

Emerging Technologies for the Circular Economy

Lecture 5a: Internet of Things Communications

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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

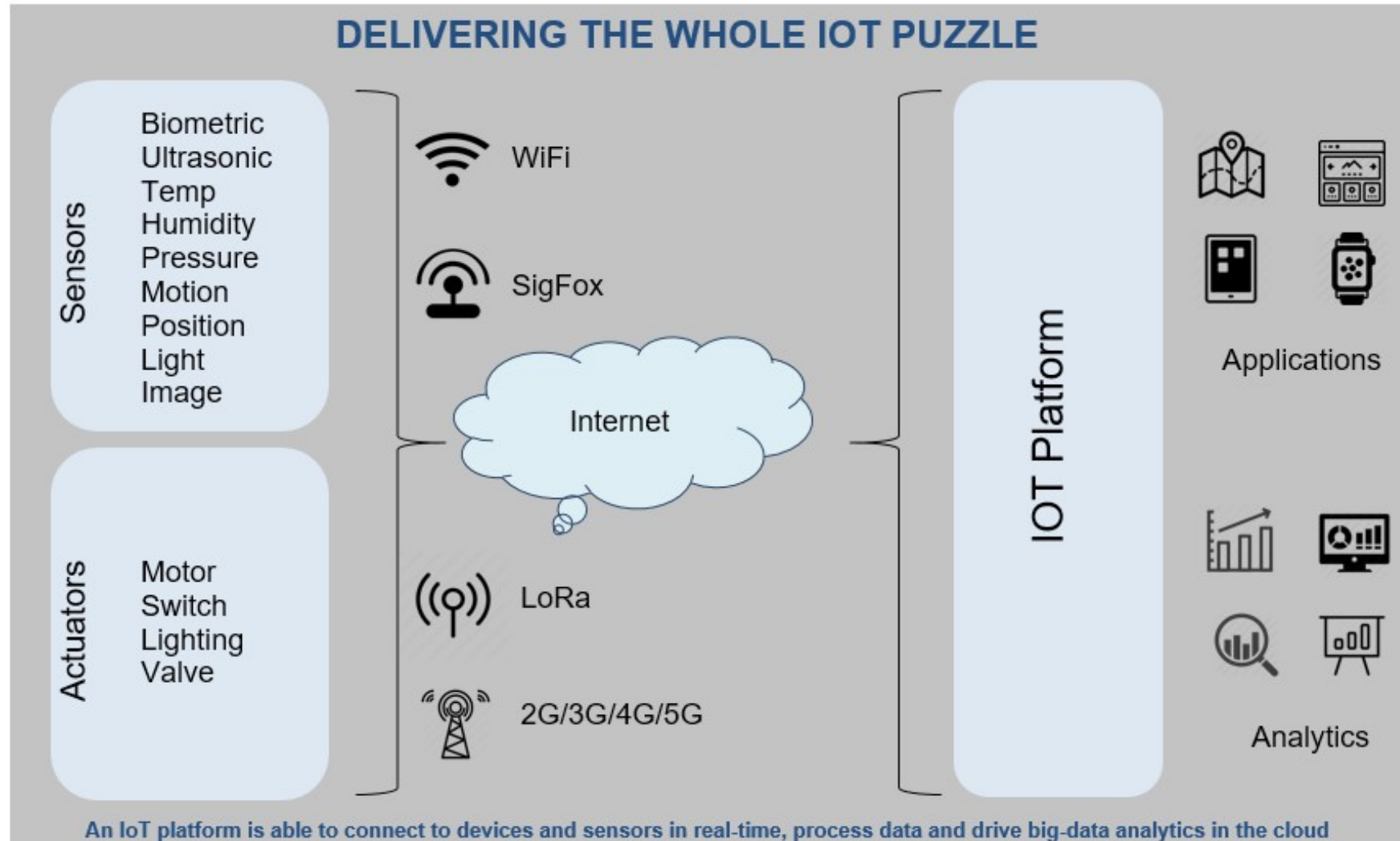
Updated Lecture Plan

- 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 Gellersdörfer (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?

