Mobile and Sensor Systems

Lecture 8: Internet of Things and Sensor Integration

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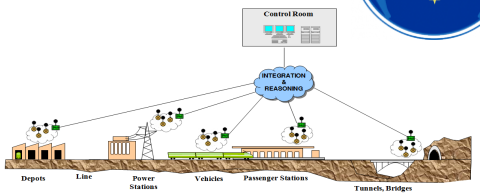
2009 2010 2011 2014 2016 2017

PROTECTRAIL



>makeSense
Easy Programming of Integrated Wireless Sensor Networks

CSIC Cambridge Centre for Smart Infrastructure & Construction

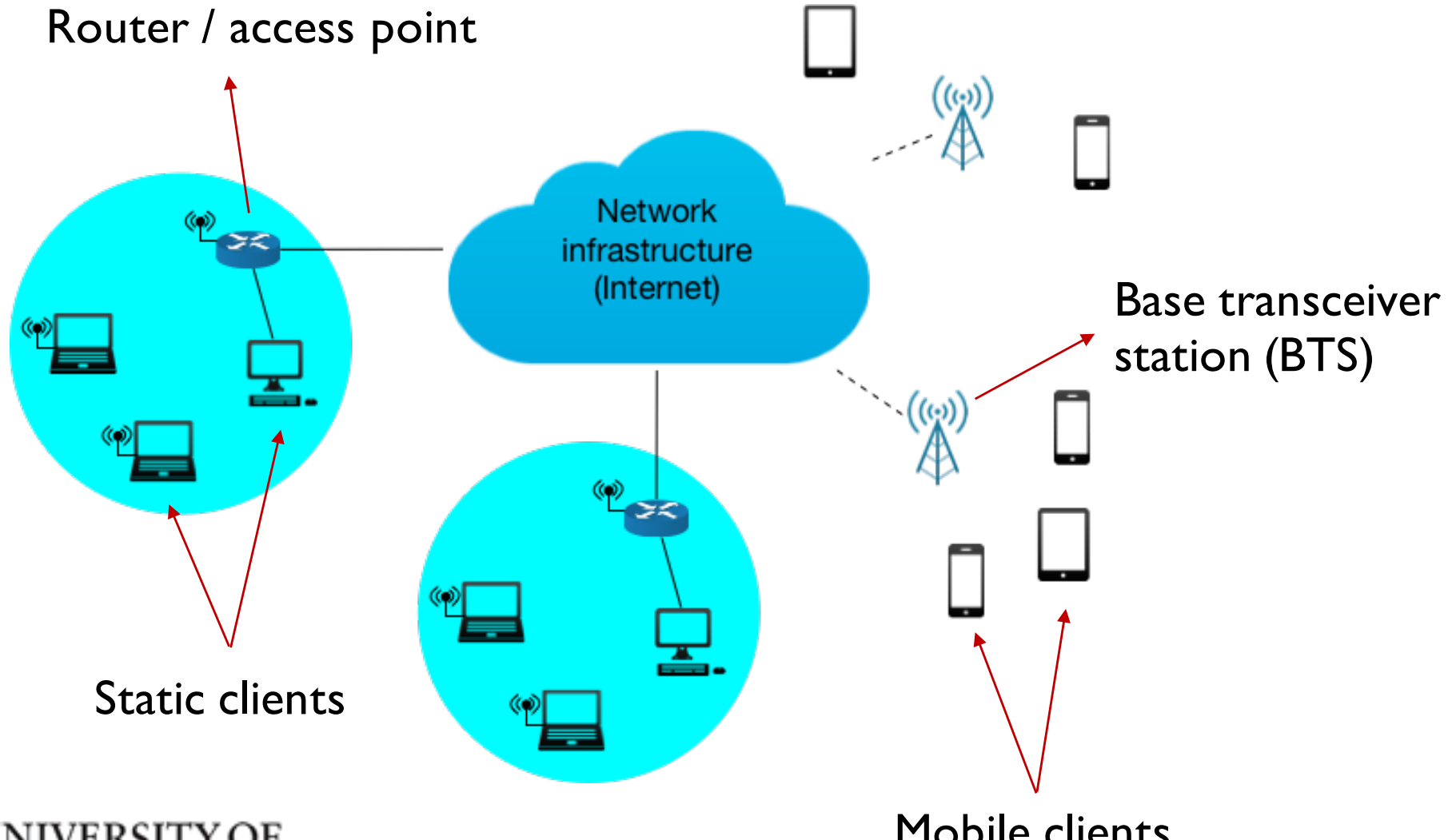
Things Connected

University of Cambridge

In this lecture

- We will introduce the Internet of Things (IoT) paradigm
- We will talk about the major challenges in the IoT ecosystem
- We will describe the 6LoWPAN and LPWAN architectures

The "classical" Internet



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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].

