DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE

IoT for Smart Cities
Part B: technologies

Andrea Zanella

zanella@dei.unipd.it

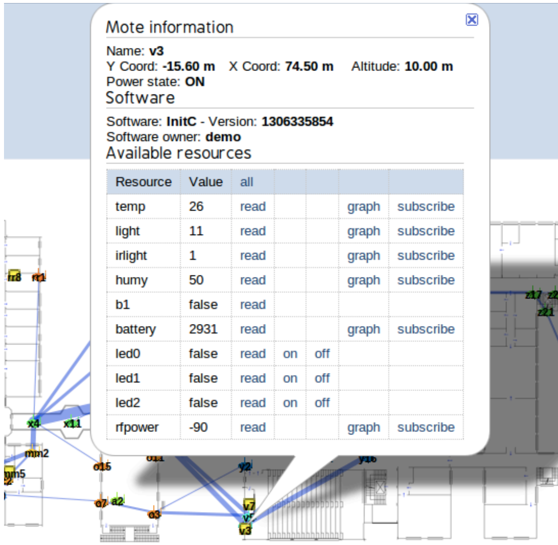
SIGnals processing &
NETworking research group

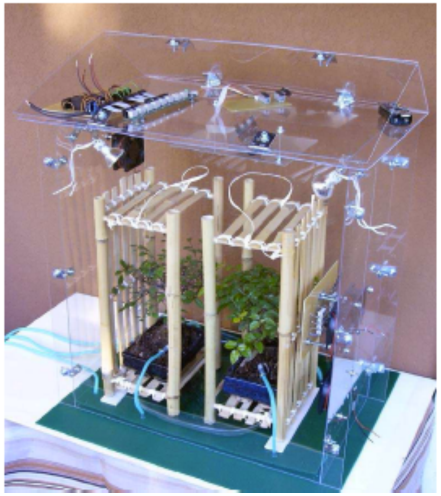
PhD School in Brain Mind and Computer Science - UNIPD

EMBEDDED DEVICES

IoT: sw&hw

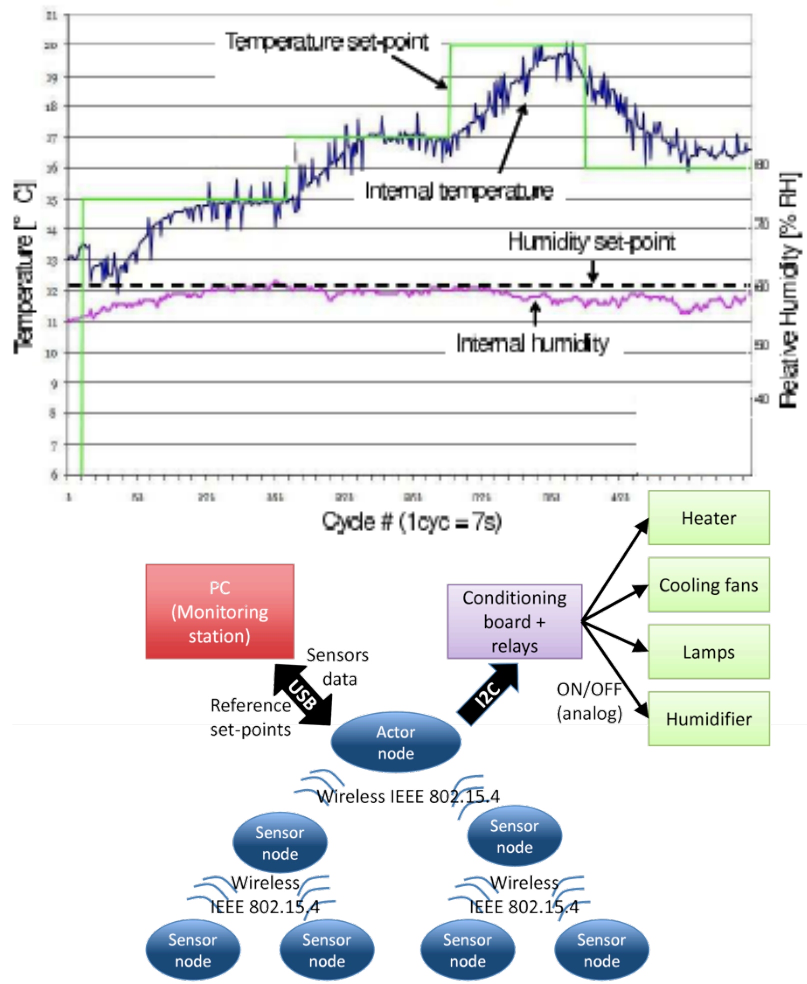
- Protocols and interfaces
  - Theory, Simulation, Implementation
  - Highly scalable
  - Easy data access
  - Robustness and security
- Performance optimization
  - Low energy consumption
  - Energy harvesting
  - Real time features
  - Data redundancy and consistency
- Optimization of the hardware and software
  - Lower devices cost
  - Lower maintenance costs



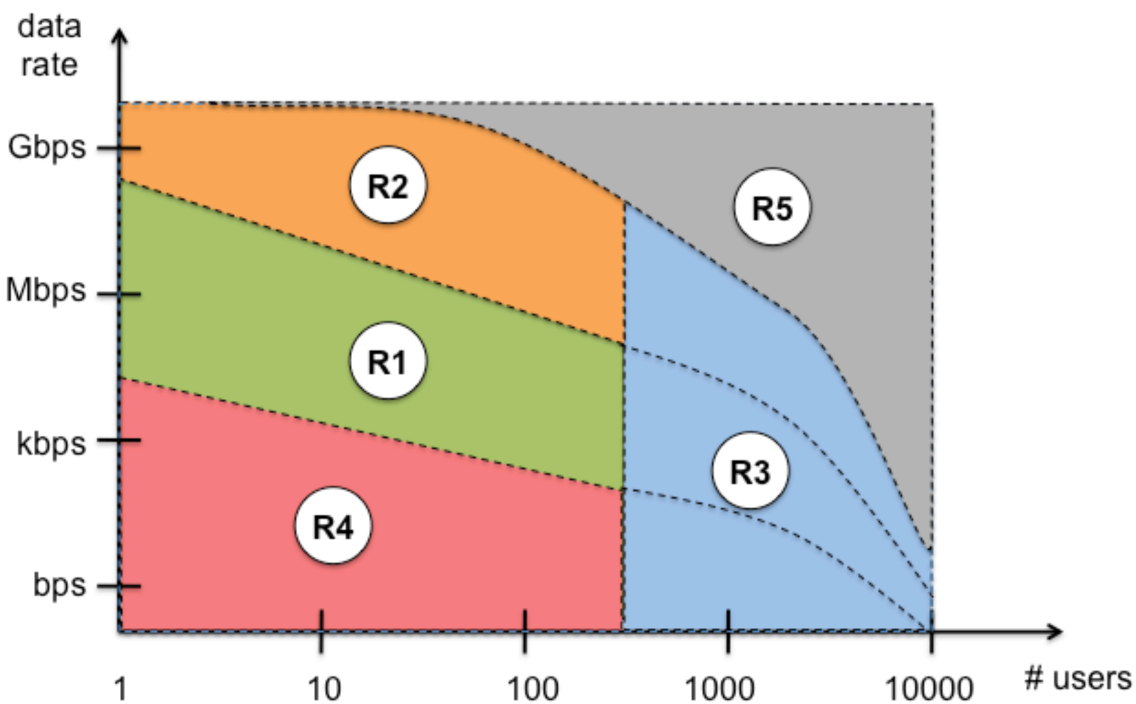


IoT: modelling and analysis

- Accurate models for environment and physical processes
  - Estimate and prediction of the monitored processes
  - Minimization of data exchange
    - Lower interferences
    - Lower power consumption



The shape of wireless to come



R1: today's systems

R2: high-speed versions of today's systems

R3: massive access for sensors and machines

R4: ultra-reliable connectivity at minimal rate

R5: physically impossible

5G=R1+R2+R3+R4

[Ref] F. Boccardi, R. W. Heath, A. Lozano, T. L. Marzetta, and P. Popovski, "Five Disruptive Technology Directions for 5G", IEEE Communications Magazine, February 2014.

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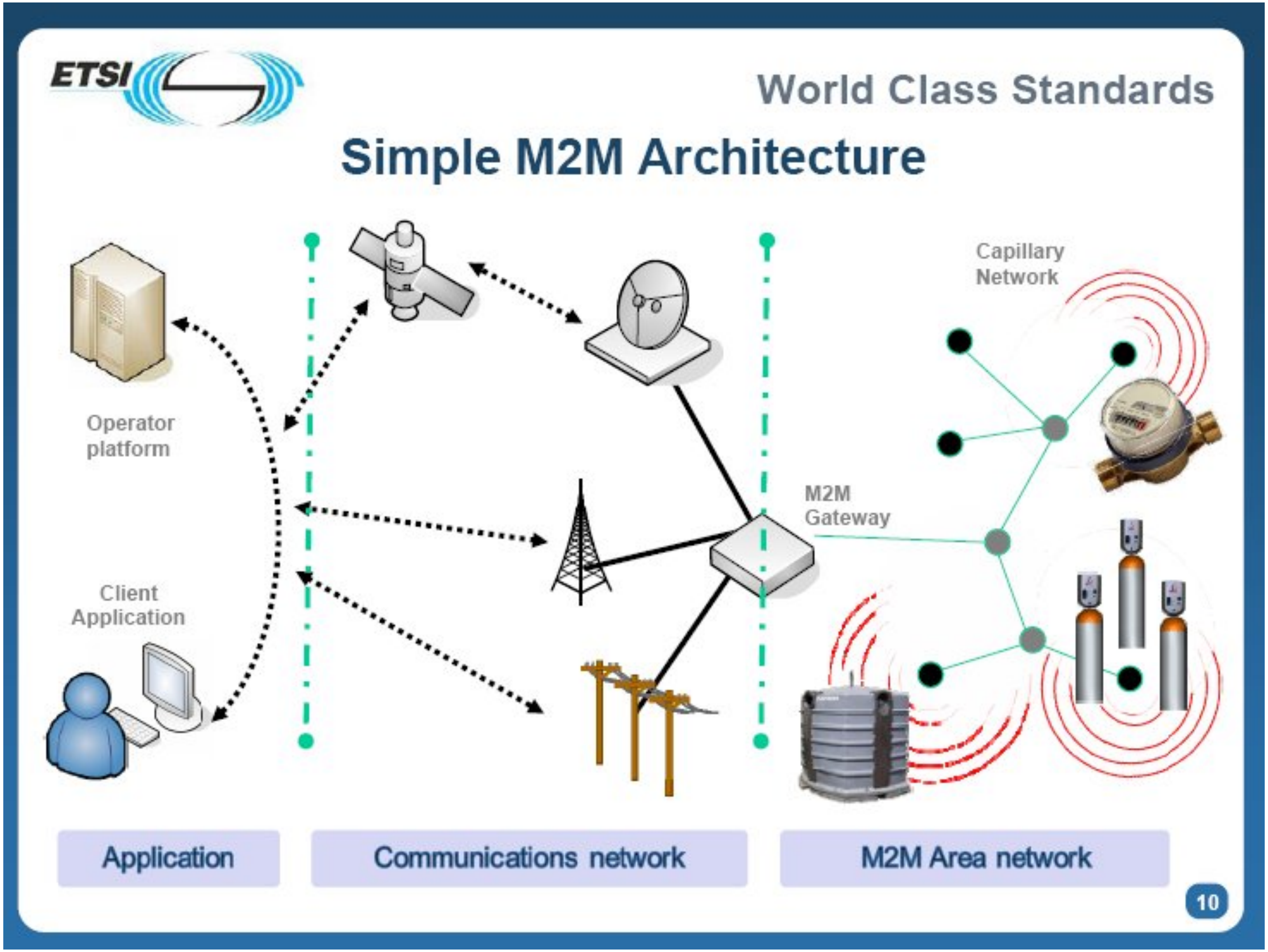
M2M reference architecture



