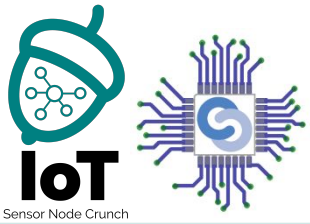


Embedded Systems Laboratory

Internet of Things

Lecture 1 - Introduction

Team and schedule

Team:

- Lectures: Laura Ruse & invited speakers
- Labs: Cosmin Chenaru & Robert Alexă

Schedule:

- Lecture: Wednesday 8-10
- Lab: TBD

Course Materials

- Wiki page (SRIC sections): https://ocw.cs.pub.ro/courses/iothings
  - Lecture slides
  - Labs
  - Project
  - Class Register
- Moodle page: https://curs.upb.ro/2022/course/view.php?id=4867

Grading

- Labs & Project & Tests
  - 1p Lab activity
  - 4.5p Project
  - 0.5p Lecture tests

  2.5p from the lab, project & tests are required to enter the exam.

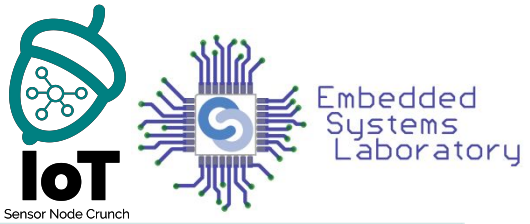
- Exam
  - 4p Final exam

  A total of 5 points are required to pass the class.

Class Project

- Goal: obtain hands-on experience
- Potential topics on the wiki
- You may choose your own topic
- Milestones:
  - Initial proposal
  - Intermediary project presentation
  - Final project presentation

Course Goals



- Learn both fundamentals and applications of IoT networks
- Obtain hands-on experiences on developing IoT applications
- Discuss challenges and opportunities

Course Topics

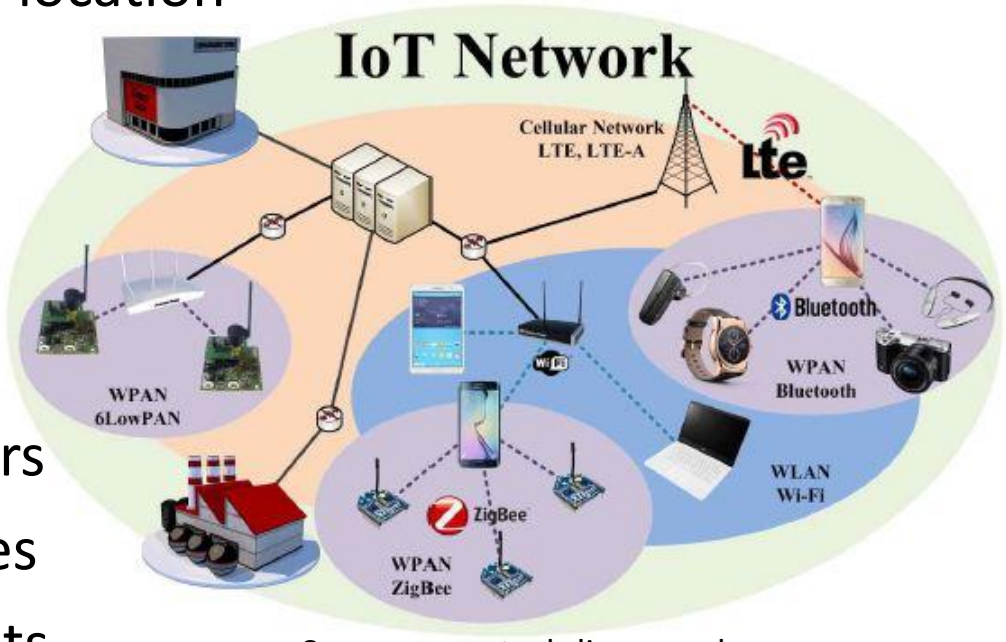
- IoT Applications
- Communication protocols
- Attacks and security solutions
- Operating Systems

Lecture Outline

- Pervasive wireless IoT applications
- Challenges facing wireless communication

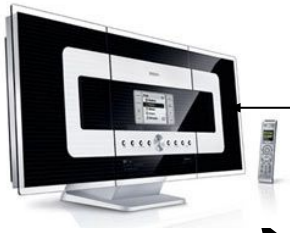
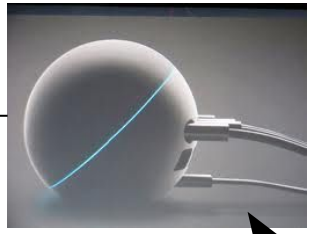
IoT

- Network of things/nodes
- Collect data from the environment
- Send data to a local/remote location
- Actuate
- Unique identifier
- Connected to the Internet
- Various types of devices:
  - sensors, RFIDs, actuators
  - wearables, smartphones
  - smart appliances, tablets



