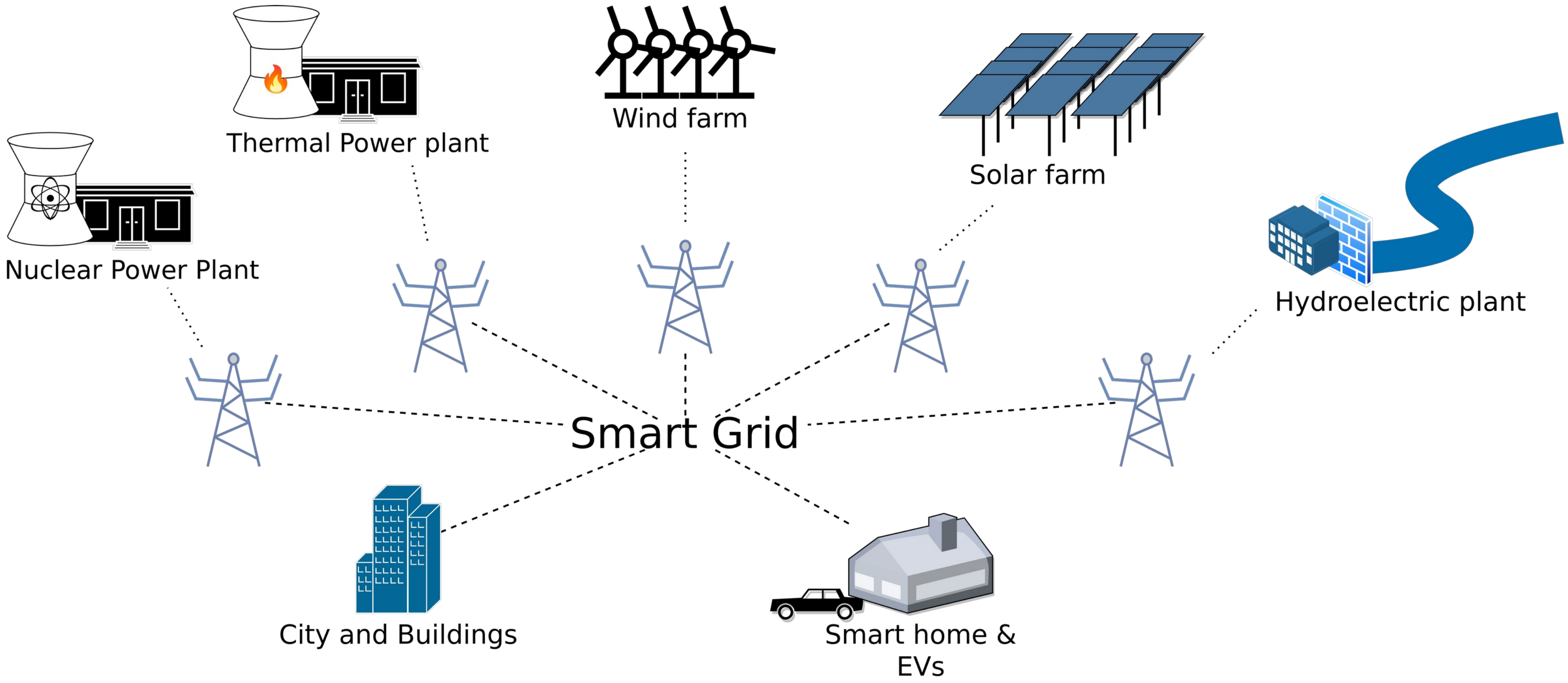


Image recreated from „Schematic layout of the Tsunami Early Warning System (taken from Schuh 2017a)", https://www.researchgate.net/figure/Schematic-layout-of-the-Tsunami-Early-Warning-System-taken-from-Schuh-2017a_fig4_320655877
https://www.pnn.de/wissenschaft/bojen-ausser-kontrolle-tsunami-messbojen-vor-indonesien-sind-defekt/21910136.html

