Inter-communicating things - IoTs

Workshop Pacific Radio-communication Workshop 2019 (PRW-19)

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Overview of the Ecosystem

Standardization

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Scope

IoTs?

Spectrum Ranges

Spectrum Availability

Going forward

Internet of Things – IoTs?

IoT? (Some Industry Definitions)

- *A network connecting (either wired or wireless) devices, or 'things', that is characterized by autonomous provisioning, management, and monitoring. The IoT is innately analytical and integrated* **(IDC)**

- *IoT is the next evolution of the Internet, connecting the unconnected people, processes, data, and things in your business today* **(Cisco)**

- *IoT devices as those capable of two-way data transmission (excluding passive sensors and RFID tags). It includes connections using multiple communication methods such as cellular, short range and others.* **(GSMA)**

- *Sensors & actuators connected by networks to computing systems. These systems can monitor or manage the health and actions of connected objects and machines. Connected sensors can also monitor the natural world, people, and animal"* **(McKinsey)**

IoT? (IEEE)

"An IoT system is a network of networks where, typically, a massive number of objects, things, sensors or devices are connected through communications and information infrastructure to provide value-added services via intelligent data processing and management for different applications (e.g. smart cities, smart health, smart grid, smart home, smart transportation, and smart shopping)."

-- IEEE Internet of Things Journal

IoT?

- **Resolution [ITU-R 66](ITU-R 66)** *(recognizing "**c**")*

IoT is a concept encompassing various platforms, applications, and technologies implemented under a number of radio communication services

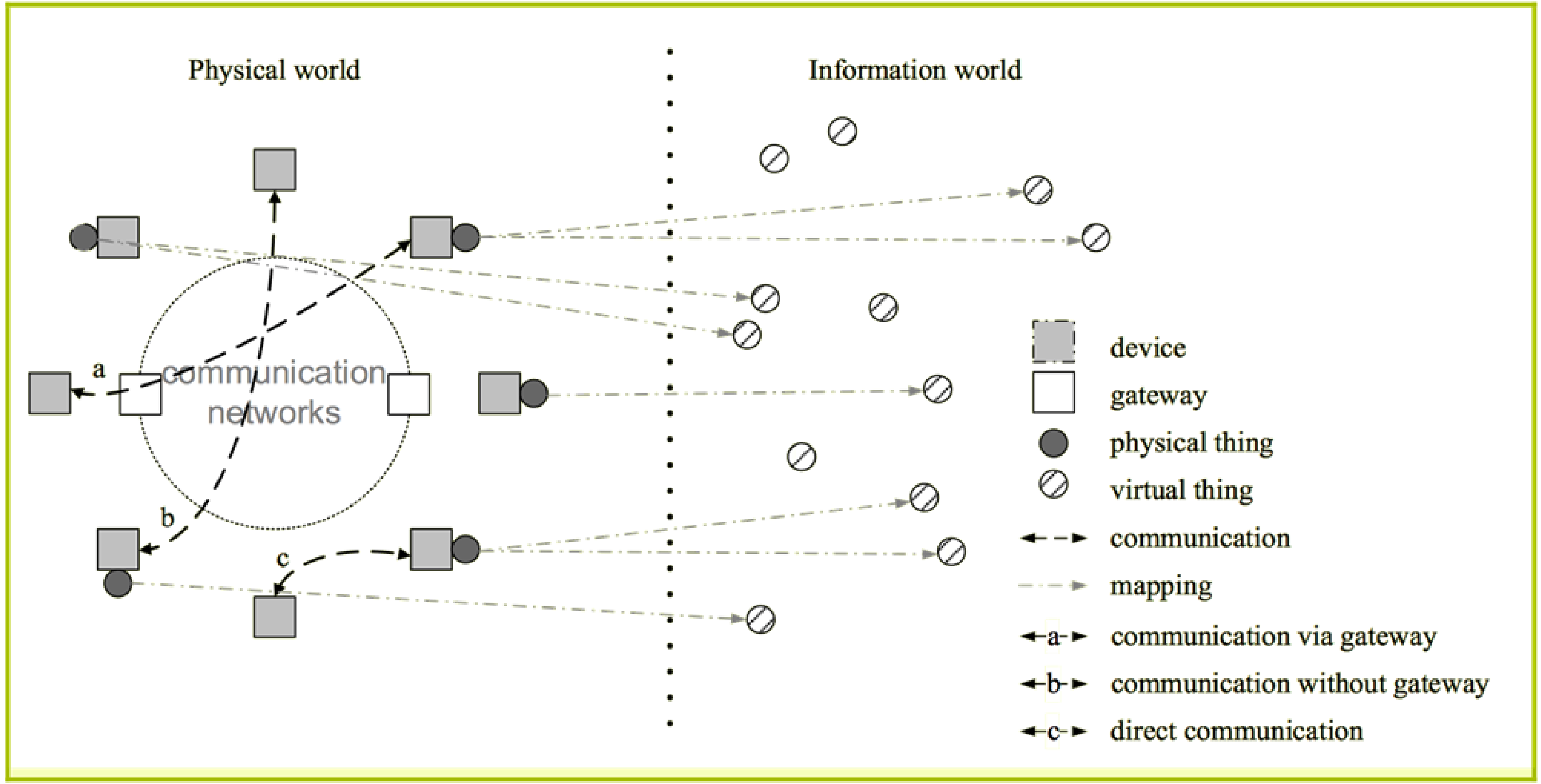
- **ITU-T Recommendation [Y.2060 renamed as Y.4000]**

A global infrastructure for the information society, enabling advanced services by interconnecting (physical & virtual) things based on existing and evolving interoperable information and communication technologies

Internet of Things - ITU Definition

- **Physical things**
  - Exist in the physical world and are capable of being sensed, actuated and connected.
  - Examples: industrial robots, goods and electrical equipment.

- **Virtual things**
  - Exist in the information world and are capable of being stored, processed and accessed.
  - Examples: Multimedia content, application software.



Source: Recommendation **ITU-T Y.2060**

Why IoT?

- **Open platforms**
  - Designed to make building and deploying applications easier, faster, secure and more accessible for everyone.
- **Allows**
  - To create the low-power, wide-area sensor and/or actuator network (WASN) systems for Machine Type Communications (MTC), Smart cities and Ubiquitous Sensor Networks (USN) applications.
- **Contributes**
  - To socio economic development such as in Agriculture, health sector and many more.
- **Efficient Management**
  - Manage utilities efficiently such as smart power, water grids, and transport management

Characteristics (IoT v/s Cellular)

- **IoT communications are or should be:**
  - Low cost,
  - Low power,
  - Long battery duration,
  - High number of connections,
  - Different bitrate requirement,
  - Long range,
  - Low processing capacity,
  - Low storage capacity,
  - Small size devices,
  - Simple network architecture and protocols

IoT?

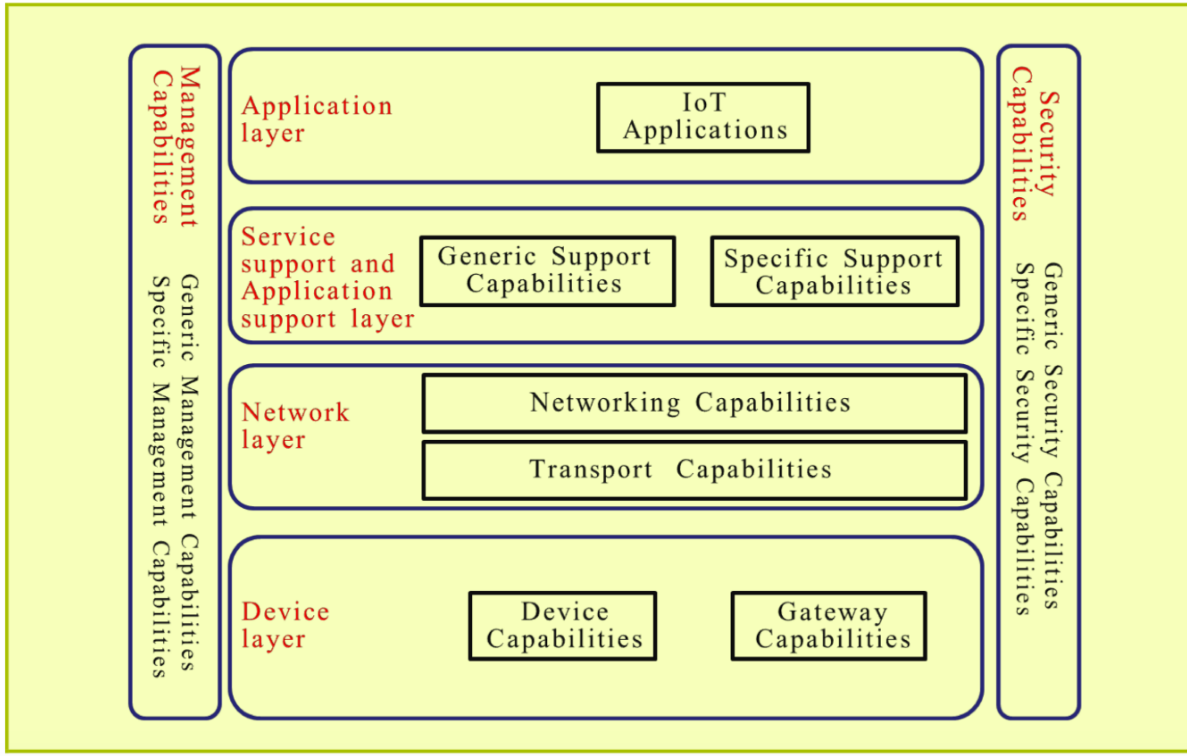
- **Wireless Technologies**

- **Diversity of IoT application requirements:**
  - Varying bandwidth requirements (how much information is sent)
  - Long-range vs short-range
  - Long battery life
  - Various QoS requirements

IoTs and cloud technologies and are the two unstoppable forces promoting digital capabilities

Spectrum needs to be made available in a range of frequency bands to cater for various cases