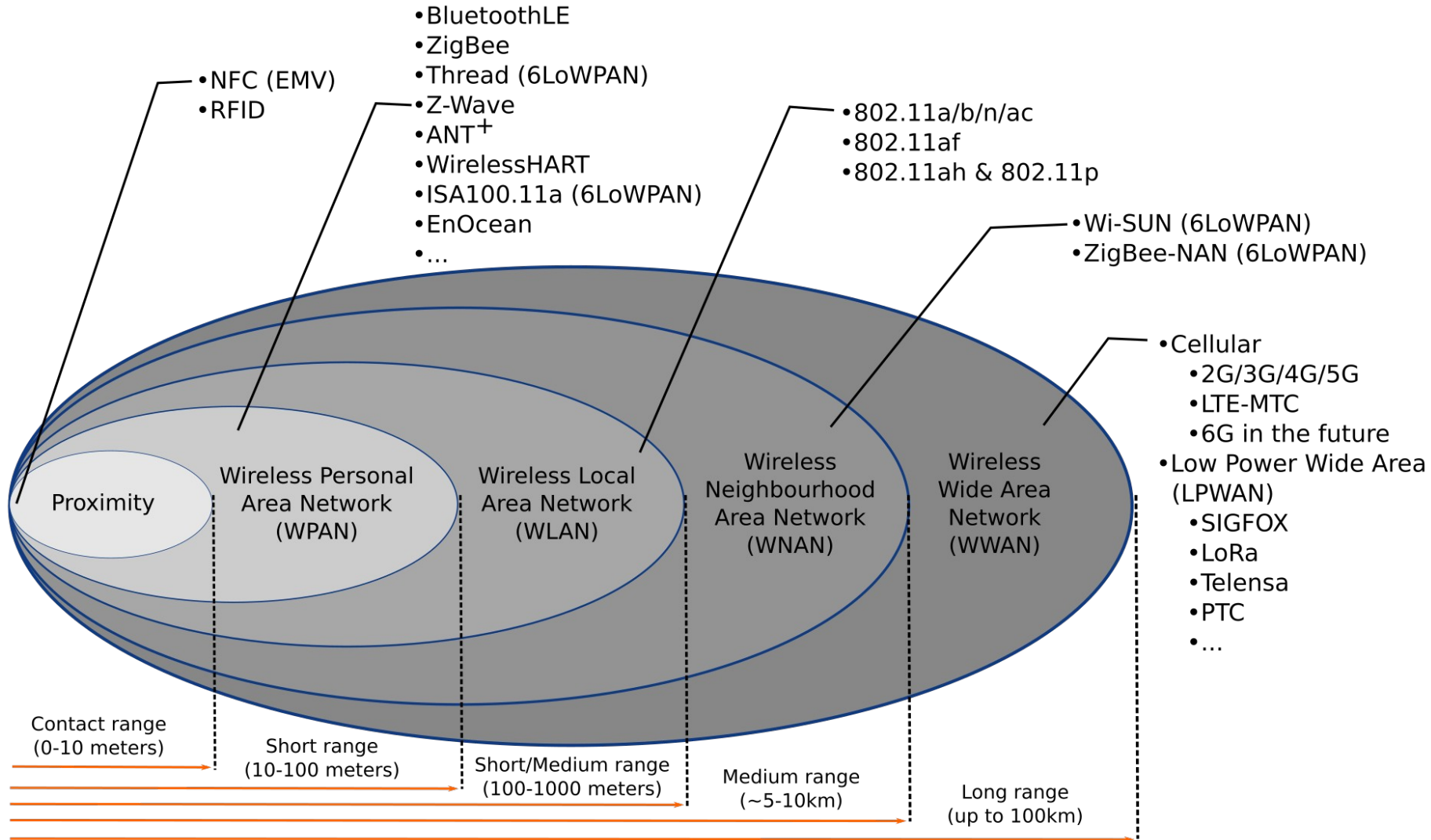


COMMUNICATIONS

Overview



Different ranges, different standards



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 (**L**ong **R**ange, 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 (Semtech)
- 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?