Source: opentechdiary.wordpress.com

Home Networks



satellite

WiFi
802.11g/n
WiFi
Bluetooth
NFC
WiFi

UWB

bluetooth

WiFi

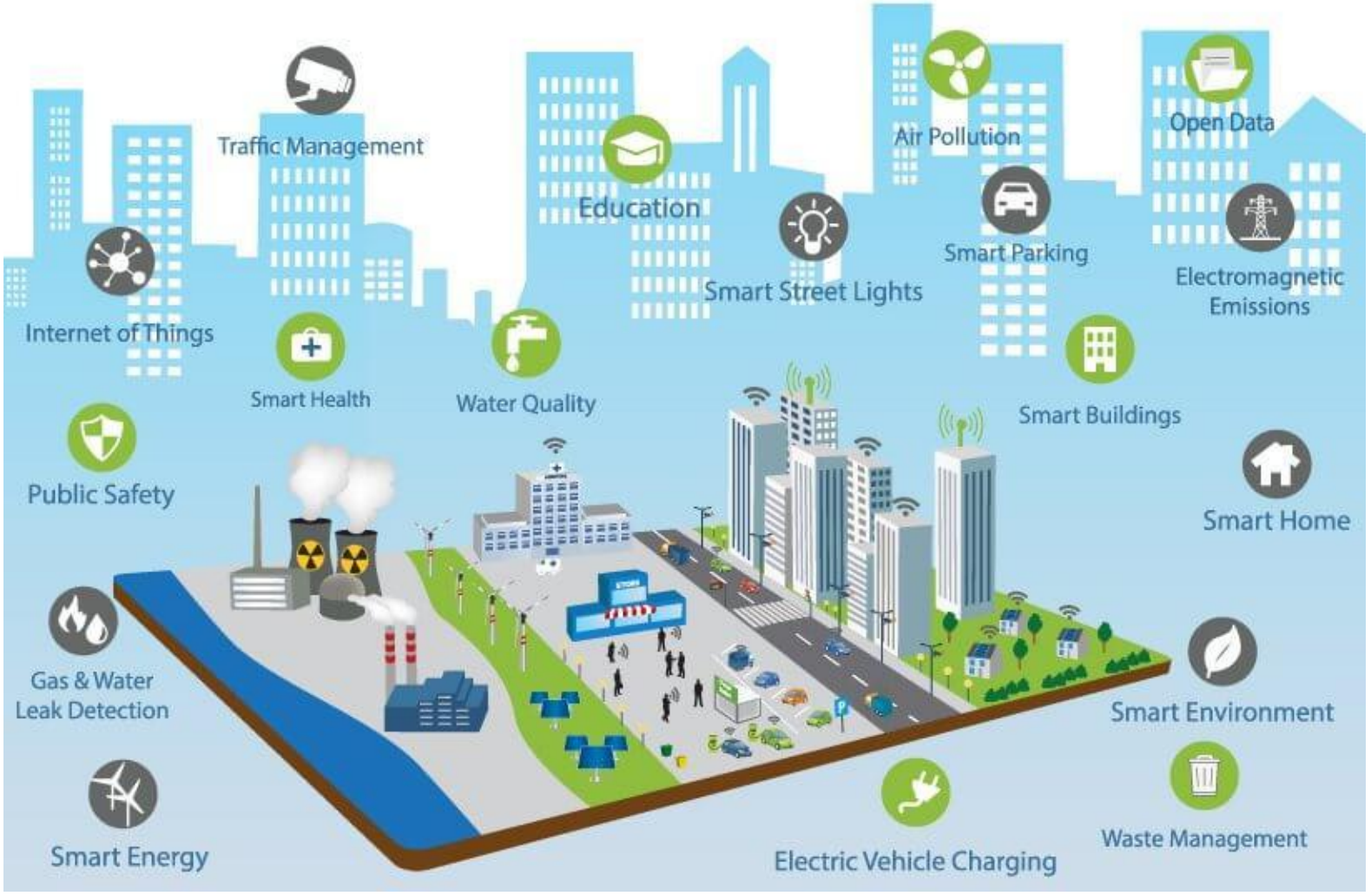
cellular

Use Case: Smart home

- Sensors
  - luminosity, temperature, humidity, pollution
- Smart meters
- Alarm system
- Smart appliances
  - Fridge, tv, AC, air filter, thermostat, light bulbs
- Everything is connected
- WiFi