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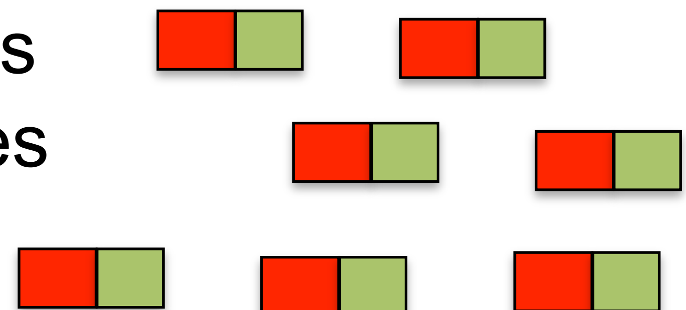
Machine Network Traffic

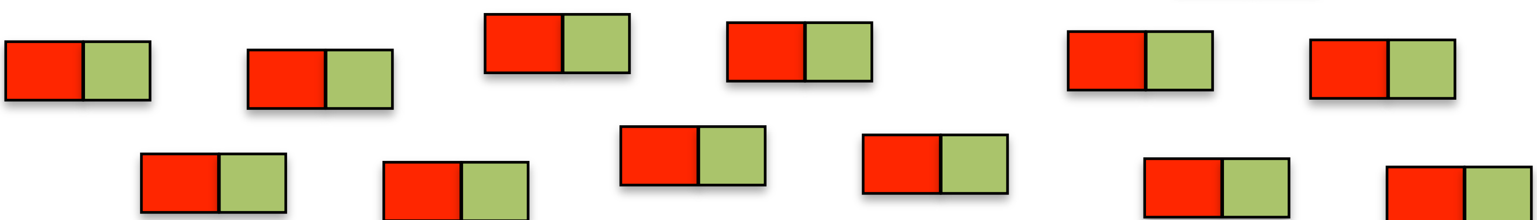
- M2M devices generate traffics of the following types
  - Periodic: smart metering application
  - Event-driven: emergency event report
  - Continuous: surveillance camera
- Large volume of different types of traffic at core network
  - Guarantee of diverse QoS traffic requirements
  - Reliability of both human-to-human and M2M traffic

high-speed wireless vs. M2M

- high-speed systems built from information-theoretic principles with small control info and **large data**

- M2M require short data packets from massive number of devices each transmitting sporadically

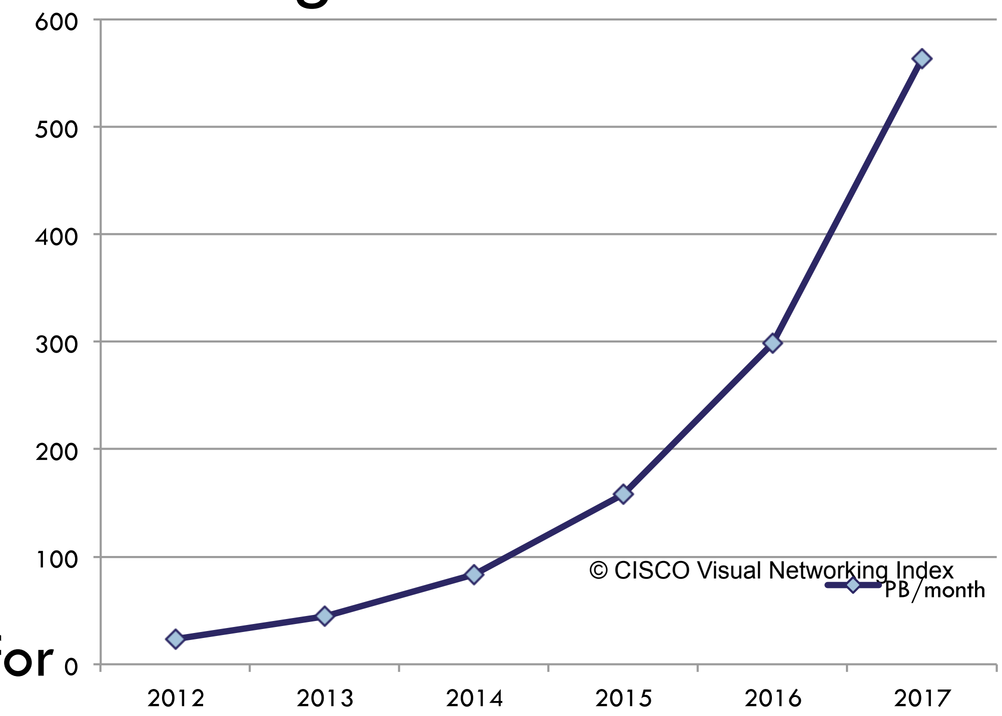




enormous M2M growth expected

- 24-fold traffic growth from 2012 to 2017
- 4.6-fold growth of M2M #subscriptions
  - from 369 million in 2012 to 1,7 billion in 2017
- M2M traffic will account for approximately 5 % of overall mobile traffic in 2017

global M2M traffic



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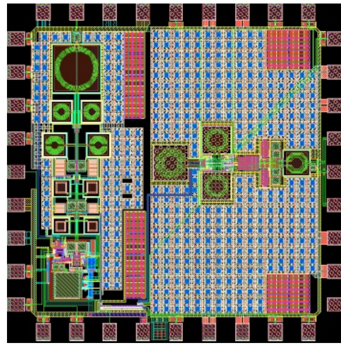
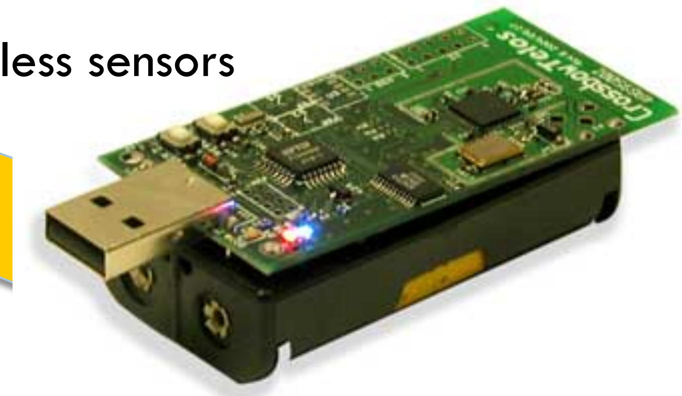
Components

- ✓ Low-power wireless transmitters



- ✓ Wireless sensors

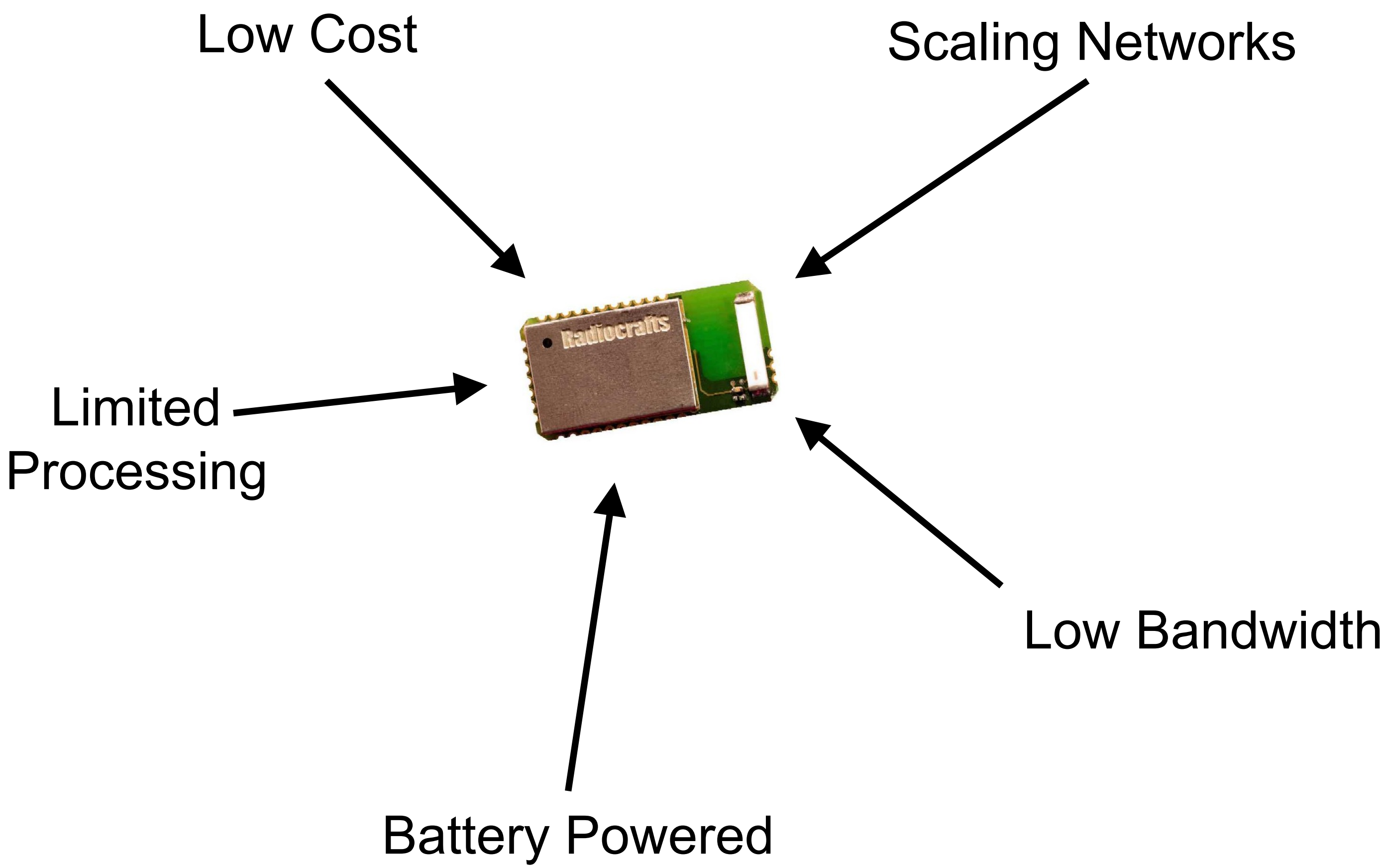


- ✓ Management systems

- ✓ Algorithms and communication protocols

- ✓ Services

What is "constrained"



Three main approaches

- Short range multi-hop
  - ZigBee
  - WiFi low energy
  - Bluetooth low energy

- Cellular
  - GSM
  - UMTS/3G
  - LTE
  - 5G (???)