IoT reference model



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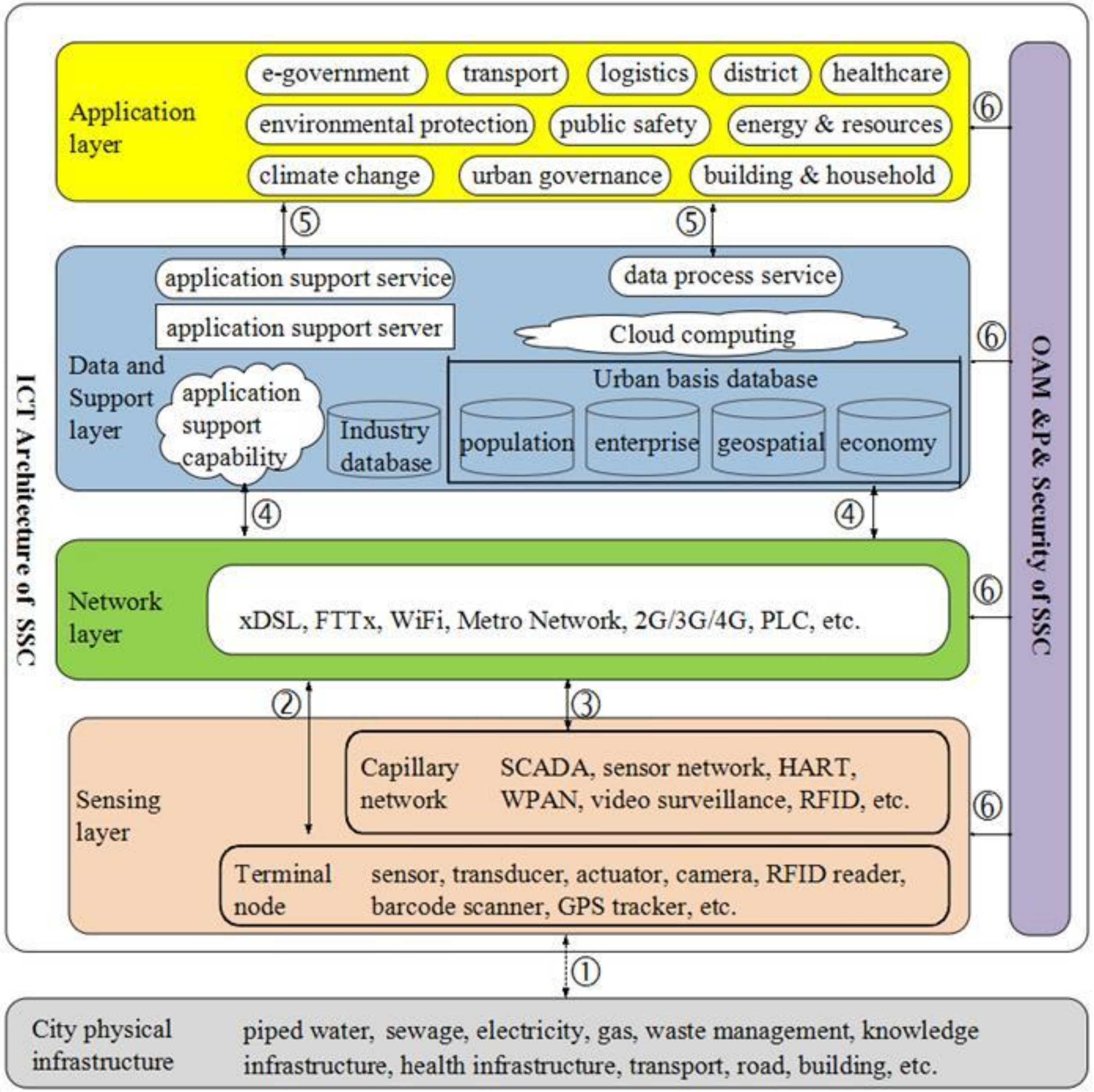
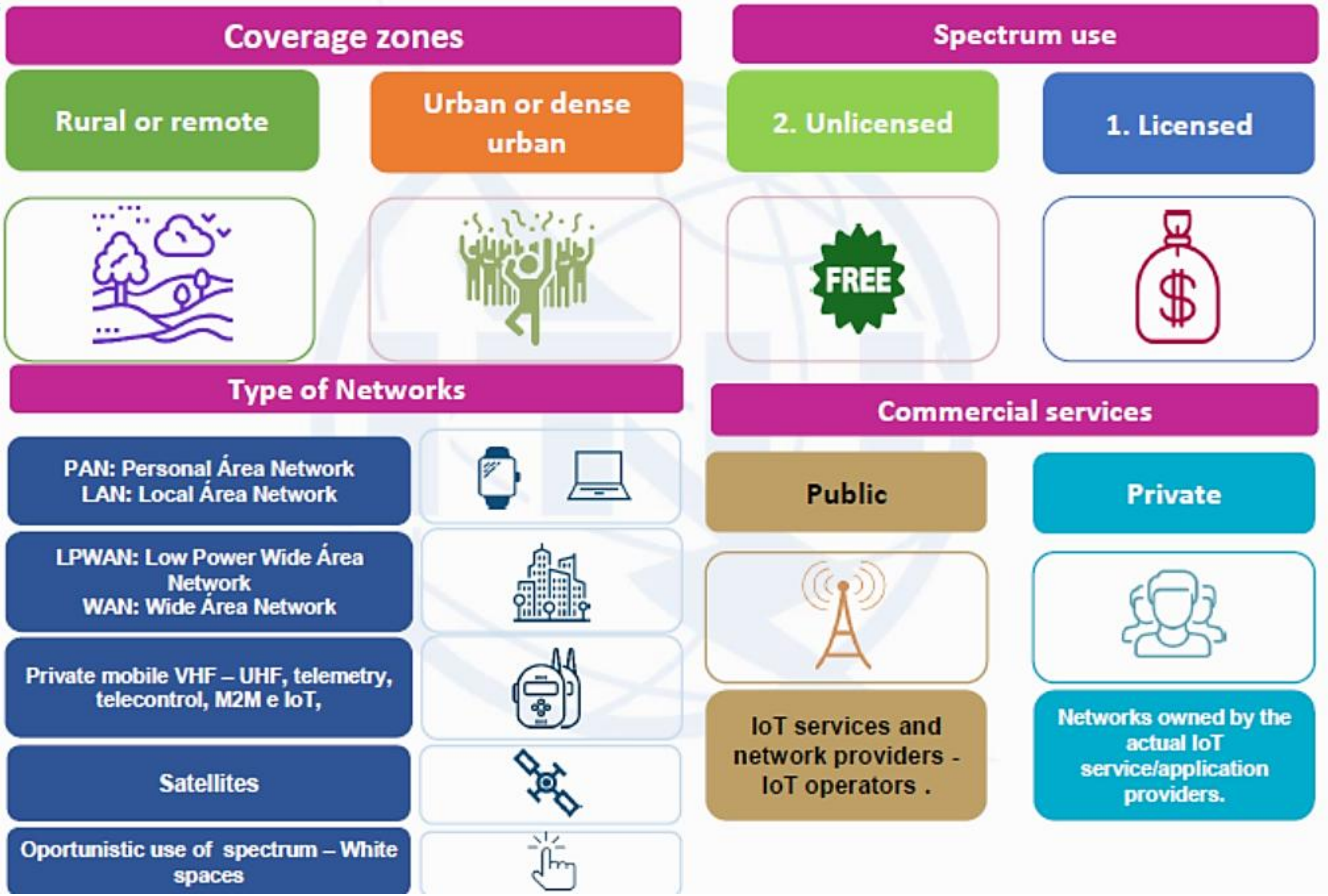
In IoT solutions supporting FC part of the application processing is executed directly at IoT objects and only when needed. More complex and resource-consuming tasks are transferred to higher level units (FC units) or directly to the cloud.



A multi-tier SSC (smart sustainable city) ICT architecture from communication view

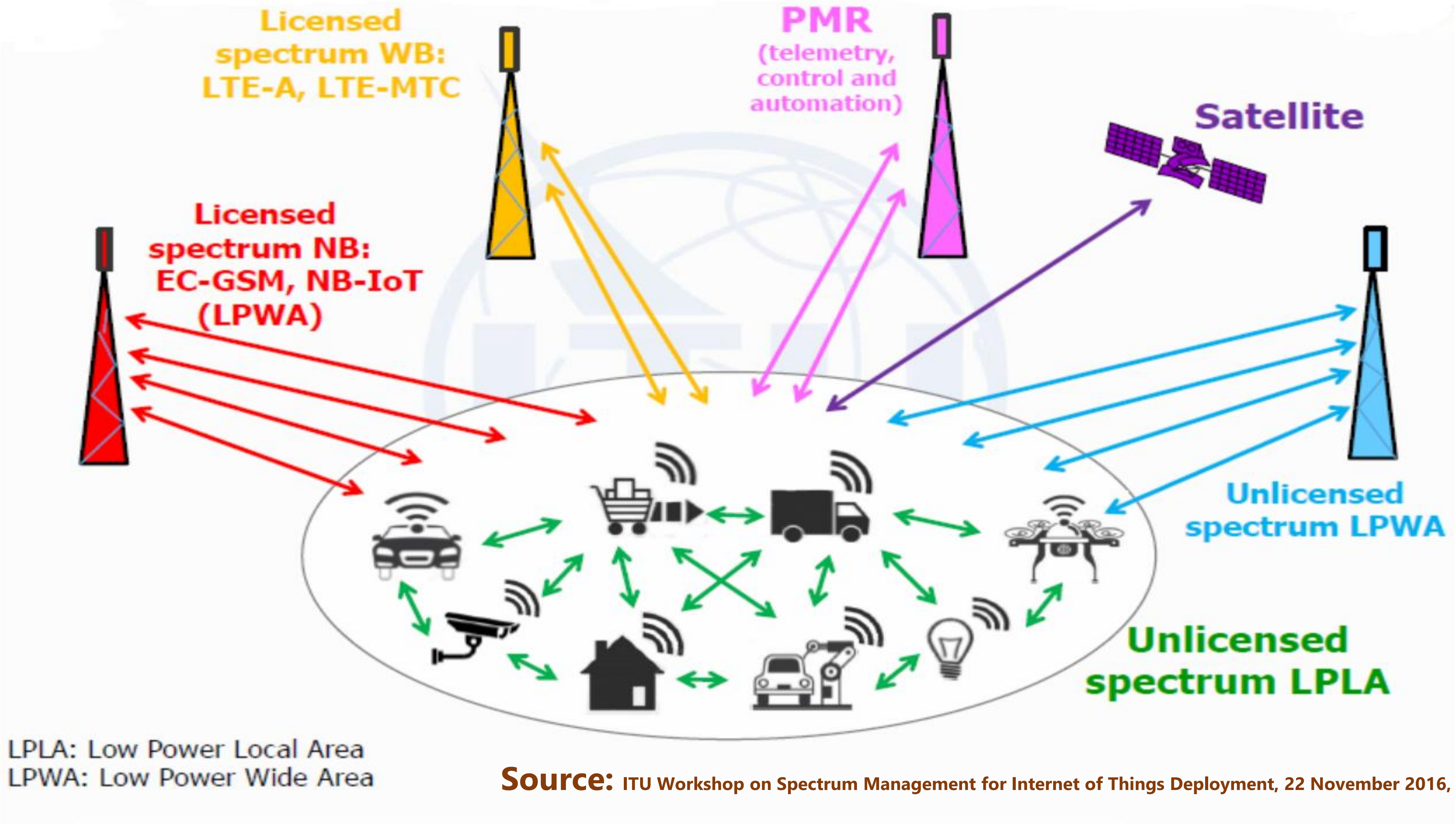
Source: ITU-T Focus Group on Smart Sustainable Cities: *Overview of smart sustainable cities infrastructure*

