Electronic Devices & Networks Annex
EDNA

G20 CDA Workshop
Paris, 20th May 2016

# Energy Efficiency of the Internet of Things

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# Key Points

## Standby energy, technologies, and standards analysis

- Already in 2025, the **standby energy consumption** of mains-connected **IoT** edge devices is **not negligible** anymore.
- **Energy saving IoT specific communication technologies and standards** are **available**. Main driver are IoT applications with battery powered edge devices.
- Smart phones as universal user interface devices drive also **energy saving mechanisms in mainstream standards** (e.g. WiFi)
- The observed examples of edge devices with high standby power are due to the use of **inappropriate technologies** or a **poor implementation** of an appropriate technology.
- **Considerable standby energy savings can be achieved** for mains-powered edge devices by using the same technologies as for battery powered devices and a proper implementation and configuration of the available power saving mechanisms.

# Content

- Project: Motivation and scope
- Structuring & prioritisation of IoT applications
- **Standby energy of prioritised IoT applications and edge devices**
- **Analysis of technology options and standards**
- General considerations for policy options

# Project «Energy Efficiency of the IoT»

## Motivation

### From media hype to reality

- **IoT is here**: In 2009 number of Internet connected devices already surpassed the world population [1)]
- **27 million additional devices** are connected **daily** to the IoT [1)]
- **50 billion** IoT things in 2020 [1) 2)]
- 200 connected things per person possible in long-term [1)] → potentially **hundreds of billions** edge devices

