Mobile and Sensor Systems

Lecture 8: Internet of Things and Sensor Integration

Dr Andrea Gaglione

About Me

LEONARDO

Imperial College London

CATAPULT Digital

Università degli Studi di Napoli Federico II

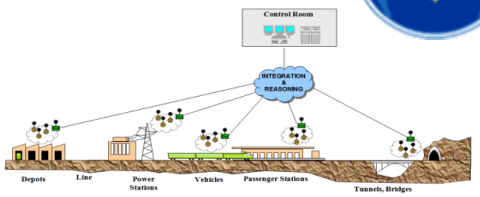
Università degli Studi di Trento

University of Cambridge

USC University of Southern California

2009 2010 2011 2014 2016 2017

PROTECTRAIL



>makeSense
Easy Programming of Integrated Wireless Sensor Networks

CSIC Cambridge Centre for Smart Infrastructure & Construction

Things Connected

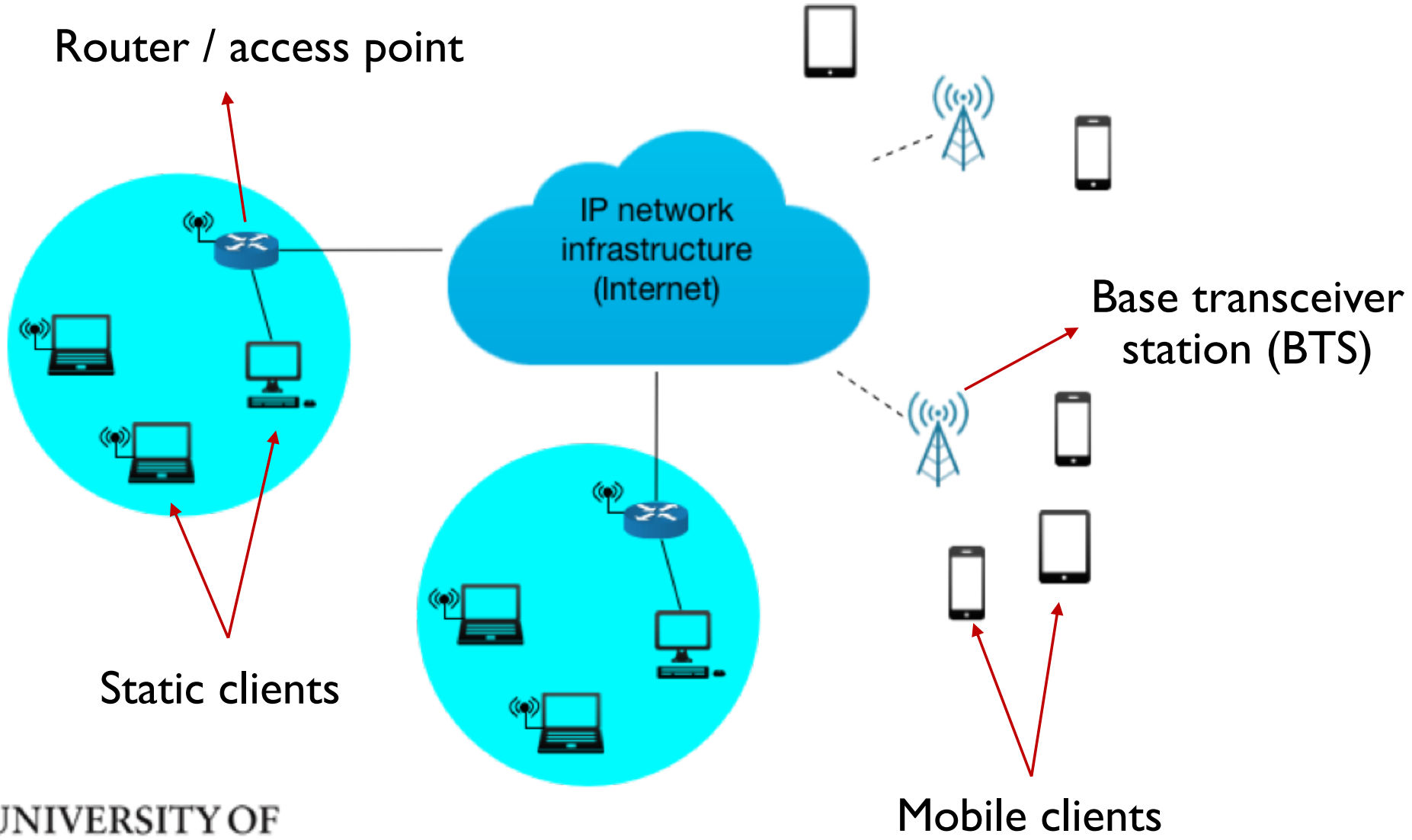
SYNCHRONICITY

UNIVERSITY OF CAMBRIDGE

In this lecture

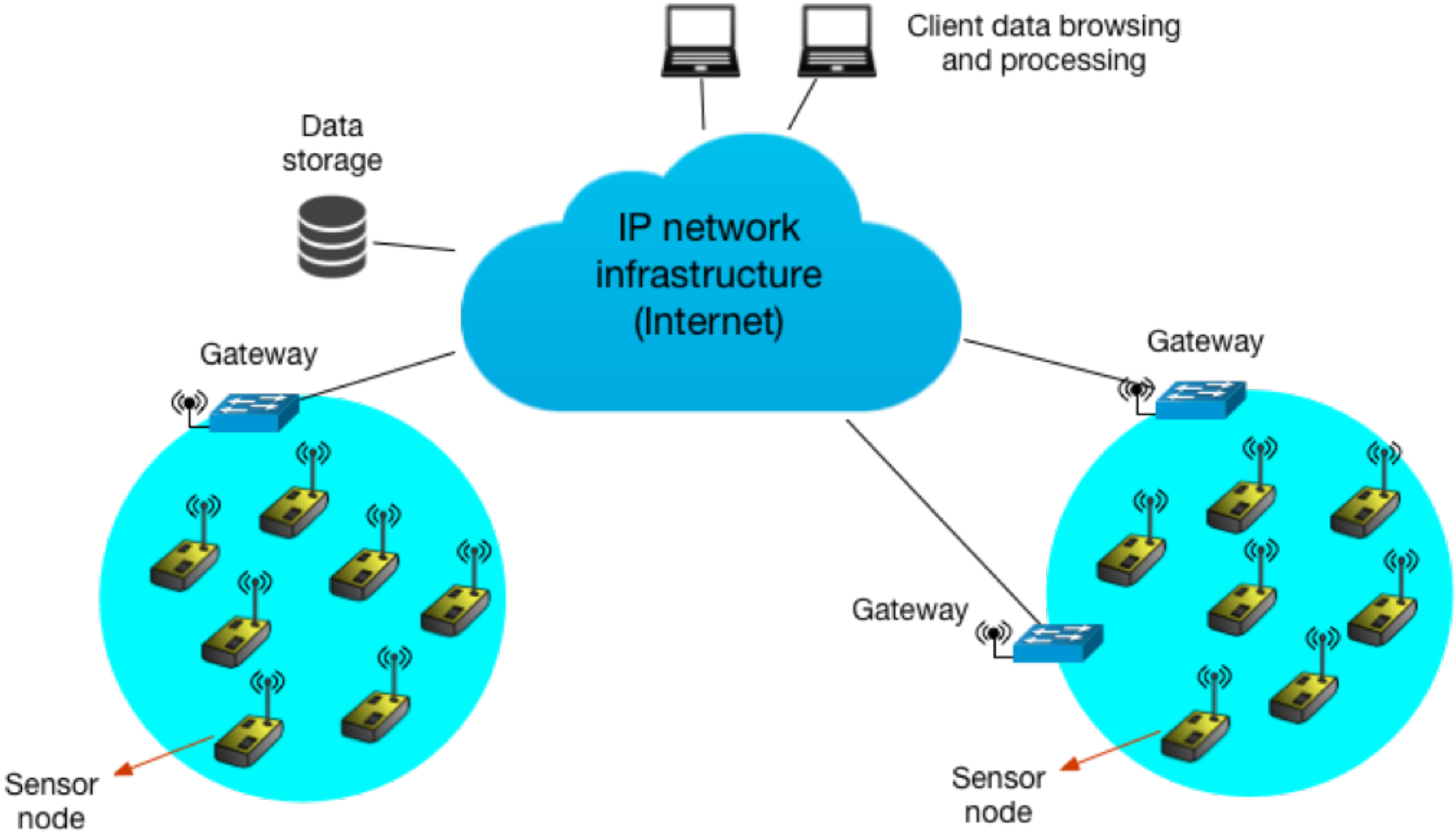
- We will introduce the Internet of Things (IoT) paradigm
- We will talk about the major LPWAN technologies
- We will deep dive into LoRaWAN