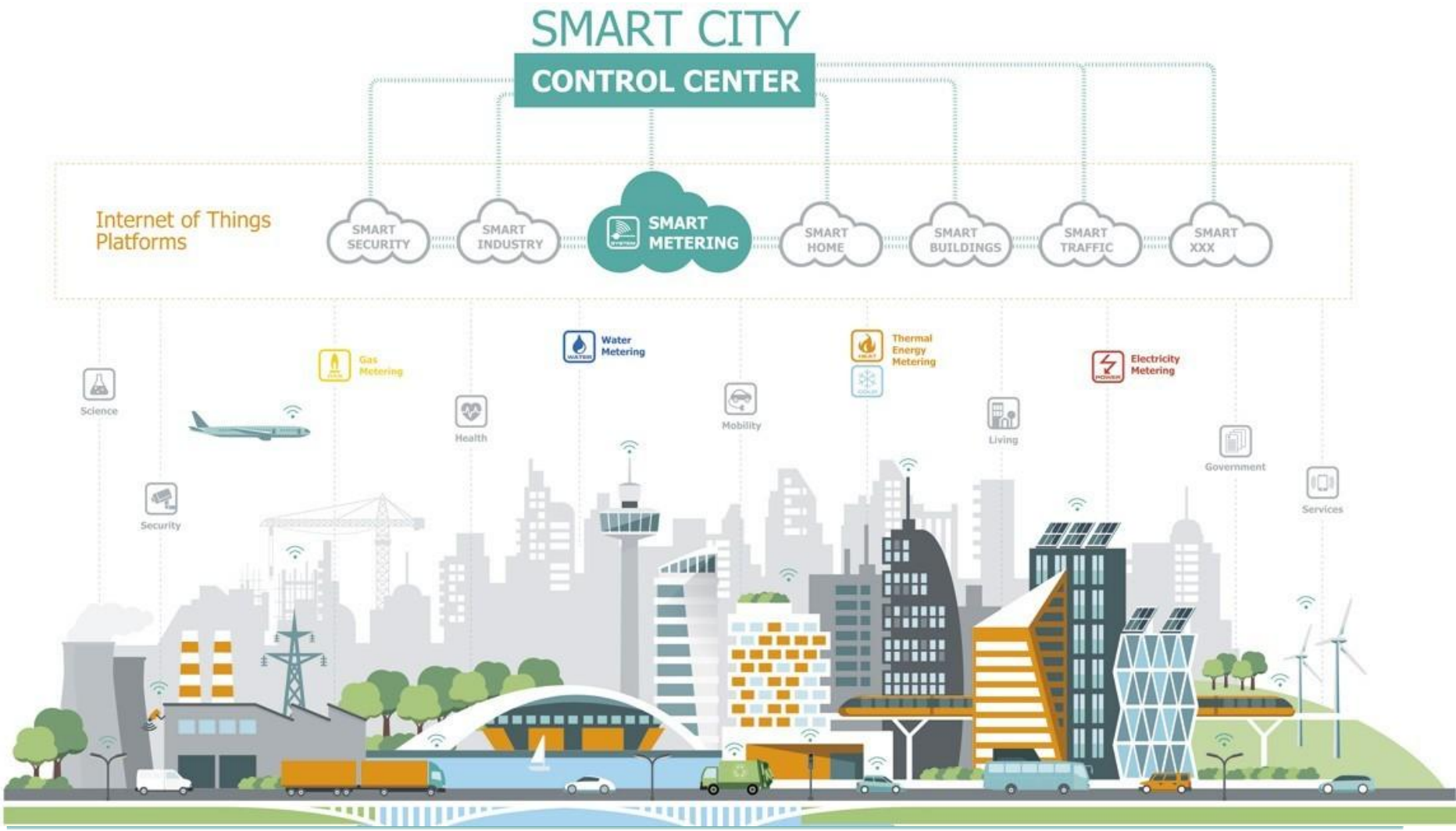
Source: https://corp.smartbrief.com/original/2019/01/5-trends-smart-home-technology

Use Case: Smart City



Source: https://internetofbusiness.com/global-smart-city-platform-market/
Smart cities: https://www.bmw.com/en/innovation/smart-cities.html

Use Case: Smart Metering

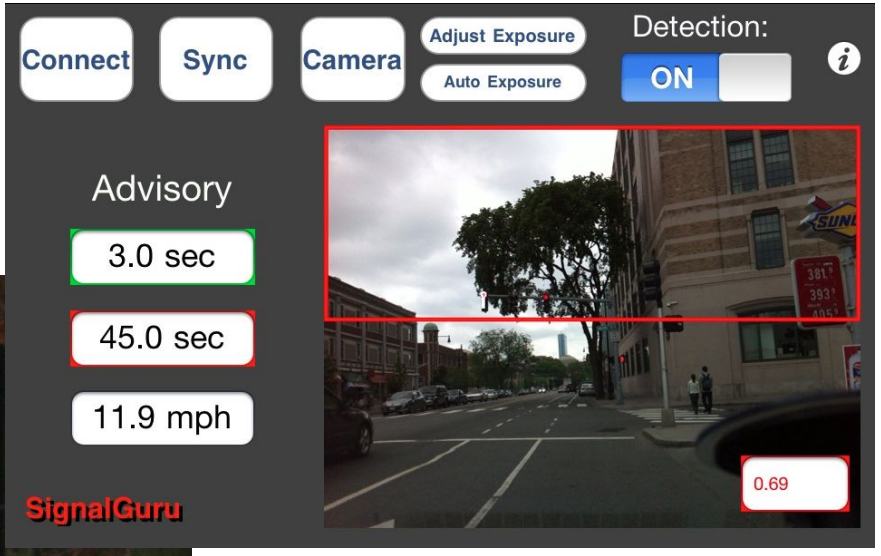


Source: https://smartwatermagazine.com/news/diehl-metering/smart-cities-and-industries-iot-solutions-diehl-metering

Use Case: Mesh Network for Disaster Recovery/Military

- 9/11, Tsunami, Hurricane Katrina, South Asian earthquake …
- Wireless communication and mobile computing capability can make a difference between life and death
  - rapid deployment
  - efficient resource and energy usage
  - flexible: unicast, broadcast, multicast, anycast
  - resilient: survive in unfavorable and untrusted environments