[1)] Cisco [2)] Gartner

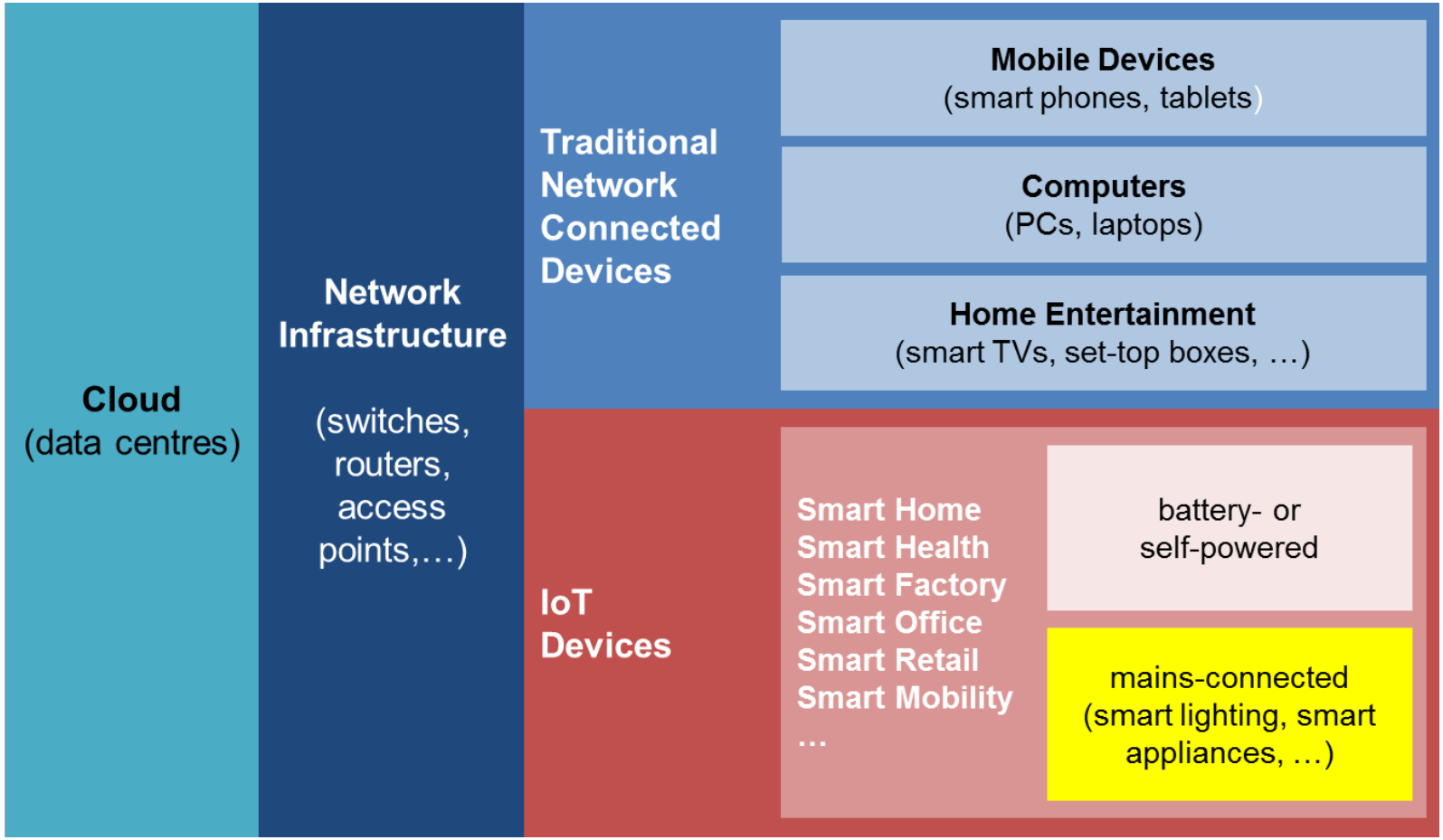
Source: Electronics Weekly

### Energy relevance

- IoT enables a **more efficient** use of energy.
- **Billions of additional IoT devices**, which are possibly **always on** due to network connection.

# Project

## Scope: Standby energy consumption of mains-connected IoT (edge) devices



# Structuring & Prioritisation

## Focus applications of project

| Application Area | Application | Device |
|---|---|---|
| Smart Home | smart lighting | smart LED bulb |
| | | gateway |
| | home automation (security, comfort, energy) | mains connected sensors (e.g. light buttons) |
| | | camera |
| | | gateway |
| | | actuators |
| | smart appliances (convenience, energy) | washing machine, dish washer, clothes dryer, coffee machine, oven, refrigerator, etc. |
| | | gateway |
| Smart Mobility | smart roads | roadside gateway |
| | smart street lighting | street light luminaires |