- Medium/long range proprietary technologies
  - Semtech LoRa
  - SigFox
  - Neul

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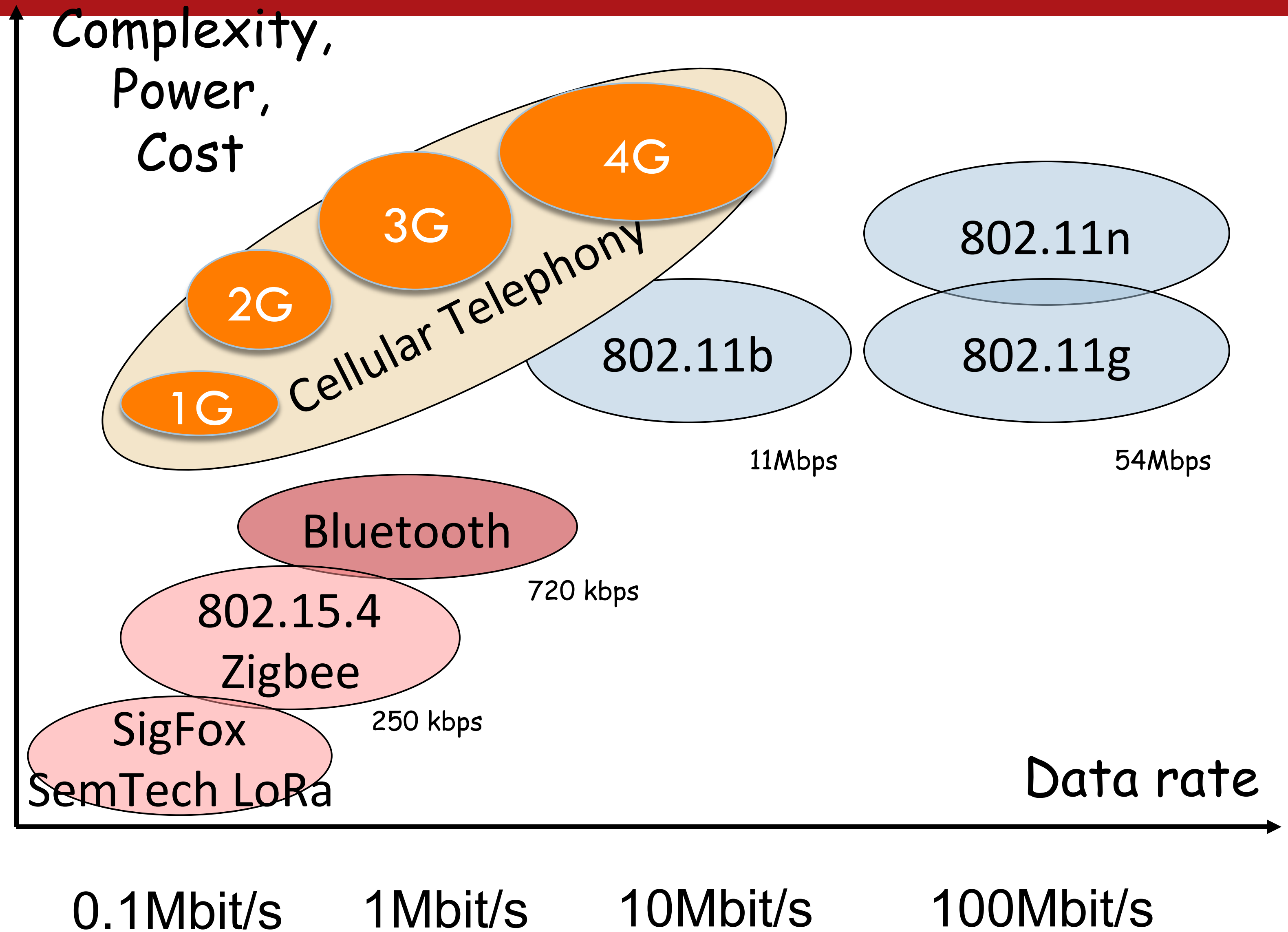
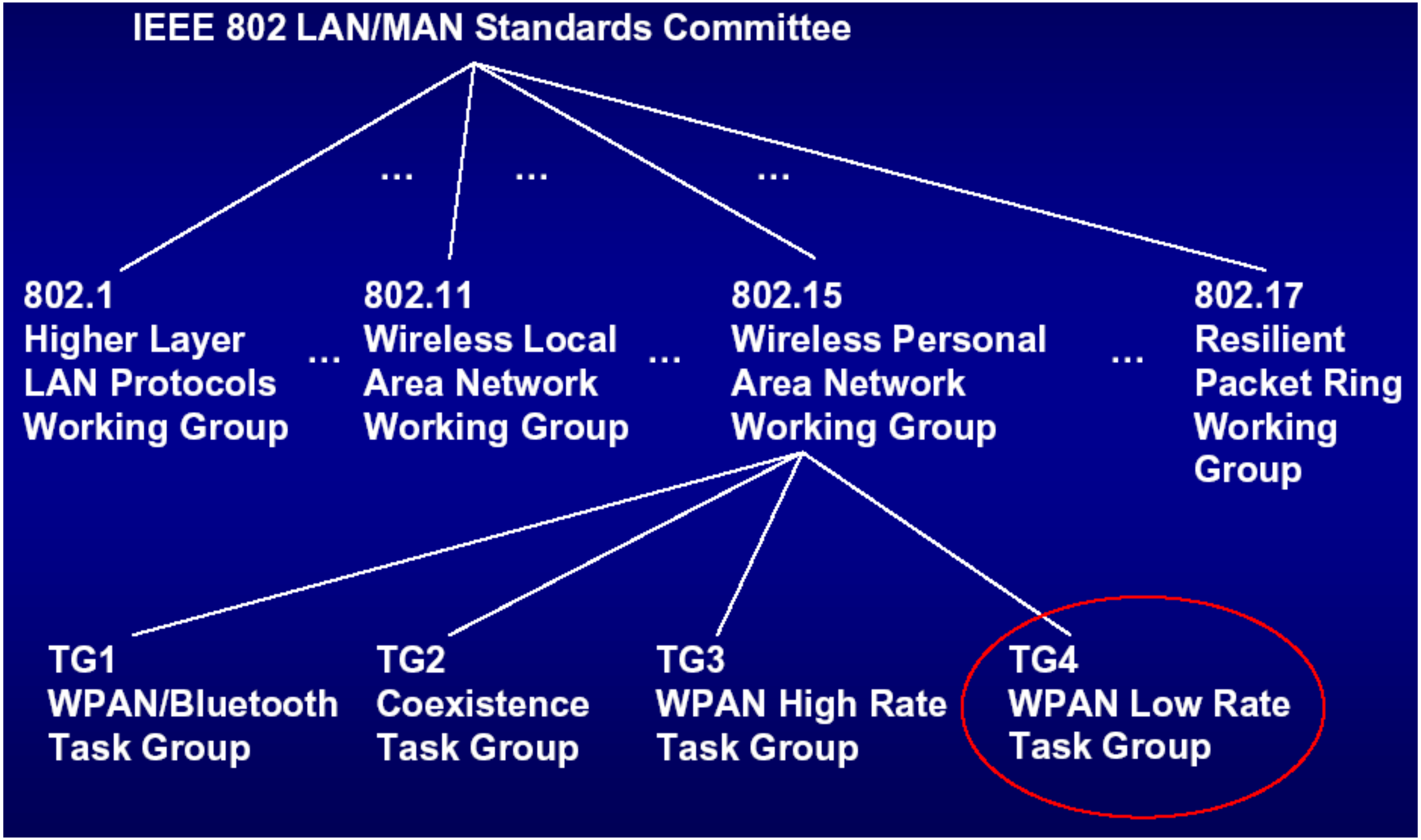
Technology Space



SHORT RANGE: 802.15.4 & ZIGBEE

IEEE 802.15 working group



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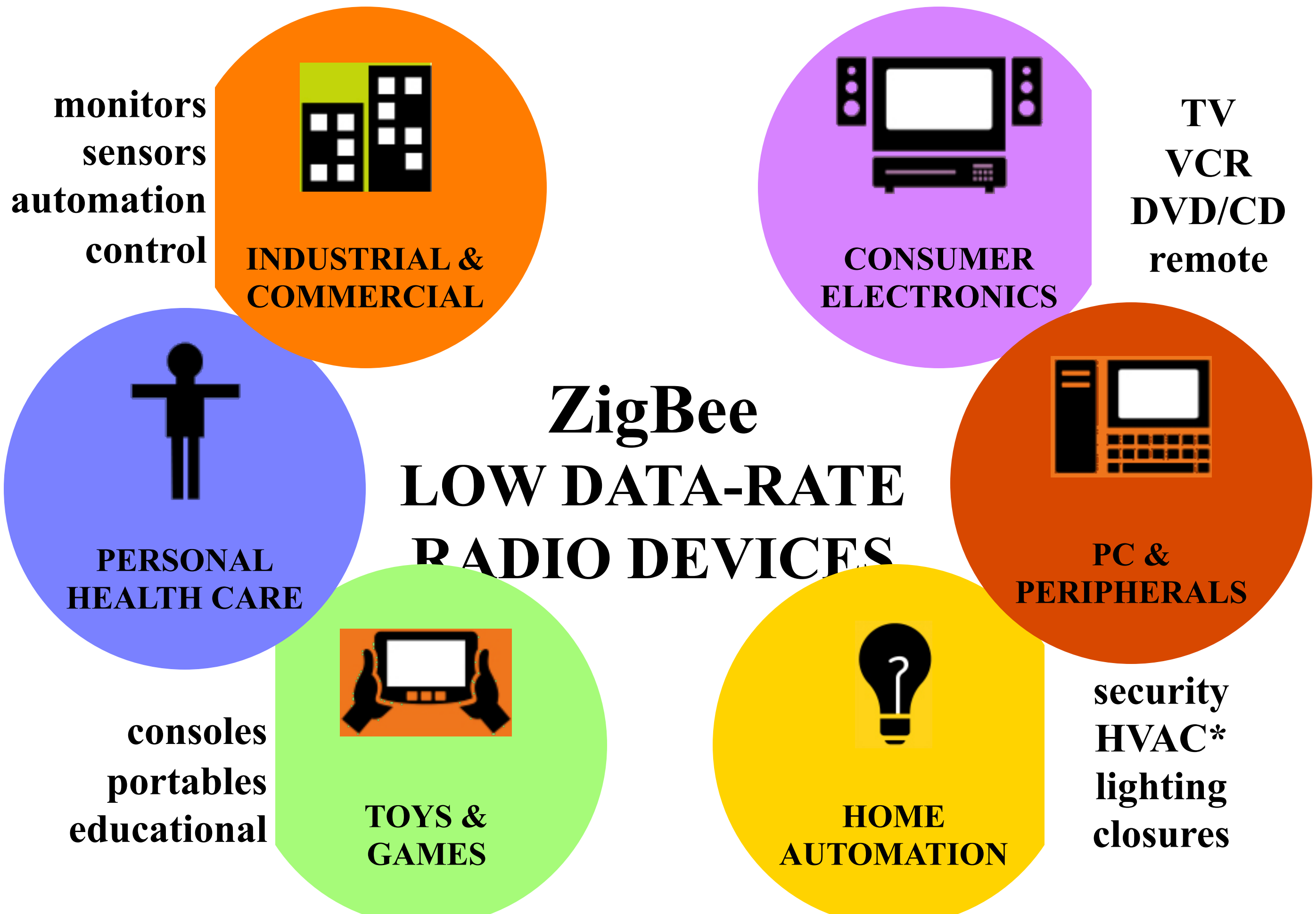
Application Sectors



*HVAC: Heating, Ventilation and Air Conditioning systems

Released Specifications

- ZigBee Home Automation
- ZigBee Smart Energy 3.0
- ZigBee Telecommunication Services
- ZigBee Health Care
- ZigBee Remote Control

ZigBee General Characteristics

- Transmission
  - 3 Frequencies bands (ISM) with 27 channels
  - Data rates of 20 kbps and up to 250 kbps
  - CSMA-CA Channel Access
- Topology
  - Star or Peer-to-Peer/Mesh networks
- Advantages
  - Support for Low Latency Devices
  - Extremely low duty-cycle (<0.1%)
    - Low Power Usage consumption

ZIGBEE PHY: IEEE 802.15.4

IEEE 802.15.4

- IEEE 802.15.4 standard was created specifically for control and sensor networks
- Intended for 2.45 GHz , 868 MHz and 915 MHz Band
- Relatively low bitrates
  - 250Kbps for 2.45Ghz, 40 Kbps 915Mhz, 20Kbps for 868Mhz band
- Low in cost, complexity & power consumption as compared to competing technologies
- Intended to network inexpensive devices

