Emerging Technologies for the Circular Economy

Lecture 5a: Internet of Things Communications

Prof. Dr. Benjamin Leiding (Clausthal)
M.Sc. Arne Bochem (Göttingen)
M.Sc. Anant Sujatanagarjuna (Clausthal)

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

Updated Bonus Task Registration

- 2 projects registered
  - The project “Value-Based Recovery Design for End of Life Products” is still looking for team members → please get in touch with us and we will establish contact with the team

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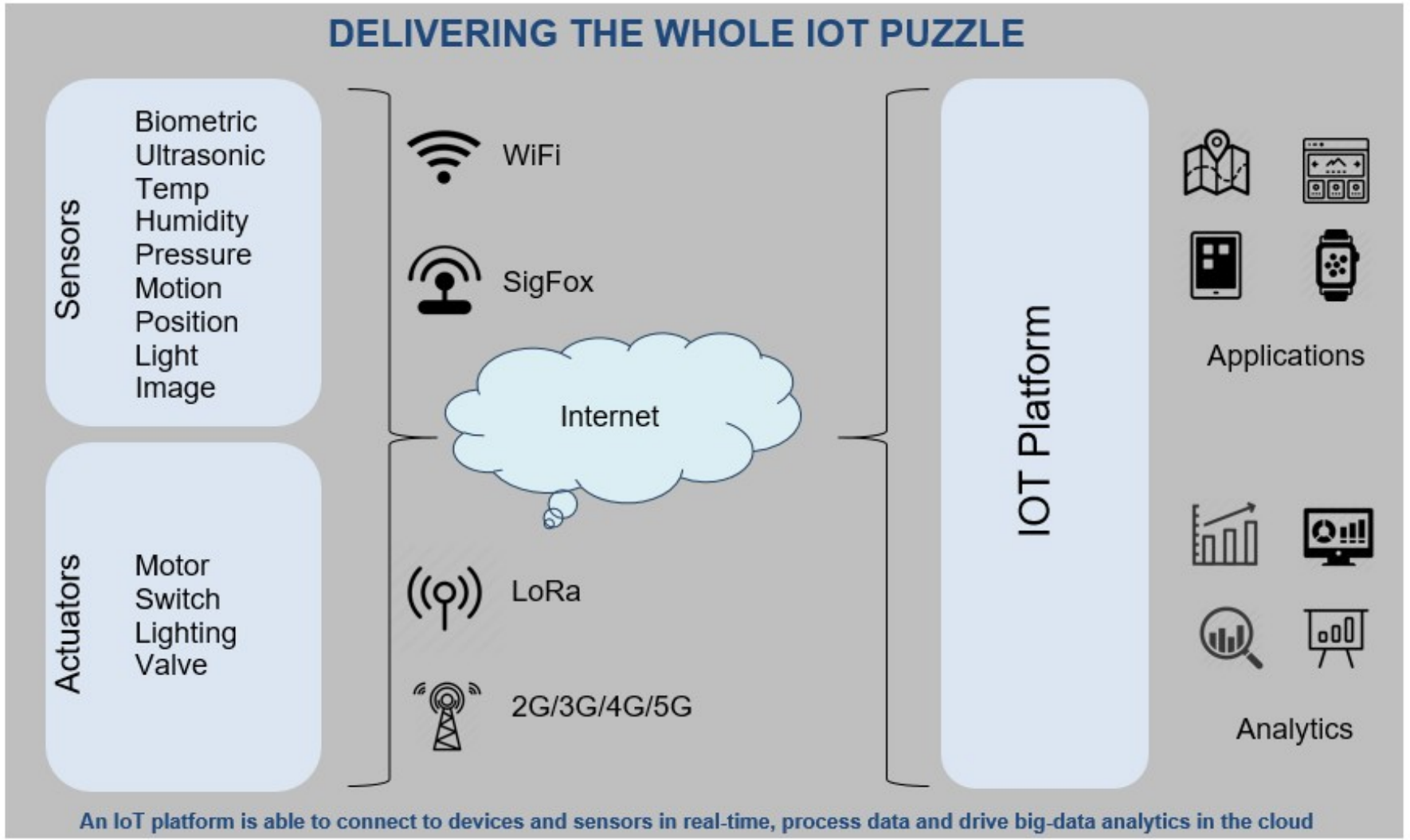
- What stopped everyone else from proposing projects?
  - a) no team
  - b) no project
  - c) no time
  - d) not interested