# Structuring & Prioritisation

## Smart Home applications

### Smart Lighting

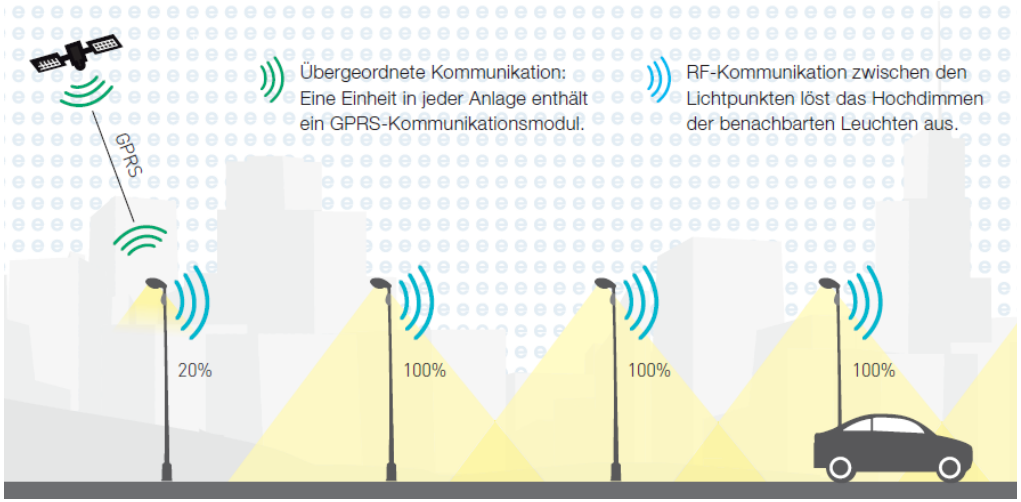
### Home Automation

### Smart Appliances

# Structuring & Prioritisation

## Smart Mobility applications

**Smart Street Lighting**




Source: Elektron

**Smart Roads (road-to-car communication)**

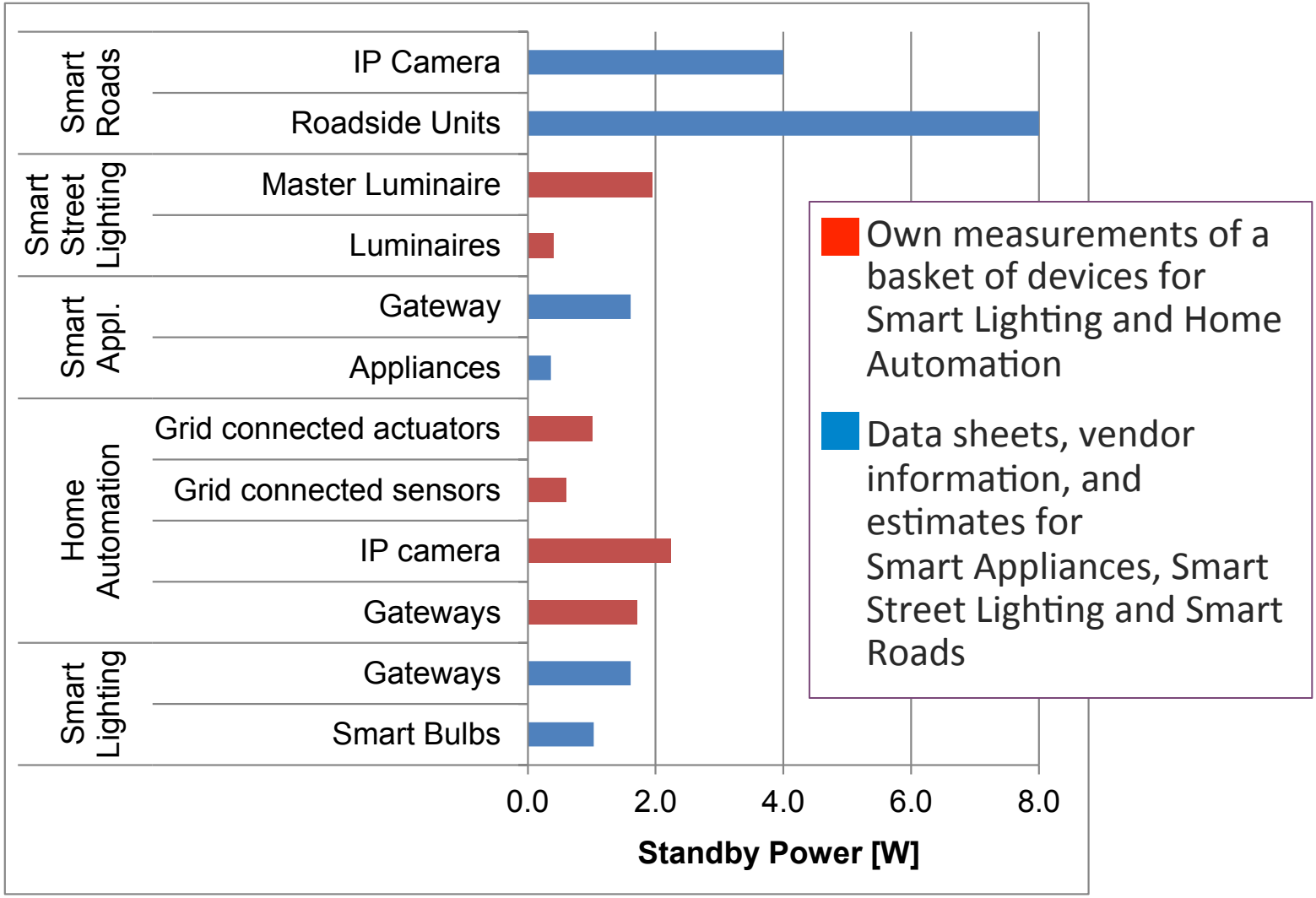
# Standby Power

## Measurements (example Smart Lighting)

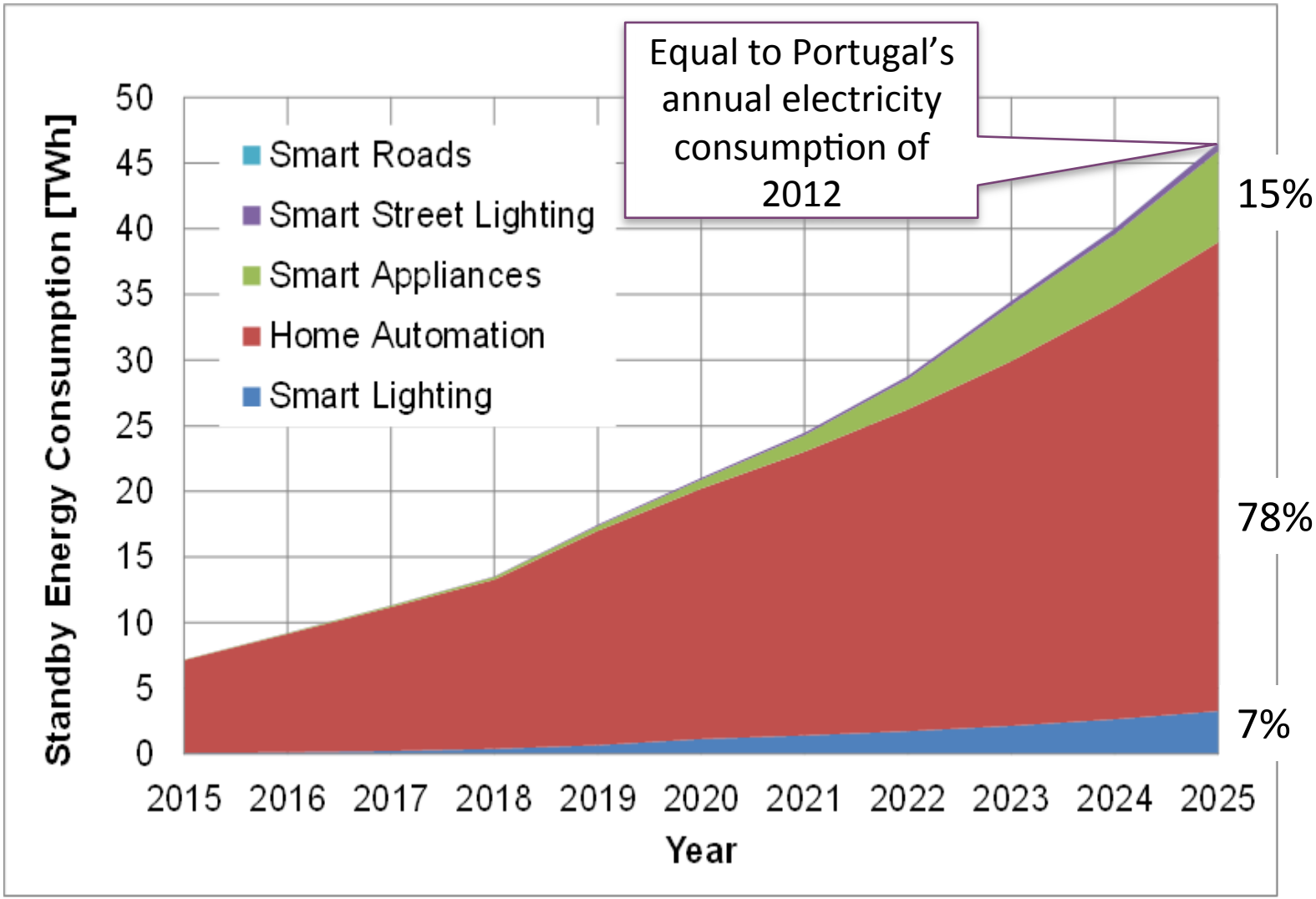
| Type | ID / Manufacturer | Needs Gateway | Communication Technology | Mean standby power [W] |
|---|---|---|---|---|
| Smart LED bulb | 1 / A | No | Wi-Fi | 3.0 |
| Smart LED bulb | 2 / B | No | Bluetooth Smart | 0.8 |
| Smart LED bulb | 3 / C | No | Bluetooth Smart | 0.7 |
| Smart LED bulb | 4 / D | Yes | ZigBee | 0.8 |
| Gateway | 5 / D | - | Wi-Fi | 1.4 |
| Smart LED bulb | 6 / E | Yes | ZigBee | 0.4 |
| Gateway | 7 / E | - | Ethernet | 1.7 |
| Smart LED bulb | 8 / F | Yes | ZigBee | 0.6 |
| Gateway | 9 / F | - | Ethernet | 1.7 |