The "classical" Internet



UNIVERSITY OF CAMBRIDGE

The rise of sensor networks



UNIVERSITY OF CAMBRIDGE

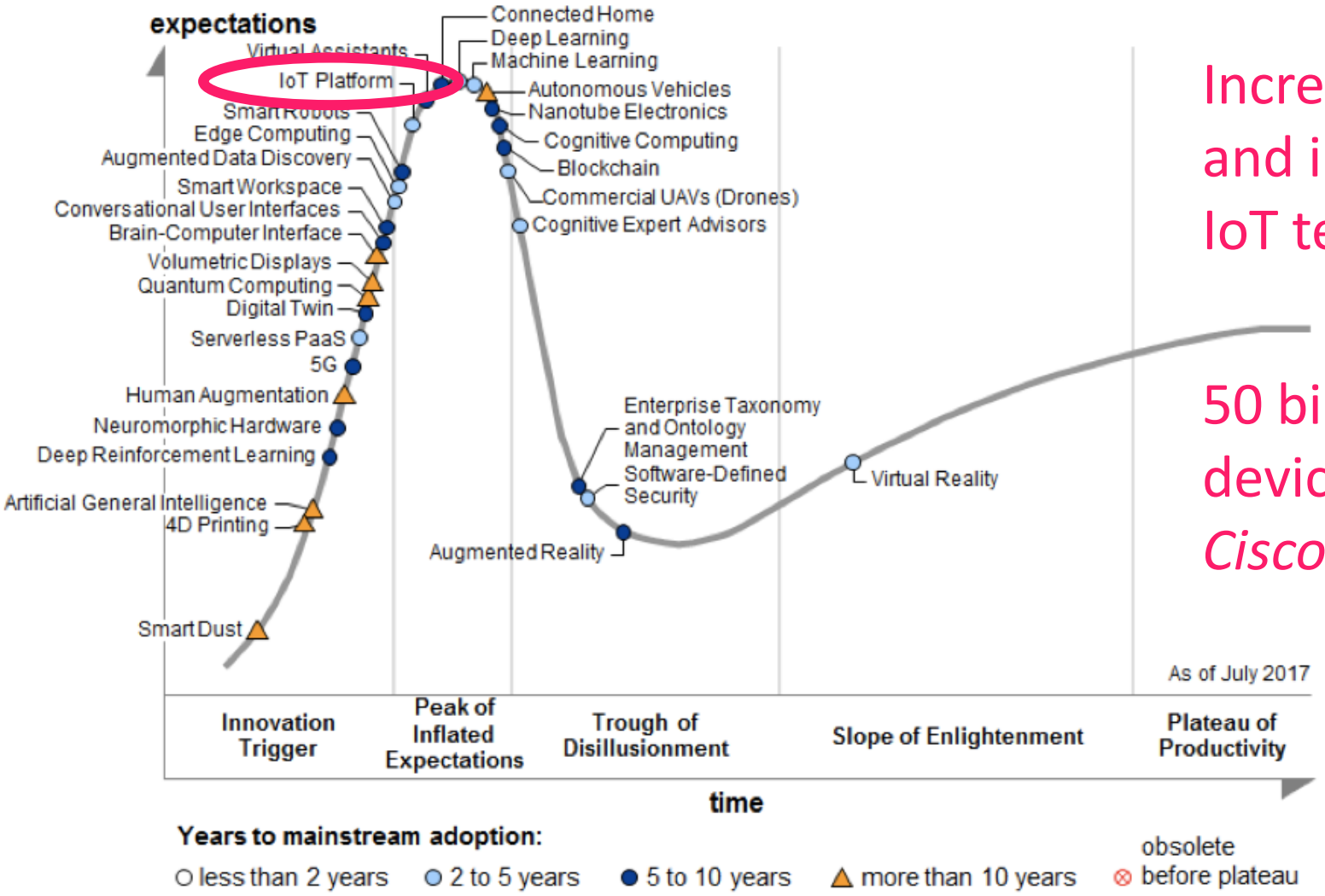
What is the IoT?

"A global infrastructure for the information society, enabling advanced services by interconnecting **things** based on existing and evolving interoperable information and communication technologies" [1].

"A system of **physical objects** that can be discovered, monitored, controlled, or interacted with by electronic devices that communicate over various networking interfaces and eventually can be connected to the wider internet" [2].

[1] ITU-T Recommendation Y.2060. Overview of the Internet of Things. 2012.
[2] D. Guinard, V. Trifa. Building the Web of Things. 2016.

Hype cycle



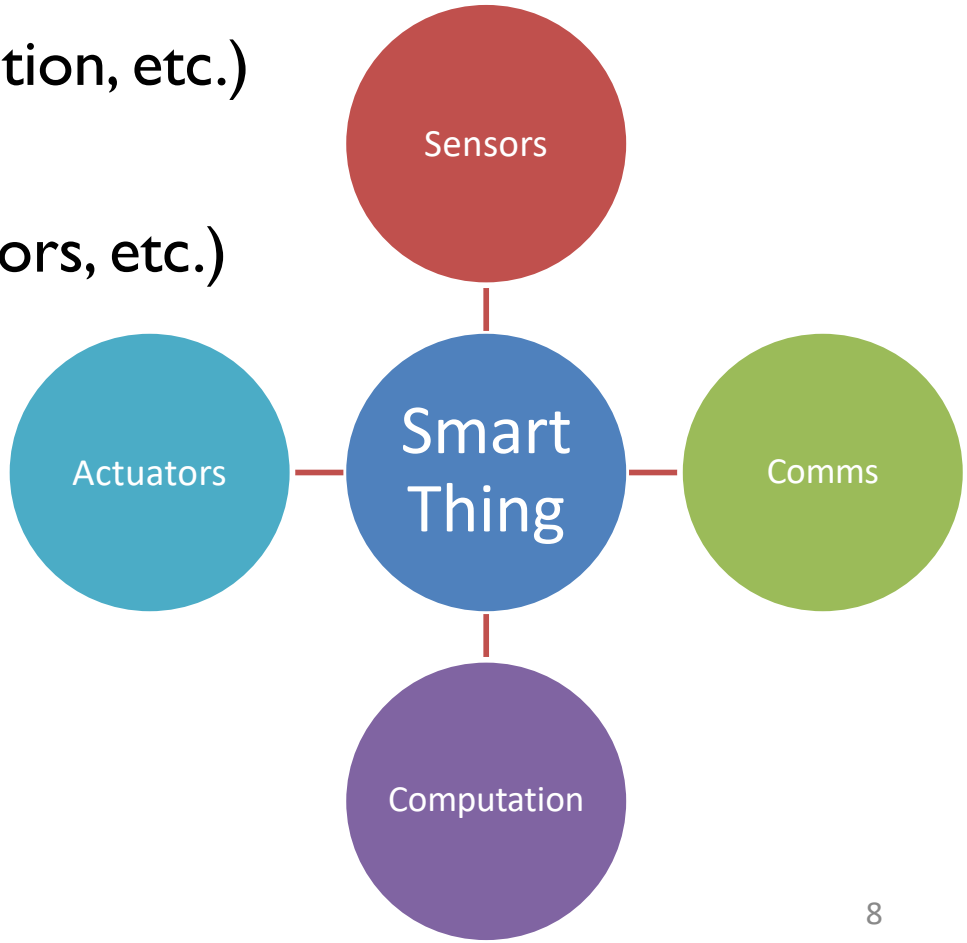
Increased interest and investments in IoT technologies

50 billion IoT devices by 2020 - *Cisco*

(Smart) Things

Physical objects digitally augmented with one or more of the following:

- Sensors (temperature, light, motion, etc.)
- Actuators (displays, sound, motors, etc.)
- Computation capabilities
- Communication interfaces



IoT landscape

Devices (tags, sensor nodes, mobile and wearable devices)

Machines (home appliances, security systems, vehicles, etc.)

Environments (smart homes, buildings, cities)

UNIVERSITY OF CAMBRIDGE

Typical IoT system architecture

IoT Cloud

Service hosting
Visualisations
Advanced analytics
Data storage

IoT Gateway

Edge analytics
Local storage

IoT Device

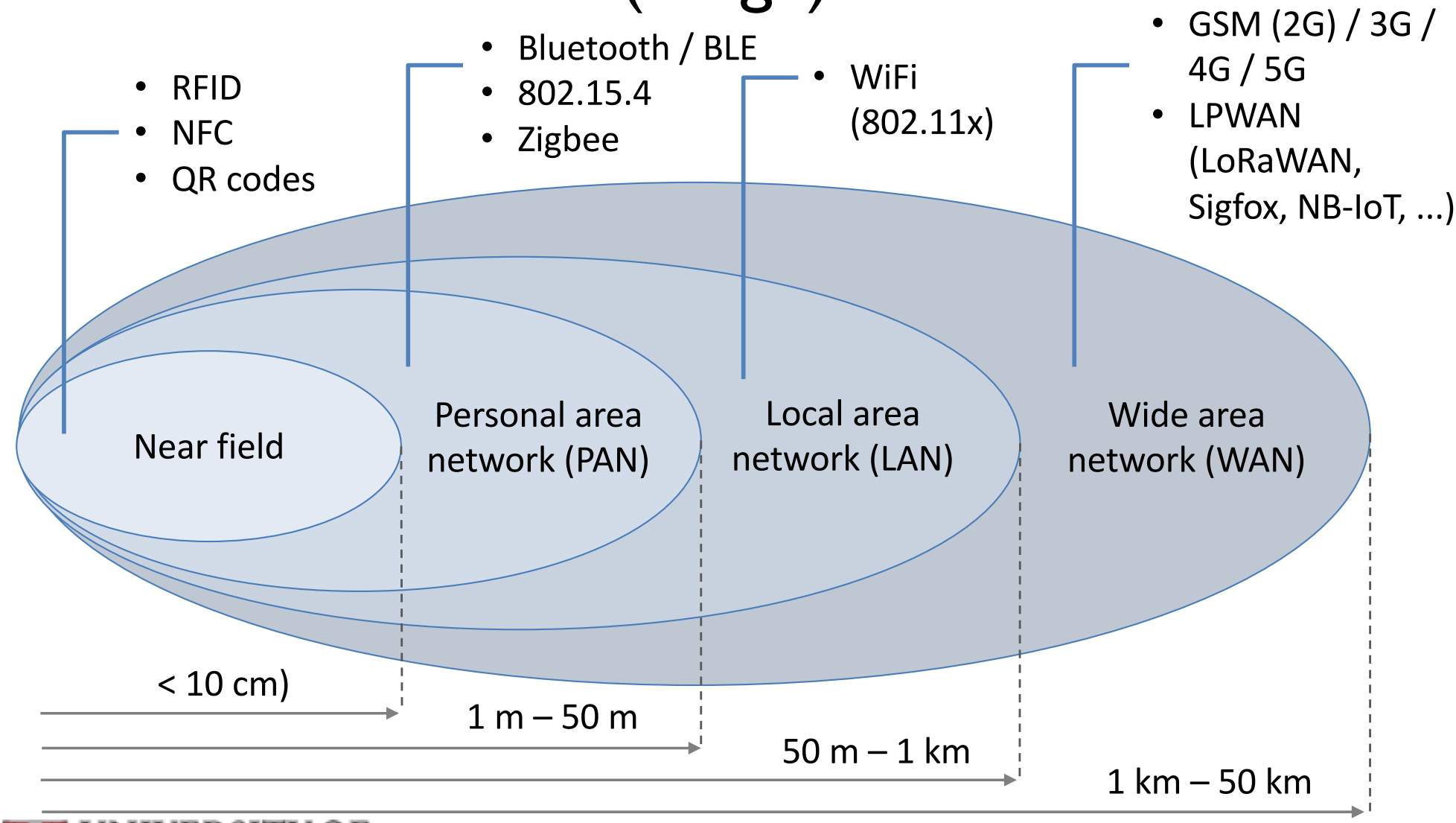
Basic processing
Short/wide comms
Sensing/actuation