IoT Example – Smart Grids



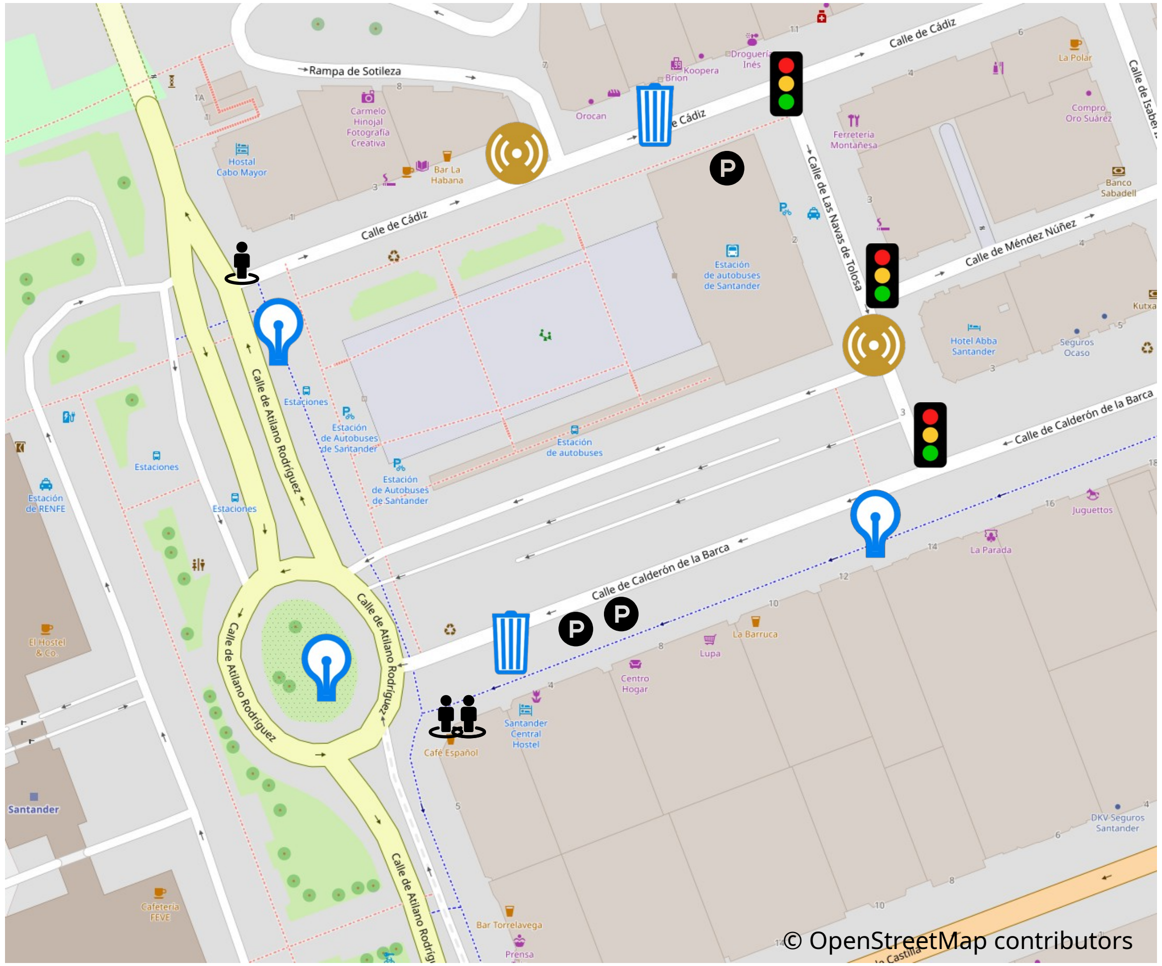
https://blog.westmonroepartners.com

IoT Example – FOAM – Location-as-a-Service

- Secure and verifiable location data through triangulation
- Uses a decentralised network of LoRa sensors (more on this later)
- Can also be used indoors

https://foam.space/

IoT Example – Smart Cities - Songdo/Santander/etc.



Example map of Santander with various sensors located around the city.

- ~12,500 sensors are placed in and around the downtown district of Santander, such as:
  - noise sensors
  - light sensors
  - sensors in garbage bins
- These sensors measure various factors, such as
  - size of crowds on sidewalks
  - available parking spaces
  - amount of trash in containers
- Vehicles such as police cars and taxis also measure pollution levels and traffic conditions.

https://www.governing.com/archive/gov-santander-spain-smart-city.html

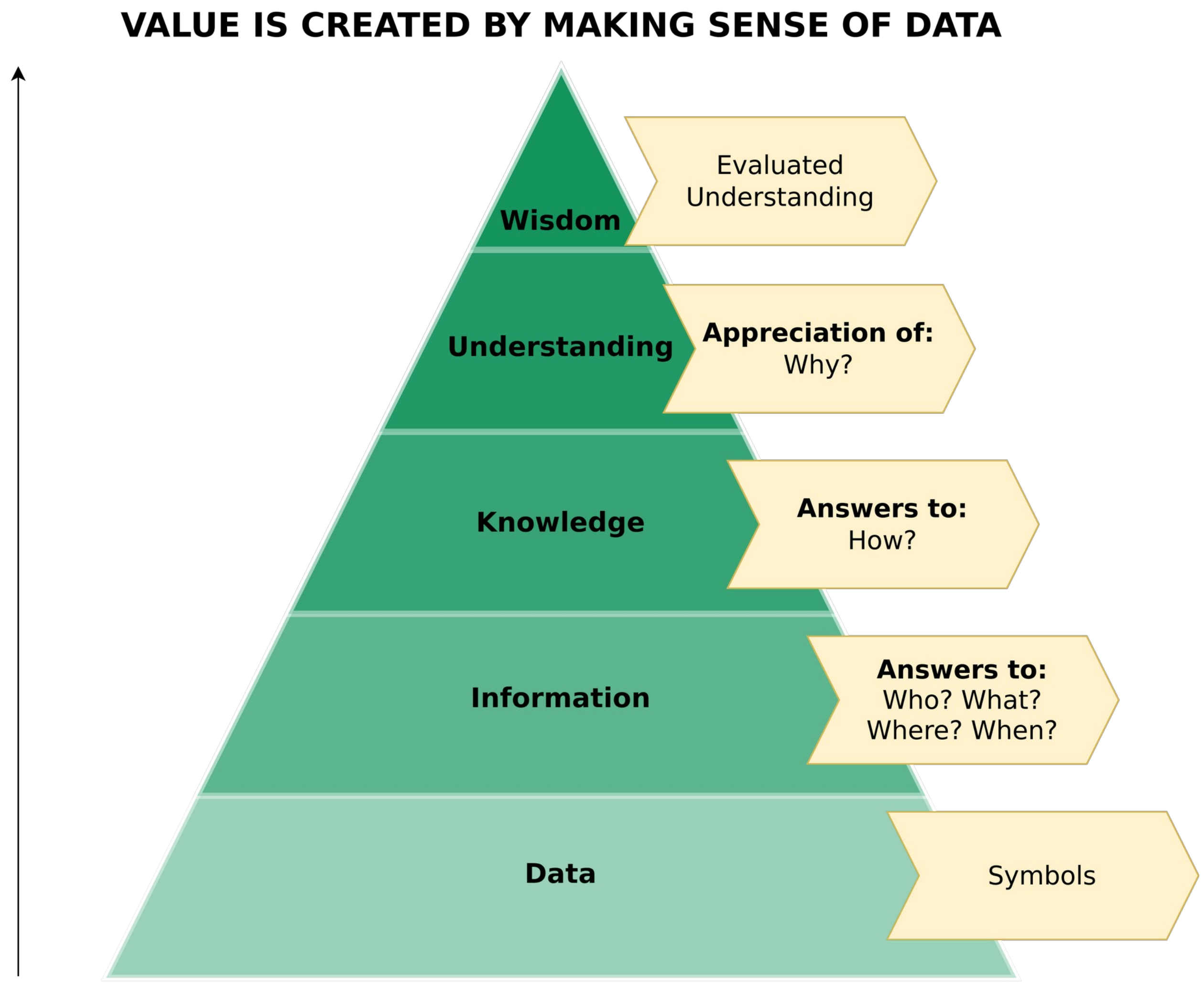
IoT Example – Smart Cities - Songdo/Santander/etc.