IoT Usage Cases



Source: ITU Workshop on Spectrum Management for Internet of Things Deployment, 22 November 2016, Geneva

IoT Connectivity Options



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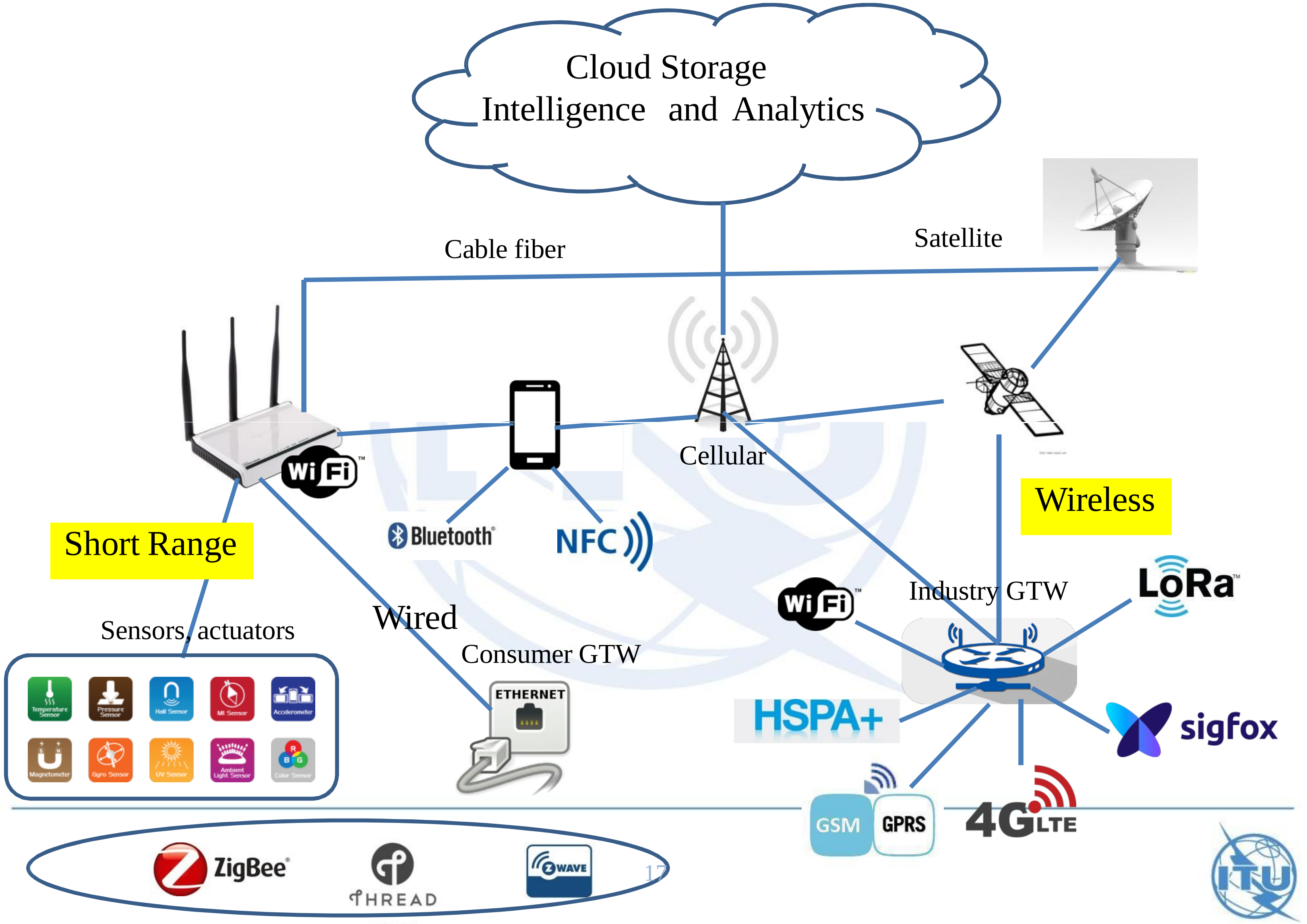
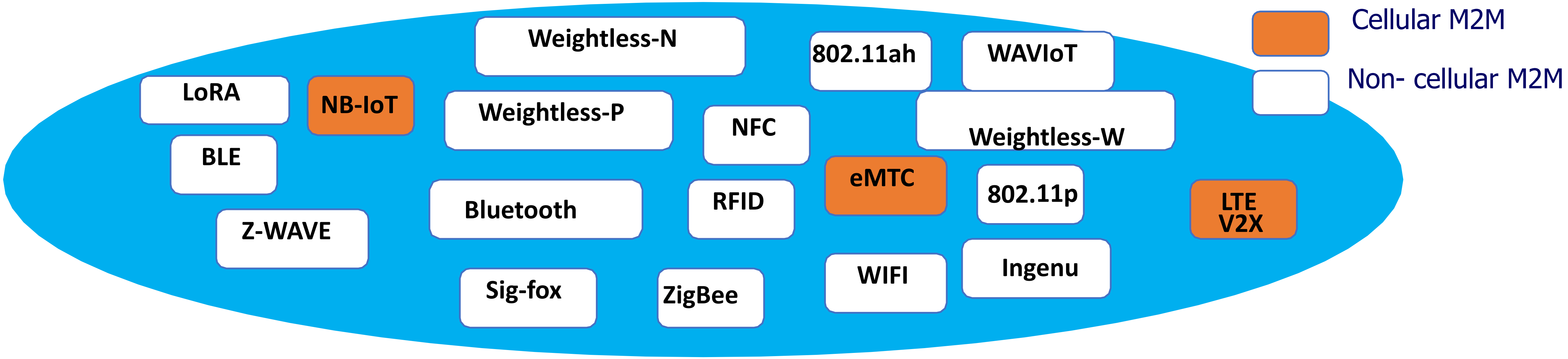
IoT: General Architecture?



IoT Technical Solutions

Study in ITU under **WRC-19 agenda item 9.1, issue 9.1.8** (Machine Type Communication - MTC)

Studies on the technical and operational aspects of radio networks and systems, as well as spectrum needed, including possible harmonized use of spectrum to support the implementation of narrowband and broadband machine-type communication infrastructures



Spectrum Needs of IoT

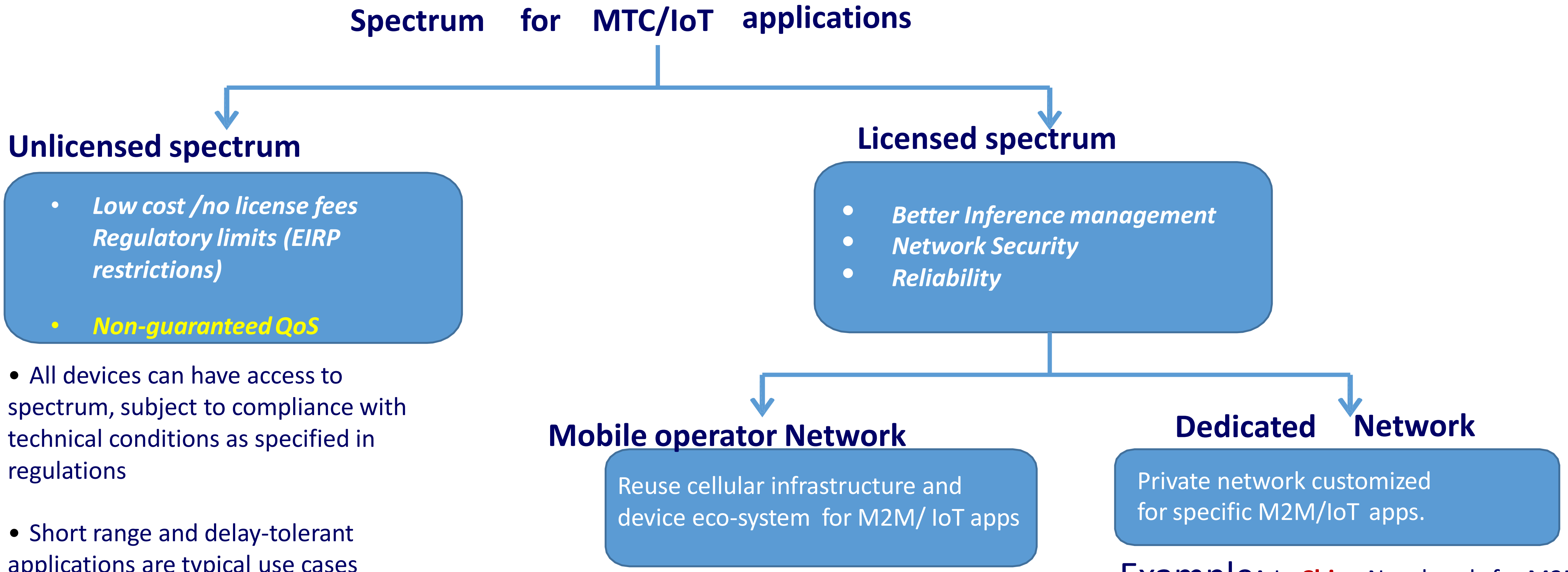
What are the spectrum needs of IoT?

- Determined by each application’s throughput requirements, but also latency
  - *For a given spectral efficiency (b/s/Hz), the lower the latency requirements the larger the bandwidth needed to send a given amount of data*
- While many IoT applications might not need high speed connections and/or have very stringent latency requirements, some do (e.g. remote surgery)

In what frequency bands?