UNIVERSITY OF CAMBRIDGE

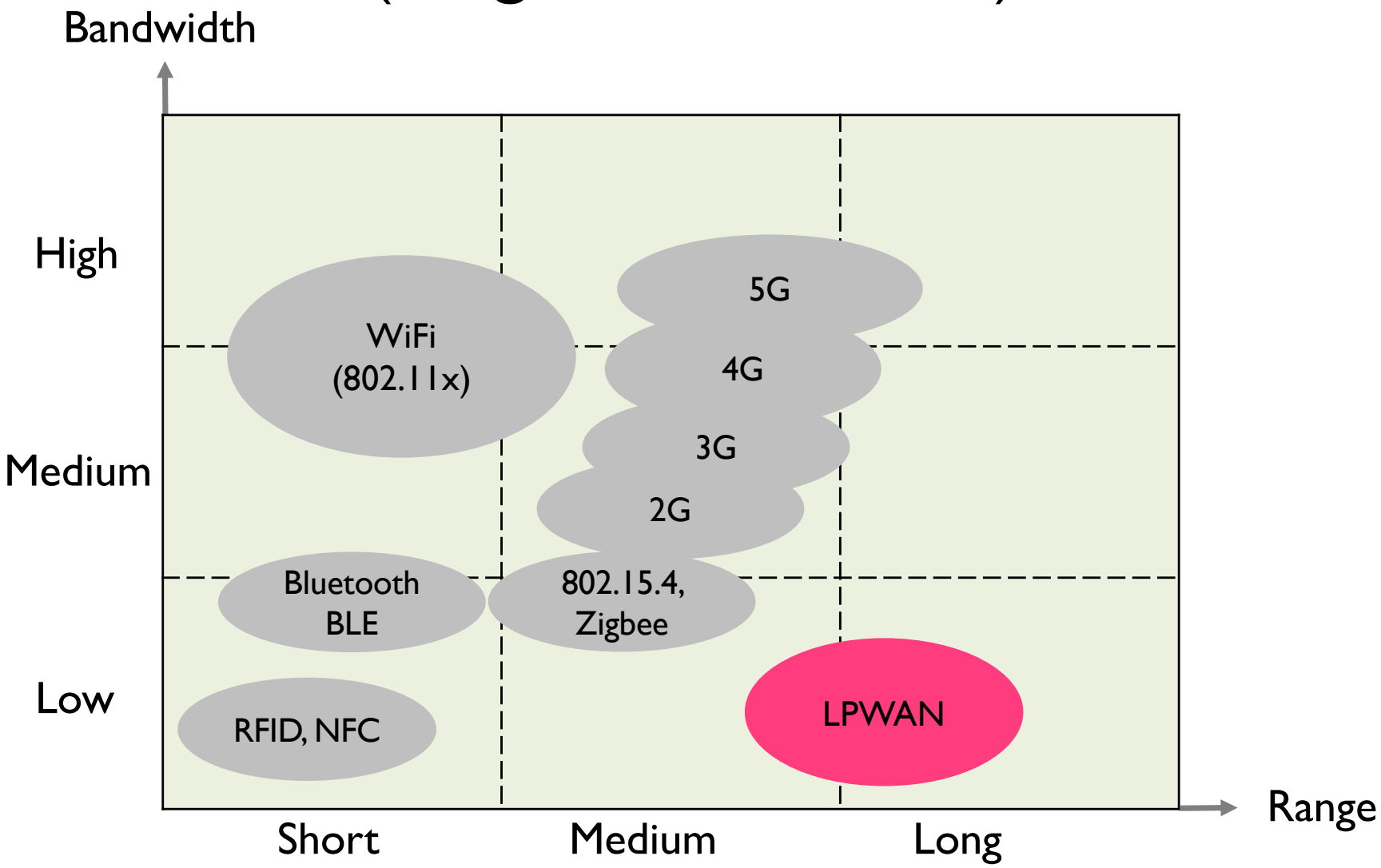
Communication technologies

- Many communication technologies can be used to connect smart things
- Several factors dictate the choice of a technology for a specific application
  - range of connectivity
  - bandwidth
  - power consumption

Classification of communication technologies (range)



Classification of communication technologies (range vs bandwidth)



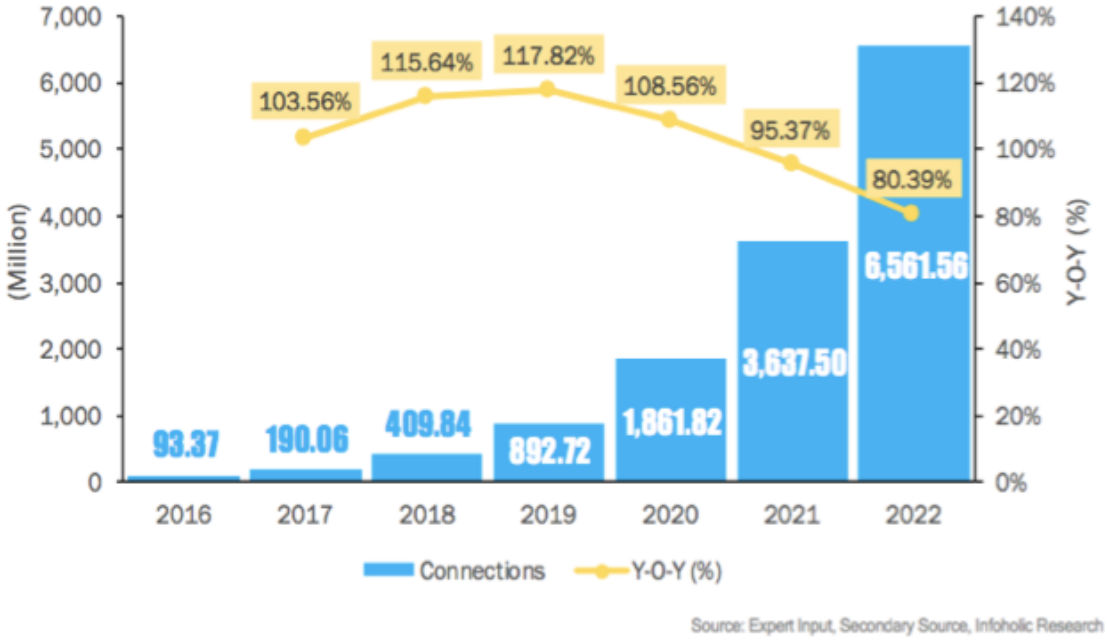
UNIVERSITY OF CAMBRIDGE

LPWAN Technologies

Main characteristics

- Long range communication links
- Low bandwidth, low power
- Deep indoor penetration
- Very cheap radio modules