Example map of Santander with various sensors located around the city.

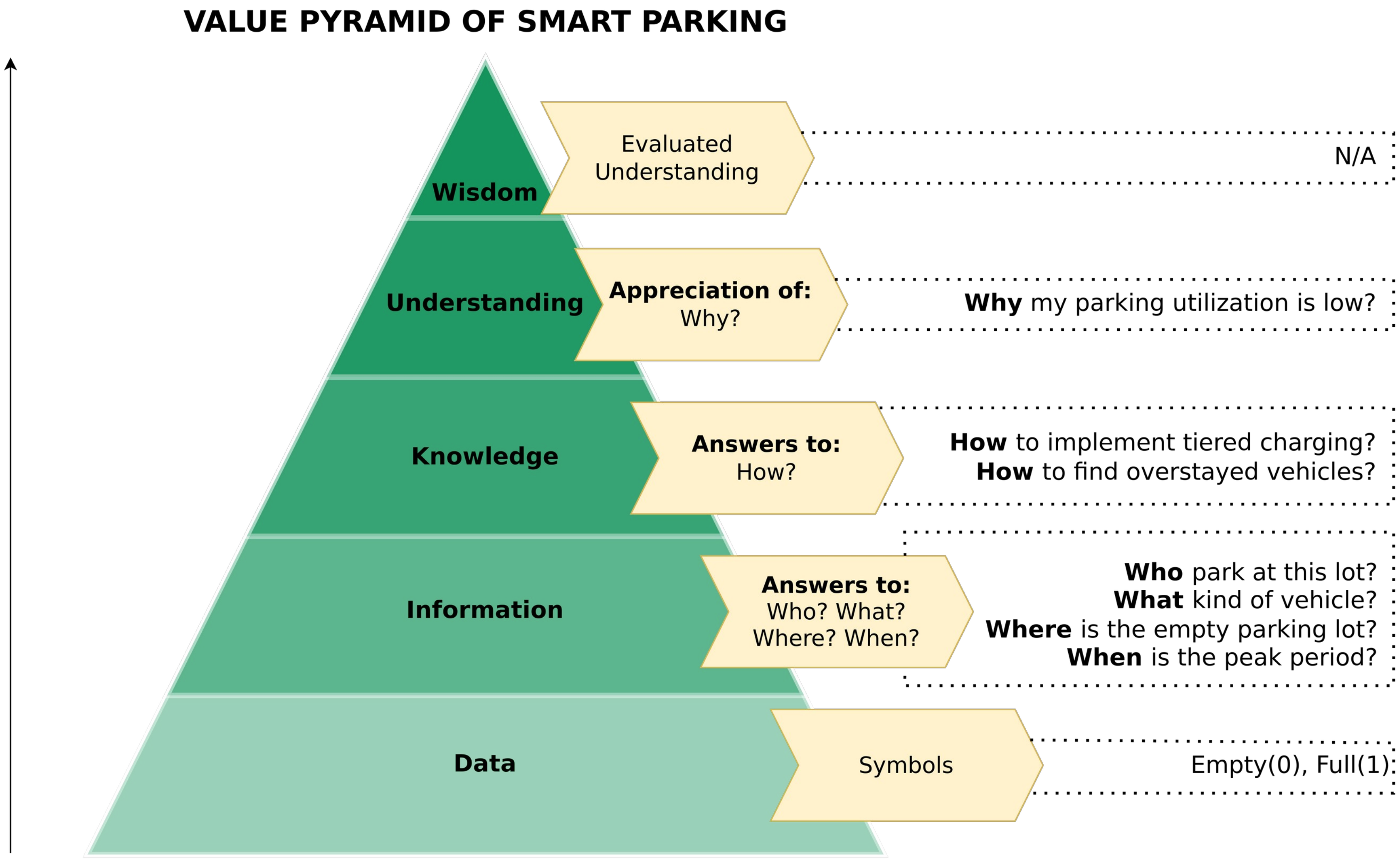
- Data from sensors is analysed by banks of computers that analyse information in real-time, which city officials may use to:
  - adjust energy usage
  - optimise trash pickups for a particular week
- Community-based traffic and navigation apps also help commuters to act as “sensors” themselves.
- The open-sourced data also benefits citizens and tourists, who can, for example: point their phone at a bus stop to know the arrival times, or know if parking spaces are available in a general area.