- Determined by each IoT application’s range and coverage requirements, but also bandwidth needs of the applications
- Range and coverage requirements also depend on deployment scenarios
  - *Point-to-point, mesh, broadcast, multi-cast, etc.*

Spectrum Licensing for IoT



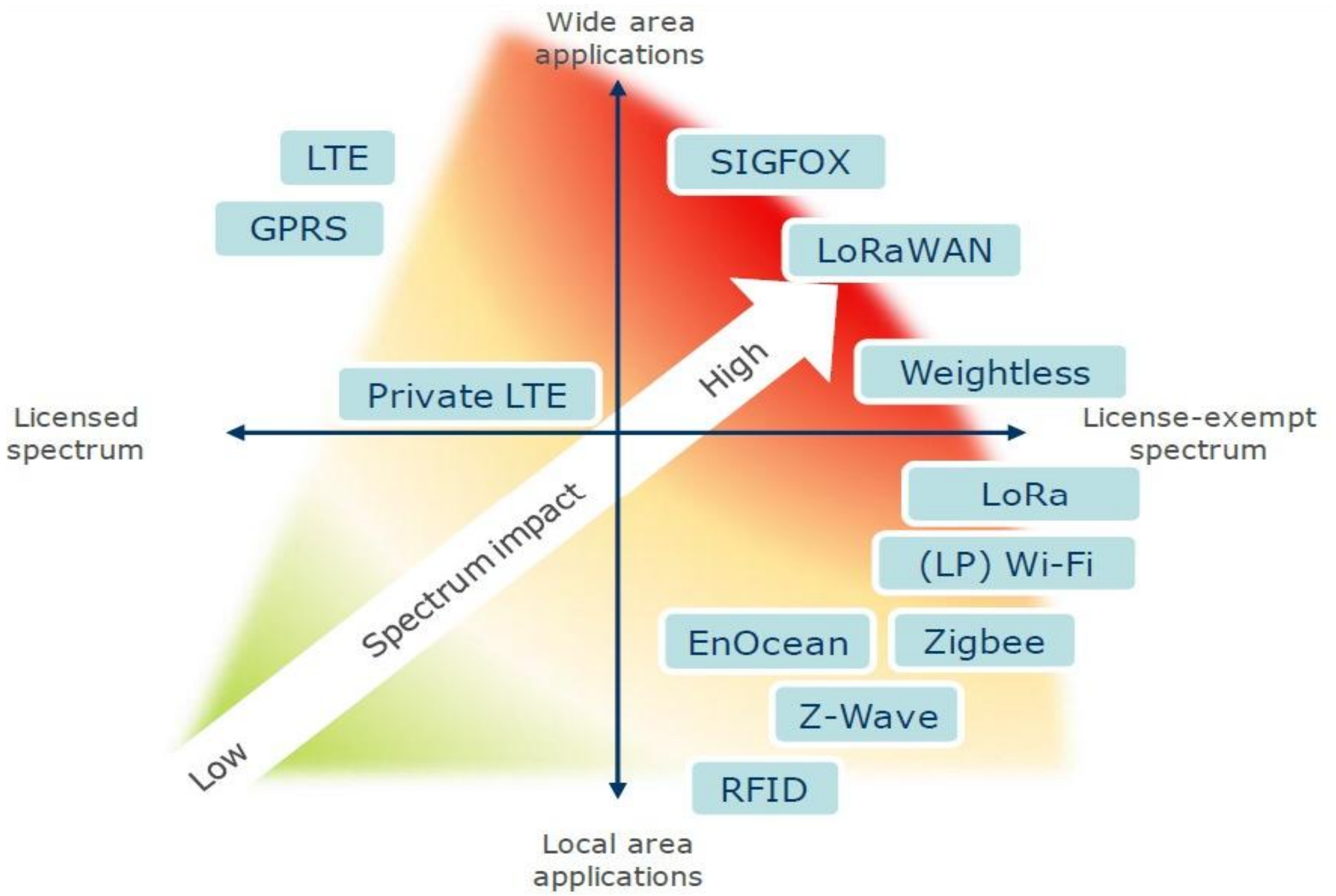
- All devices can have access to spectrum, subject to compliance with technical conditions as specified in regulations
- Short range and delay-tolerant applications are typical use cases

- IMT spectrum can be used for supporting NB-IoT, eMTC and LTE-V2N (eNB-to–vehicle)
- MBB spectrum can also be used for M2M/IoT

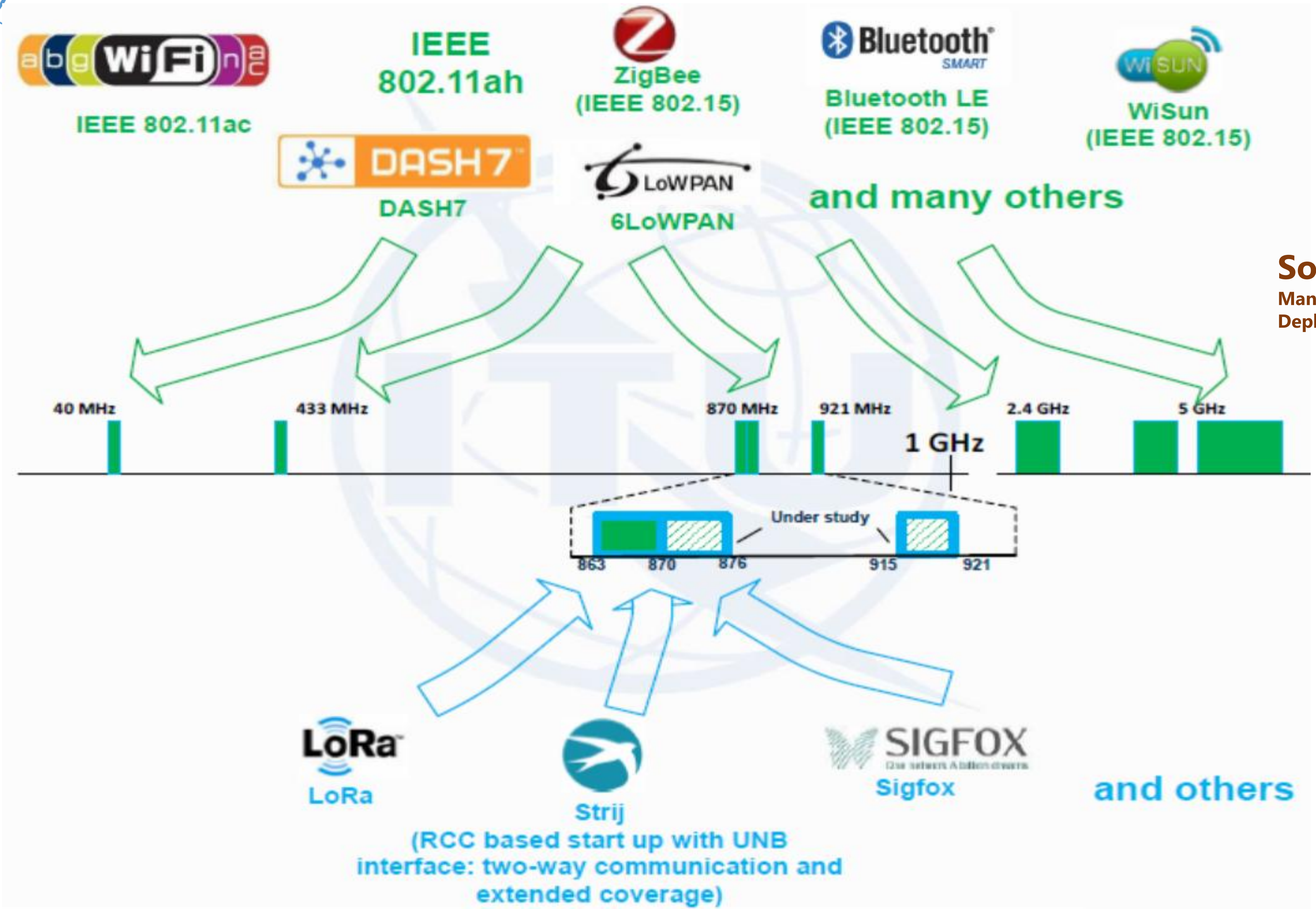
Example: In **China** New bands for M2M:

- 5 905 -5 925 MHz for LTE-V2X trials
- 2 x 2.3 MHz in 800MHz can be used for NB-IoT

IoT technologies summary



Spectrum usage for IoT - SRDs



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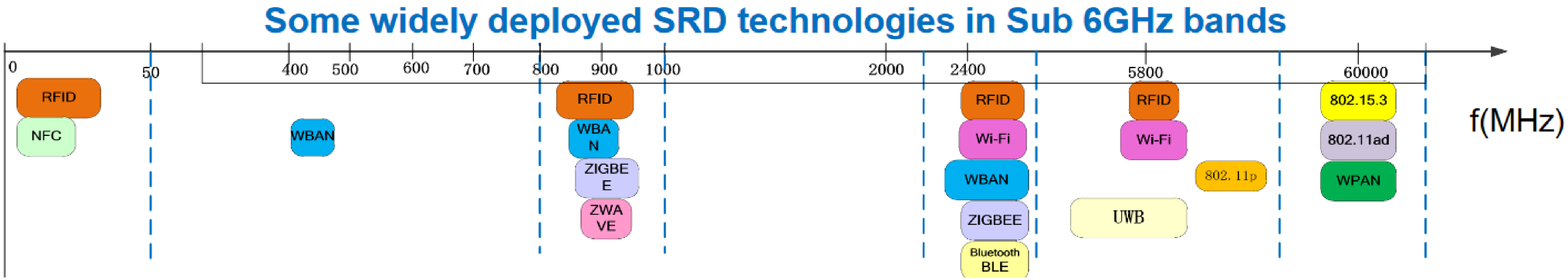
Spectrum usage for IoT - SRDs



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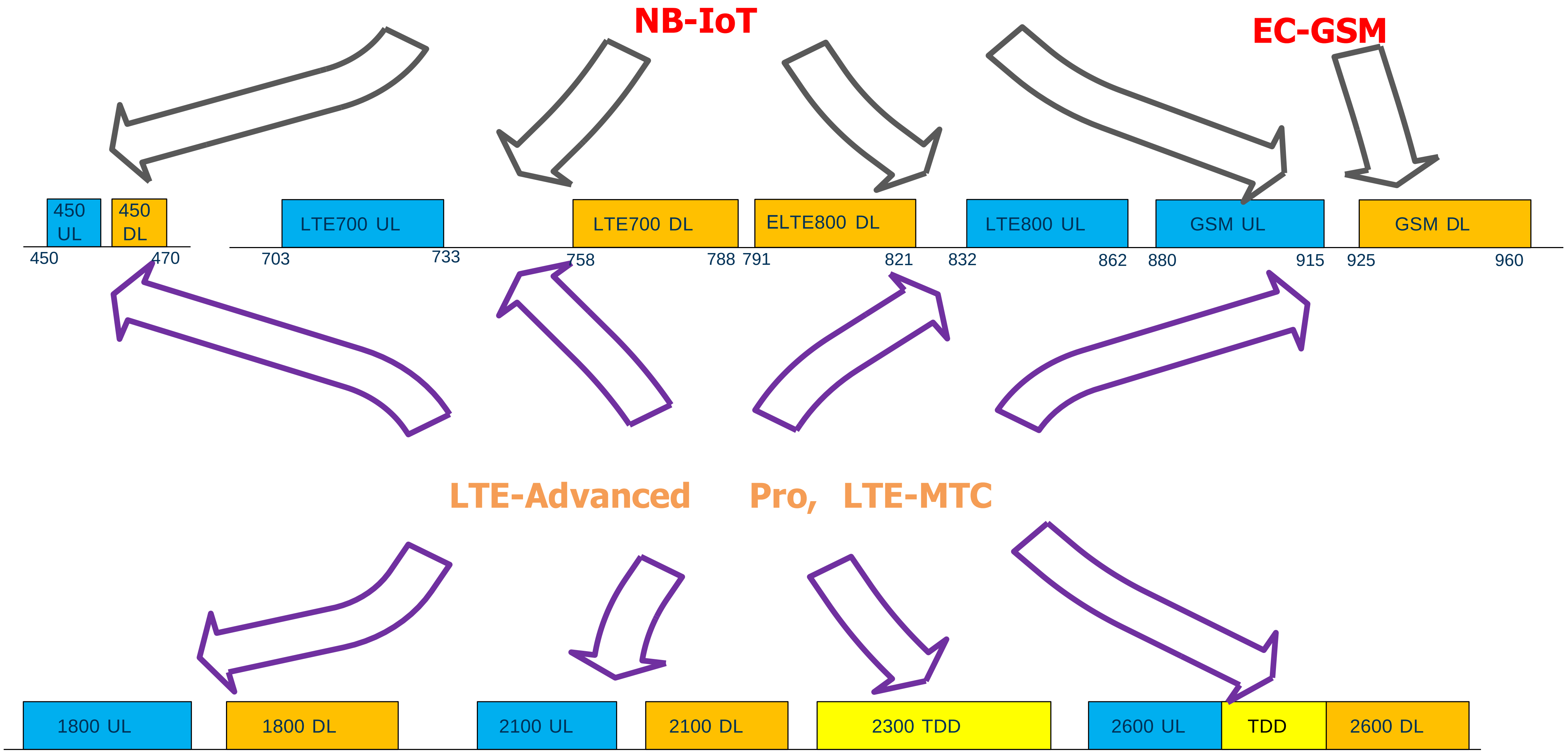
IoT deployments in Licensed Spectrum