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IEEE 802.15.4 Statistics

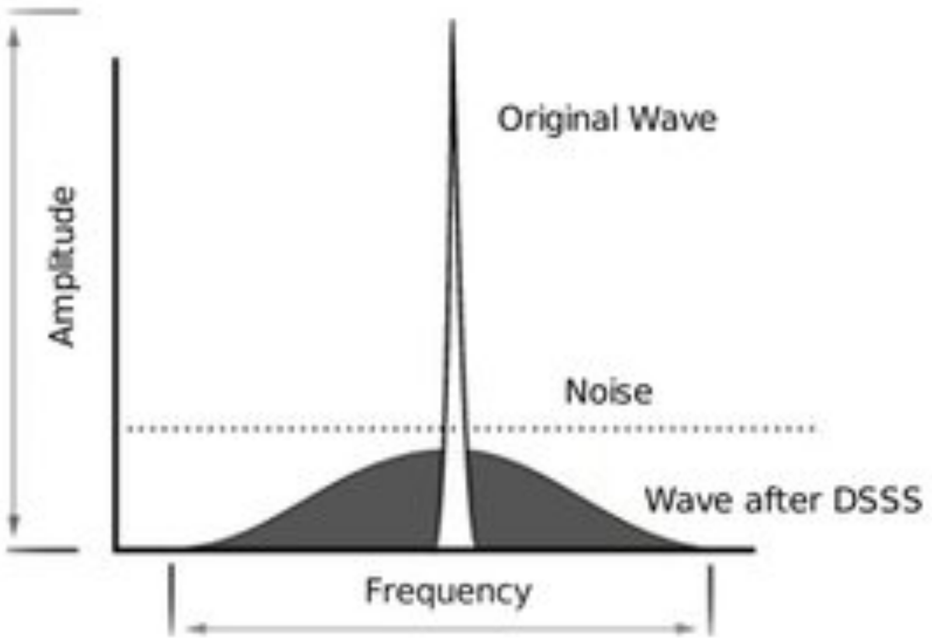
Higher bitrates and worldwide spectrum availability

Band (ISM)	# channels	Coverage	Data rate
2.40-2.48 GHz	16	Worldwide	250 kbit/s
902-928 MHz	10	Americas	40,250 kbit/s
868.0-868.6 MHz	1	Europe	20,100 kbit/s

Better coverage ranges

802.15.4 tx & noise

- The 802.15.4 makes use of Direct Sequence Spread Spectrum (DSSS) modulation



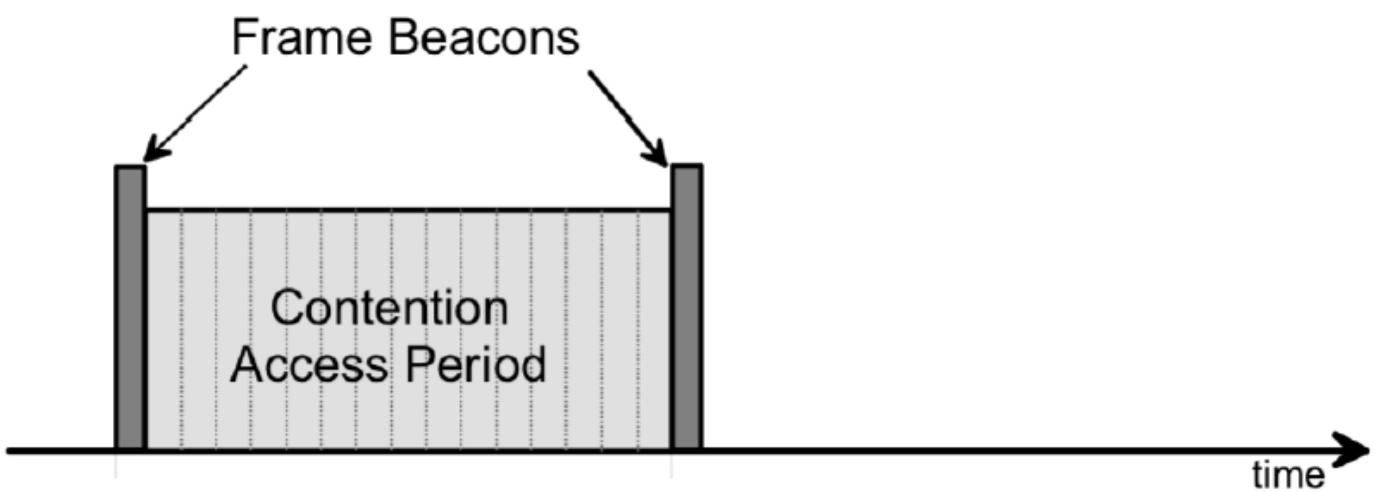
IEEE 802.15.4 Device Definitions

- Full function device (FFD)
  - Any topology
  - Network coordinator capable
  - Talks to any other device
  - Capable to act as network coordinator and as end-device
  - Consume more energy
- Reduced function device (RFD)
  - Limited to star topology
  - Cannot become a network coordinator
  - Talks only to a network coordinator
  - Very simple implementation
  - Requires little memory, processing and power resource
  - E.g., sensor nodes, actuators, ….

802.15.4 MAC STRUCTURE

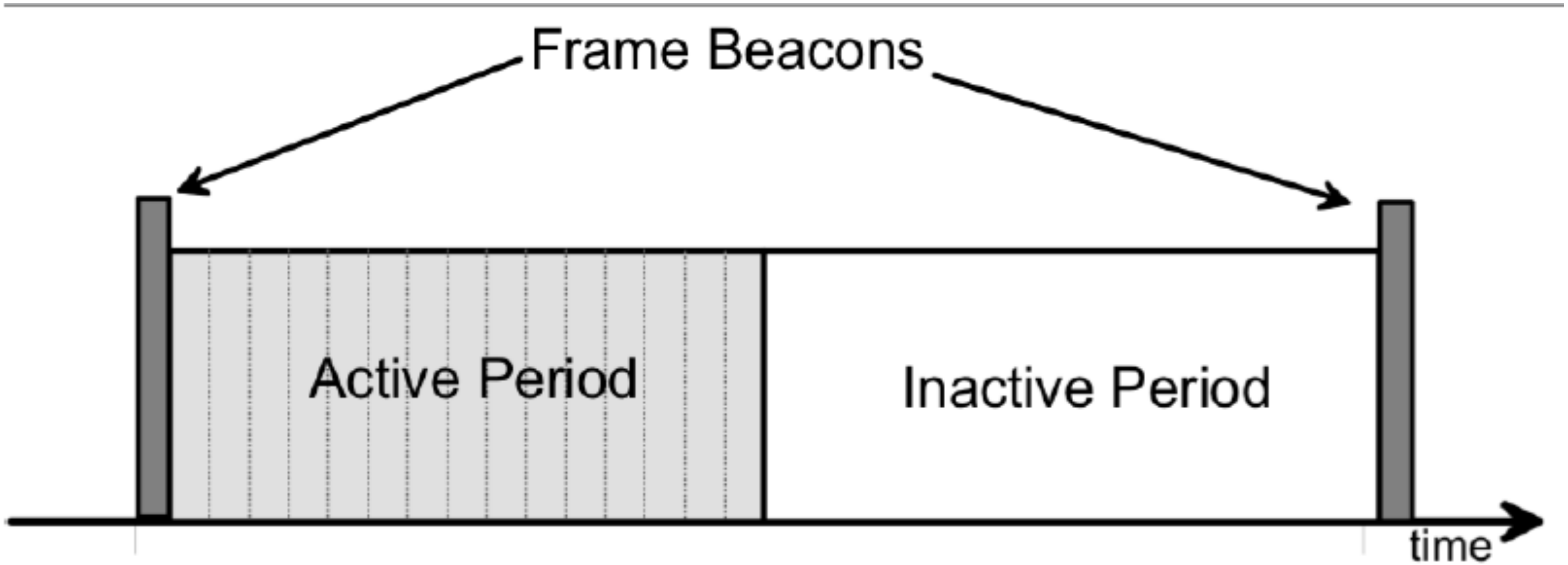
IEEE 802.15.4: superframe structure

- Superframe structure
  - standard allows for the **optional** use of a **superframe** structure
  - The format of the superframe is defined by the coordinator
  - The superframe is bounded by network *beacons* sent by the coordinator and is divided into 16 equally sized slots



Superframe

- Optionally, the superframe can have an **active** and an **inactive** portion
  - During the inactive portion, the coordinator may enter a low-power mode
  - ZigBee nodes only takes 15ms to wake up from sleep mode



Superframe structure and duty cycle

- An active portion can be divided into the CAP(Contention Access Period) and CFP(Contention Free Period).

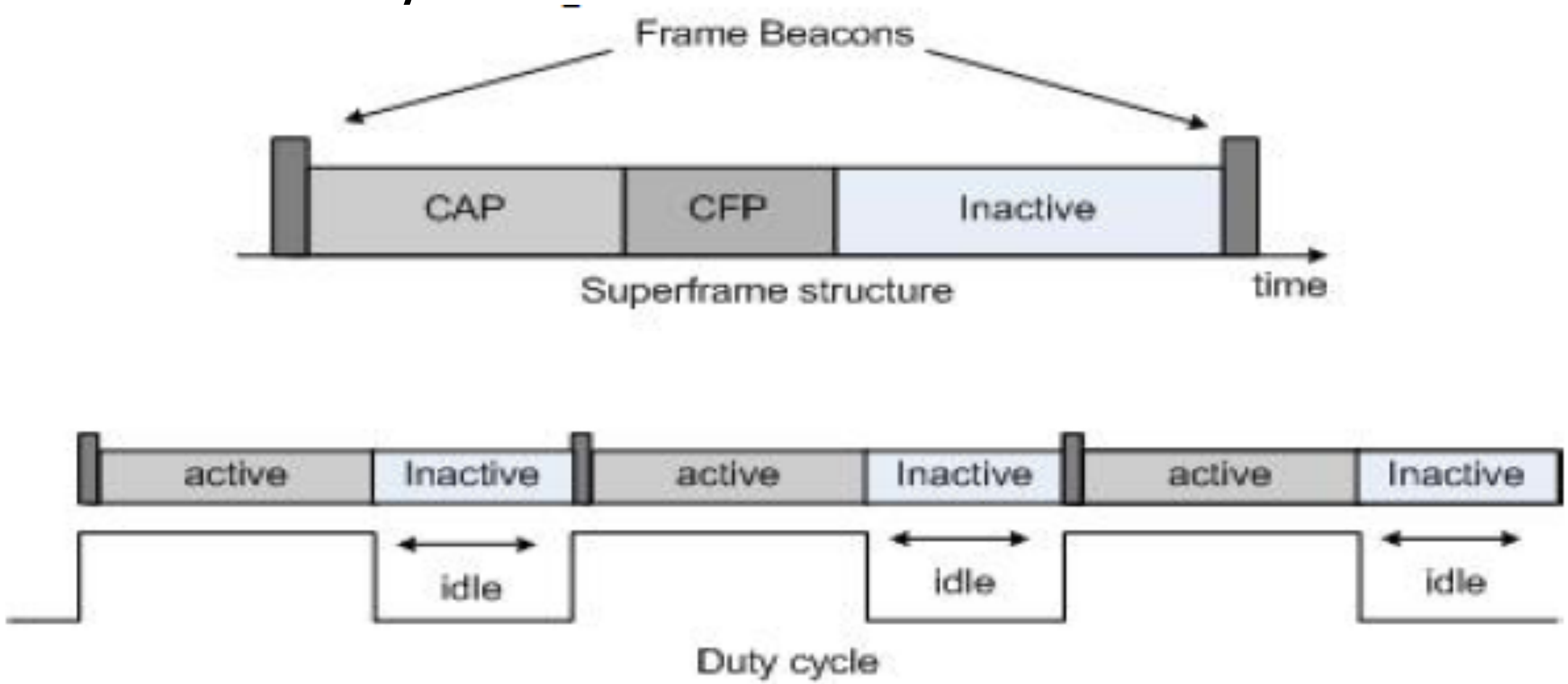
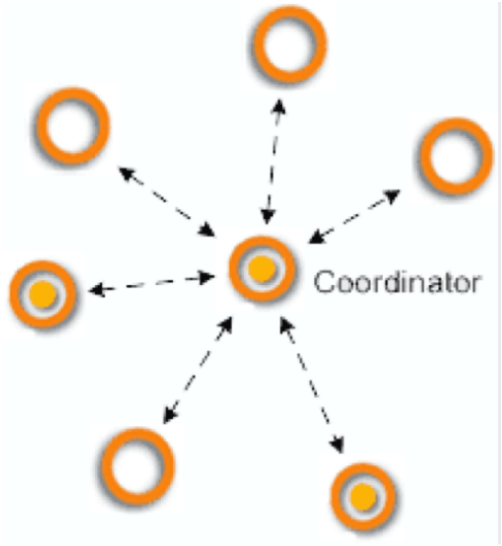