# Standby Power per Device

## of priorisised devices (average values)



# World Wide Standby Energy Consumption

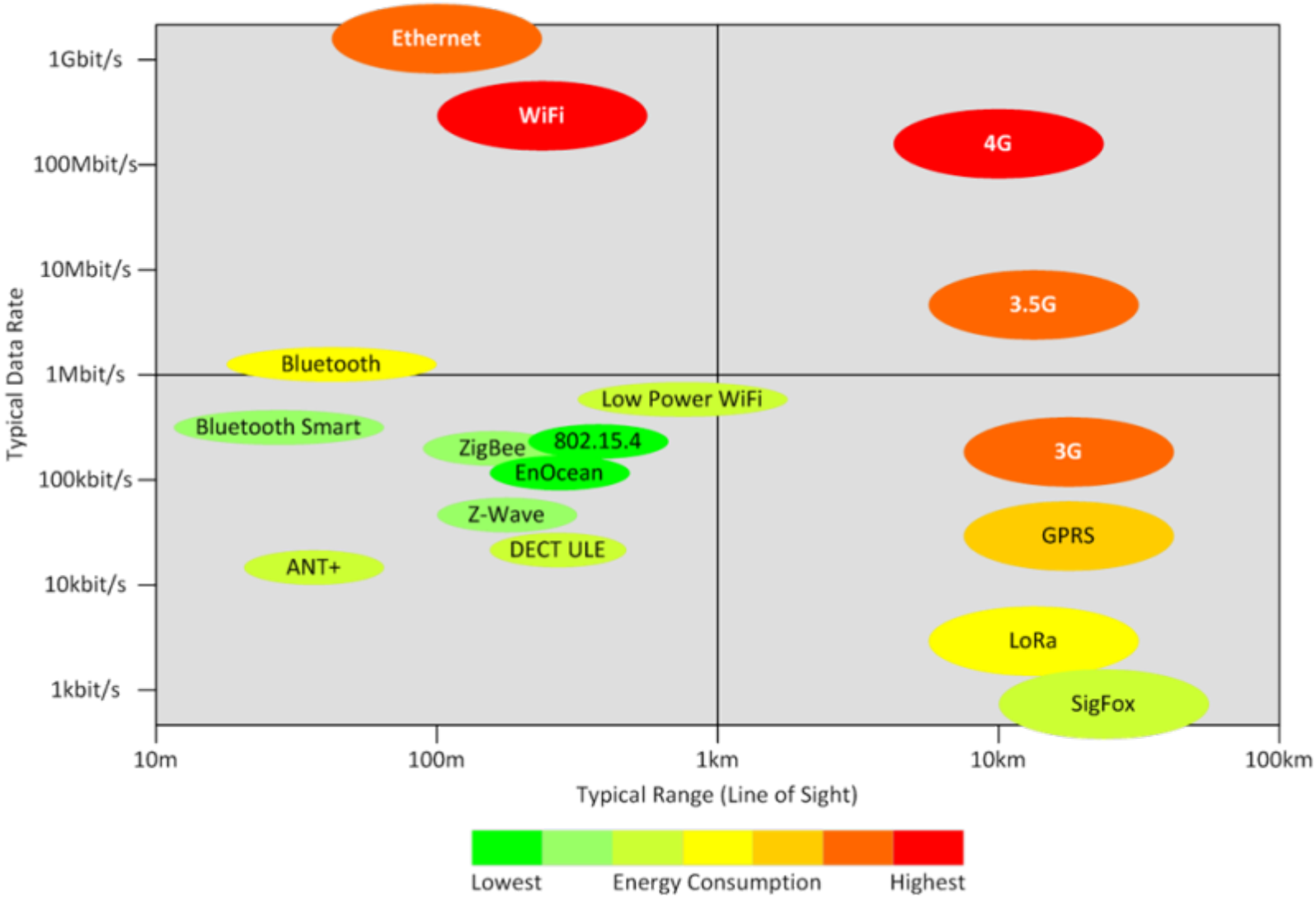


# Analysis of Standards

- OSI-Layers 1/2/7 determine energy consumption:
  - Layer 1 and 2 define physical communication and power saving mechanisms
  - Layer 7 defines use of power saving mechanisms
- Lowest power standards typically define entire OSI stack
- New **energy saving, application specific standards available**
  - Short range: EnOcean, Bluetooth Smart, Z-Wave, ZigBee, DECT-ULE, Low-Power WiFi (WiFi Halo)
  - Long range: LoRa, Sigfox
- **Energy saving mechanisms in established mainstream standards** (such as WiFi) available
  - Energy Efficient Ethernet
  - Wake-on-Lan (WOL)
  - Various WiFi power saving mechanisms
- Main driver: IoT applications with **battery powered edge devices**.