Use Case: Traffic Signal Advisor



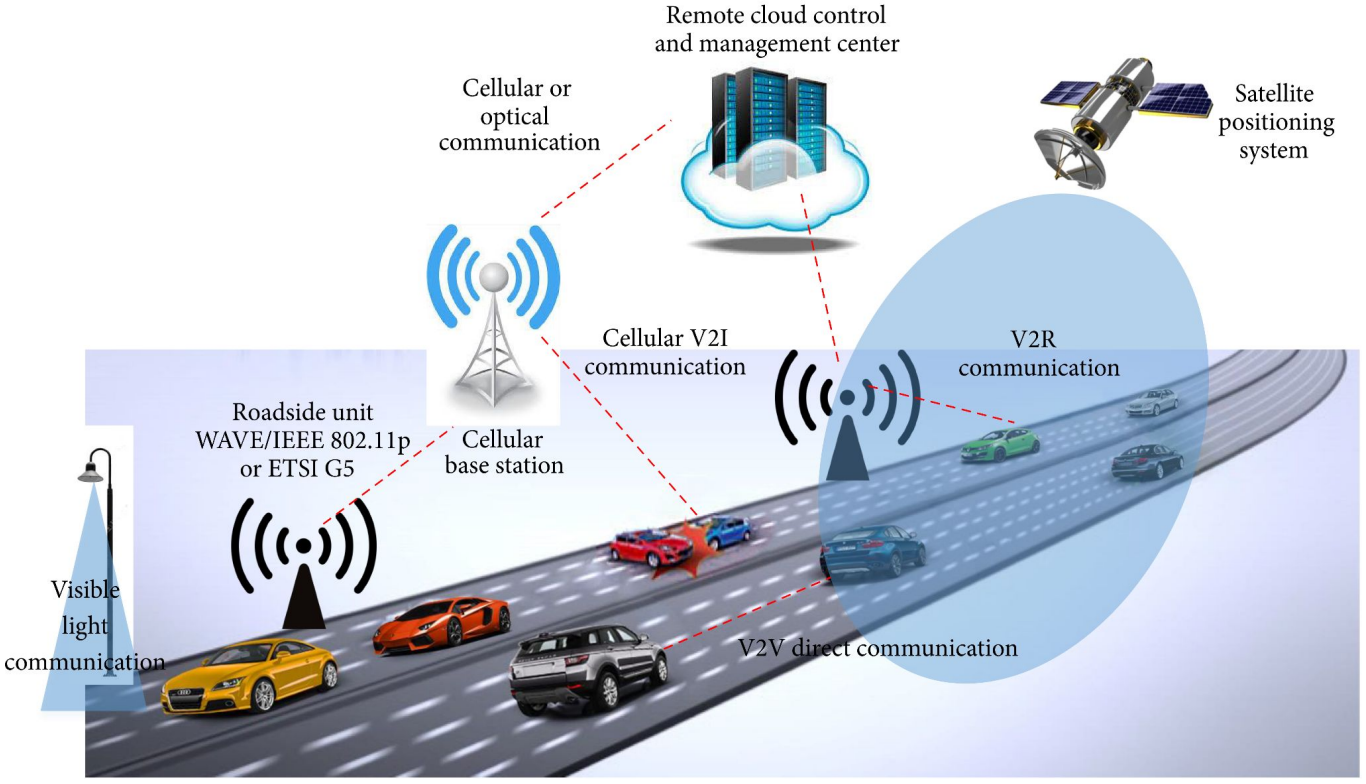
Source: http://www.princeton.edu

Use Case: Traffic Signal Advisor

Source: http://www.princeton.edu

Use Case: Vehicular Networks

- vehicle-to-vehicle (V2V),
- vehicle-to-infrastructure (V2I)
- vehicle-to-hand-held-devices (V2D) communications



Source: A Survey on Infrastructure-Based Vehicular Networks, Silva et al.