Figure 3. Superframe structure and duty cycle

802.15.4 TOPOLOGIES

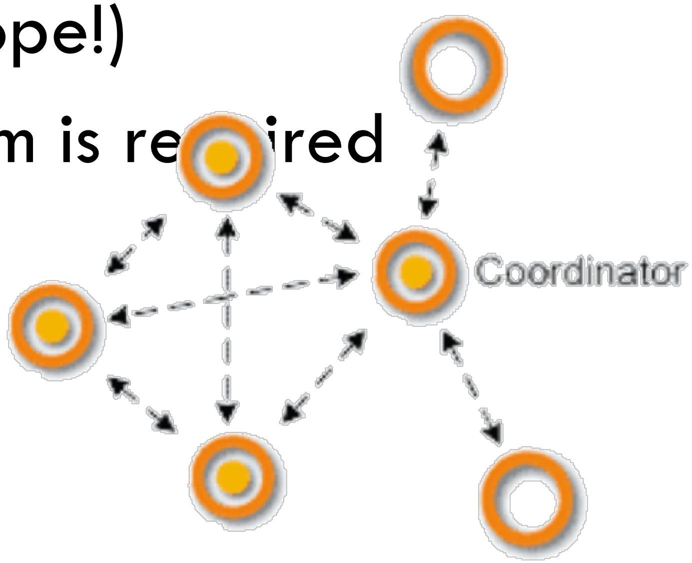
Star topology

- Network is simple in set up and deployment
- Data forwarding is possible only by coordinator (two-hop only)
- Coverage area is limited by one-hop transmission range (tens of meters indoor)



Peer-to-peer

- Data frames can be delivered via several intermediate node
- Large spatial areas can be covered buy a single network
- Nodes need to be always on or keep time coordination (out of standard scope!)
- Complex packet routing algorithm is required



Cluster tree

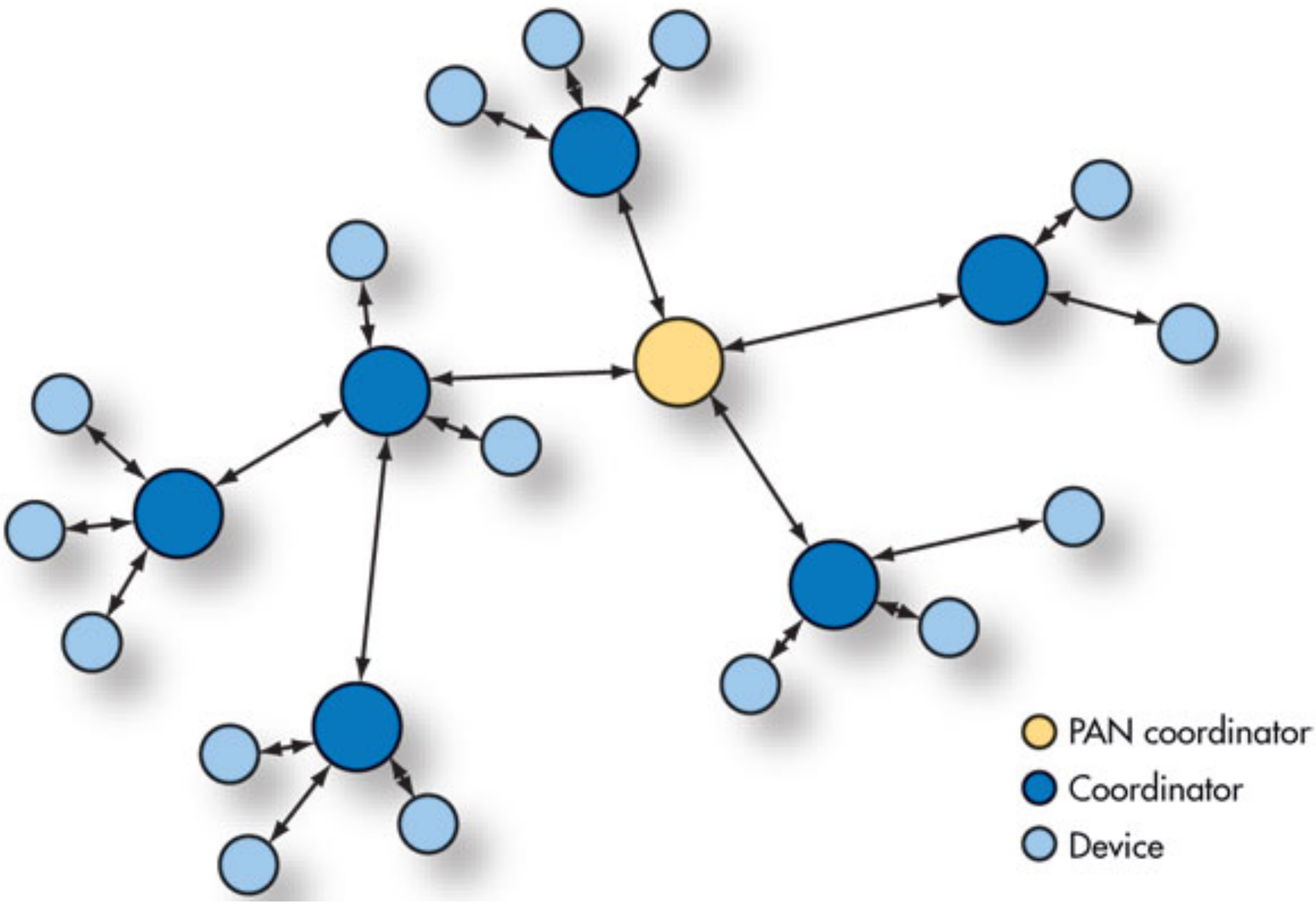
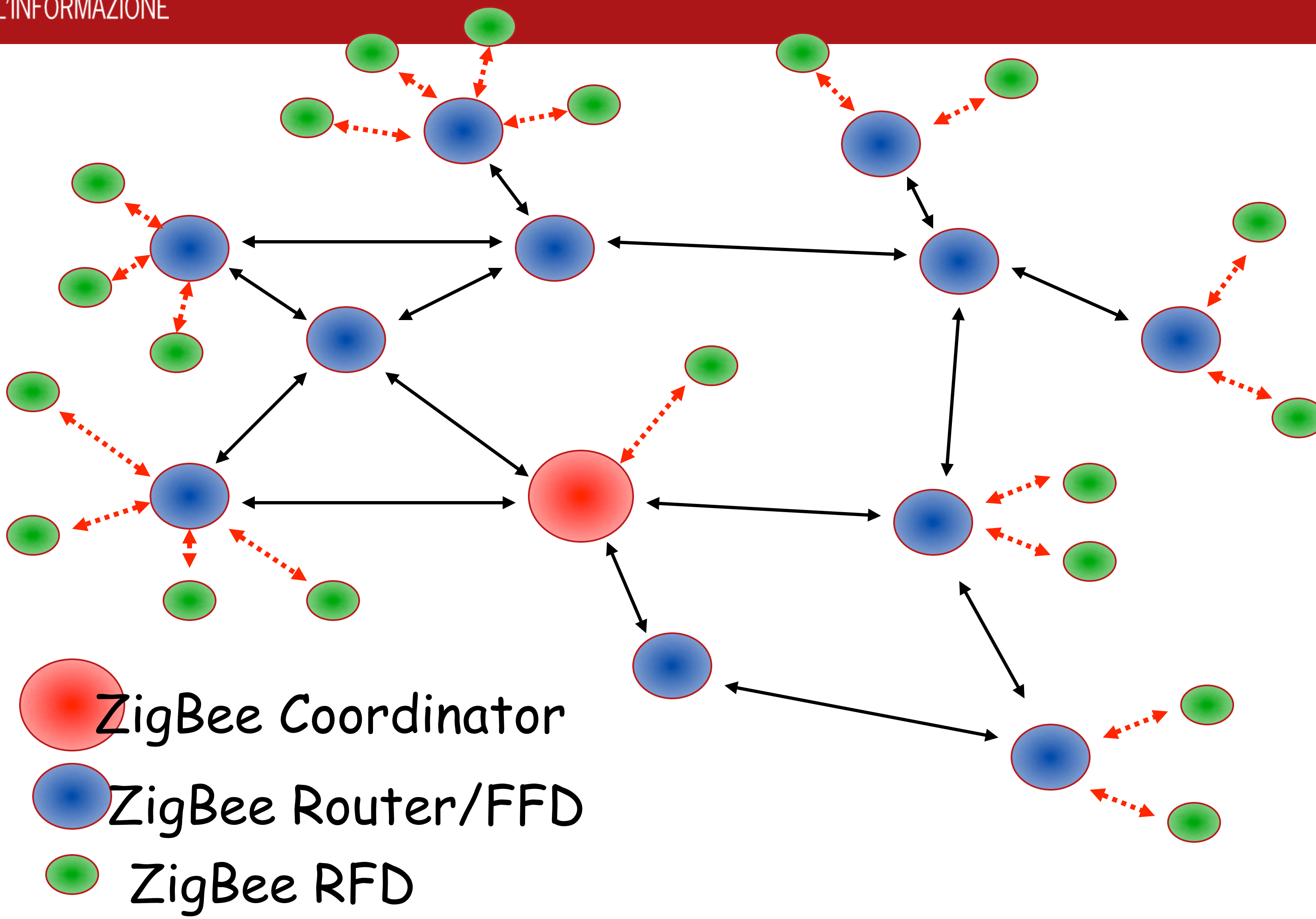
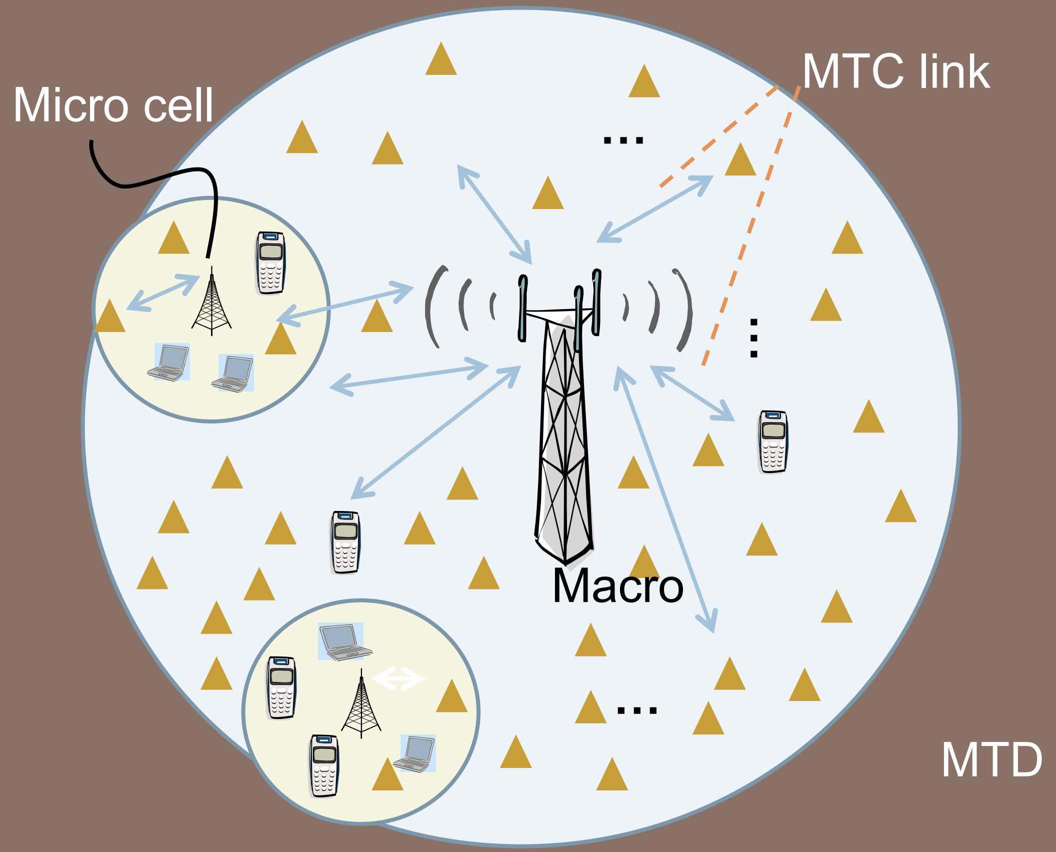