Estimated LPWAN market size



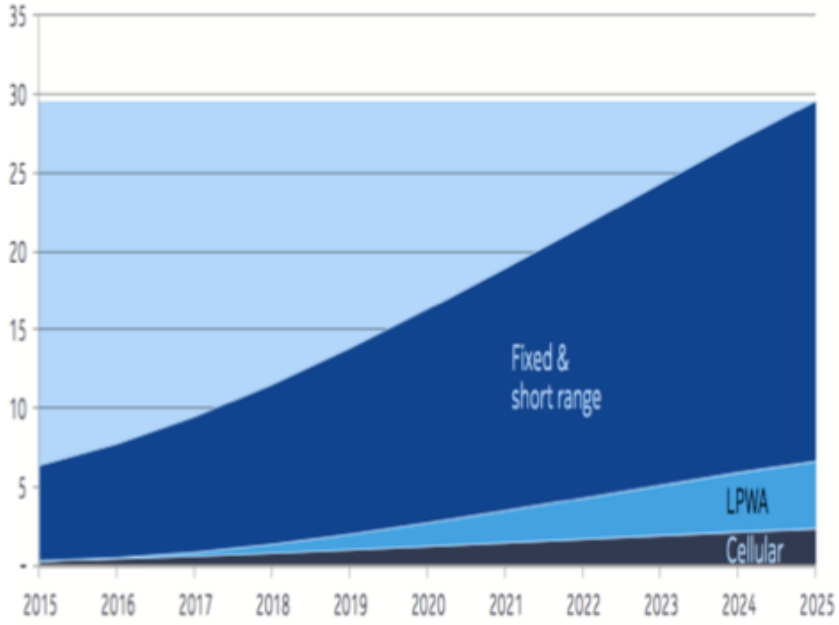
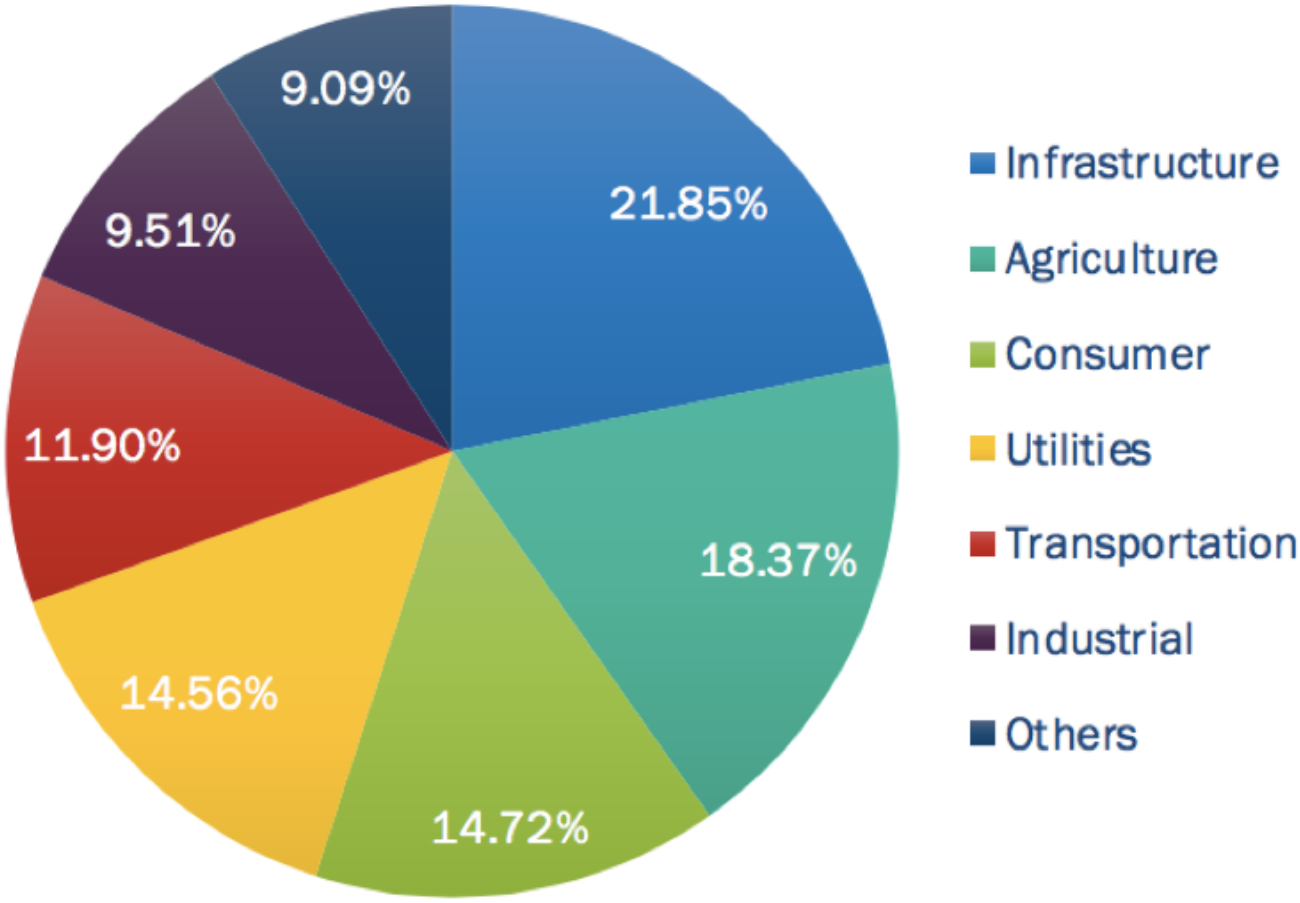


Figure 1. Billion global connections, 2015-2025 (Machina Research, May 2015)

UNIVERSITY OF CAMBRIDGE

LPWAN market share by sector



UNIVERSITY OF CAMBRIDGE

Source: Infoholic Research, 2016

Major LPWAN contenders

NB-IoT

CAT-M1

Who is the winning competitor?

- There is no winner (yet)
- In the current market situation, there is space for all the contenders
- The choice of a technology over another is dictated by the application requirements

Typical LPWAN applications

- Smart metering
- Air quality monitoring
- Smart lighting
- Asset tracking (not real-time)
- Tank monitoring
- Waste management

These applications are typically delay tolerant and require the transmission of only a few packets per hours

LoRaWAN

Deep dive into LoRaWAN

LoRa Alliance ecosystem

- LoRa Alliance members collaborate to drive the global success of LoRaWAN

460+ companies

UNIVERSITY OF CAMBRIDGE

What is LoRa?

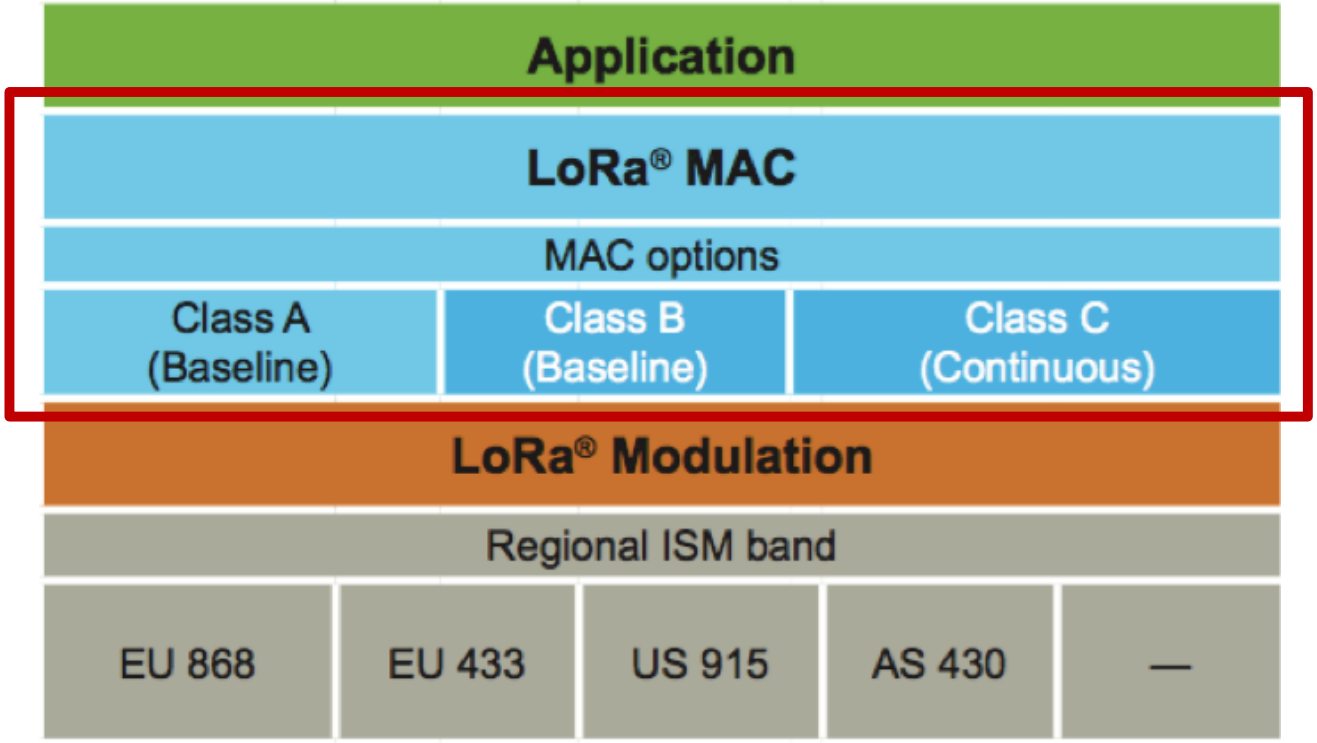
- Physical layer or the wireless modulation utilised to create long distance communication link

- Spread spectrum technology
  - Chirp modulation
  - Low power, long range at expense of low data rate
  - Resistance to interference
  - Geolocation

- First commercial implementation of chirp spread spectrum technology

What is LoRaWAN?