Updated Lecture Plan

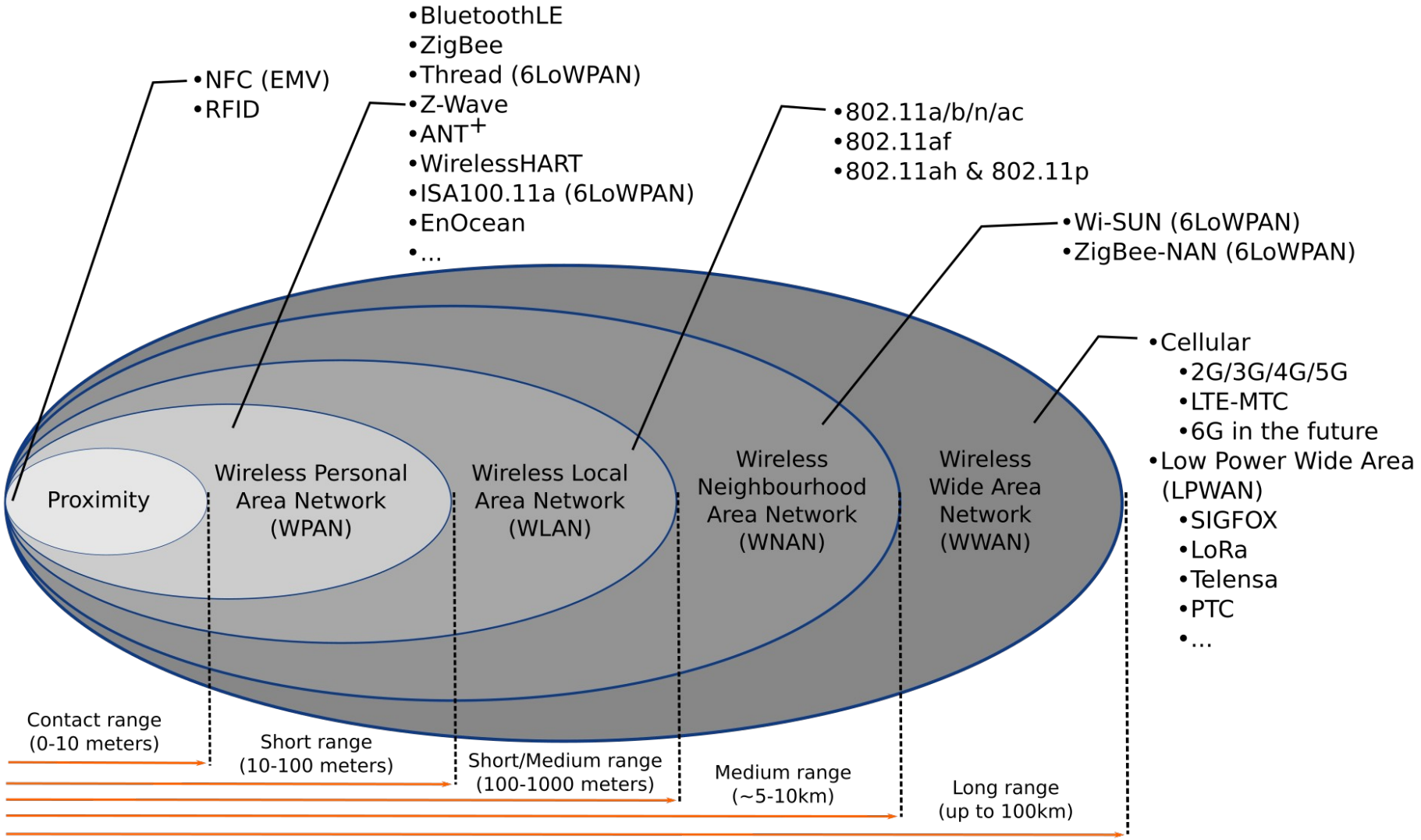
- 20.04.2022 → Organization + Introduction
- 27.04.2022 → Emerging Technologies for the Circular Economy I
- 04.05.2022 → Emerging Technologies for the Circular Economy II
- 11.05.2022 → Introduction to the Internet of Things
- 18.05.2022 → Internet of Things – Communication + Privacy and Security
- 25.05.2022 → Internet of Things – Cloud and BigData
- 01.06.2022 → Introduction to Blockchain Technology
- 15.06.2022 → Blockchain Technology – Consensus
- 22.06.2022 → Blockchain Technology – Ethereum and Smart Contracts Part 1
- 29.06.2022 → Blockchain Technology – Ethereum and Smart Contracts Part 2
- 06.07.2022 → Invited speaker → Dr. Uli Gallersdörfer (TU Munich)
- 13.07.2022 → Invited speaker → Prof. Dr. Steffen Herbold (TU Clausthal)
- 20.07.2022 → Blockchain Technology and Sustainability
- 27.07.2022 → The Machine-to-Everything Economy – A step towards the CE 2.0?