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[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*

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Revised hype cycle (2016)

Source: Gartner (July 2016)

The focus on the development of IoT platforms

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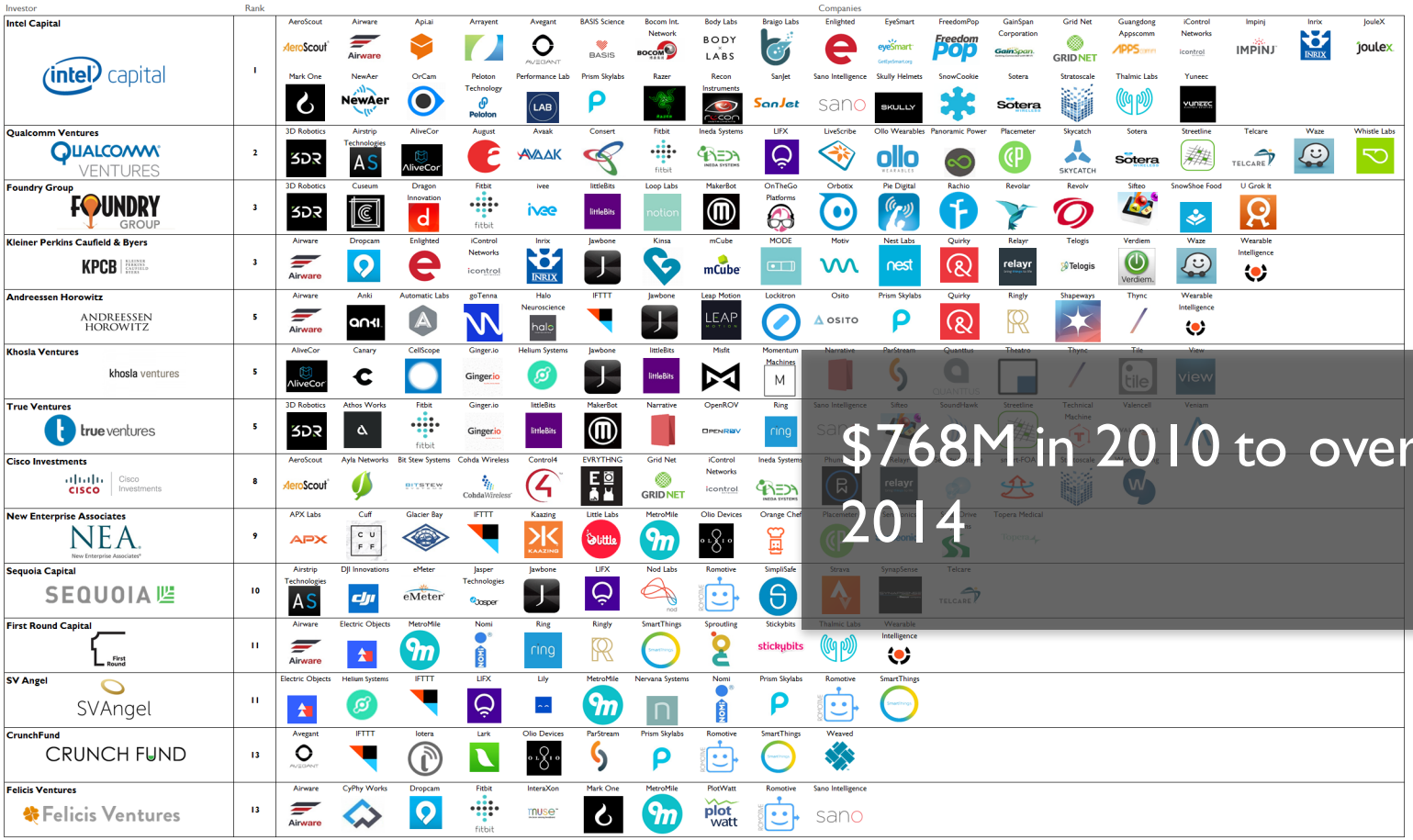
Recent IoT investments



$768M in 2010 to over $1.9B in 2014

Source: CBInsights
https://cbi-blog.s3.amazonaws.com/blog/wp-content/uploads/2015/12/IoT-InfoGraphic11.png

(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

Blend the physical and the digital world in novel ways

New computing revolution

50 B devices will be connected by 2020 - Cisco

Enabling technologies

- Identification (e.g., RFID, NFC)
  - tag and track goods
  - smart logistics and supply chain
- Sensing
  - microelectromechanical systems (MEMS)
- Computation & communication
  - hardware platforms able to run embedded software
  - wireless communication technologies
  - operating systems, wireless sensor networks (WSN)
- Cloud computing & data analytics
  - smart object data combined to provide insight and recommendations

IoT landscape

Tags (RFID, NFC, QR codes)

Devices (sensor nodes, mobile and wearable devices)

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

Environments (smart homes, buildings, cities)