Spectrum Needs of IoT

M2M
Radiocommunication Technologies

Technology	Spectrum band
NB-IoT	MBB bands
eMTC	MBB bands
Sigfox	868MHz
LTE-V2X	MBB bands (Uu) 5.8,5.9GHz (PC5)
Bluetooth	2.4GHz
ZigBee	868/2450MHz
RFID	13.56/27.12/433/ 860MHz ...
NFC	13.56MHz
Z-WAVE	868 MHz
Ingenu	2.4GHz

Frequency range

- Sub-1 GHz band are most suitable for efficient provision of wide area coverage;

Authorization

- Sharing spectrum with unlicensed authorization to achieve low cost and low power requirements

- Licensed (exclusive) spectrum is more suitable for wide area coverage and/or higher reliability requirements for delay sensitive applications

IMT- Identified Spectrum

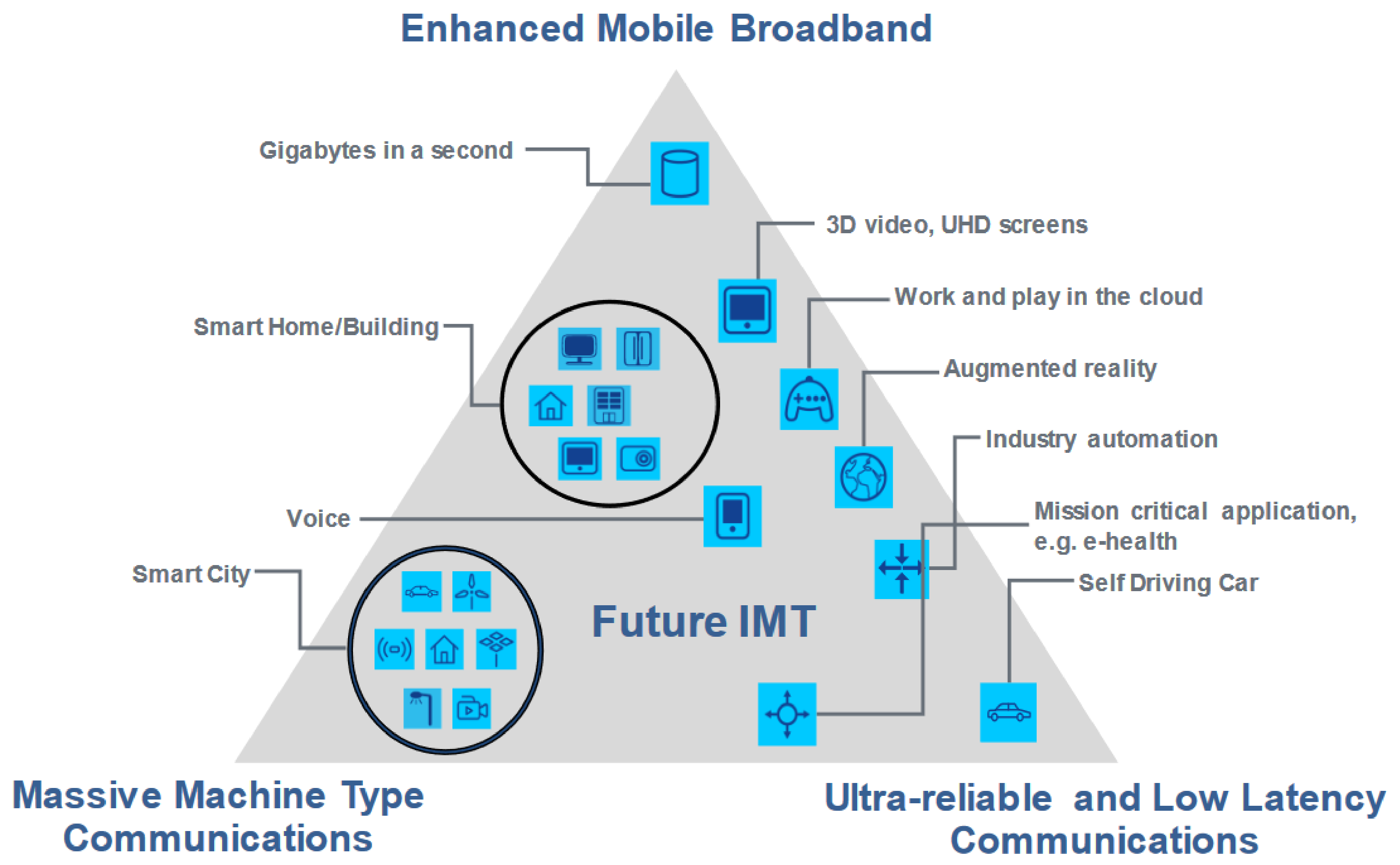
Definition

➢ **Res. ITU-R 56-1:** ***Naming for International Mobile Telecommunications***

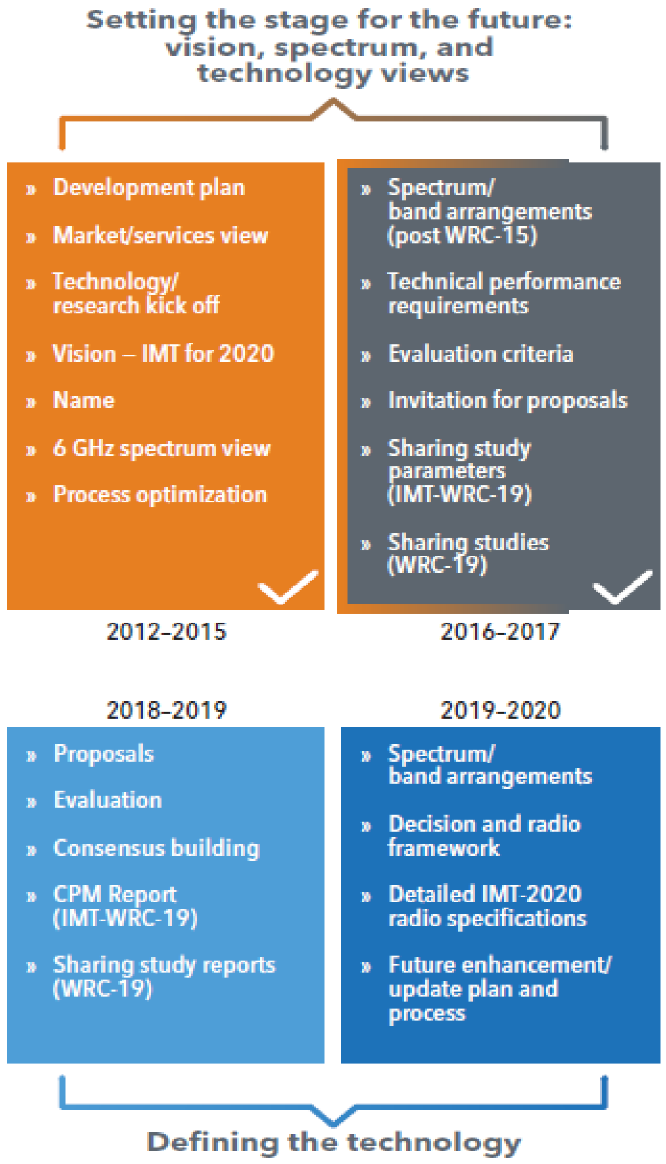
Since ITU is the internationally recognized entity that has sole responsibility to define and to recommend the standards and frequency arrangements for IMT systems, with the collaboration of other organizations such as standard development organizations, universities, industry organizations and with partnership projects, forums, consortia and research collaborations, therefore the RA-15 debated especially on naming of IMT systems.

- *the existing term* **IMT-2000** *continues to be relevant and should continue to be utilized;*
- *the existing term* **IMT-Advanced** *continues to be relevant and should continue to be utilized;*
- *However for systems, system components, and related aspects that include new radio interface(s) which support the new capabilities of systems beyond IMT-2000 and IMT-Advanced, the term "***IMT-2020***" be applied*
- *In addition it was resolved that the term "IMT" would be considered the root name that encompasses all of IMT-2000, IMT-Advanced and IMT-2020 collectively.*