COMMUNICATIONS

Overview


DELIVERING THE WHOLE IOT PUZZLE
Sensors
Biometric
Ultrasonic
Temp
Humidity
Pressure
Motion
Position
Light
Image
Actuators
Motor
Switch
Lighting
Valve
WiFi
SigFox
Internet
LoRa
2G/3G/4G/5G
IOT Platform
Applications
Analytics
An IoT platform is able to connect to devices and sensors in real-time, process data and drive big-data analytics in the cloud

Different ranges, different standards



Source: M.S. Mahmoud, A. Mohamad, "A Study of Efficient Power Consumption Wireless Communication Techniques/ Modules for Internet of Things (IoT) Applications", January 2016, Advances in Internet of Things 06(02):19-29, DOI:10.4236/ait.2016.62002

WPAN

Wireless Personal Area Network

IP based

- 6LoWPAN (IPv6 over Low-Power Wireless Personal Area Networks)
- IEEE 802.11p (V2V)
- RuBee (IEEE standard 1902.1)

- Not IP based

- Bluetooth
- ZigBee (IEEE 802.15.4-based)
- IrDA (Infrared Data Association)
- Z-Wave

And more.

Bluetooth

Pros
- Low power requirements
- Resilient against interference

Cons
- Low bandwidth
- Limited range
- Limited number of participants in network

Applications
- Beacons
- Fitness trackers, smart watches
- Medical applications
- Smart homes
- Smart cars
- Earbuds, headsets etc.

Classes for different applications with different ranges/power usages.

Zigbee

Pros
- Low power requirements
- Scales to large network sizes (~6500 nodes)

Cons
- Low range
- Low bandwidth
- Security issues (fixed, known fallback keys in at least one profile)

Applications
- Wireless sensor networks (WSN)
- Industrial automation
- Smart homes

6LoWPAN

Pros
- IPv6 based
- Built-in security
- Scalability
- Interoperability

Cons
- Higher minimum requirements due to IPv6 minimum complexity
- Not as popular as ZigBee

Applications
- Wireless sensor networks (WSN)
- Internet of Things
- Industrial Internet of Things

IEEE 802.11p

Vehicular network optimized

- Vehicle to vehicle (V2V)
- Vehicle to infrastructure (V2I) such as road side units (RSU)
- Built in time synchronization

Applications

- Vehicular networks

WAN

Wide Area Network

- Service/subscription model based
- Service provider runs infrastructure such as base stations and radio towers

Examples:

- Cellular networks (UMTS/LTE/5G)
- LoRa (**Lo**ng **Ra**nge, physical layer), LoRaWAN (MAC layer)
- Sigfox

Cellular network architecture

- Grid of cell towers
- Overlapping cells
- Requires handover for mobile stations between cells

Network planning

- Space division multiple access
- Minimize interference
- Avoid allocating overlapping spectrum on nearby cells

5G

- New radio communication techniques and spectrum
- Support for device to device communications (D2D)
- Improved performance
  - Theoretical latency in single digit ms
  - Bandwidth in gbps range
  - Ability to provide connectivity in fast moving vehicles
  - Enables more dense connectivity and scalability (more devices)

LoRa/LoRaWAN

- Uses unlicensed spectrum
- Low number of base stations (Gateways) covers wide area
  - 7 are enough to cover Belgium
- Only produced by a single company (Simtech)
- High latency, no realtime applications
- Subscription based
- Misses some common features from LTE networks
  - Only physical and MAC layers are covered => Higher OSI layers have to be implemented on top

Sigfox

- Uses unlicensed spectrum
- Uplink
  - 100bps
  - 12B payloads
  - Maximum of 6 messages per device and hour (140 per day)
- Downlink
  - 600bps
  - 8B payloads
  - Maximum of 4 messages per day
- Open hardware
- Network subscription based

ROUTER AND GATEWAYS

Router and Gateways

Router

- Bridges two networks
- Can translate between protocols
- Routes data
- Port forwarding and network address translation (mainly end user or carrier grade)
- VNETs

Gateways (not in the routing sense)

- Bridges wireless network and internet
- Can translate between protocols
- Edge/Fog computing capabilities (see next lecture)
- Routers can be gateways

Gateway example

- Wireless sensor nodes running Contiki RPL with Ipv6
- Node attached to gateway over USB acts as gateway
- IPv6 connectivity between networks provided through SLIP (Serial Line Internet Protocol)

Questions?