Image from: http://electronicdesign.com/content/content/62518/62518-fig4.jpg

Mesh

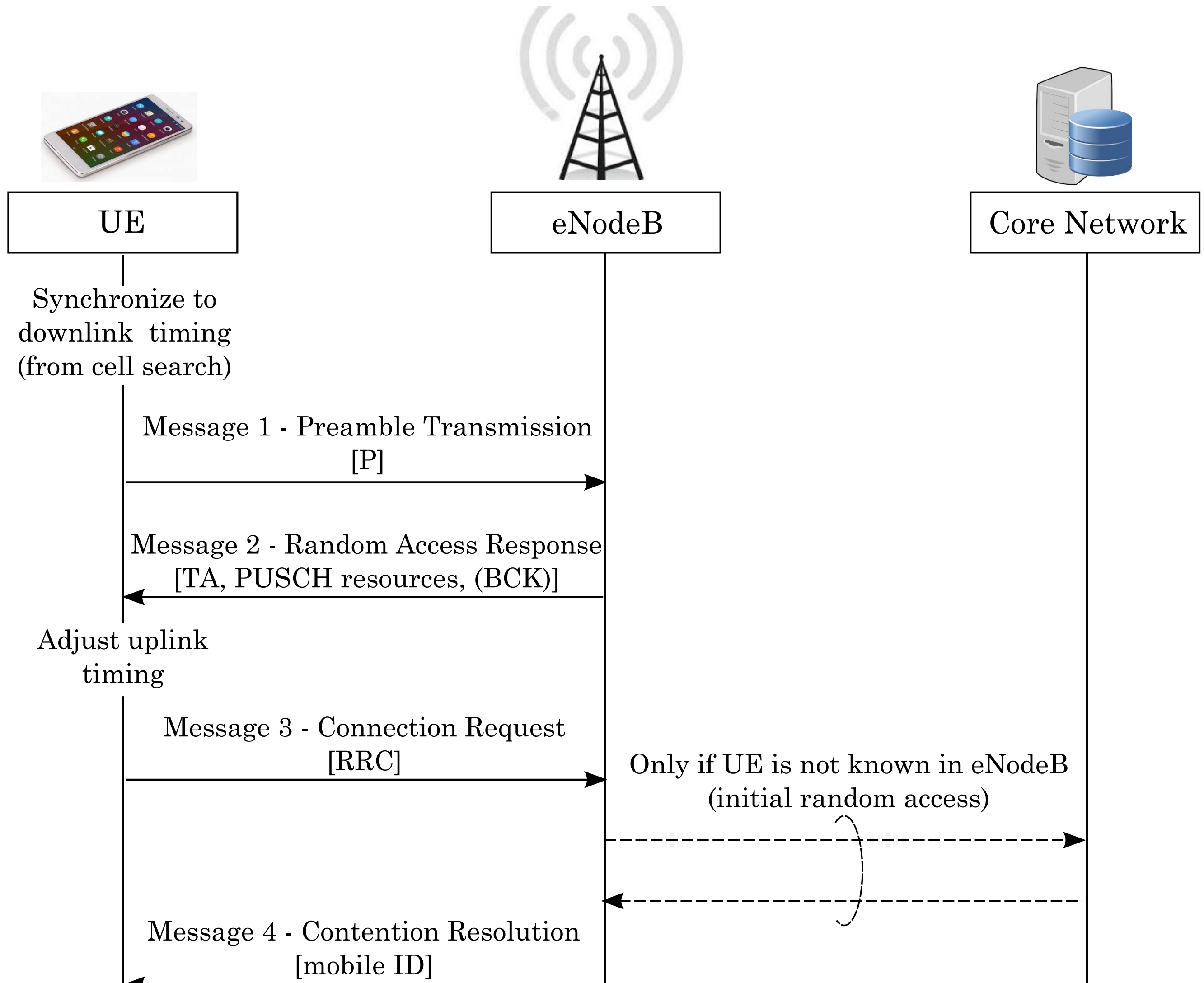




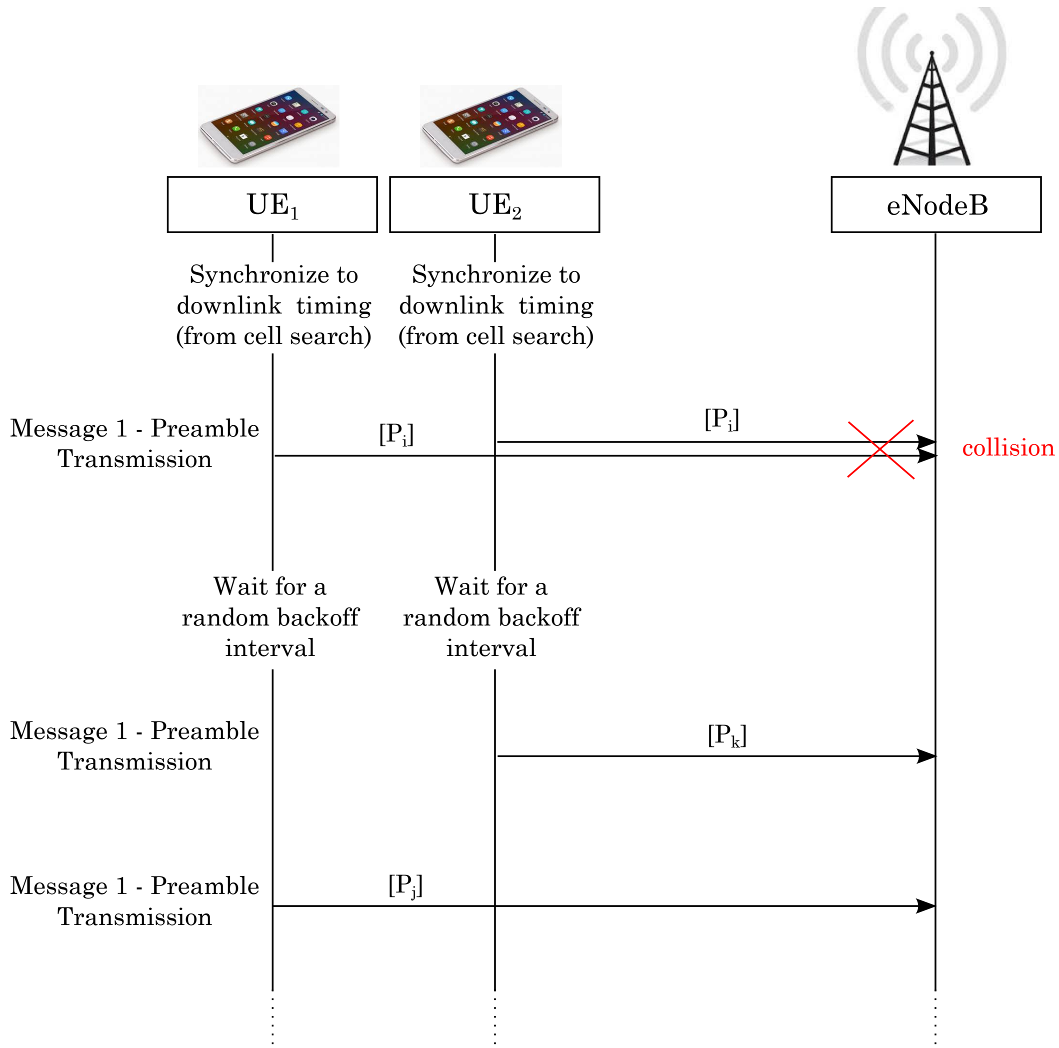
CELLULAR SYSTEMS

The challenge of massive M2M access

Contention-based Random Access procedure in LTE



Massive access issue



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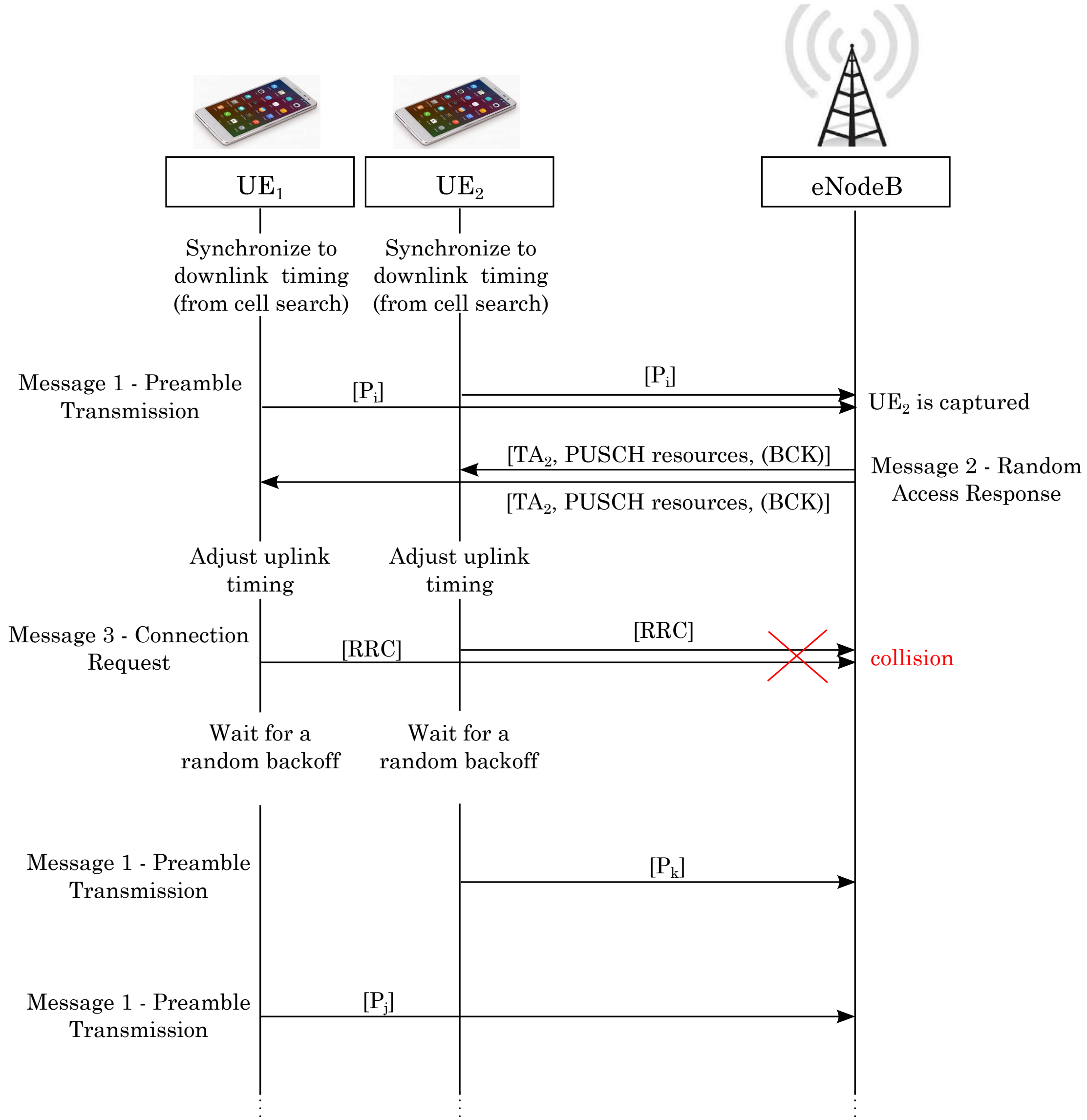
Massive access issue (cont)