- LoRaWAN is the network which uses LoRa as the underlying radio modulation



3 classes of devices

A. Battery powered devices, bi-directional comm.

B. Battery powered devices, bi-directional comm., extra receive windows

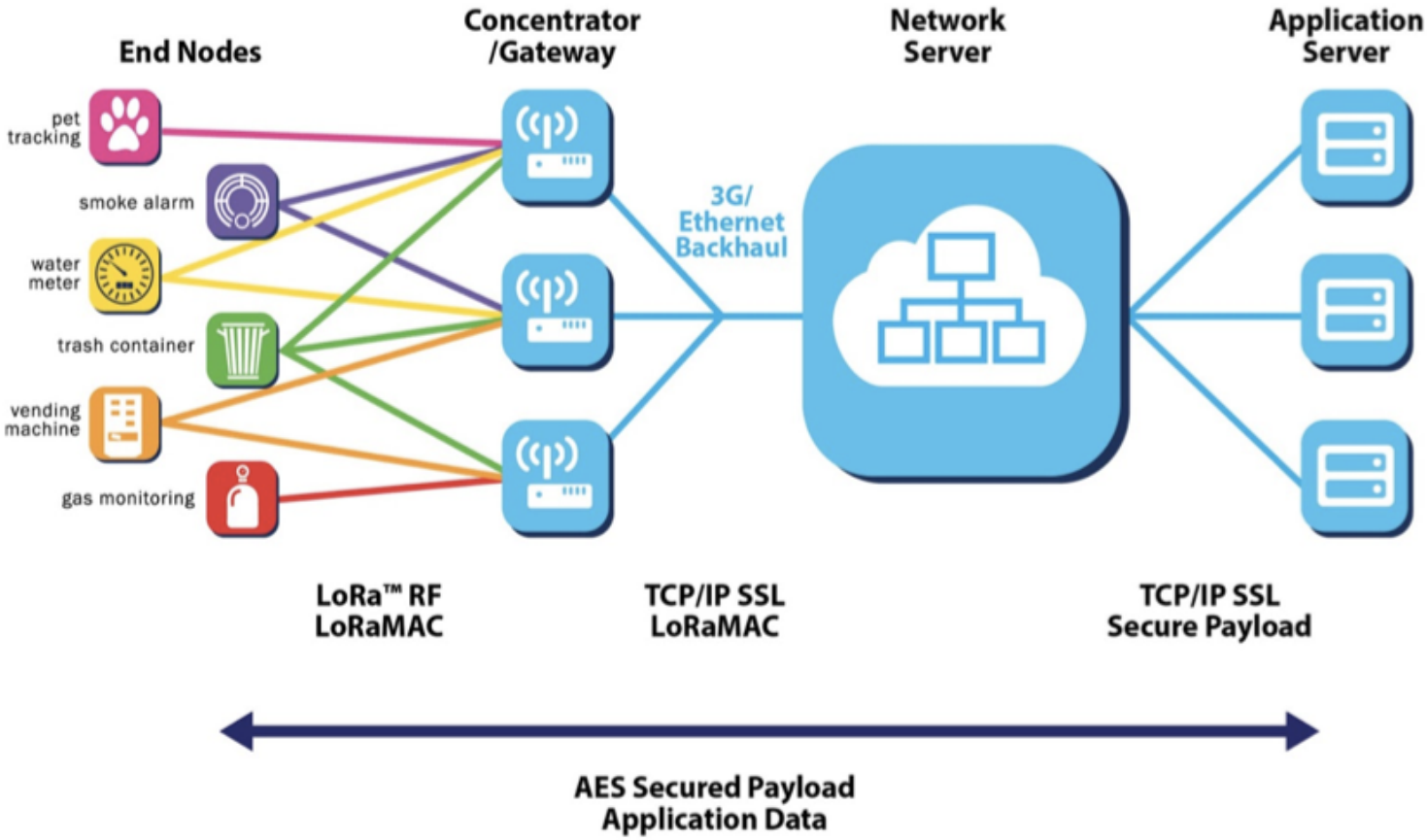
C. Main powered devices

UNIVERSITY OF CAMBRIDGE

Network topology

Long-range star topology

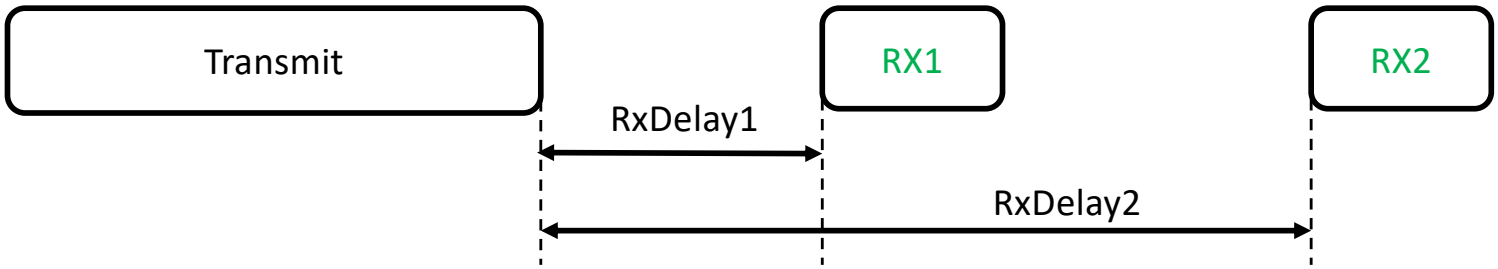
Preserve battery life



UNIVERSITY OF CAMBRIDGE

End-device classes

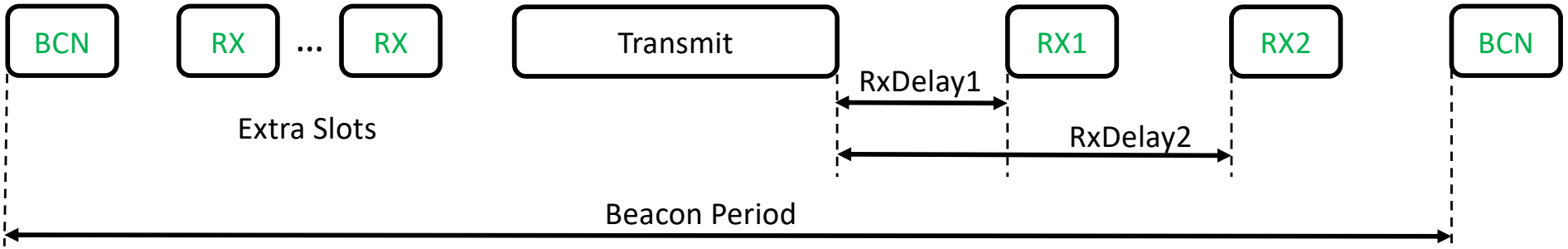
- Battery powered – Class A
  - Bidirectional communications
  - End-device initiates communication (uplink)
  - Server communicates with end-device (downlink) during predetermined response windows
  - For every uplink, there are two possible downlink slots
  - Low power consumption, high latency



UNIVERSITY OF CAMBRIDGE

End-device classes

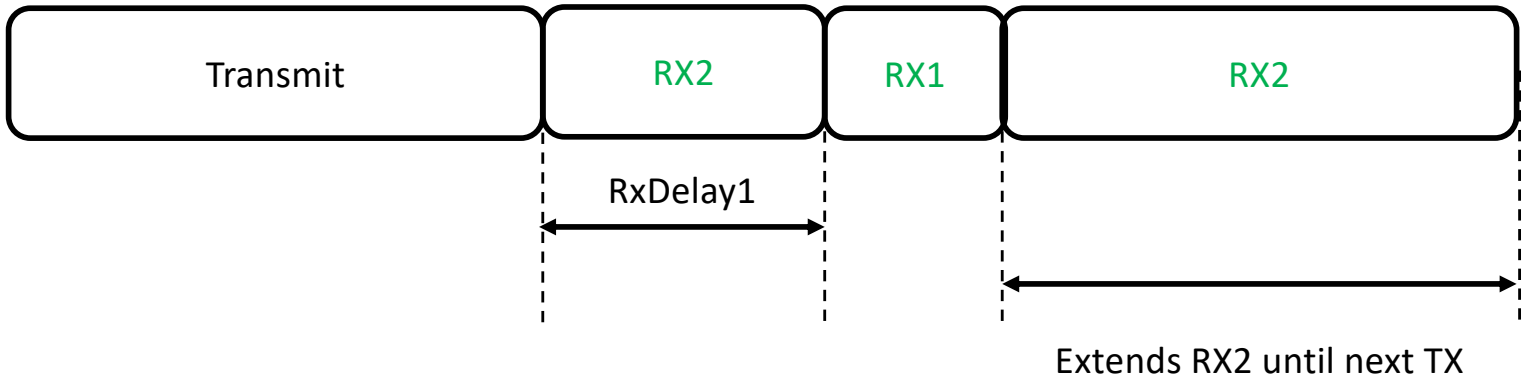
- Low latency – Class B
  - Bidirectional with scheduled receive slots
  - There are pre-programmed downlink slots. Downlink is possible at these times
  - Periodic beacon from gateway to synchronize downlink slots
  - High power consumption, low latency



UNIVERSITY OF CAMBRIDGE

End-device classes

- No latency – Class C
  - Bidirectional communications
  - Server can initiate transmission at any time
  - End-device is constantly receiving
  - Main-powered devices, no latency



End-device activation (joining)

- Before an end-device can communicate on the LoRaWAN network, it must be activated

- The following information is required:
  - Device Address (DevAddr)
  - Network Session Key (NwkSKey)
  - Application Session Key (AppSKey)

End-device activation (joining)

- Device Address (DevAddr)
  - 32-bit identifier
  - Unique within the network
  - Shared between end-device, network server, and application server

- Differentiates nodes within the network, allowing the network to use the correct encryption keys and properly interpret the data

End-device activation (joining)

- Network Session Key (NwkSKey)
  - 128-bit AES encryption key
  - Unique per end-device
  - Shared between end-device and network server

- Provides message integrity for the communication
- Provides security for end-device to network server communication

End-device activation (joining)

- Application Session Key (AppSKey)
  - 128-bit AES encryption key
  - Unique per end-device
  - Shared between end-device and application server
  - Used to encrypt / decrypt application data messages

- Provides security for application payload

End-device activation (joining)

- To exchange this information, two activation methods are available:

Over-the-Air Activation (OTAA)	Activation By Personalization (ABP)
• Over the air message handshaking 	• Shared keys stored at production time 

End-device communications (Class A)