IMT Supports IoT

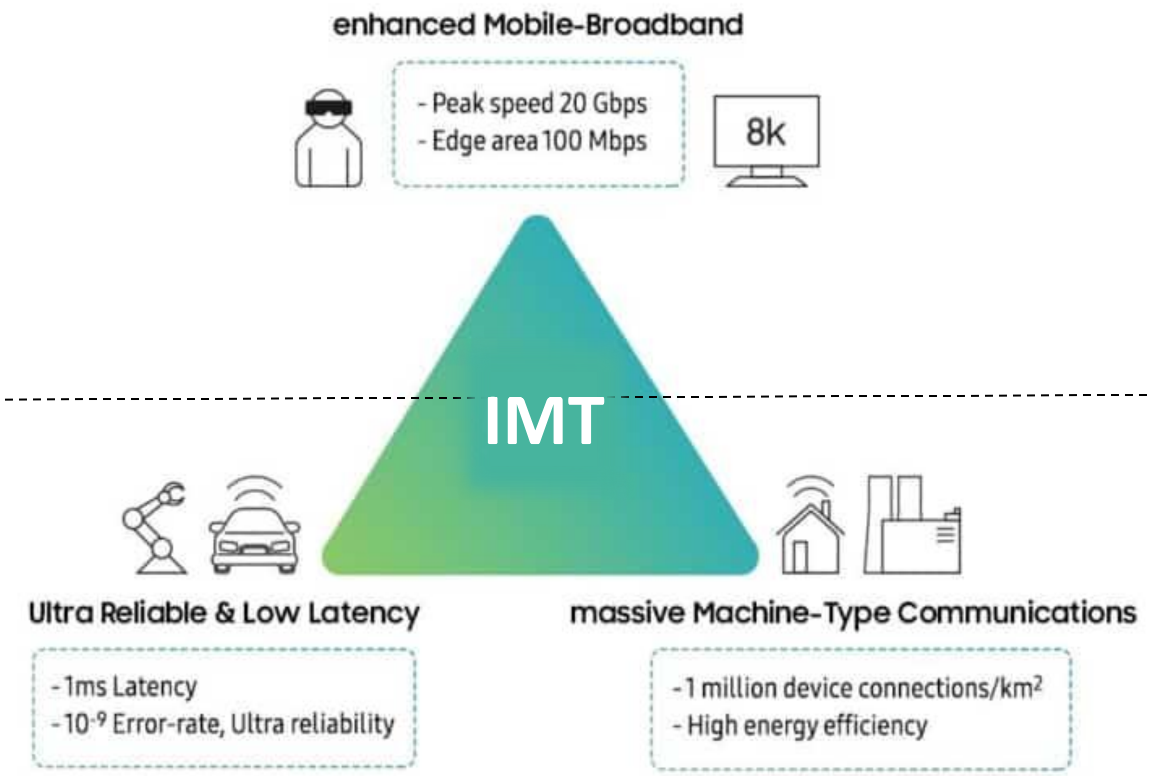


IMT-2020 standardization process



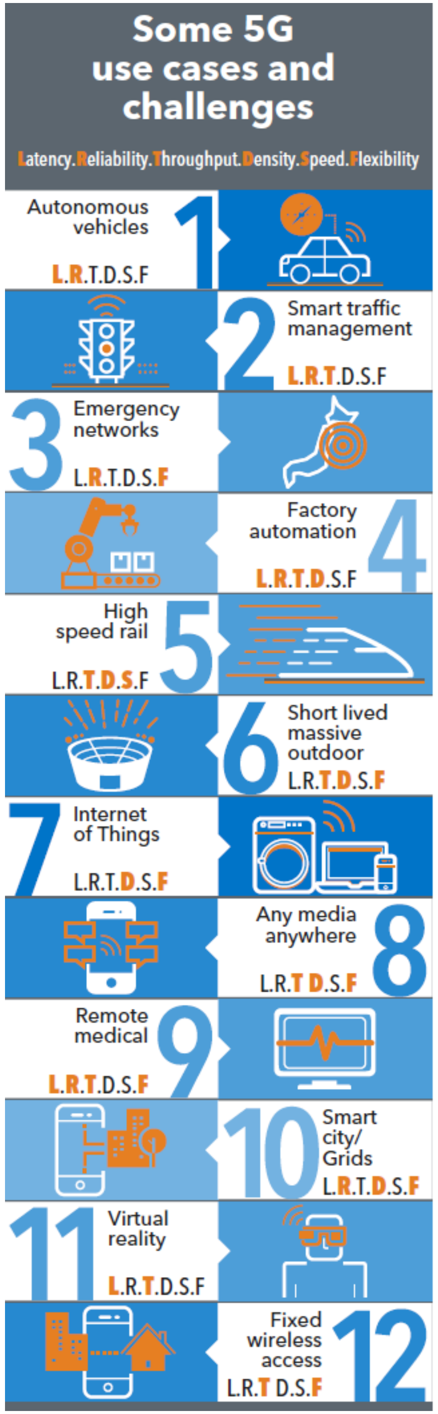
Source: Forging paths to IMT-2020 (5G), Stephen M. Blust, Chairman, ITU Radiocommunication Sector (ITU–R) Working Party 5D, Sergio Buonomo, Counsellor, ITU–R Study Group 5, ITU News, 02/2017

Understanding IMT applications



Consumer – Fixed wireless

Business



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Recalling WRC-15 outcomes

Mobile Broadband (MBB)

(agenda Item 1.1 and 1.2)

Outcomes of WRC-15

New spectrum Identified

WRC - 15

Band (MHz)	Bandwitdh (MHz)	R1	R2	R3
470 – 608	138		some	
608 – 698	84		some	
1427 – 1452	25	any	any	any
1452 – 1492	40	some	any	any
1492 – 1518	26	any	any	any
3300 – 3400	100	some	some	some
3600 – 3700	100		some	
4800 – 4990	190		some	some
	New BW 709			

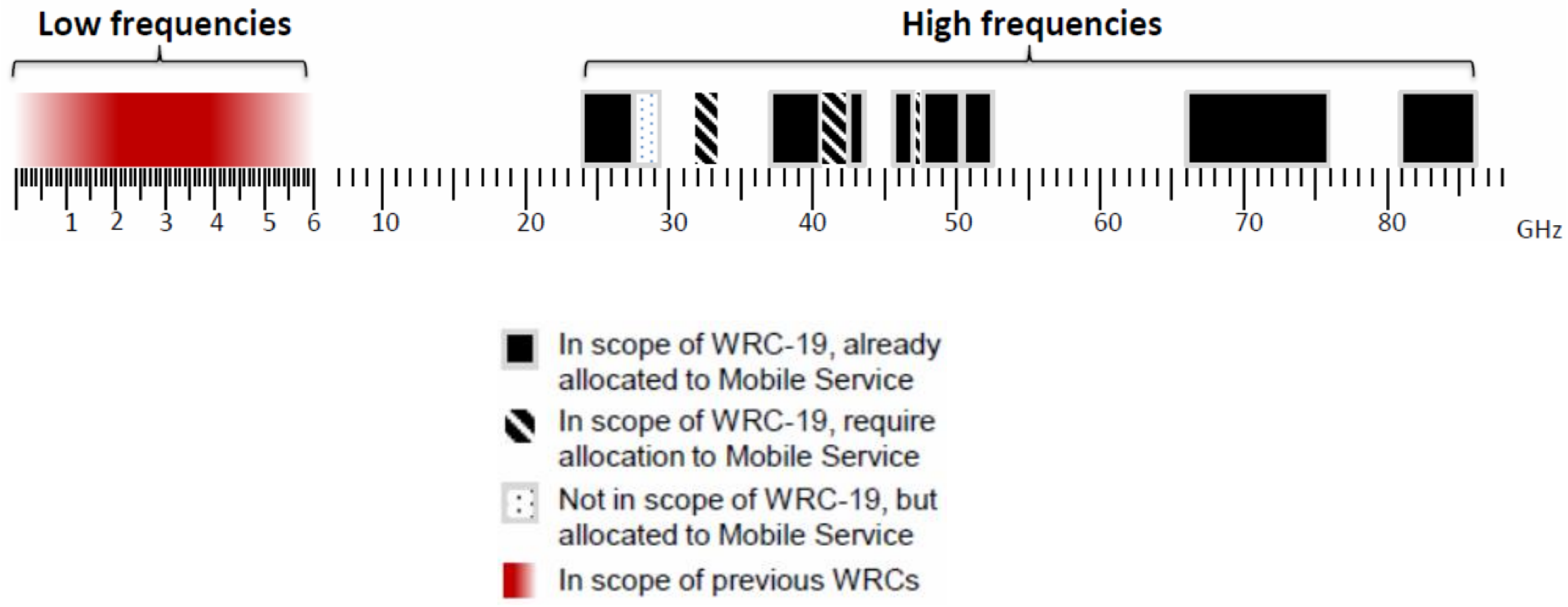
Outcomes of WRC-15

Spectrum for IMT

Band (MHz)	Footnotes identifying the band for IMT			Bandwidth
	Region 1 or parts thereof	Region 2 or parts thereof	**Region 3 or parts thereof**	
450-470	**5.286AA**			20
470-698	-	5.295, 5.308A	**5.296A**	228
694/698-960	5.317A	5.317A	**5.313A, 5.317A**	262
1 427-1 518	5.341A, 5.346	5.341B	**5.341C, 5.346A**	91
1 710-2 025	**5.384A, 5.388**			315
2 110-2 200	**5.388**			90
2 300-2 400	**5.384A**			100
2 500-2 690	**5.384A**			190
3 300-3 400	5.429B	5.429D	**5.429F**	100
3 400-3 600	5.430A	5.431B	**5.432A, 5.432B, 5.433A**	200
3 600-3 700	-	5.434	-	100
4 800-4 990	-	5.441A	**5.441B**	190
Total Bandwidth	**1,886** *(Regional allocations vary and therefore totals can be different for a specific region)*			

Going Forward

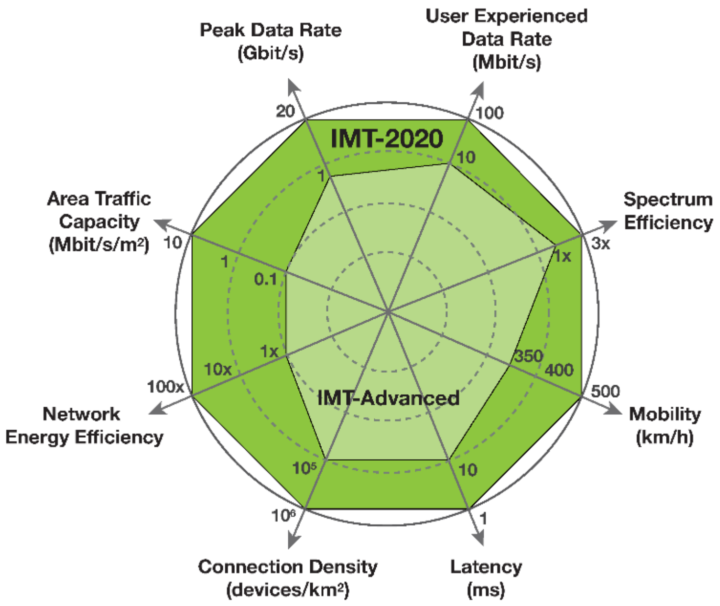
IMT spectrum requirements and WRC-19



BB applications in MS
(WRC-19 Agenda item 1.13 and 1.16)

➢ The following bands, which are already allocated to mobile, will be studied with a view to an IMT-2020 identification:

- 24.25 – 27.5 GHz
- 37 – 40.5 GHz
- 42.5 – 43.5 GHz
- 45.5 – 47 GHz
- 47.2 – 50.2 GHz
- 50.4 – 52.6 GHz
- 66 – 76 GHz
- 81 – 86 GHz



➢ The following bands will also be studied, although they do not currently have global mobile allocations: Res. 238 (WRC-15)

- 31.8 – 33.4 GHz
- 40.5 – 42.5 GHz
- 47 - 47.2 GHz

Overlapping Bands in WRC-19 Agenda Items

1.6 – NGSO FSS Res. 159 (WRC-15)	1.13 – IMT Res. 238 (WRC-15)	1.14 – HAPS Res. 160 (WRC-15)	9.1 (9.1.9) – FSS Res. 162 (WRC-15)
	24.25 - 27.5	24.25 - 27.5 (Reg. 2)	
37.5 - 39.5 (s-E*)	37 - 40.5	38 - 39.5 (globally)	
39.5 - 42.5 (s-E*)	40.5 - 42.5		
47.2 - 50.2 (E-s*)	47.2 - 50.2		
50.4 - 51.4 (E-s*)	50.4 - 52.6		51.4 - 52.4 (E-s*)