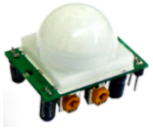














Typical IoT system architecture

IoT Cloud

Service hosting
Visualisations
Advanced analytics
Slow control
Data storage

IoT Gateway

Edge analytics
Fast control
Short/wide comms
Local storage

IoT Device

Basic processing
Short/wide comms
Sensing/actuation

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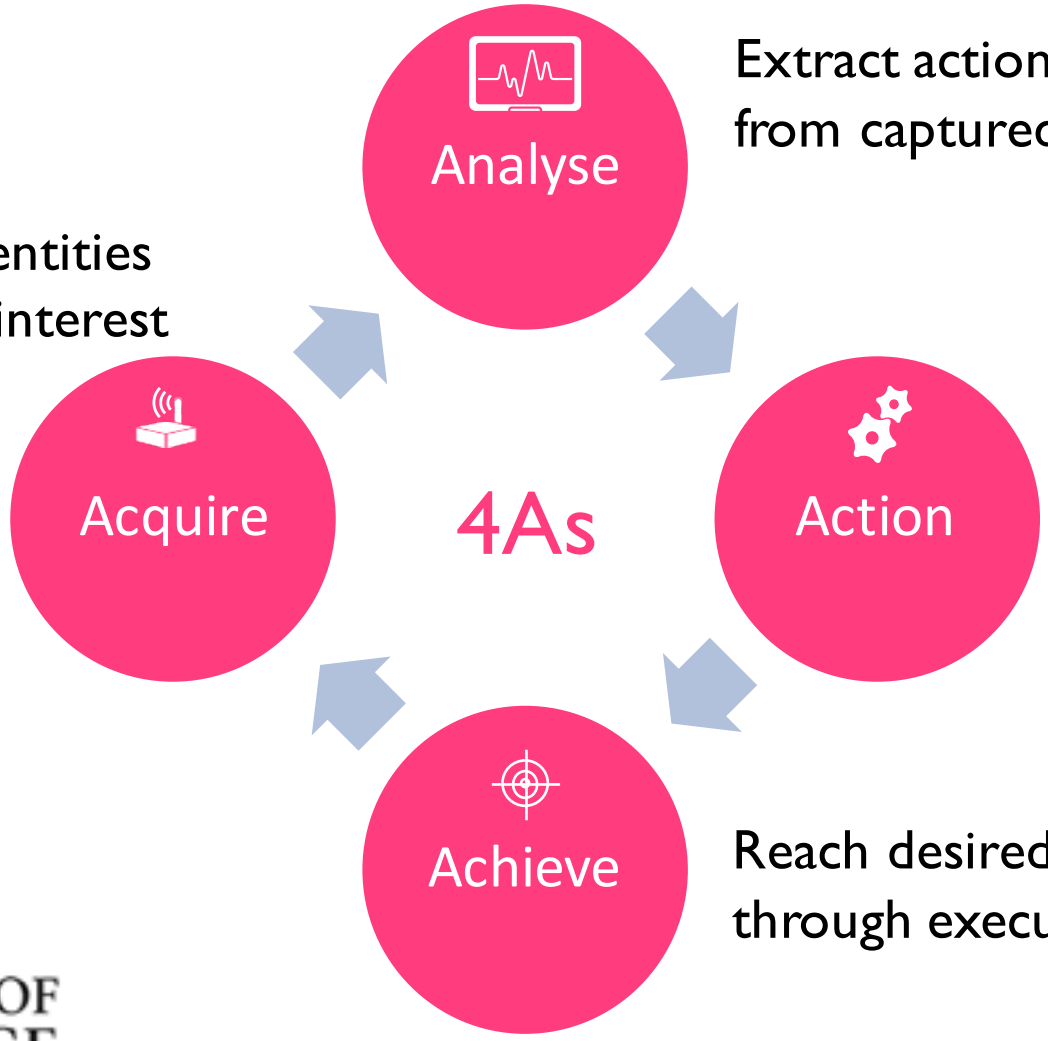
IoT service pattern

Capture real world information about entities and process(es) of interest



Extract actionable insights from captured information

Trigger action that impacts real world process(es) and entities

Reach desired impact/goals through executed actions

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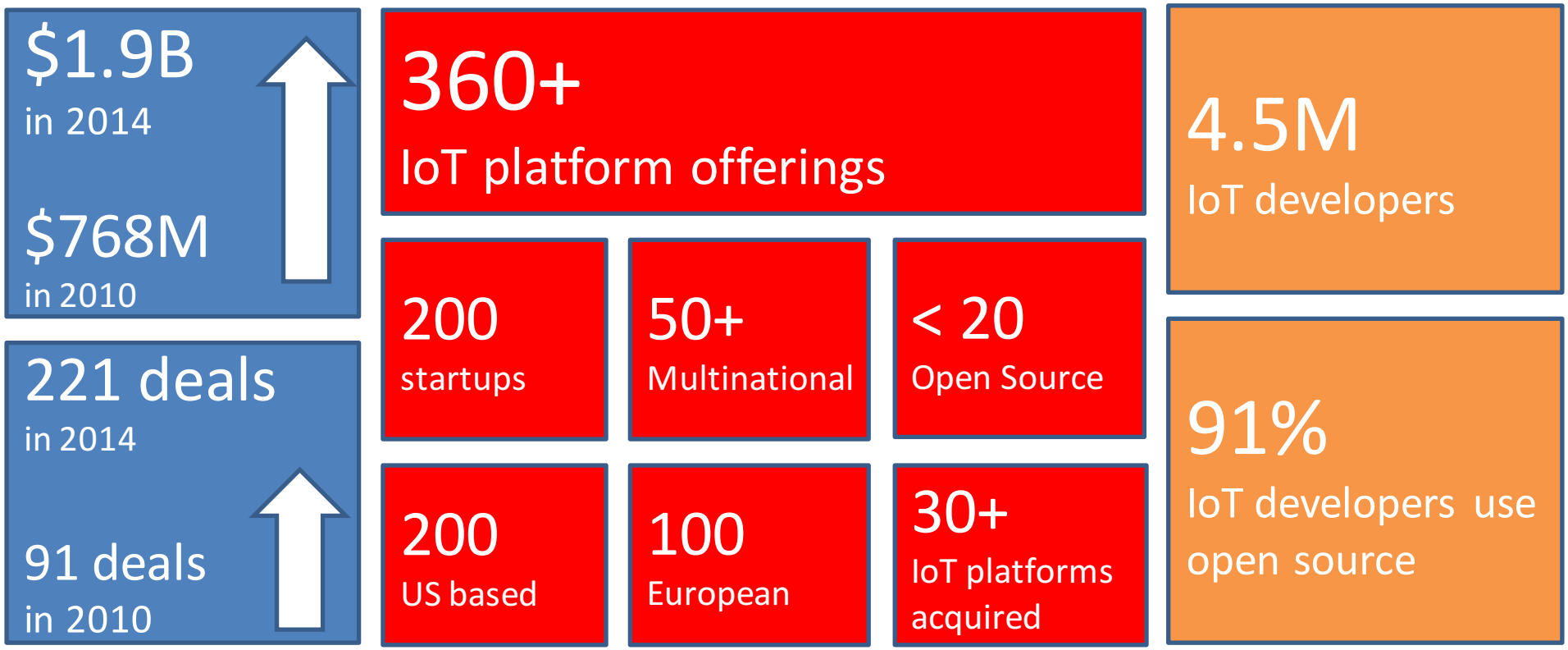
IoT platform ecosystem