Cellular-based solutions

- Pros
  - Long range
  - Almost ubiquitous coverage
  - Well-established technology
  - Easy integration with rest of the world
- Cons
  - Costs
    - Terminal hardware costs are tens of dollars rather than the one or two dollar price point
    - Subscription costs are high rather than a few dollars per year
  - Energy efficiency
    - Battery life cannot be extended much beyond a month
  - Architectural limits
    - GSM based networks are often ill-suited to the short message sizes typical in IoT use cases
    - Significant overheads associated with signaling in order to move terminals from passive to active states

LONG RANGE LOW POWER TECHNOLOGIES

LoRa: Long Range RF platform

- Developed by Semtech Corporation (USA)
- Transmission
  - Proprietary modulation technique based on spread spectrum as well as an adaptive rate adaptation technique
    - TX rate from 0.3 to 37.5 kbit/s
  - 868 MHz & 915 MHz bands for European and USA operations as well as on 169 MHz band for smart metering systems
  - Indoor/urban areas coverage of about 2 km and reaching 15 km in outdoor, rural areas
- Topology
  - long-range star→ peripheral nodes directly connected to a *LoRa concentrator*
  - Every node selects the rate and modulation which best fit its distance from the gateway, optimizing the network capacity and the battery lifetime

SIGFOX

- Company providing global cellular connectivity for the IoT, headquartered in France
- Collaborating with ETSI for the standardization of low throughput networks
- Transmission
  - Patented radio technology based on Ultra Narrow Band (UNB)
  - ISM bands, 868 MHz – 902 MHz in EU/USA
  - Each base station can handle up to a million connected objects, with a coverage area of 30-50 km in rural areas and 3-10~ m in urban areas
  - Able to manage up to 140 daily messages per node, each message carrying a payload of 12 bytes, and a wireless throughput up to 100 bit/s
- Topology
  - Star, default communication: device to base station

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Weightless

- Promoted by Weightless SIG: a non-profit global standards organisation formed to coordinate the activities needed to deliver Weightless standards
- Open Standard!
- Transmission
  - 868MHz in Europe, 915MHz in the US
  - Bidirectional (half-duplex mode)
  - Ubiquitous coverage: 5km urban, more in a rural setting
  - TX rates from a few bit/s up to 100 kbit/s → 10 years battery life
- Advantages
  - *starlong battery life*: 10–15 years, depending on the use case;
  - *ultra-low endpoint cost*, due to the simple protocol design and highly integrated silicon;

ABOVE THE HARDWARE

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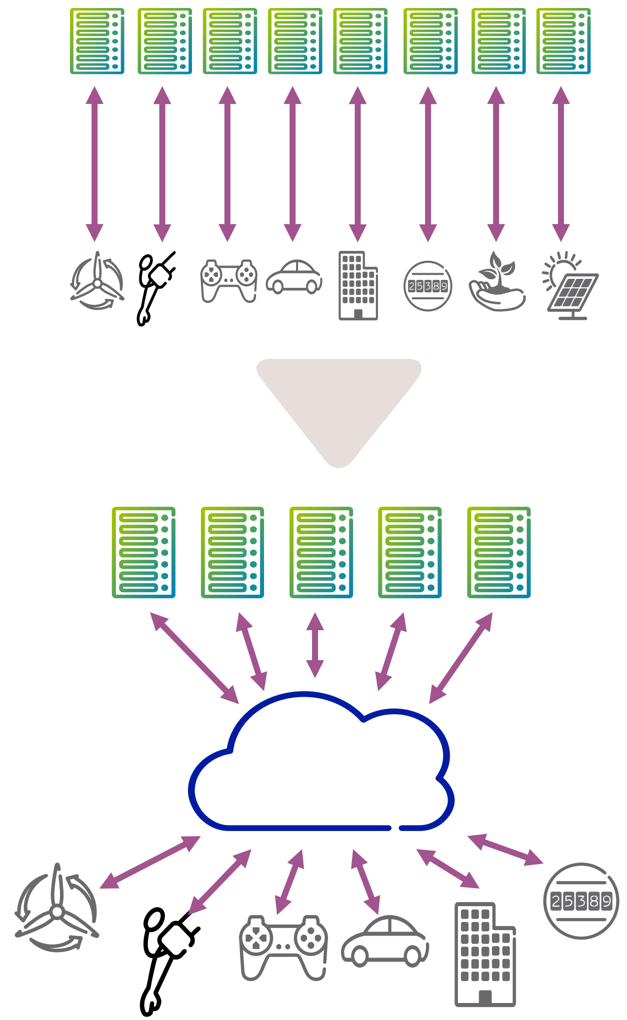
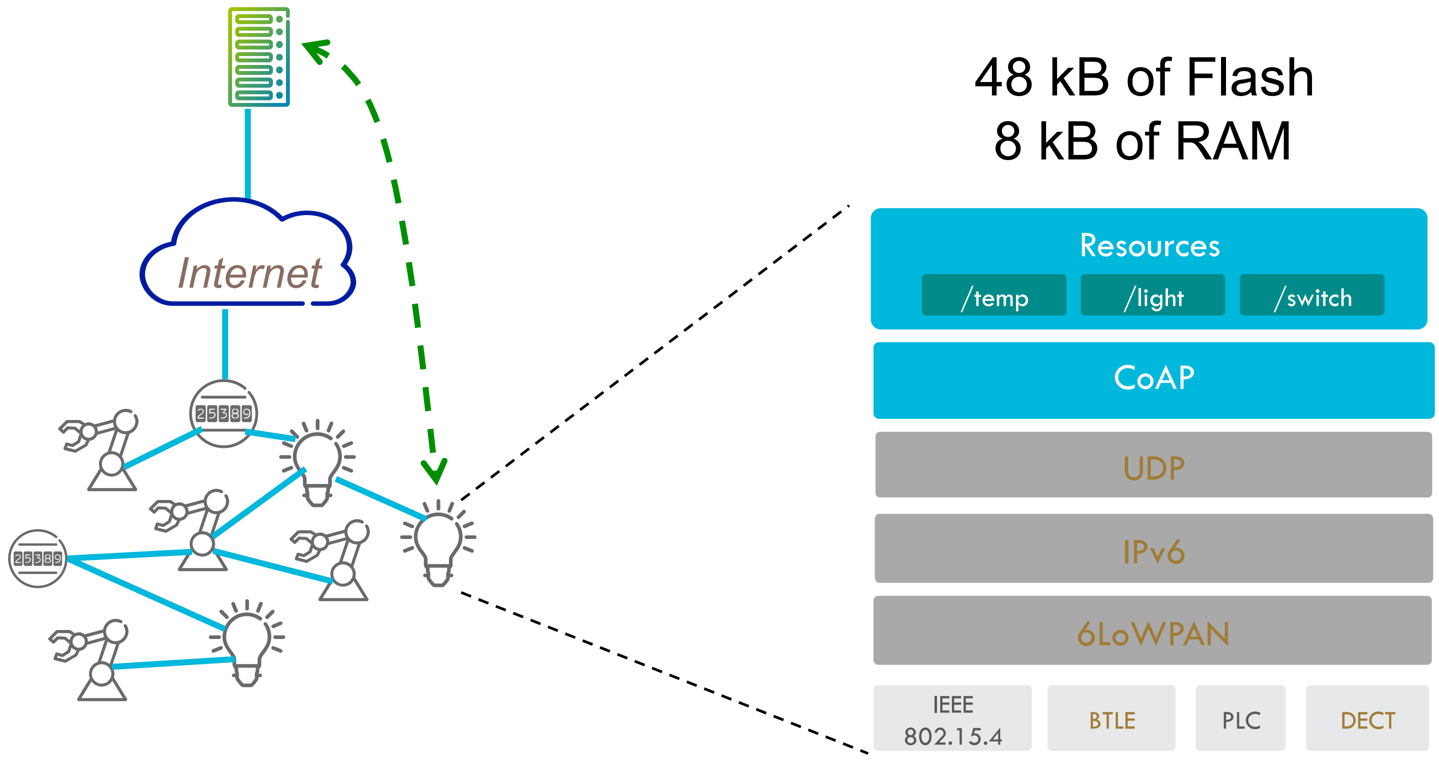
Constrained IoT Environments

- Endless applications in the IoT domain
- Embedded low cost and low power devices
- Current practice is stove pipe solution
  - single device – single application
- Transformation needed
  - application independent devices
  - many-to-many
- IP and the Web Paradigm paves the way to hide and avoid complexity and to provide simpler lower cost solutions



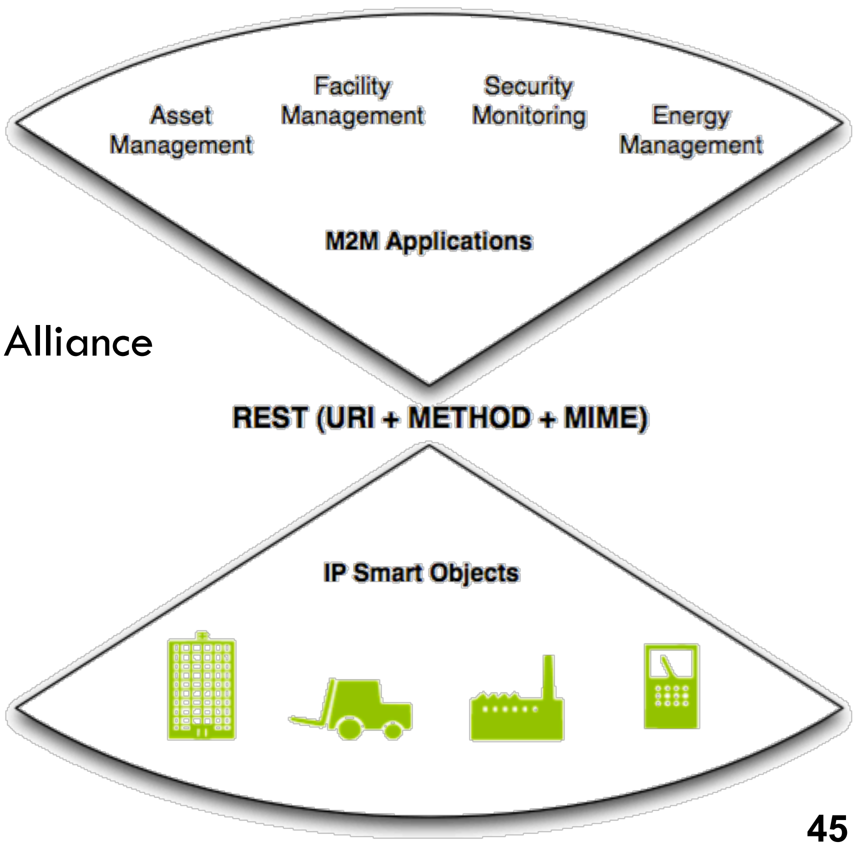
Constrained but still Internet

- Today - a complete IP based Web stack can be run on small devices with microcontrollers