- **E-s: Earth-to-space; s-E: space-to-Earth.**
- **All bands in GHz**

Studies to **address mutual compatibility & sharing feasibility** among the **services/applications** for which **allocation/identification is envisaged** under the corresponding Res. relating to the AI in the overlapping bands

Future Spectrum need estimation for IMT

(24.25 GHz - 86 GHz)

Deployment scenarios	Indoor hotspot	Dense urban		Urban macro
		Micro	Macro	
Frequency range	24.25-86 GHz	24.25-43.5 GHz	<6 GHz	<6 GHz

Deployment scenario	Micro	Indoor hotspot
Total spectrum needs for 24.25-86 GHz	14.8-19.7 GHz*	
Spectrum needs for 24.25-43.5 GHz	5.8-7.7 GHz	9-12 GHz
Spectrum needs for 45.5-86 GHz	–**	

** Considering the coexistence between multiple network operators (e.g. the guard band(s) may be required in the case of multiple network operators scenarios), the total spectrum needs are expected to be increased.*

*** The division in this table regarding frequency ranges and deployment scenarios is just an indicative example on how spectrum needs could be distributed for different spectrum sub-ranges within 24.25-86 GHz and different deployment scenarios. This table should not be understood nor used to exclude any possible IMT-2020 deployment options in the range 45.5-86 GHz.*

Source: WP 5D Liaison statement to Task Group 5/1

Some 5G Deployments strategies

Regulator	Low (1 GHz)	Medium (<6GHz)	High (mmWave)
FCC	600MHz auctioned – T-Mobile using for 5G	3.5GHz band to be shared under CBRS	28GHz available; 64GHz for unlicensed
Ofcom	700MHz spectrum available by 2020	3.5GHz cleared; 3.7GHz under consultation	26GHz to be repositioned for mobile data
MISP (KOR)	700MHz and 1.3GHz to be freed up in 2018	3.5GHz to be allocated	28GHz – 1GHz available; 38GHz to be allocated
MIIT (CHN)	800MHz for NB-IoT	3.3GHz, 3.5GHz, 4.4GHz, 4.9GHz being considered	26GHz and 40GHz reallocation underway
MIC (JPN)	700MHz assigned for LTE	3.4GHz & 4.4-4.9GHz under review, 3.5GHz done	27.5-29.5GHz to be reassigned for mobile BB
	For coverage – mobile BB and massive IoT	**3.5GHz has wide support – for eMBB and mission-critical apps**	**26 – 28GHz has wide support – high density and high capacity**

3.5GHz IMT vs FSS will be evaluated and coordinated with neighbouring countries

IoT and regulatory issues

- Licensed Vs Non Licensed spectrum
- Area of license
- Numbering
- Standardization
- Infrastructure sharing
- Access to data and open IOT platforms
- Data analytics
- Mobile data roaming
- Consumer protection
- Quality of Service
- USO
- Taxation

https://news.itu.int/one-world-one-global-sim/

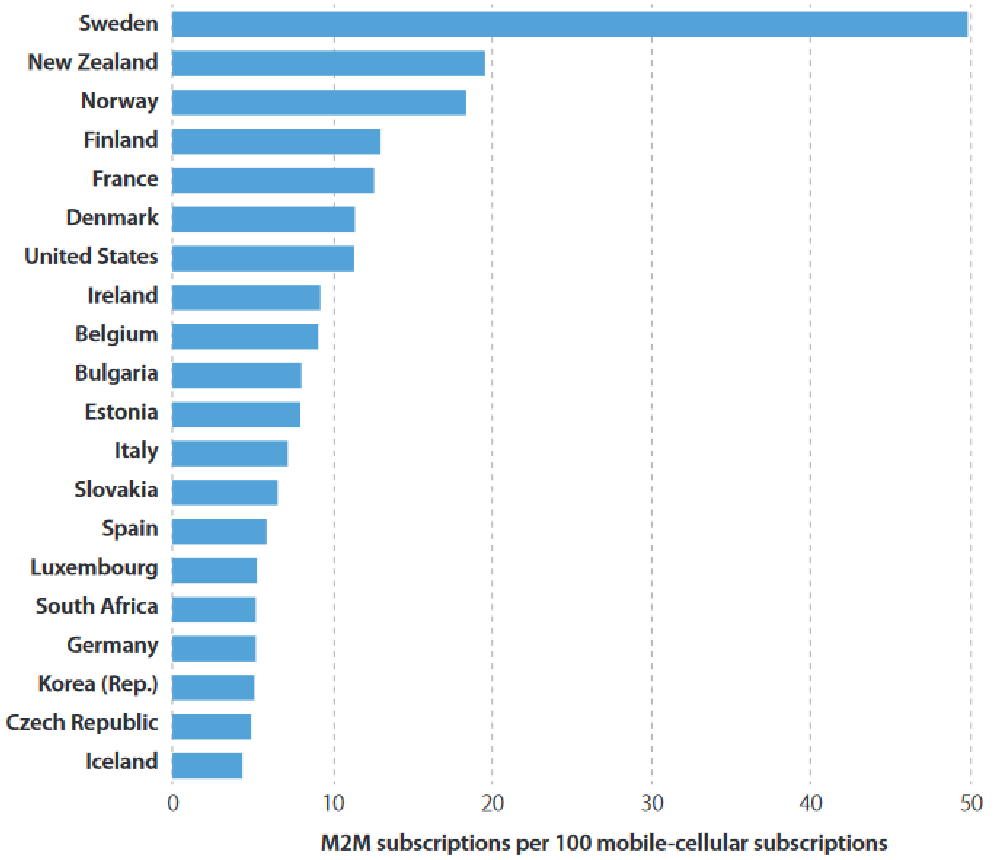
! Global International Mobile Subscriber Identity (IMSI) ranges are signified by the shared Mobile Country Code '**901**', a code without ties to any particular country.

Conclusion

- IoTs are in early stage of deployment
  - Some operators already provided services

- Spectrum requirements vary with usage cases
  - Could be Unlicensed or Licensed.

- IMT supports numerous applications including support for IMT services



Based on available data, there were 22 mobile-cellular subscriptions for each machine-to-machine (M2M) subscription worldwide at the beginning of 2015.

The countries with the highest M2M penetration rates are highly industrialized, advanced economies, including the Northern European countries of Sweden, Norway, Finland and Denmark

Source: ITU. Note: Data refer to early 2015.