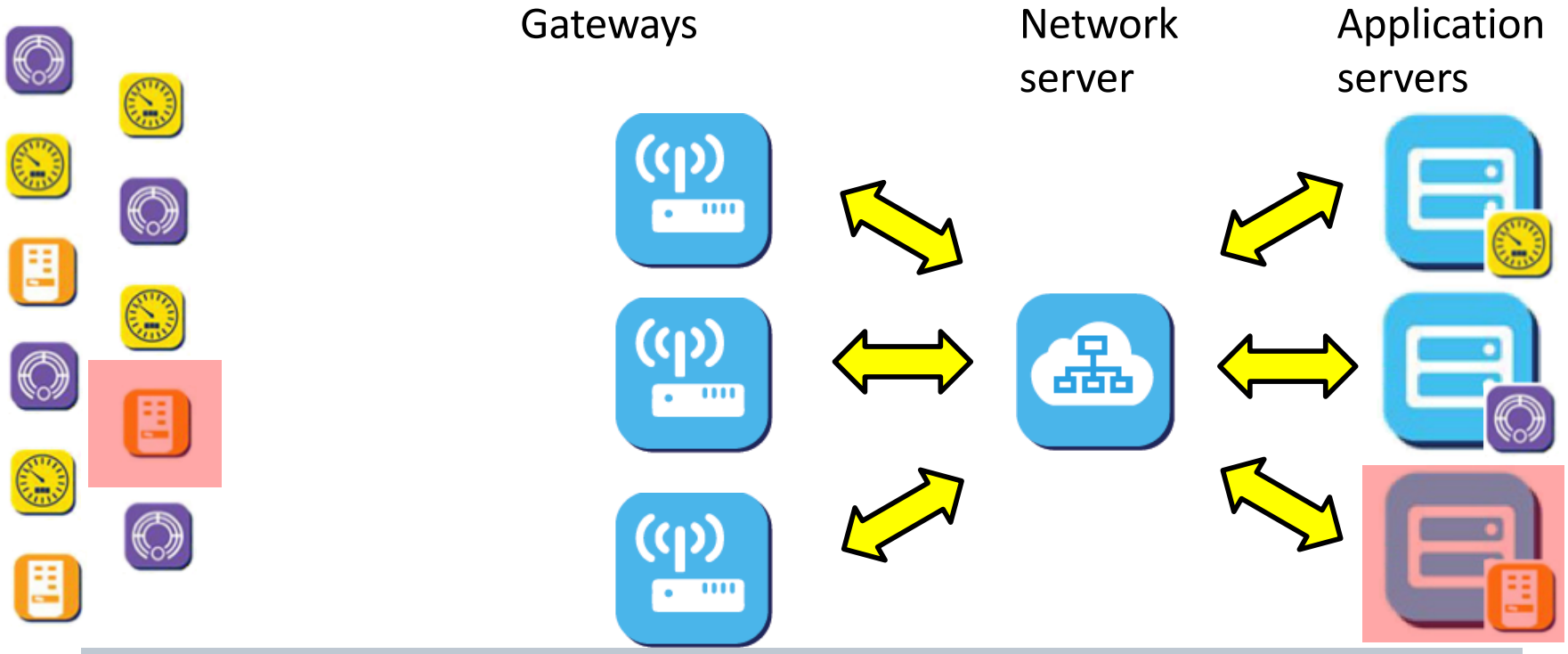
Confirmed-data message

End-device data message has to be acknowledged by the receiver

Let's look at an example…

End-device communications (Class A)

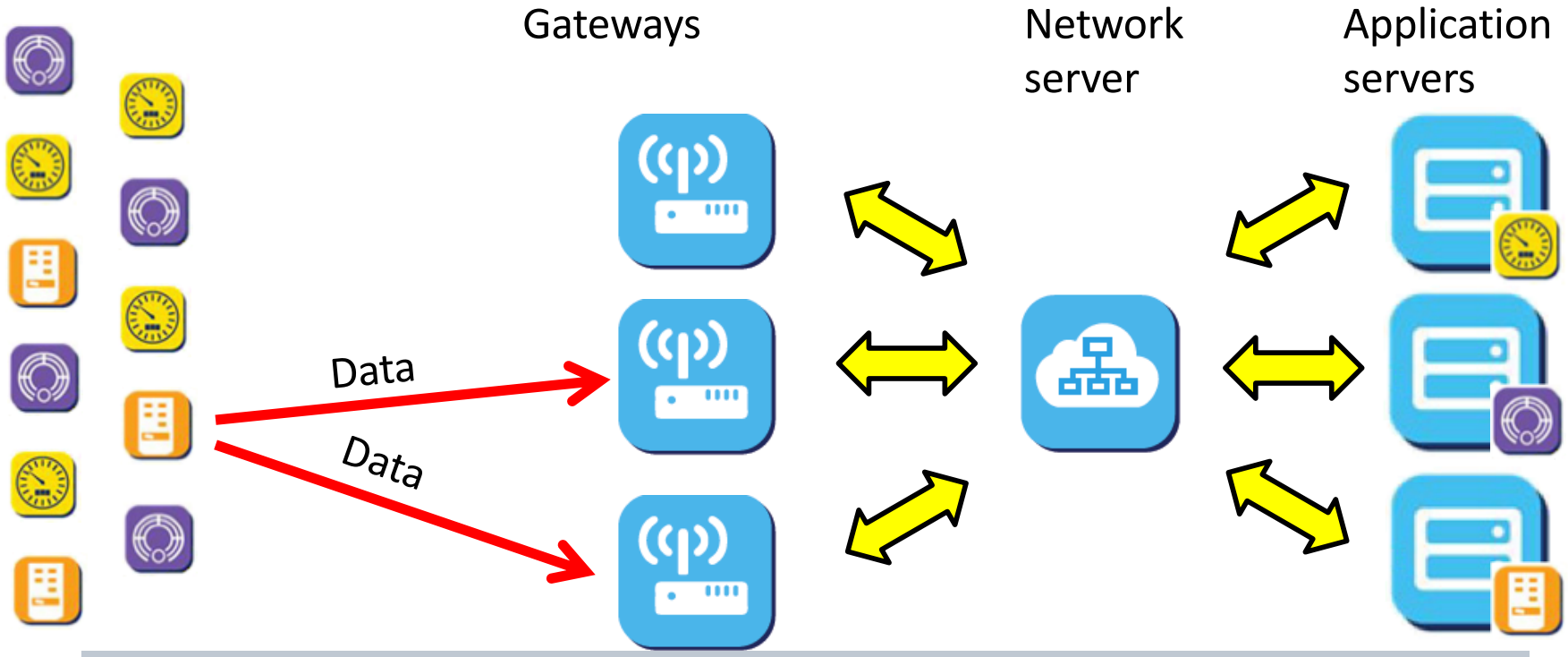
Confirmed-data message



1. Vending machine needs to send information to the related application server

End-device communications (Class A)

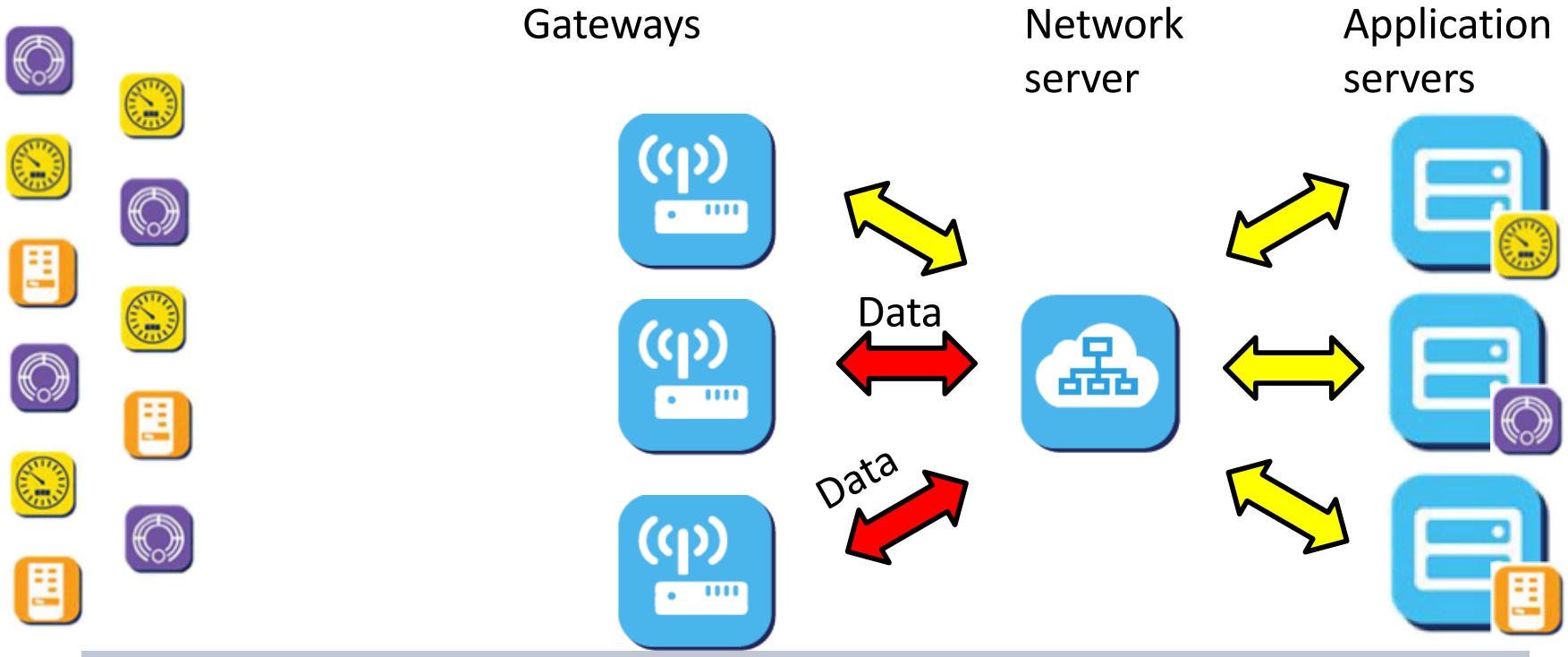
Confirmed-data message



1. Vending machine transmits data.
It is received by two gateways.

End-device communications (Class A)