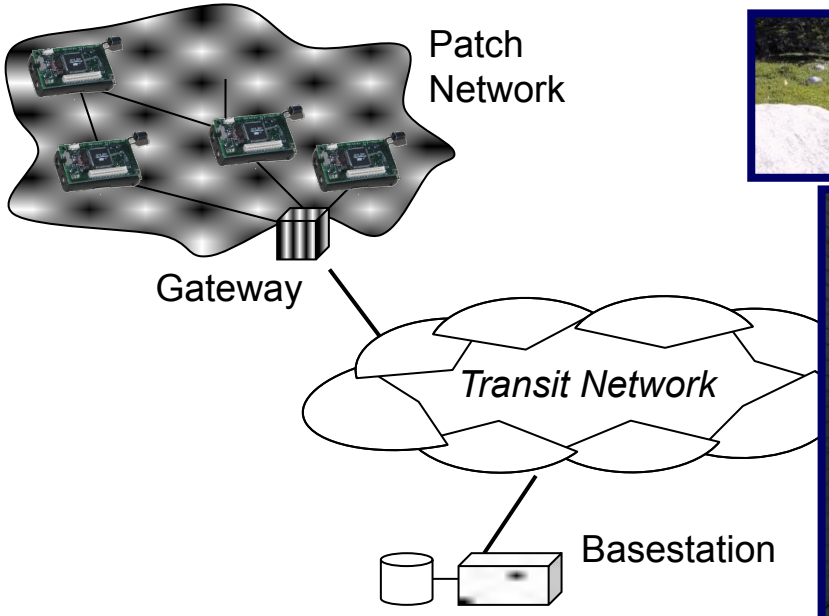
Collision Avoidance : V2V Networks

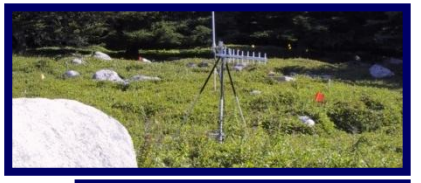
Stalled vehicle warning

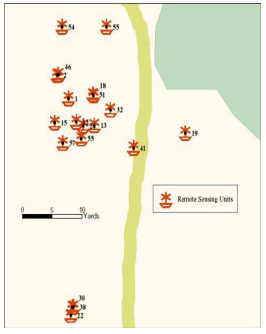
Blind spots

Use Case: Habitat Monitoring

A 15-minute human visit leads to
20% petrel offspring mortality







Source: Wireless Sensor Networks for Habitat Monitoring, Mainwaring et al.

Sensing Capabilities
*Regular Smartphone

Enabling Infrastructures

- Development and deployment of wireless infrastructures
  - WiFi, Bluetooth, NFC, LoRaWAN, UWB, ZigBee, etc.
- Development and deployment of localization infrastructures
  - Outdoor: GPS
  - Indoor: sensors+fingerprinting (Wireless, BLE, Magnetic)
- Development and deployment of sensor networks

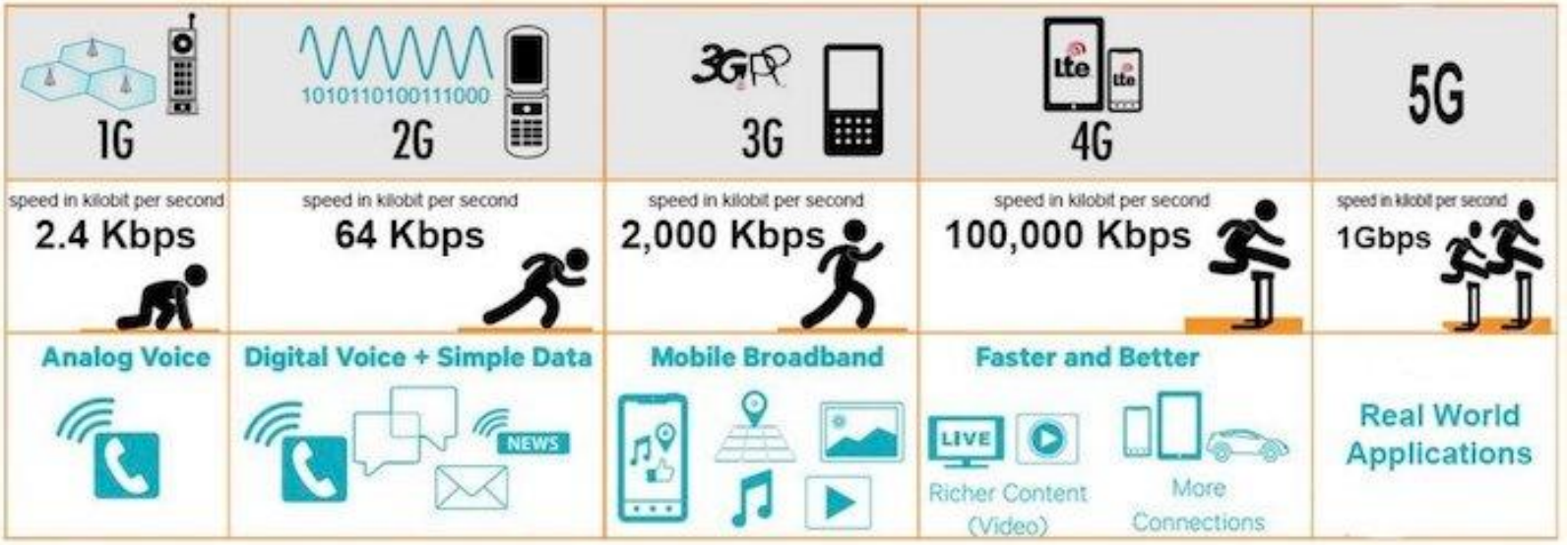
Wi-Fi

Wi-Fi generations

Generation/IEEE Standard	Maximum Linkrate	Adopted	Frequency
Wi-Fi 6 (802.11ax)	600–9608 Mbit/s	2019	2.4/5 GHz 1–6 GHz ISM
Wi-Fi 5 (802.11ac)	433–6933 Mbit/s	2014	5 GHz
Wi-Fi 4 (802.11n)	72–600 Mbit/s	2009	2.4/5 GHz
Wi-Fi 3 (802.11g)	3–54 Mbit/s	2003	2.4 GHz
Wi-Fi 2 (802.11a)	1.5 to 54 Mbit/s	1999	5 GHz
Wi-Fi 1 (802.11b)	1 to 11 Mbit/s	1999	2.4 GHz

Source: https://evanmccann.net/blog/wifi-101/faq

Cellular networks



1G

Released: 1979

Standards: NMT, AMPS & TACS

Capabilities:
- Analog voice

2G

Released: 1991

Standards: GSM & CDMA

Capabilities:
- Digital voice
- Encrypted communication
- Limited roaming
- SMS & MMS