https://www.governing.com/archive/gov-santander-spain-smart-city.html

The Value of Data



The Value of Data – Smart Parking



A Data-Driven Smart CE Framework

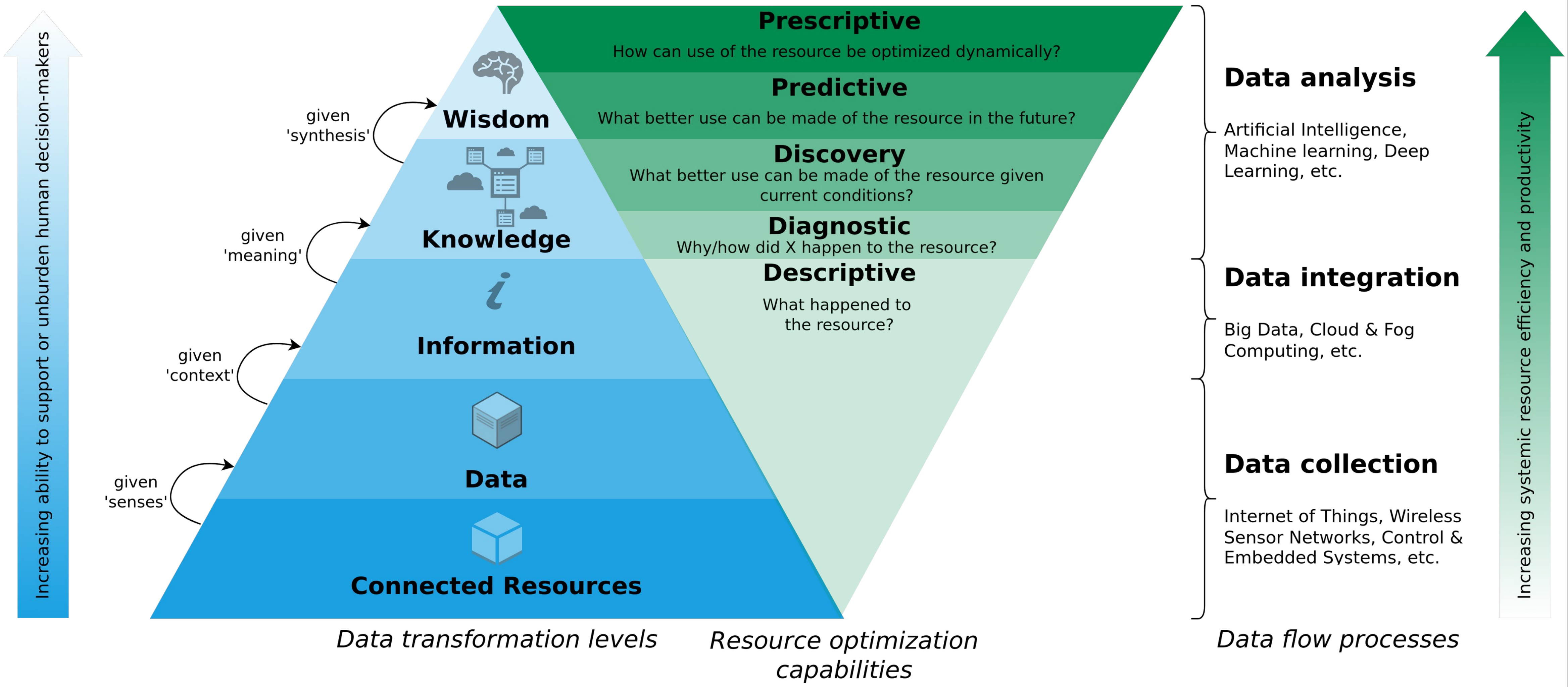


Image adapted from: Kristoffersen et al. (2020) – The smart circular economy: A digital-enabled circular strategies framework for manufacturing companies.

SO WHAT IS THE INTERNET OF THINGS?

Internet of Things (IoT) – Definitions

- Hundreds of definitions, here are a few:

Internet of Things (IoT) – Definitions

- Hundreds of definitions, here are a few:

Cambridge Dictionary: *"Objects with computing devices in them that are able to connect to each other and exchange data using the internet."*

Internet of Things (IoT) – Definitions

The Internet of Things (IoT) is the inter-networking of physical devices, vehicles (also referred to as “connected devices” and “smart devices”) buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data. – **Wikipedia contributors**

D.R. Kiran (2019) – Production Planning and Control: A Comprehensive Approach.

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The Internet of Things (IoT) is a computing concept that describes the idea of everyday physical objects being connected to the internet and being able to identify themselves to other devices. The term is closely identified with Radio Frequency Identification (RFID) as the method of communication, although it also may include other sensor technologies, wireless technologies or QR codes. – **Technopedia**

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D.R. Kiran (2019) – Production Planning and Control: A Comprehensive Approach.