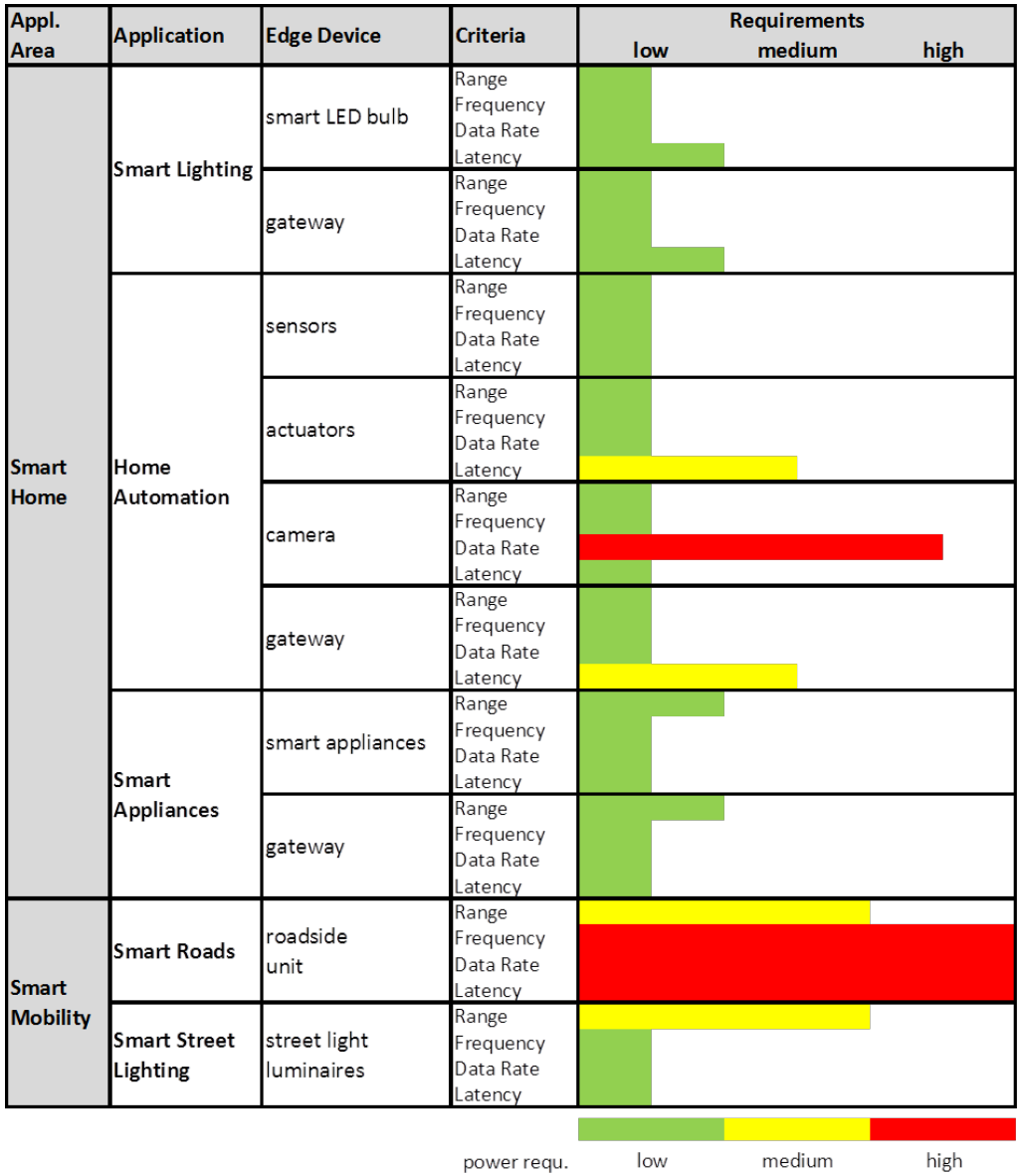
# Available Standards/Technologies

## Range versus bandwidth



# Technical Requirements of Applications

- Criteria:
  - Range
  - Bandwidth
  - Frequency
  - Latency
- The greater the requirements, the higher the energy consumption



# Matching Technologies and Applications

## Preferred technologies regarding standby energy

| Appl. Area | Application | Edge Device | ANT+ | Bluetooth | Bluetooth Smart | DECT ULE | Z-Wave | ZigBee | 802.15.4-2011-based | EnOcean | WiFi | Low Power WiFi | Ethernet | GPRS | 3G (UMTS) | 3.5G (HSPA) | 4G (LTE) | LoRa | Sigfox |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Smart Home | Smart Lighting | smart LED bulb | y | n | b | y | y | y | y | y | n | y | x | x | x | x | x | x | x |
| | | gateway | x | x | x | x | x | x | x | x | y | b | y | y | n | n | n | x | x |
| | Home Automation | sensors | y | n | y | y | y | y | b | b | n | y | n | x | x | x | x | x | x |
| | | actuators | y | n | y | y | y | y | b | b | n | y | n | x | x | x | x | x | x |
| | | camera | x | x | x | x | x | x | x | x | y | x | b | x | y | y | y | x | x |
| | | gateway | x | x | x | x | x | x | x | x | y | x | b | x | y | y | y | x | x |
| | Smart Appliances | smart appliance | y | n | b | y | y | y | b | b | n | y | n | x | x | x | x | x | x |
| | | gateway | x | x | x | x | x | x | x | x | y | b | y | y | n | n | n | x | x |
| Smart Mobility | Smart Roads | roadside unit | x | x | x | x | x | x | x | x | b | x | x | x | x | x | x | x | x |