Extensions:
- GPRS (2.5G)
- CDMA2000 (2.5G)
- EDGE (2.75G)

3G

Released: 2002

Standards: UMTS & EV-DO

Capabilities:
- Mobile broadband
- Locating services
- Multimedia streaming
- Seamless global roaming

Extensions:
- HSPA+ (3.5G)

4G

Released: 2009

Standards: LTE

Capabilities:
- High Speed mobile Internet
- IP-based packet switching
- HD multimedia streaming
- Seamless global roaming

Extensions:
- Feature extension through new category/releases

5G

Released: 2019

Standards: 5G

Capabilities:
- Private networks (local use frequency)
- (I)IoT Ready
- Massive Machine Type communication
- Ultra-low-latency
- Ultra-high reliability
- Millimeter wave support

Extensions:
- Feature extension through new categories/releases

Sources: http://ioarp.org/ioarp-admin-panel/upload/articles/1460357886_IDL-ICCN15-011.pdf
https://www.symmetryelectronics.com/blog/the-advancement-of-cellular-network-standards/

Improving Infrastructure: Power Efficiency

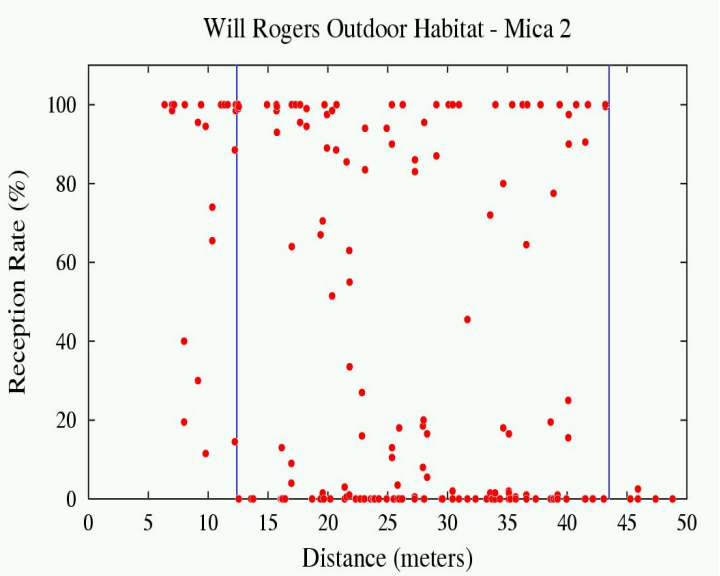
	α_u (mW/Mbps)	α_d (mW/Mbps)
LTE	438.39	51.97
3G	868.98	122.12
WiFi	283.17	137.01

Source: A Close Examination of Performance and Power Characteristics of 4G LTE; Mobisys'12

Challenge 1: Unreliable and Unpredictable Wireless Coverage

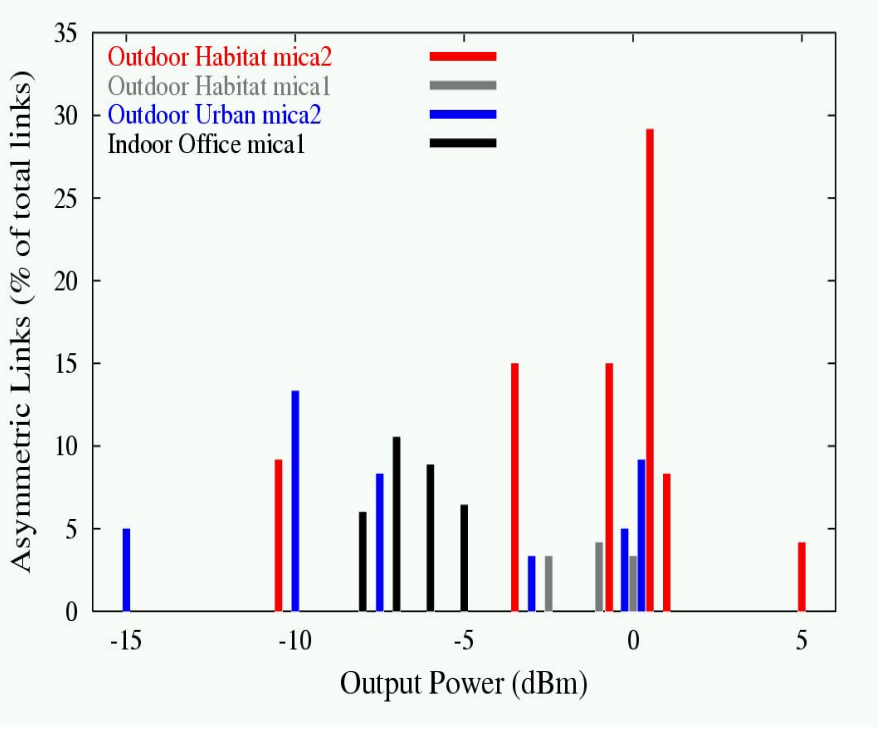
Wireless links are not reliable: they may vary over time and space