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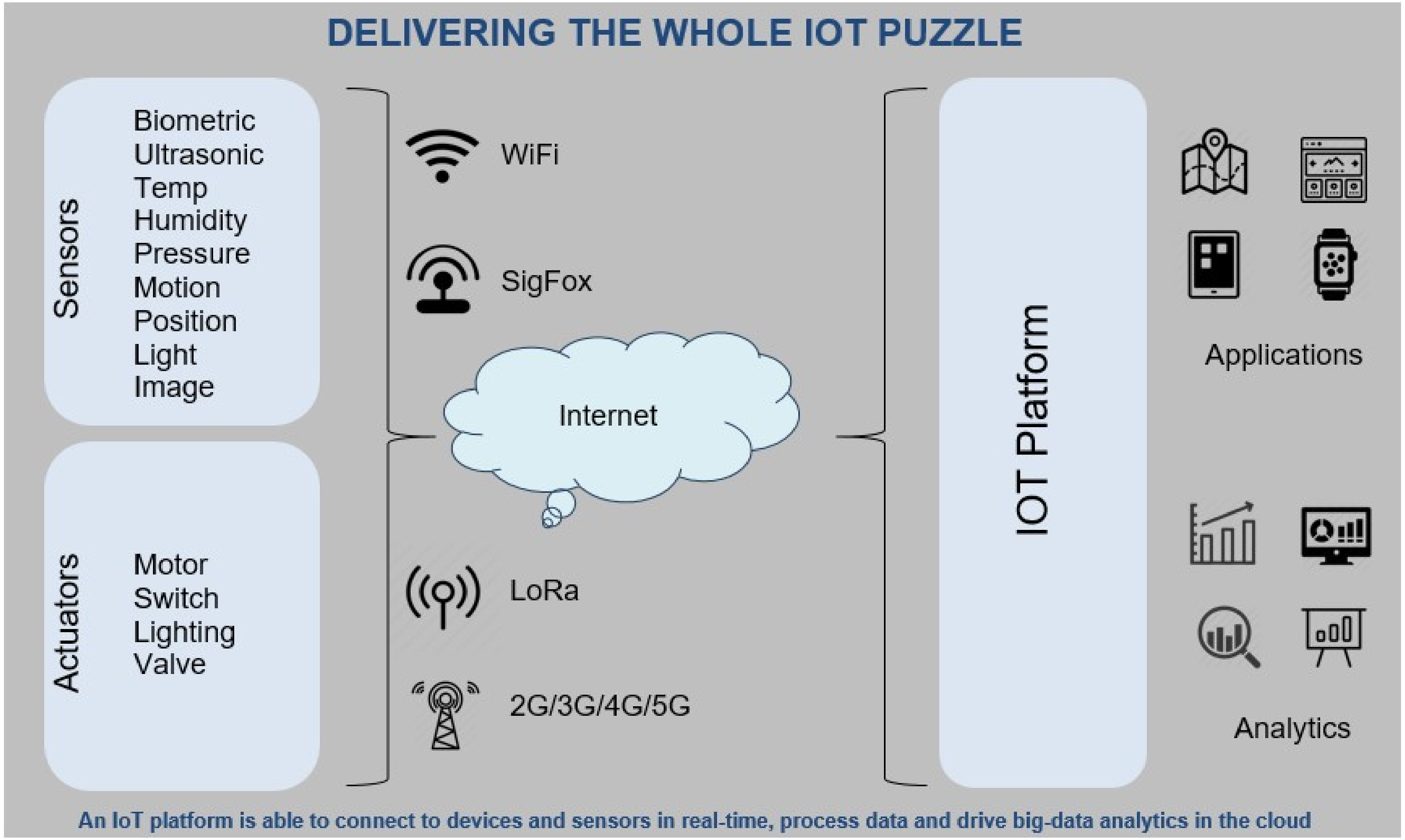
What‘s next?



SENSORS

Conventional Sensors

- Status values:
  - Deliver a defined (voltage) value once the measurement event has occurred.
  - Examples:
    - Push-button
    - Reed switch
    - Hall sensors
    - Light barriers
    - Temperature/(ultra) sound/radar sensors
- Continuous values:
  - Provide a continuous value (e.g. voltage value) depending on the measured value
    → requires A/D converter

Temperature Sensors – Overview

Type	NTC Thermistors	Thermocouple Sensors	Platinum Sensors	Thermopiles	Digital Sensors
Features	Small Size High sensitivity	Extremely small Size, High temperature, Rugged	Superior long-term stability, PTC (Positive Temp. Coefficient) Linear output, Rugged	Non-contact sensor, High temperature, can take measurements from several meters away.	Ease of use, Board mounting, Small size
Range	-150°C to 300°C	-270°C to 1800°C	-200°C to 600°C	-270°C to 2000°C	-150°C to 300°C
Interchangeability rating	5/5	3/5	5/5	1/5	3/5
Linearity rating	1/5	3/5	5/5	1/5	5/5
Accuracy rating	5/5	3/5	5/5	3/5	5/5
Ruggedness	3/5	5/5	5/5	1/5	3/5
Usefulness	Dialysis, HVAC, Calorimetry, Stoves, Industrial reference	Cryogenics, Oven, Soldering Iron, Exhaust Gas detection, Independent vehicle heater	Calorimetry, Oven, Soldering Iron, Cooking Stove, Independent Vehicle Heater	Ear and Forehead thermometers	Dialysis, HVAC, Calorimetry, Industrial reference

https://www.te.com/usa-en/industries/sensor-solutions/insights/temperature-sensor-insights.html

Smart Sensors

- Complex sensors with integrated information processing, e.g.
  - Programmable temperature sensor and thermostat
  - Magnetometer (compass)
  - MEMS (micro-electro-mechanical system) sensors
    - Accelerometer (acceleration sensor)
    - Gyroscope (angular rate sensor)