Source: CBInsights

Source: IOT Analytics

Source: Vision Mobile

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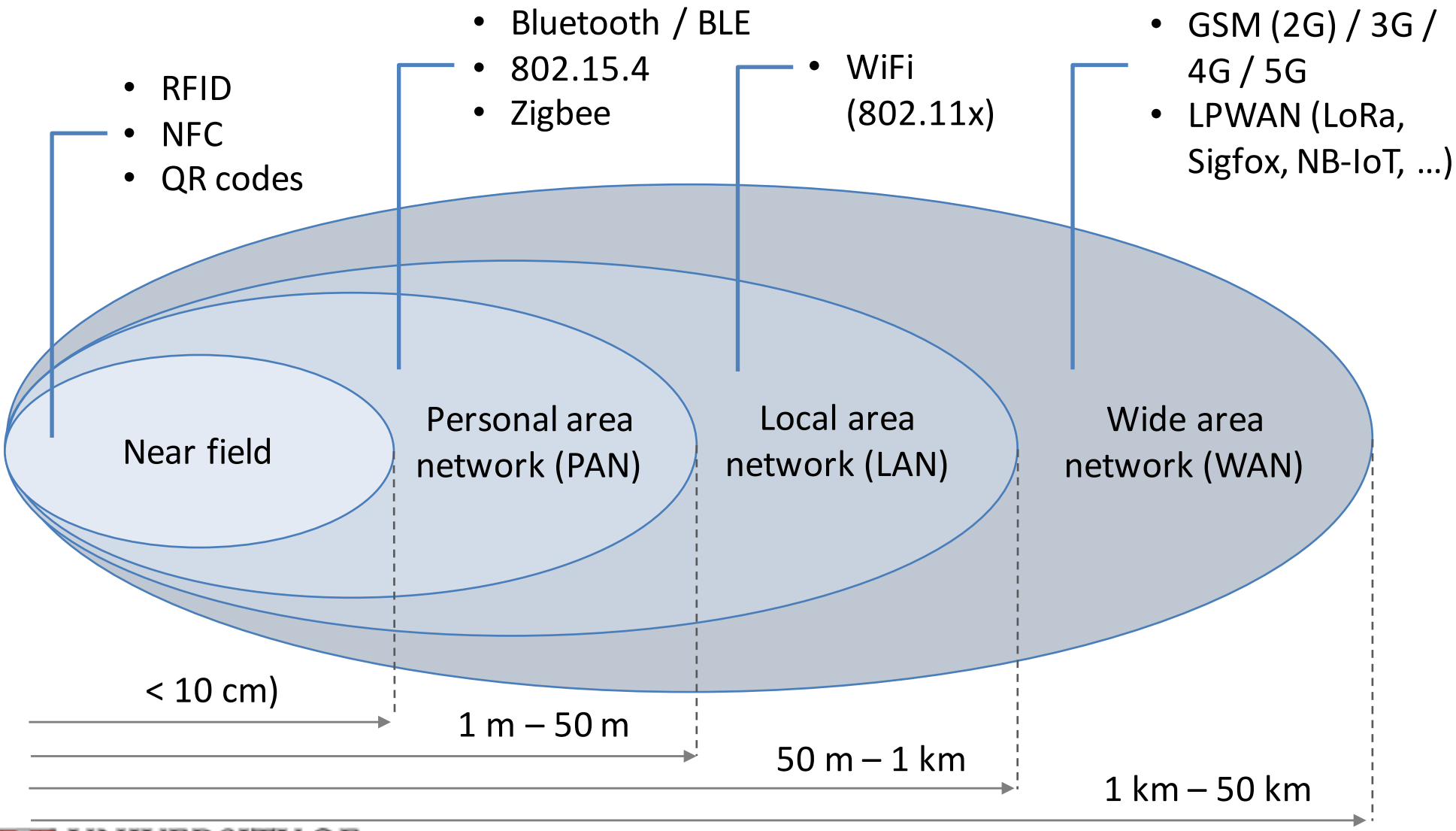
IoT platform scope

Source: IOT Analytics

Communication technologies



Interoperability

- Ability for devices from different manufacturers to exchange data
- Problem of complex nature
  - heterogeneity of devices, communication technologies
  - existence of many data formats
  - dynamic landscape

Extremely difficult to define a widely accepted specification

Addressing issues

- Incredibly high number of nodes
- IPv4 uses 32-bit addresses
  - 2^{32} = 4,294,967,296 unique addresses
  - IPv4 exhaustion occurred in 2011!

IPv6

  - 128-bit addresses → 2^{128} unique address

Is it enough? Can we just run the Internet Protocol on smart devices?