Reception v. Distance



*Cerpa, Busek et. al

Reception vs. Power

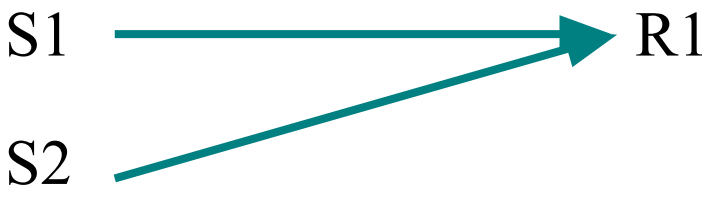


Challenge 2: Open Wireless Medium

- Wireless interference

Challenge 2: Open Wireless Medium

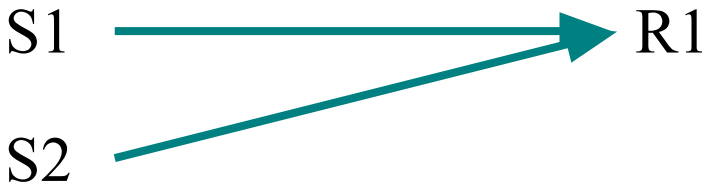
- Wireless interference



- Hidden terminals

Challenge 2: Open Wireless Medium

- Wireless interference



- Hidden terminals

- Exposed terminal

Challenge 2: Open Wireless Medium

- Wireless interference

- Hidden terminals

- Exposed terminal

- Wireless security
  - eavesdropping, jamming, denial of service

Challenge 3: Mobility

- Mobility causes poor-quality wireless links
- Mobility causes intermittent connection
- Mobility changes context
  - Location
  - Type of connection