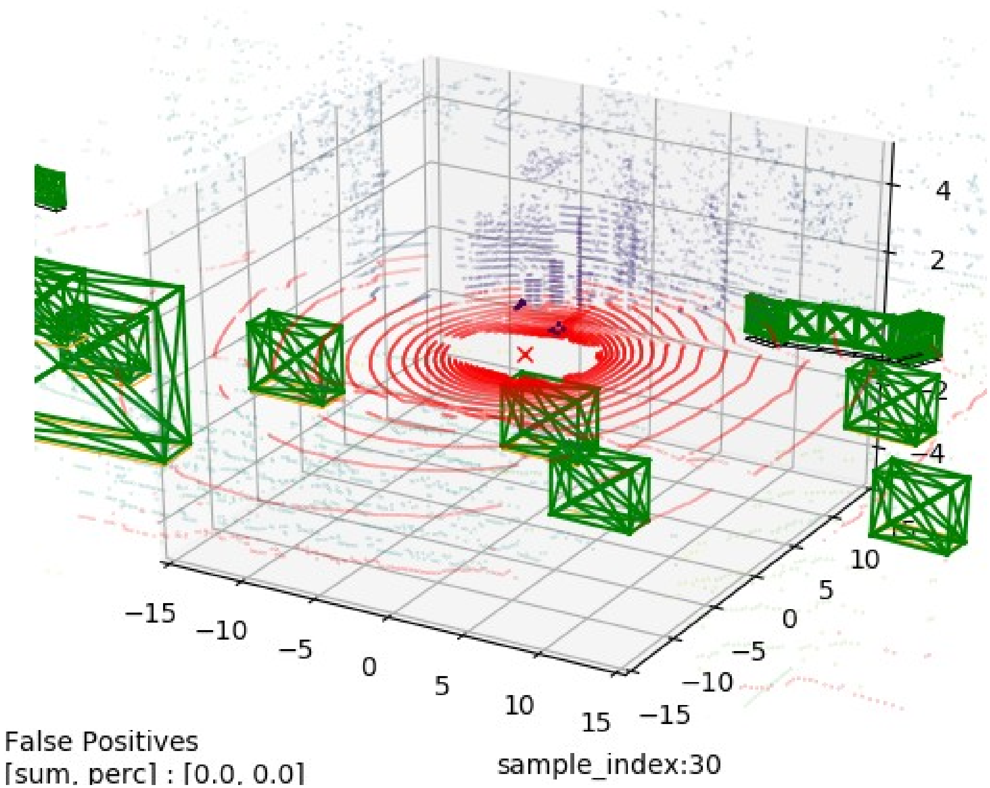
Further Sensors

- Distance sensor
- Ultrasound, radar or infrared with position sensitive detector (PSD → like PIR on next slide)
- (Circular) movements, velocities
- PIR sensors
- Person detection or face recognition
- Cameras with image processing

PIR-Sensor – Motion Detector

Image adapted from: http://hqdesigns.de/en/interior-guide/motion-sensor/

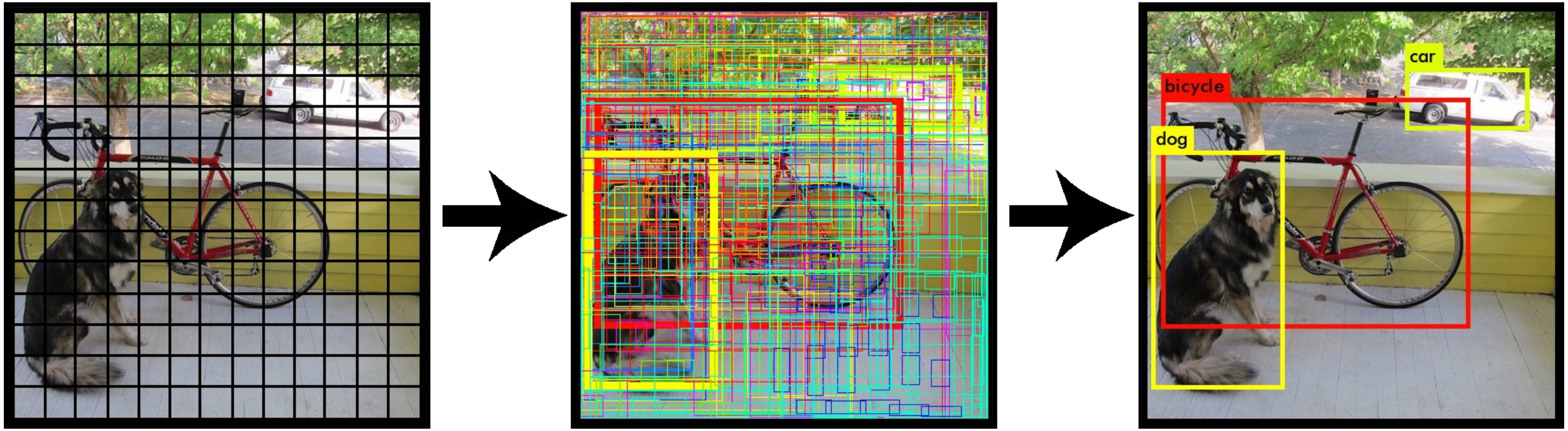
LIDAR



LIDAR → **L**ight **D**etection **A**nd **R**anging

Images of Lidar and Radar Point cloud data redered using the [nuScenes dataset] which is CC BY-NC-SA 4.0 International licensed (https://creativecommons.org/licenses/by-nc-sa/4.0/)
"Cruise Automation, Chevrolet Bolt EV third generation seen in San Francisco with 5 LIDAR sensors" by Dllu is CC BY-SA 4.0 International licensed (https://creativecommons.org/licenses/by-sa/4.0/)

Camera Image Processing and Object Recognition



https://www.iotforall.com/objects-recognition-live-stream-yolo-model/
YOLOv3: An incremental Improvement, Redmon, Joseph and Fahradi, Ali https://arxiv.org/pdf/1804.02767.pdf

Sensors in Smartphones

Sensor	Function Type	Software/ Hardware-based
Accelerometer	Motion sensor	Hardware-based
Gyroscope	Motion sensor	Hardware-based
Gravity	Motion sensor	Software-based
Rotation vector	Motion sensor	Software-based
Magnetic field	Position sensor	Hardware-based
Proximity	Position sensor	Hardware-based
GPS	Position sensor	Hardware-based
Orientation	Position sensor	Software-based
Light	Environmental sensor	Hardware-based
Thermometer	Environmental sensor	Hardware-based
Barometer	Environmental sensor	Hardware-based
Humidity	Environmental sensor	Hardware-based

Actuators

- Light sources as indicators
  - LED
  - Lightbulb
- LCD, LED, intelligent displays
- Acoustic indicators
  - Bell, buzzer, piezo sound transducer
- Electrical switches and drives

Source of Power

- Solar energy
- Piezo generator (conversion of mechanical energy – vibration, motion, sound)
- Radio wave energy generation (RFID)
- Thermal energy
- Radioactive power sources
- Direct connection to any power supply/grid
- etc.