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IPv6 main challenges

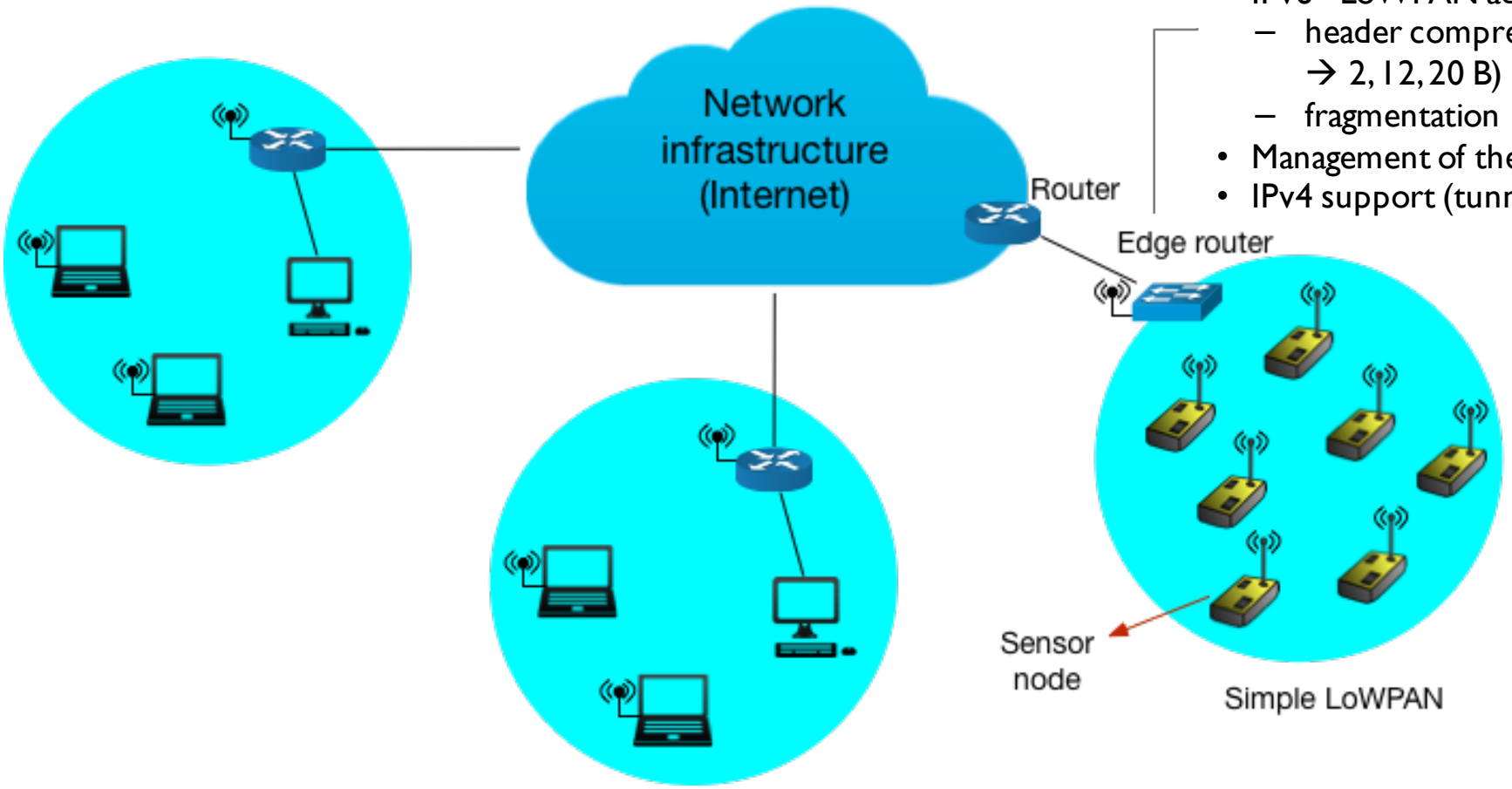
- Frame size and bandwidth
  - 1280 Bytes → reflects the advances in link layer technologies the Internet uses
  - low power wireless embedded radio technology has limited frame size (400 – 200 Bytes) and bandwidth (20 – 250 Kbit/s)
  - Limited buffering and processing capabilities of embedded devices
- Power and duty cycle
  - the basic assumption of IP is that a device is always connected
- Security
  - Security mechanisms (e.g., IPsec) too complex for embedded devices
- Reliability
  - Transport layer not designed (and optimized) for low power wireless networks

6LoWPAN

- IPv**6** over **Lo**w power **W**ireless **P**ersonal **A**rea **N**etworks
- Enable the use of IPv6 over 802.15.4 radio links
- Efficient adaptation layer between 802.15.4 link layer and TCP/IP stack

HTTP	Application	Application protocols (e.g., CoAP)
TCP/UDP	Transport	UDP/ICMP
IPv4/IPv6	Network	IPv6, RPL
Ethernet/WiFi MAC	Data Link	6LoWPAN
		802.15.4 MAC
Ethernet/WiFi PHY	Physical	802.15.4 PHY

IPv6/6LoWPAN architecture



- Route traffic in and out of the LoWPAN
- IPv6 - LoWPAN adaptation
  - header compression (40 B → 2, 12, 20 B)
  - fragmentation
- Management of the LoWPAN
- IPv4 support (tunneling)