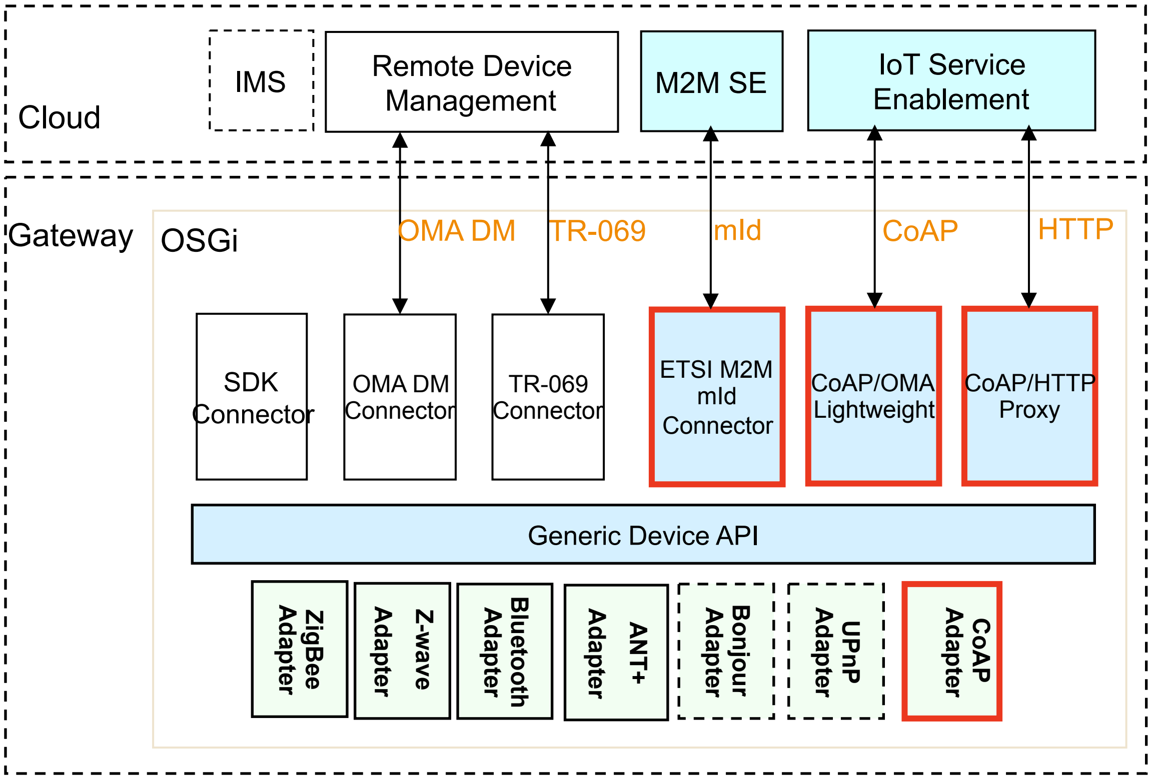
Embedded Web

- The Internet of Things will be powered by Web technology
- Technology from the IETF
  - Constrained Application Protocol (CoAP)
  - Web Linking
  - Resource Directory
  - Security
- Application Semantics
  - IPSO
    - Internet Protocol for Smart Objects Alliance
    - http://www.ipso-alliance.org
  - OMA Lightweight
    - Open Mobile Alliance
    - http://openmobilealliance.org
  - M2M Objects



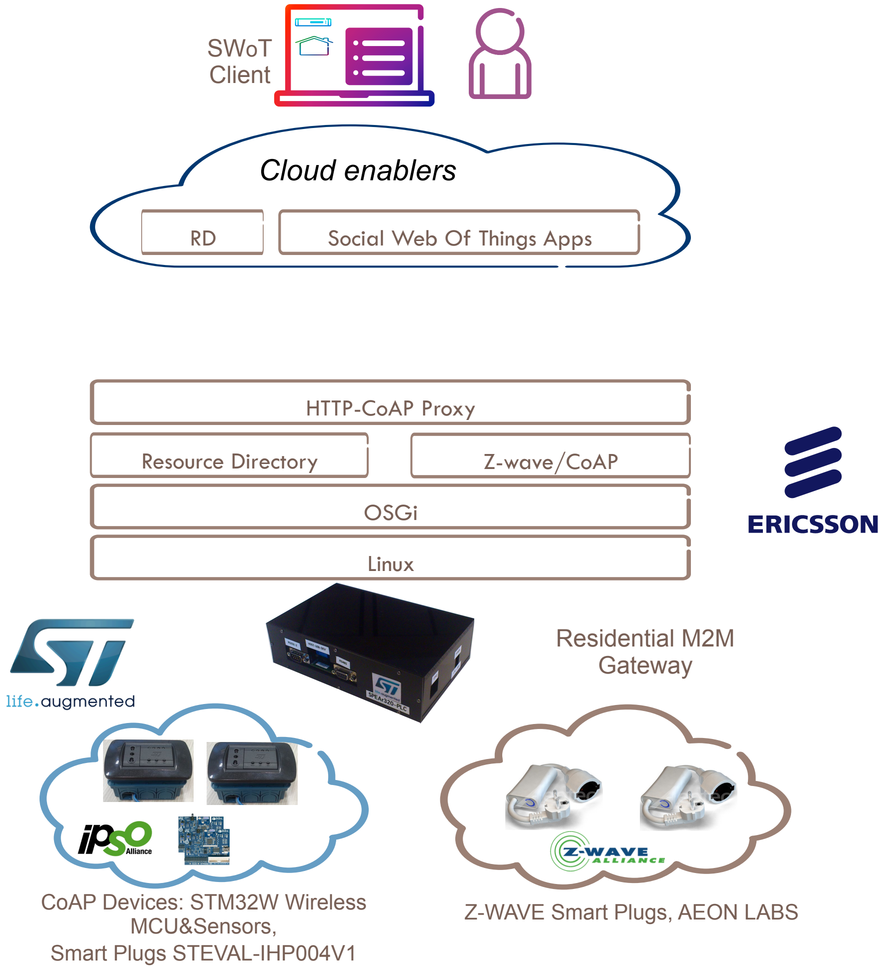
Uniform IoT Resource Access

- Decouple IoT level issues from Device level issues
  - IoT resource abstraction
  - Separate bindings for Device Management vs. handling IoT resources
- Provide normalization of M2M device capabilities
  - Generic Device API framework
- Avoid stove pipe profiles
- Go for simple profiles that are application independent to ensure interoperability
  - IPSO Application Framework
  - OMA Lightweight Objects
- Allow adaptation to different cloud environments
  - Native Embedded Web Services – IETF CoRE
  - ETSI M2M mId
  - OMA DM and TR-069

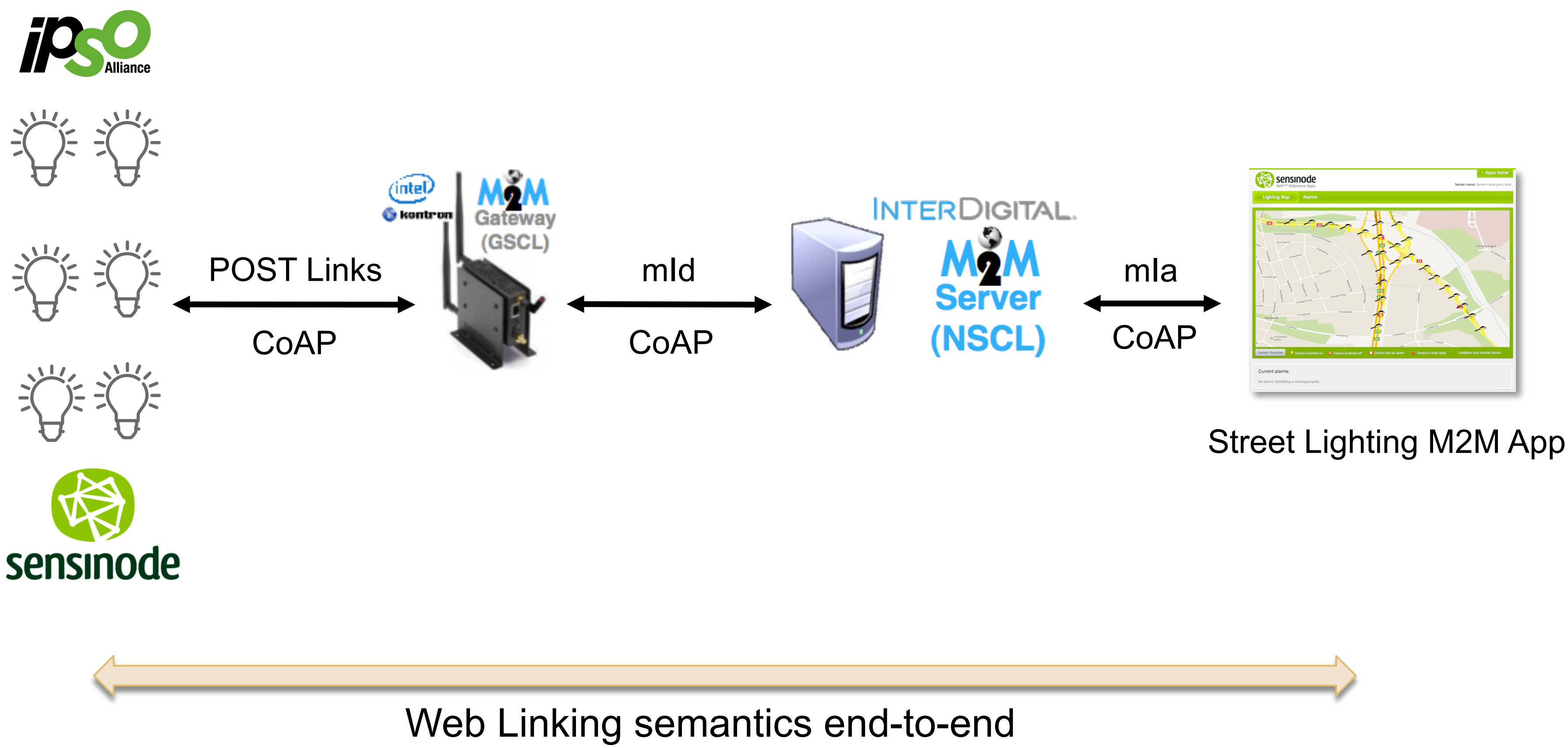


Embedded Web in Smart Home Demo

- Smart Energy use case
- Heterogeneous device integration
  - CoAP sensors and actuators
  - Z-Wave Smart Plugs
- Uniform device exposure
  - REST via HTTP and CoAP
  - IPSO Application Framework
- Supported:
  - CoAP
  - HTTP-CoAP proxying
  - Local caching and Observations
  - Resource Directory



Embedded Web in ETSI M2M Demo



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Break!!!! We all need it!

http://www.overstock.com/Home-Garden/Keep-Calm-and-Drink-Coffee-Unframed-Print/7967447/product.html

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