Confirmed-data message

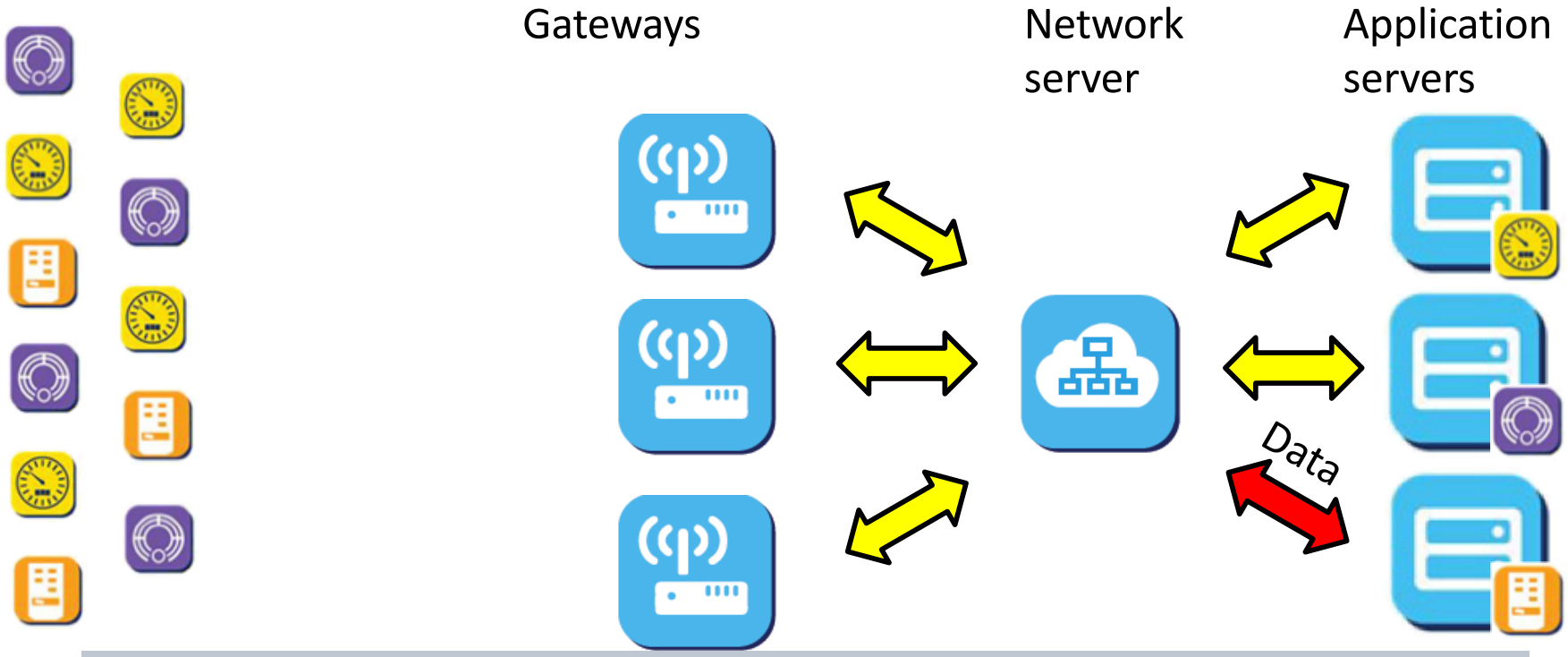


2. Both gateways “pass through” the data to the network server.

UNIVERSITY OF CAMBRIDGE

End-device communications (Class A)

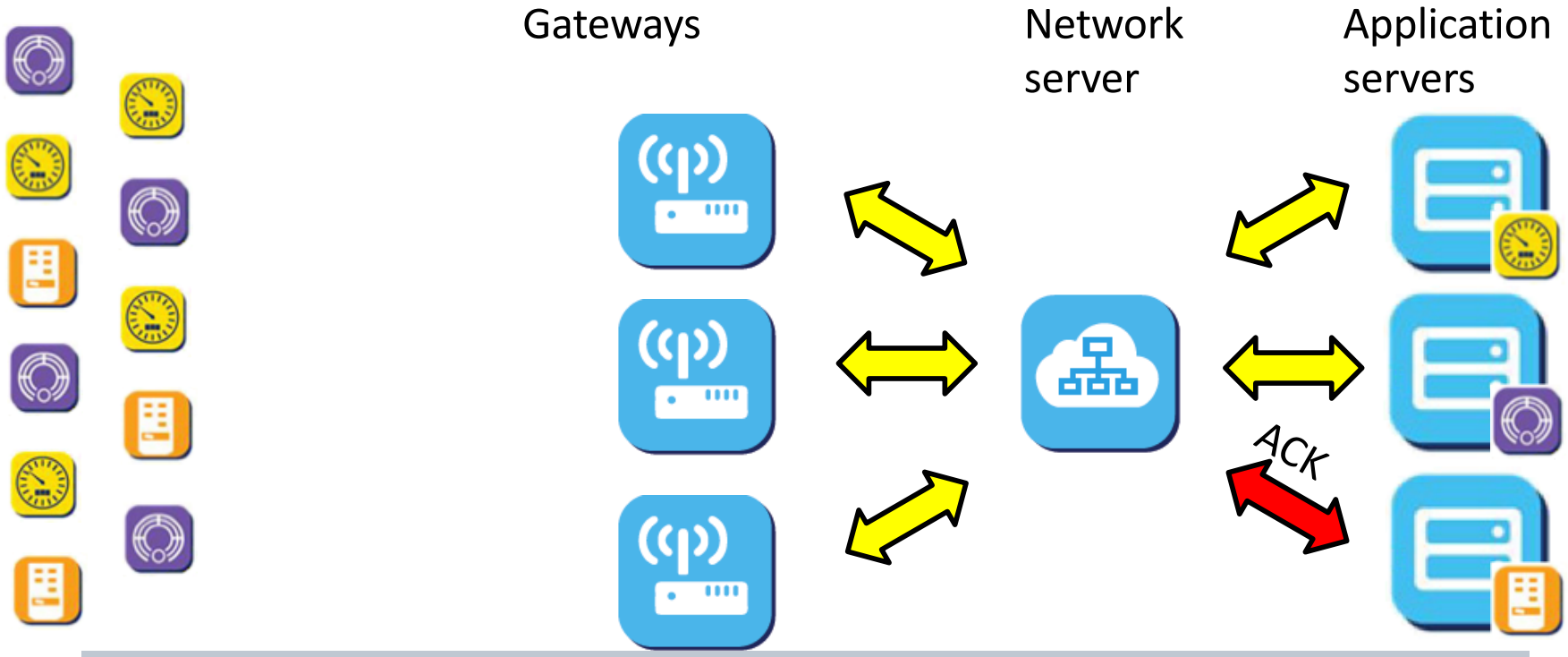
Confirmed-data message



3. The network server forwards the data to the vending machine application server.

End-device communications (Class A)

Confirmed-data message

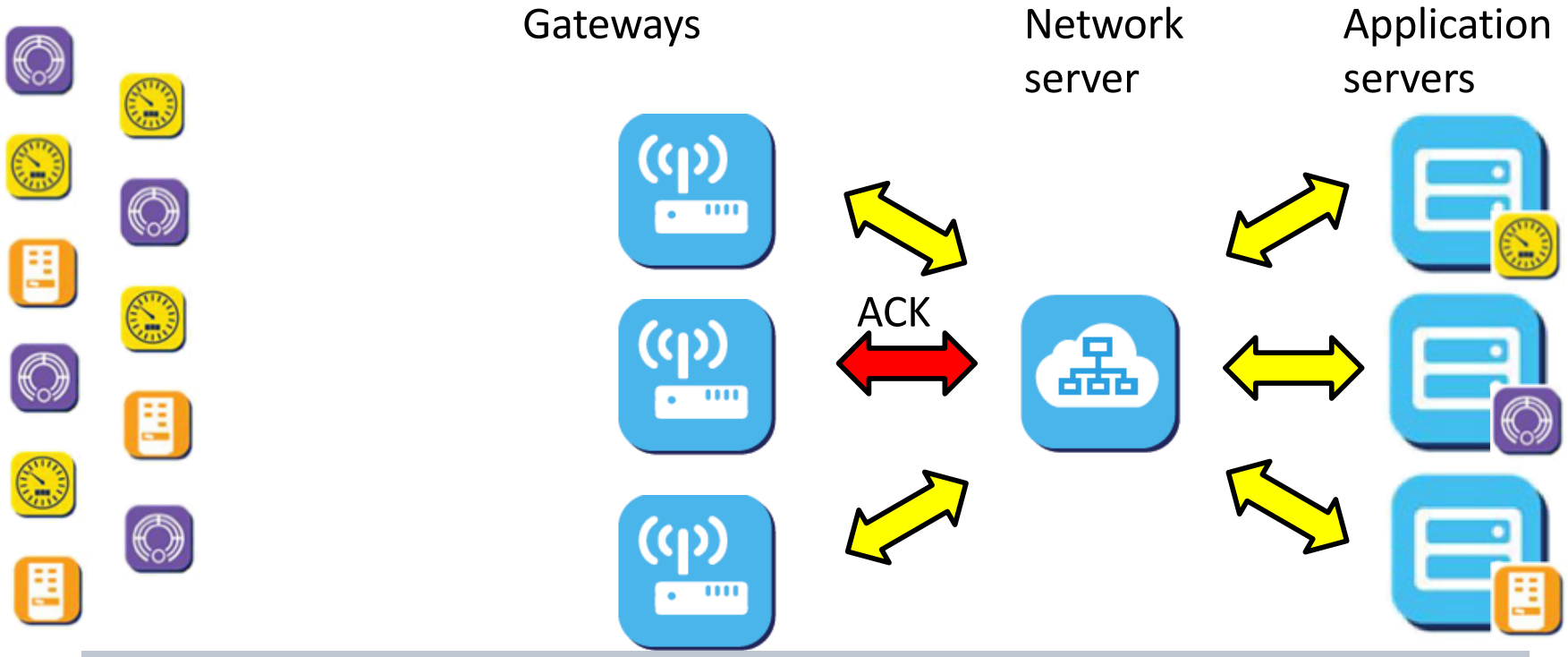


4. The vending machine application server sends an acknowledgement.

UNIVERSITY OF CAMBRIDGE

End-device communications (Class A)