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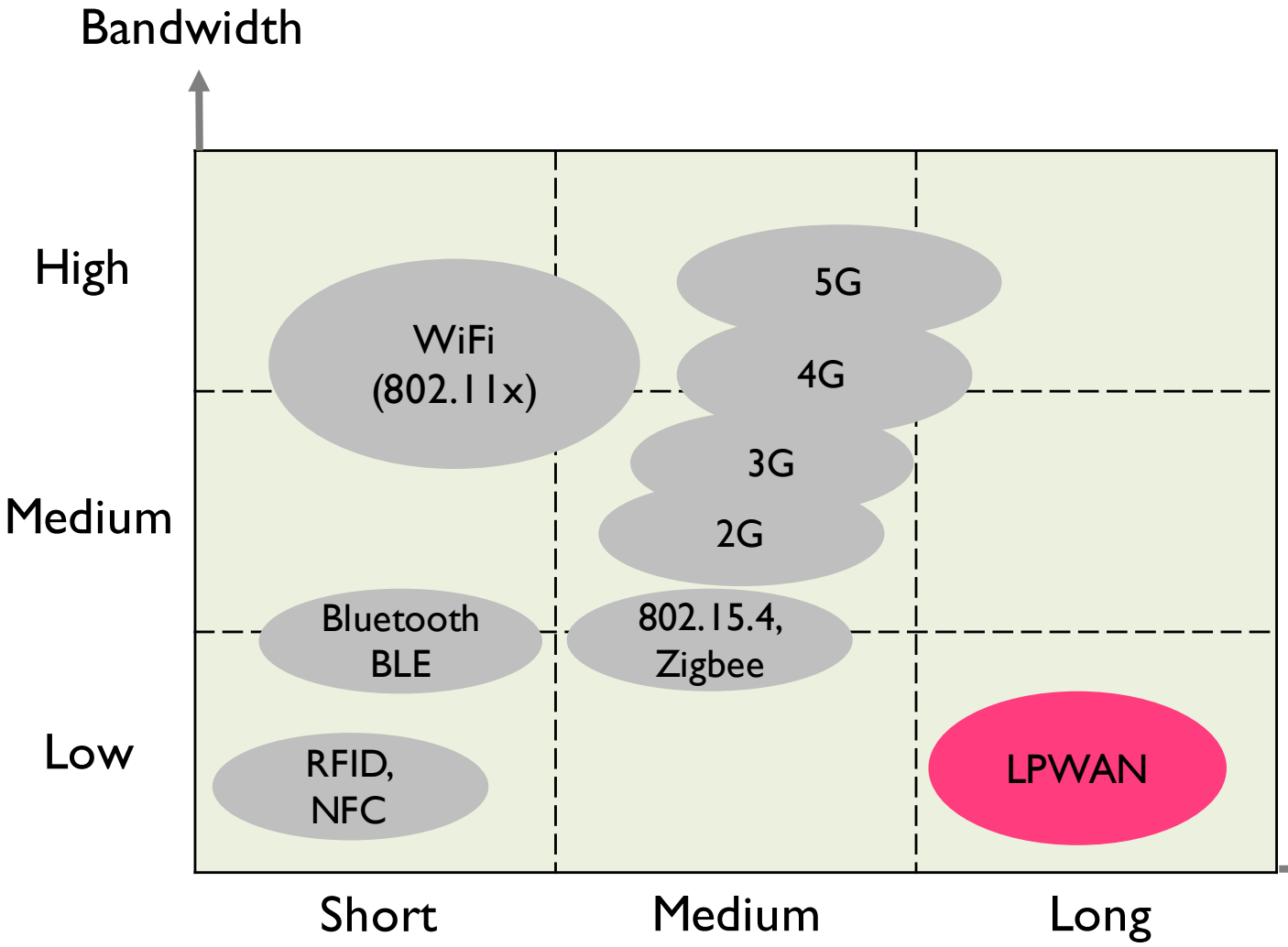
Security and Privacy

- Wide scale of IoT systems expected to magnify security threats
  - how could encryption and authentication technologies be implemented within IoT devices?
  - tradeoffs, e.g., what will motivate device designers and manufacturers to accept additional product design cost to make devices more secure?
- Privacy challenges have implications on basic rights and our collective ability to trust the Internet and the devices that connect to it
  - users have no knowledge or control over the way in which their personal data is being collected and used
  - marketplace relationship between data sources and data collectors

Low Power Wide Area Networks (LPWAN)



- Long range, low bandwidth
- Deep indoor penetration
- Very cheap radio modules
- High latency

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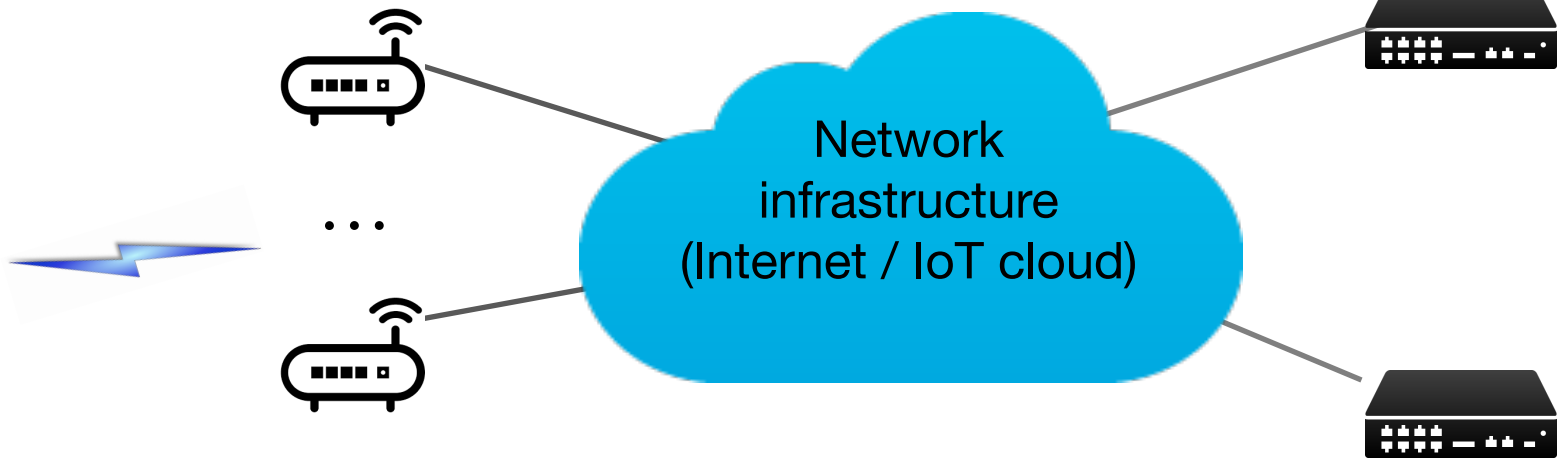
LPWAN architecture