Challenge 4: Portability

- Limited battery power
- Limited processing, display and storage

Sensor node
- 802.15.4
- Wi-Fi
- Bluetooth

Wearable
- simple graphical display
- Wi-Fi, Bluetooth, NFC

Smartphone
- small graphical display
- Wi-Fi, Bluetooth
- 3G/4G/5G, NFC

Tablet/Laptop
- large graphical display
- Wi-Fi, Bluetooth

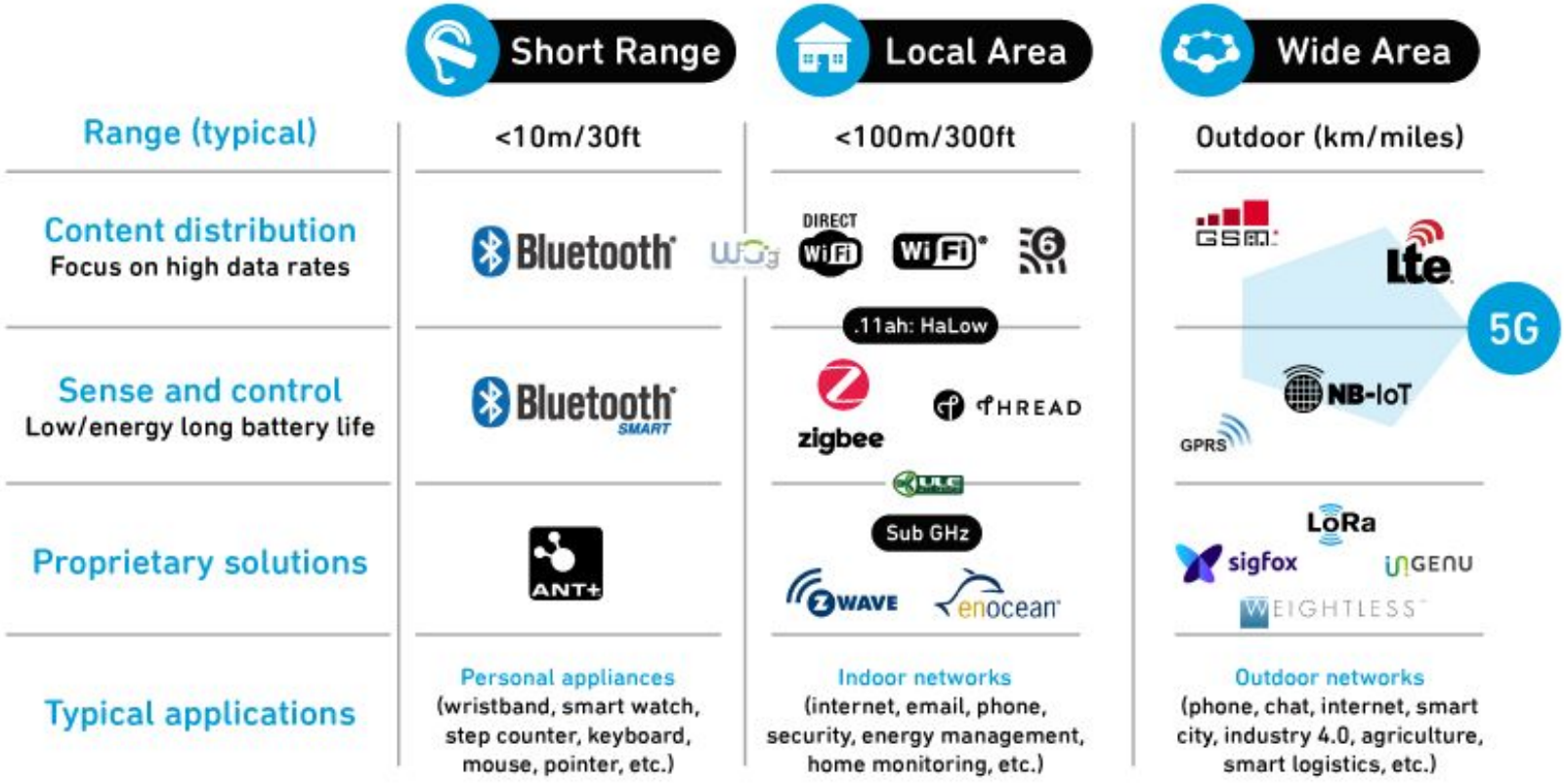
Performance/Weight/Power Consumption

Challenge 5: Changing Regulation and Multiple Communication Standards

- Different standards and frequencies in different areas
- Mobile devices must implement various standards and frequencies
- While roaming - adapt to local requirements
- The complexity of producing standards
- IEEE, IETF, ETSI

Challenge 5: Changing Regulation and Multiple Communication Standards

IoT: A Mix of Industry Standards



qorvo

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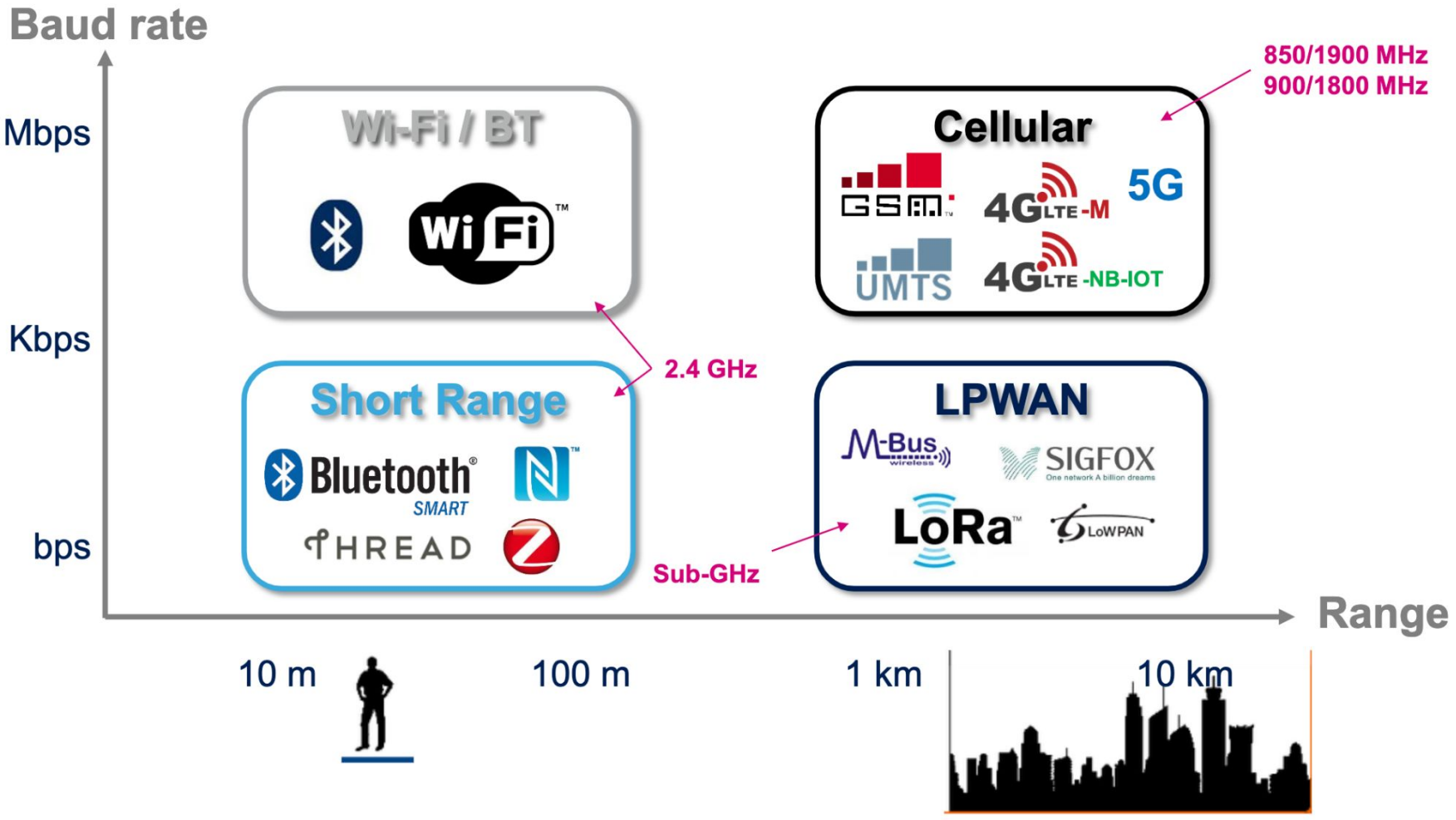
Source: https://www.qorvo.com/design-hub/blog/iot-standards-the-end-game

Challenge 5: Changing Regulation and Multiple Communication Standards



Source: https://www.enib.fr/~kerhoas/lora_pres.html

Keywords

- Internet of Things
- Wireless Sensor Networks
- Smart home
- Smart city
- Mobile Devices
- Wireless Communication
- Wi-Fi
- LTE
- ZigBee
- LoRa