Energy Consumption

Depends on:

- Computing power
- Active sensors
- Frequency of data collection (samples per time unit)
- Communication method
- Communication frequency
- Other energy losses (cold/heat, inefficiency of energy supply, etc.)
- Actuators, LEDs, displays, etc.

Energy Consumption – Example

TI SensorTag C2650 (Bluetooth SensorTag IoT-Kit):

- Standby: 0.24 mA
- Switched on, but all sensors off: 0.33 mA
- All sensors switched on (100ms/sample) and data transmission via BLE: 5.5 mA
- Temperature sensor: 0.84 mA
- Light sensor: 0.56mA
- Accelerometer and gyroscope: 4.68 mA
- Barometer: 0.5 mA

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- Barometer: 0.5 mA

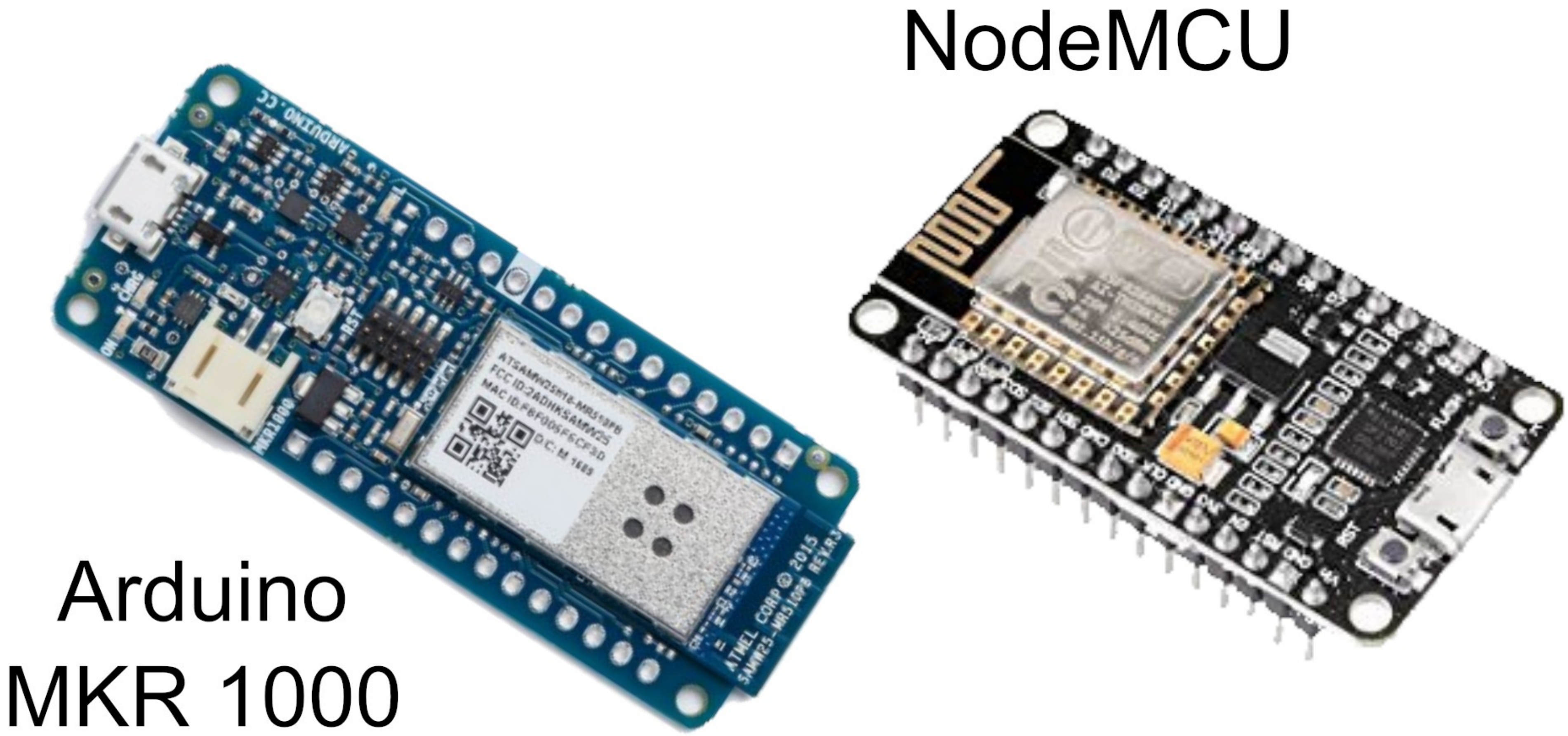
⇒ CR2032 battery (240 mAh) → Maximum runtime of 44h.

Energy Storage

- Does a battery fit into the system?
- What is the capacity of the battery?
- Can a battery provide sufficient voltage and current?
- Can the battery be replaced?
- Battery weight
- Battery charging frequency
- Is the battery exposed to temperature fluctuations?
- Deep discharge?
- Type of battery (Li-ion, lead, NiCd, etc.)