End nodes

Gateways / concentrators

Application servers



- **Single hop** communication (star topology) between end nodes and gateways
- Gateways are connected to the network infrastructure via standard IP connections
- Application servers allow for the development of complex services over IoT data

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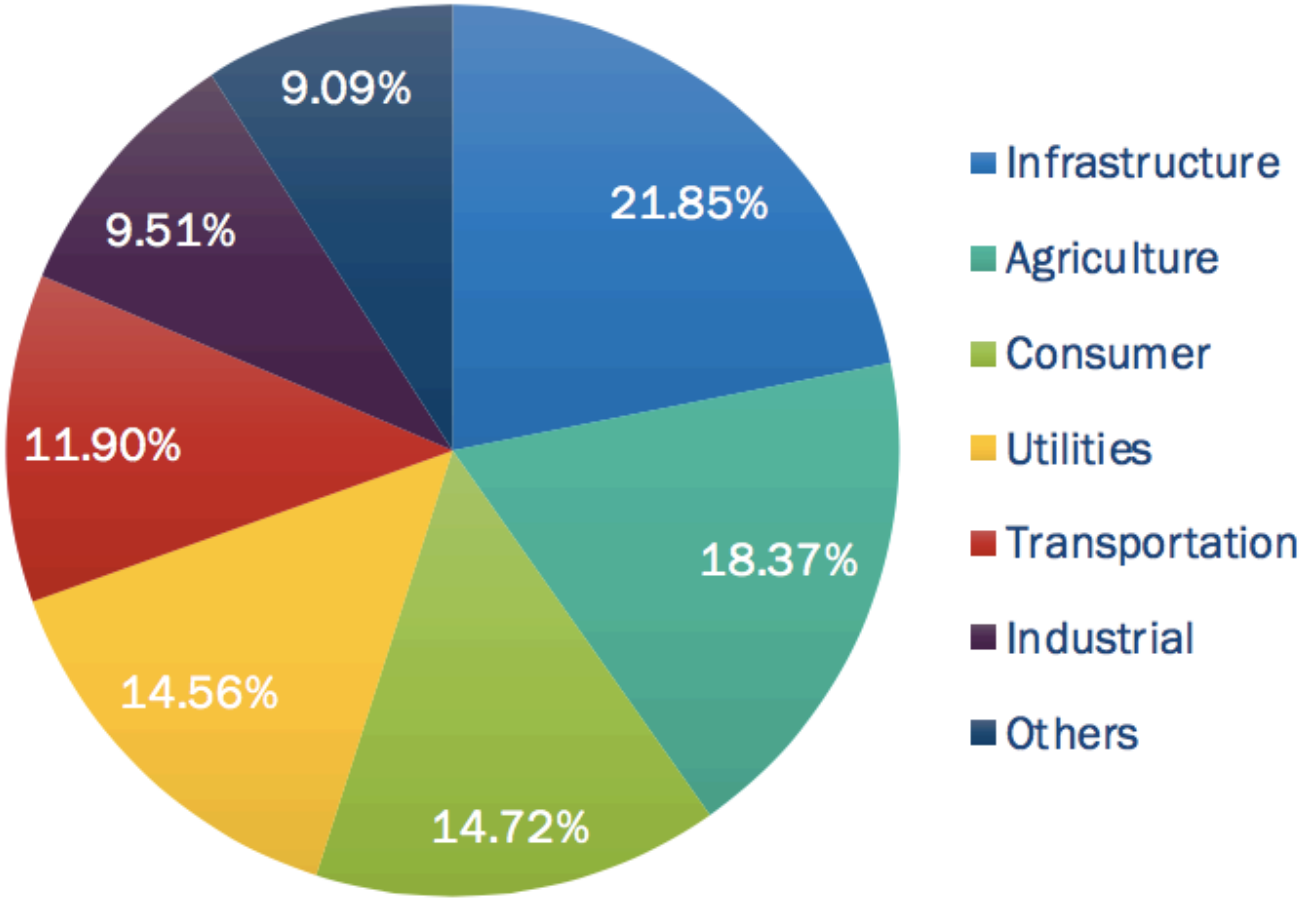
LPWAN technologies