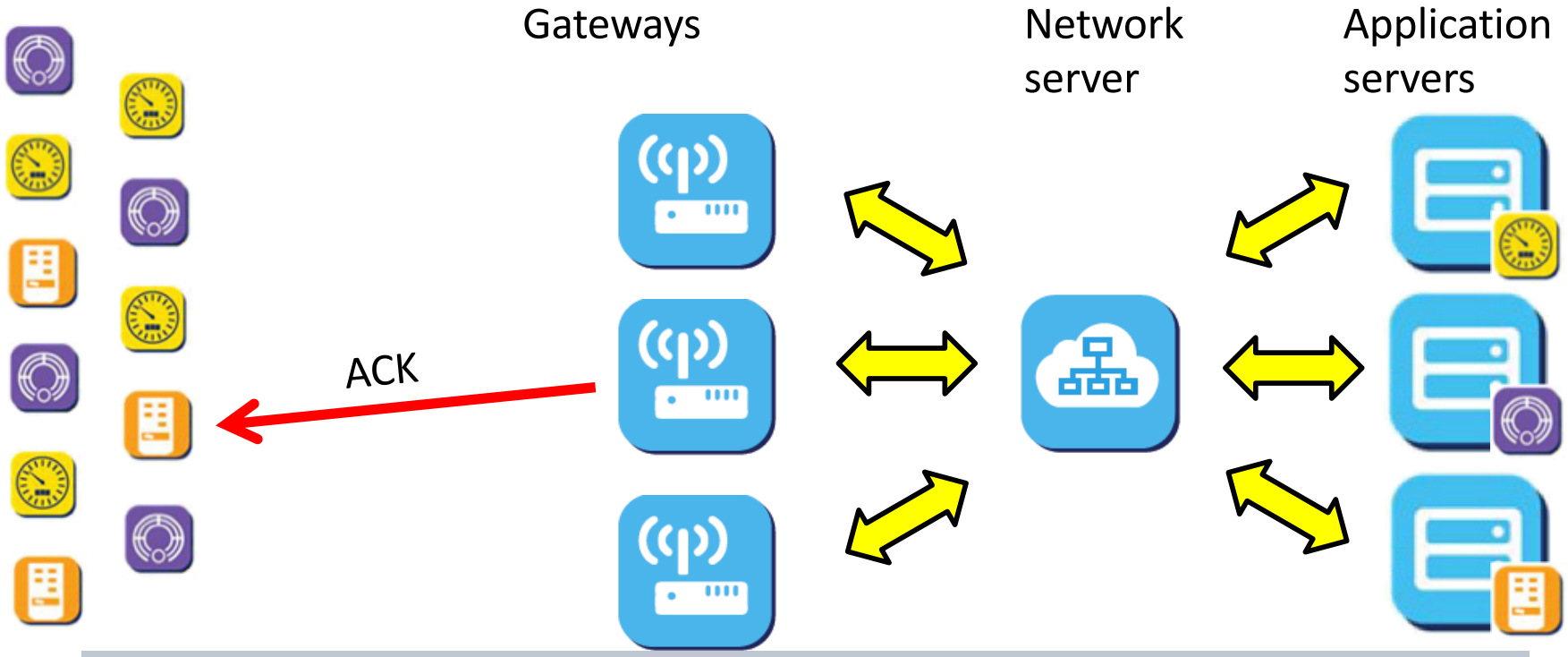
Confirmed-data message



5. The network server selects the best path (gateway) to transmit the acknowledgement to the end-device.

End-device communications (Class A)

Confirmed-data message



6. The gateway transmits the acknowledgement to the end-device.

Introduction to Things Connected

Objectives

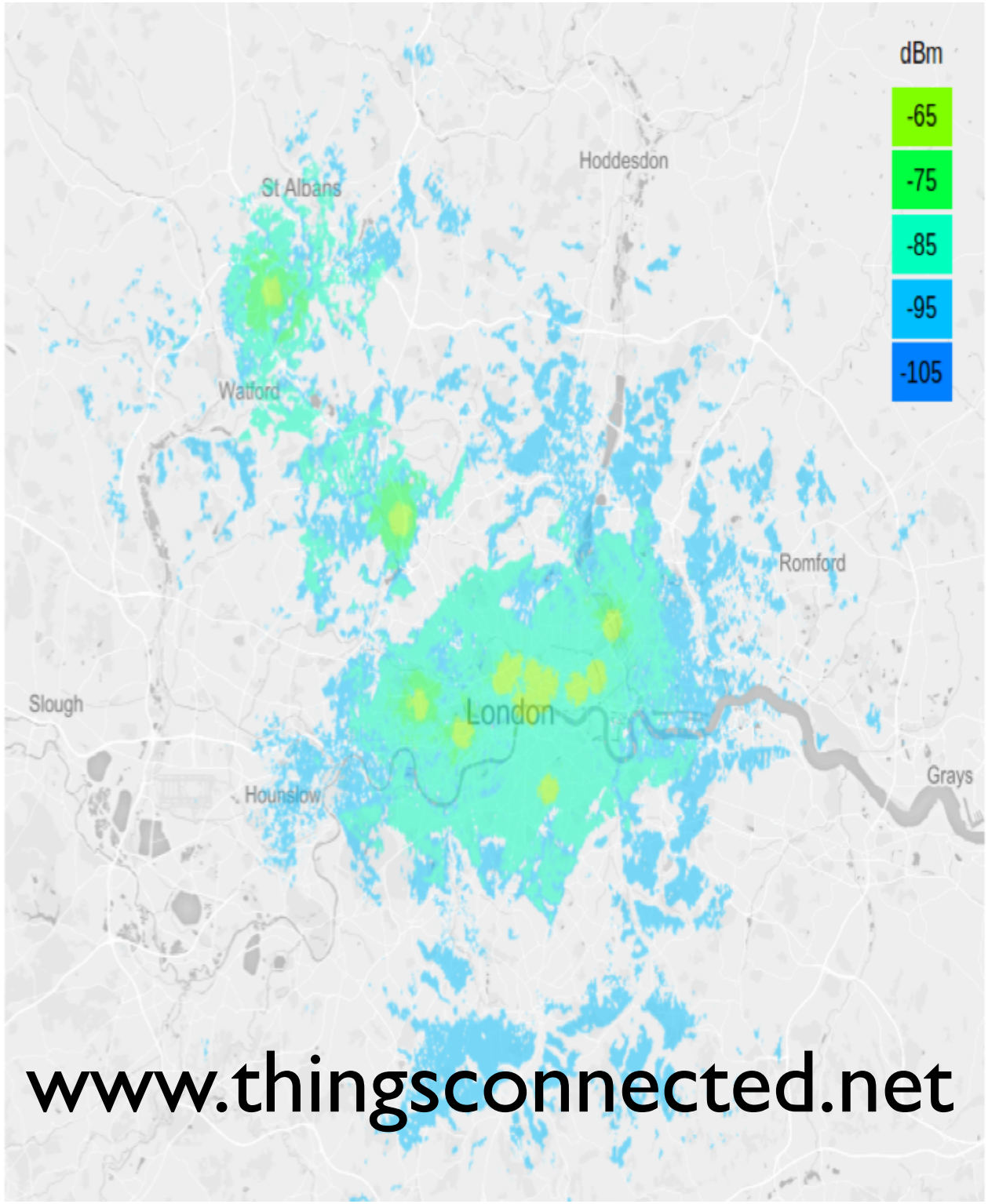
- Jumpstart the UK low power wide area network (LPWAN) ecosystem through a innovation support programme

- Establish an open low power wide area network (LPWAN) in London to be used as innovation testbed for the IoT community

- Empower UK businesses, innovators and communities with the knowledge and skills to become quickly productive on top of LPWANs

Things Connected

- London wide LoRaWAN deployment
- Launched open call Sep 2016 with 110+ expressions of interests, mainly SMEs
- LPWAN London community of 500+ members
- First cohort of 20 UK SMEs on-boarded successfully
- Currently working to expand the network



UNIVERSITY OF CAMBRIDGE

www.thingsconnected.net

Things Connected London partners

Programme delivery
SME innovation support

Research
Knowledge transfer
Work force skill-up
Node-hosting

LORA net provider

App Enablement

Knowledge partner

Certification & testing

UNIVERSITY OF CAMBRIDGE

Key take aways

- IoT is past its hype as it moves into real commercial reality
- The hype has created a lot of market uncertainty and due to oversupply of proprietary solutions and fragmentation
- Several LPWAN technologies will have a significant role to play in the future
- Plenty of challenges to solve and exciting opportunities. It's worth to work in this space!

Suggested readings

- O. Vermesan and P. Friess (eds.). Internet of Things – From Research and Innovation to Market Deployment. River Publishers Series in Communication. 2014
- ITU-T Recommendation Y.2060. Overview of the Internet of Things. June 2012.
- Z. Shelby and C. Bormann. 6LoWPAN: The Wireless Embedded Internet. Wiley Publishing. 2010.
- N. Sornin, M. Luis, T. Eirich, T. Kramp, O. Hersent. LoRaWAN Specification. Version V1.0. Lora Alliance. January 2015.