| | Smart Street Lighting | street light luminaires | x | x | x | x | x | x | x | x | x | x | x | y | n | n | n | b | b |

| | |
|---|---|
| b | Best Available Technology |
| y | Possible Technology |
| n | Not Recommended Technology |
| x | Not Appr. Technology |

# Matching Technologies and Applications

## Example Smart Lighting

- Technical requirements
  - Moderate range, sporadic data transmission, small data volumes, low latency requirements
- Currently used technologies
  - Bluetooth Smart, WiFi, Z-Wave, ZigBee
- Preferred technology regarding standby energy: **Bluetooth Smart**
  - Low standby power of edge device
  - No gateway needed (direct connection to mobile device possible)
- Possible Technologies
  - DECT ULE, Z-Wave, ZigBee, EnOcean, LP-WiFi
  - Low standby power, but gateway needed
- Not recommended regarding standby energy
  - WiFi: High standby power, high bandwidth not needed

# Policy Options

## General considerations

- Special characteristics of IoT markets and technologies
  - The IoT market is forecast to grow rapidly.
  - The used technologies evolve constantly at a high pace.
  - The IoT is not homogeneous, but comprises many and diverse product categories.
- Quickly implementable policies preferred
  - generic
  - adaptable to easily cater for technology changes
  - focus on high-impact areas (i.e. high-volume product categories), and
  - use existing policy frameworks wherever possible

# Thank you for your attention.