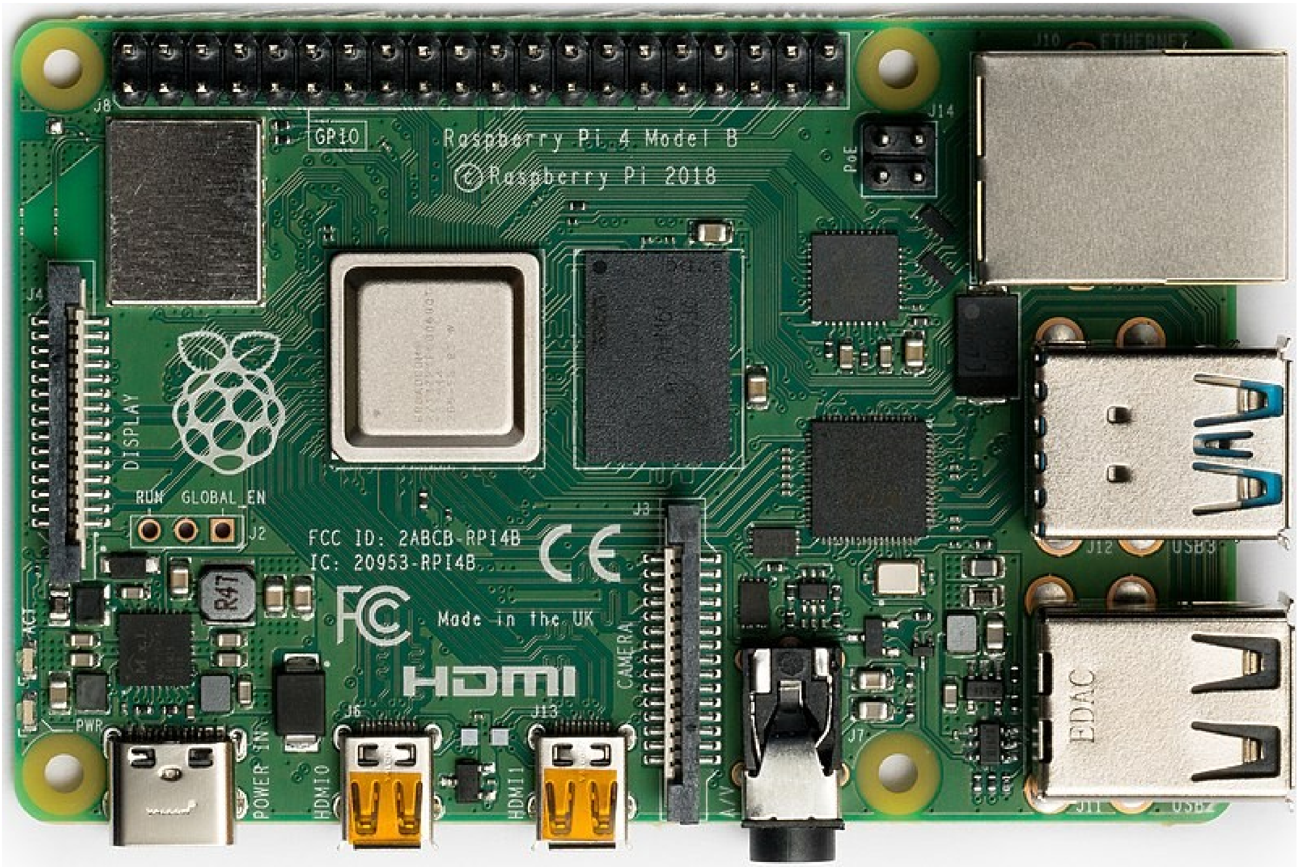
IOT DEVICES

IoT Devices – Development (Low power WiFi)



IoT Devices – Development (Higher powered)

Raspberry Pi



IoT Devices – Development (WSN)

TelosB based

- Wireless Sensor Networks
  - Low powered devices (8bit microcontrollers)
  - Some common architecture
    - TelosB, IRIS, MicaZ, Mica2
  - Standardized connectors for sensor boards (51-pin Hirose)
  - Low power wireless standards (ZigBee, IEEE 802.15.4, LoRa)

IRIS

IoT Devices – Consumer

- Smart home devices
- Locks
- Lights
- Watering plants
- Smart anything-you-can-think-of

IoT Devices – Industrial

- Sensing state of machinery
- Irrigation
- Environmental monitoring
- Smart grid (metering, distribution)

Protection Against External Forces – Ingress Protection (IP) Codes

- IP Codes: Degree of protection provided by mechanical casings and electrical enclosures against intrusion, dust, accidental contact, and water.

1st Digit	Protection From Dust
0	Non-protected
1	Protected against solid objects greater than 50mm
2	Protected against solid objects greater than 12mm
3	Protected against solid objects greater than 2.5mm
4	Protected against solid objects greater than 1.0mm
5	Dust-protected
6	Dust-tight

2nd Digit	Protection From Moisture
0	Non-protected
1	Protected against dripping water
2	Protected against dripping water when tiled up to 15°
3	Protected against spraying water
4	Protected against splashing water
5	Protected against water jets
6	Protected against heavy waves
7	Protected against the effects of immersion
8	Protected against submersion

EXERCISE E04

E04 – IoT Sensing

1) Imagine a smart electric vehicle (EV) charging station that is connected to a solar panel. The goal of the smart charging station is to serve as many EVs with as much solar energy as possible. To do so, the smart charging station is interested in weather information (e.g., temperature, precipitation, cloudiness) from different sources in different locations. Bad (rainy, cloudy) indicates a lower output from the solar panel and thus less energy to charge EVs. However, lots of sun and a blue sky increase the solar panel output which allows the smart charging station to sell more energy.

Questions?

Further Resources

- Dimitrios Serpanos und Marilyn Claire Wolf. Internet-of-Things (IoT) Systems Architectures, Algorithms, Methodologies (2018).
- Perry Lea. Internet of Things for Architects: Architecting IoT solutions by implementing sensors, communication infrastructure, edge computing, analytics, and security (2018).