	LoRaWAN	Neul	NWave	SigFox	Weightless-N	Weightless-P
Range (km)	2-5 urban 45 rural	Up to 10	Up to 10	<10 urban, 50 rural	5	2
Deep Indoor performance	yes	ISM yes, WS no	yes	yes	yes	yes
Freq band	Varies, subGHz	ISM or WS	SubGHz	Freq indep 868/902	SubGHz	SubGHz
ISM	Yes	Yes	Yes	Yes	Yes	Yes
Fully bi-directional	Yes	Yes	No	No	Uplink	Yes
Data rate	0.3-50 kbps	10-100 kbps	100 bps	10-1000 bps	30-100 kbps	Up 100 kbps
Power profile	Low	Low	Low	Low	Low	Low
Authentication	Yes	-	Yes	Yes	Yes	Yes
E2E encryption	Yes	-	Yes	Yes	Yes	Yes
OTA SW upgrade	Yes	-	No	No	No	Yes

LPWAN market share by sector



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Source: Infoholic Research, 2016

Public LPWAN networks

- Footprint in 24 countries
- Extensive coverage in Spain and France

- France (Orange, Bouygues)
- Belgium (Proximus)
- Netherlands (KPN)
- Swiss (Swisscom)
- US (Senet)
- India (Tata Communications)
- Korea (SK Telecom)

Things Connected

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

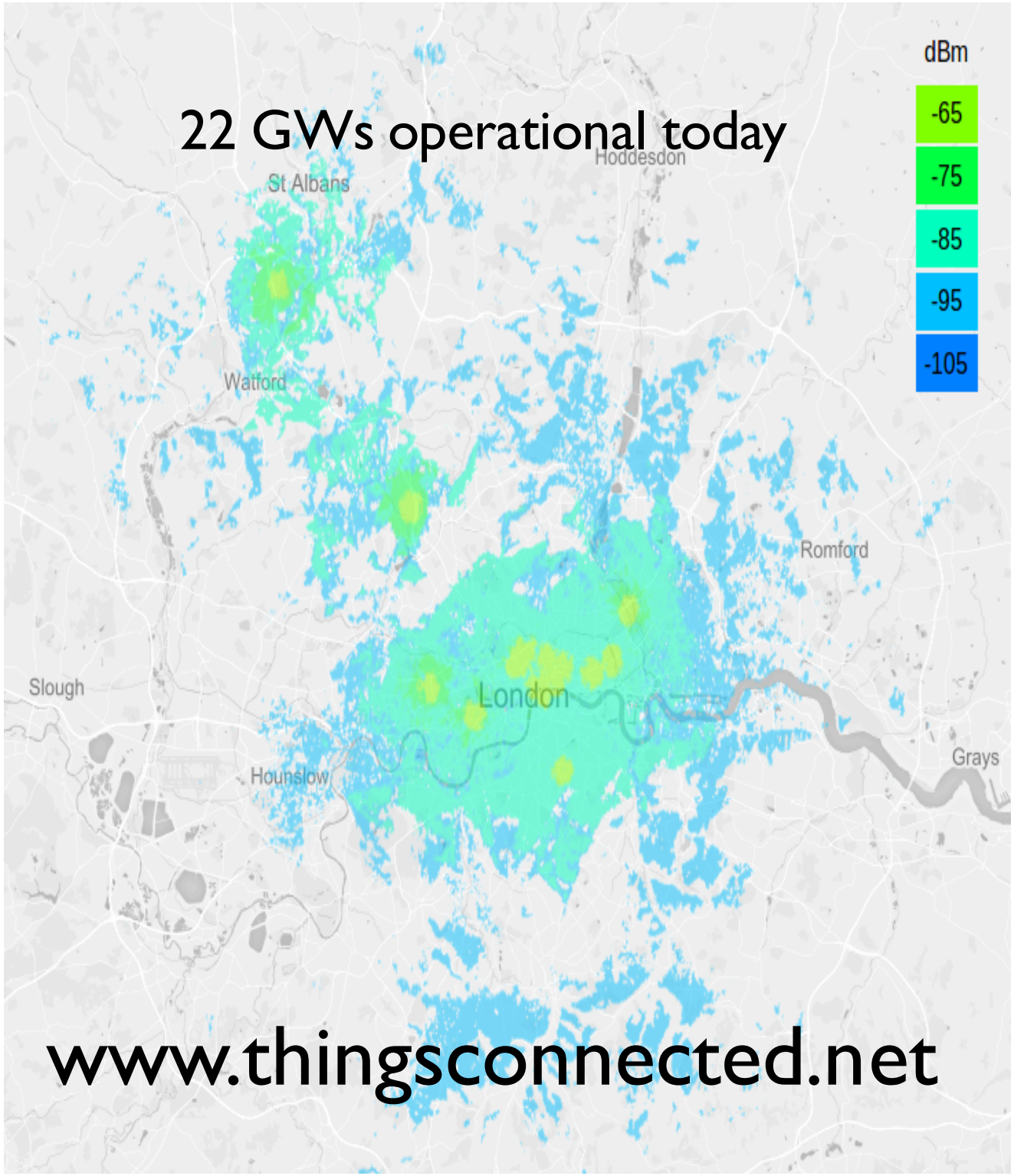
- Establish an open low power wide area network (LPWAN) in London to be used as innovation testbed for the IoT community

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

Things Connected

First London-wide LoRaWAN

- Open, free to use network for experiments and innovation
- First phase roll out to cover central London
- Second phase Demand based extensions within M25 boundary
- Up to 50 LoRaWAN gateways to cover greater London area in 2017



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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
- Both IoT data platforms and LPWANs are key technology enablers for the IoT and will have an significant role to play in future
- There are plenty of challenges to solve and exciting opportunities, so its 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.