Overview of the Ecosystem

Standardization

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Scope

IoTs Design and Planning requirements

Short Range IoT Solutions

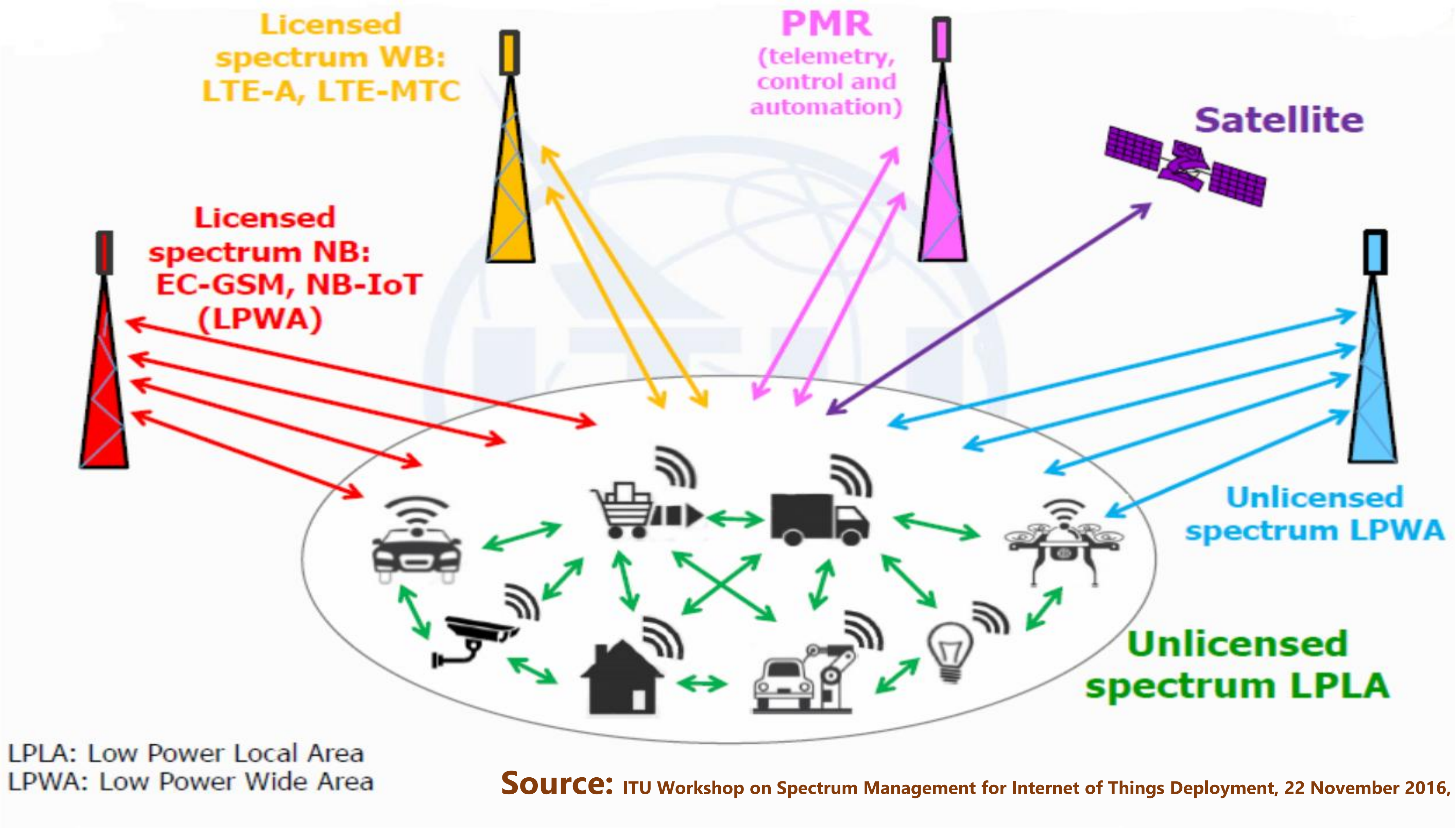
Long Range IoT Solutions

IMT2020 (5G Supporting) IoT

Examples from of current IoT Market

- Regulation
- Pricing
- Future analysis and issues

IoT Connectivity Options



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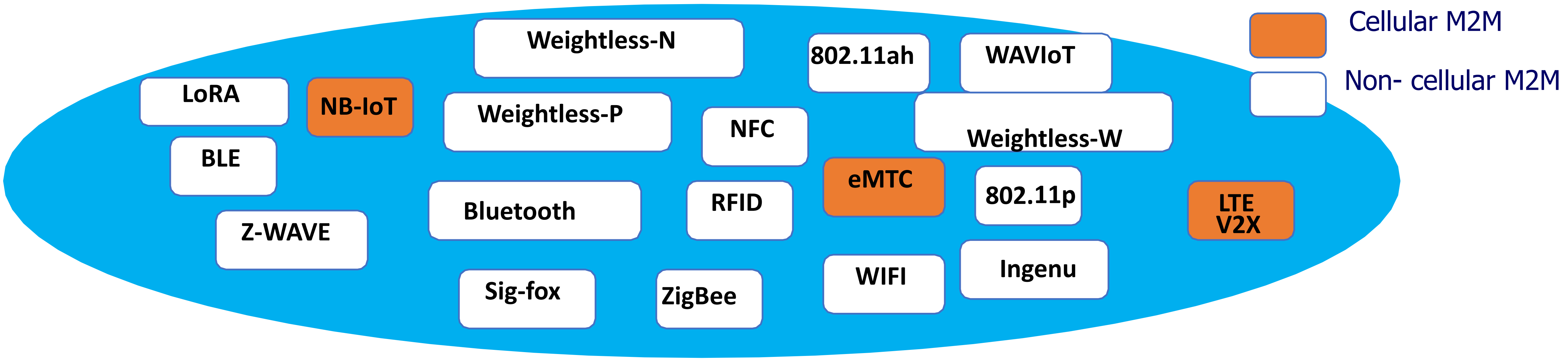

IoT: 4 layer Model

Integrated Applications

Information Processing

Network Infrastructure

Sensing and Identification

IoT: Refernce Model

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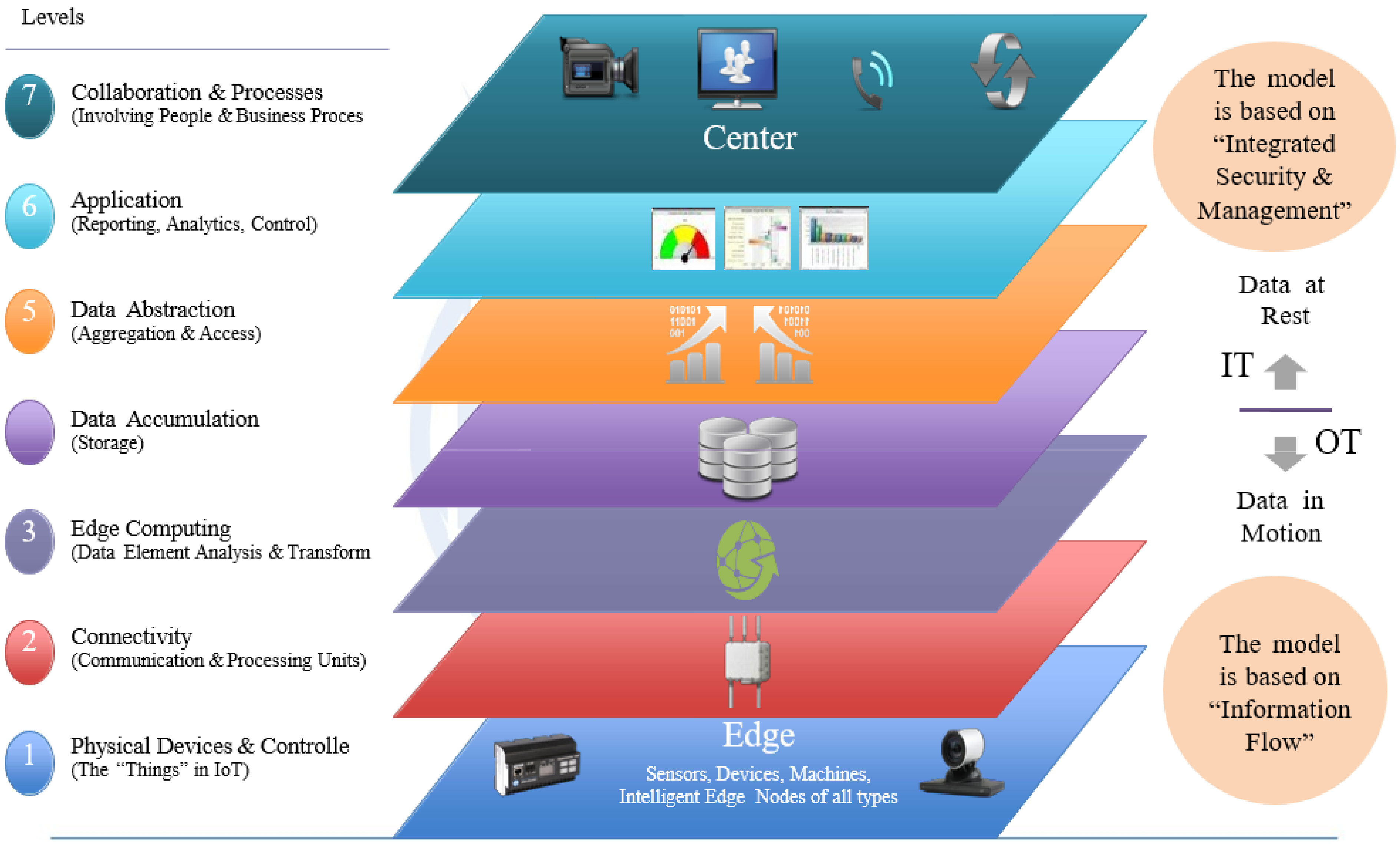
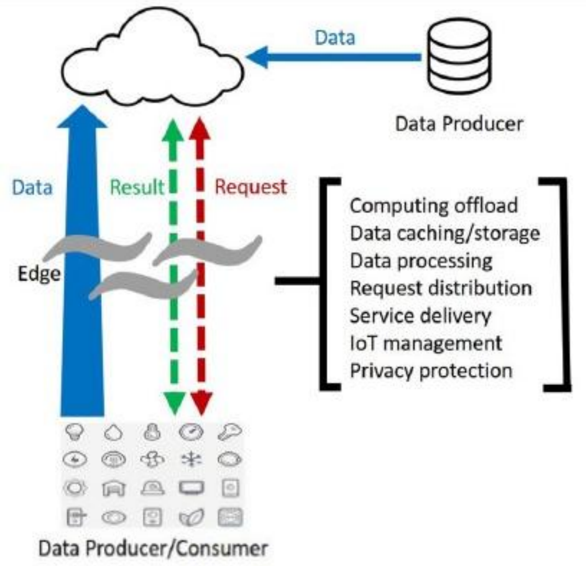




IoT design requirements

IoT Network	Impact on IoT Systems Design
Scale	**Tens of thousand sensors in a given site; or millions distributed geographically** More pressure on application architectures, network load, traffic types, security, non-standard usage pattern
Heterogeneous end-points	**Vast array of sensors, actuators, and smart devices – IP or non-IP** Diverse data rate exchange, form factor, computing and communication capabilities, legacy protocols
Low Capex and Opex requirement	**May be deployed before activation, maybe or cannot-be accessed once deployed** • Low numbers of gateways Link budget: e.g: UL: 155 dB (or better), DL: Link budget: 153 dB (or better) • Devices deliver services with little or no human control, difficult to correct mistakes, device management is key
Criticality of services	**Human life critical (Healthcare), Critical infrastructure (Smart Grid)** Stringent latency (10ms for SG) and reliability requirements, may challenge/exceed network capabilities of today
Intrusiveness	**Things with explicit intent to better manage end-users (eHealth, Smart Grid)** Issues of Privacy become major obstacles
Geography	**Movement across borders** Issues of numbering for unique identification

Source: ITU CoE training on BB networks planning, Bangkok, Sep 2017

IoT network connectivity requirements

IoT Network	Impact on IoT Systems Design
Resource-constrained endpoints	**Severely resource constrained (memory, compute)** Cost motivation: compute/memory several orders of magnitude lower, limited remote SW update capability, light protocols, security
Low Power	**Some end-point types may be mostly 'sleeping' and awakened when required** • Sensors cannot be easily connected to a power source • Reduced interaction time between devices and applications (some regulations state duty cycle of no more than 1%) • Idle mode most of the time (energy consumption of around 100 µW). Connected mode just for transmission (mA) • < 100 MHz clock frequency • Embedded memory of few Mb
Embedded	**Smart civil infrastructure, building, devices inside human beings** Sensors deployed in secure or hostile operating conditions, difficult to change without impacting system, Security
Longevity	**Deployed for life typically, have to build-in device redundancy** Very different lifetime expectancy, rate of equipment change in IoT business domains much lower than ICT Industry
High Sensitivity on reception	**Gateways and end-devices with a high sensitivity around** -150 dBm/-125 dBm with Bluetooth lower than -95 dBm in in cellular

Source: **ITU CoE training on BB networks planning, Bangkok, Sep 2017**

IoT Technical Solutions

- **Fixed & Short Range**
  - RFID
  - Bluetooth
  - Zigbee
  - WiFi
  - ….

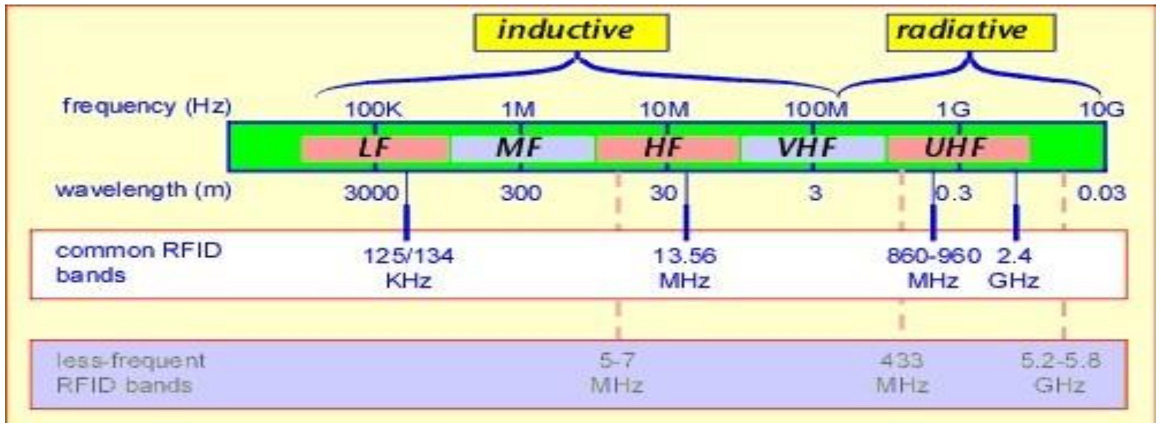
- **Long Range technologies**
  - Non 3GPP Standards (LPWAN)
  - 3GPP Standards

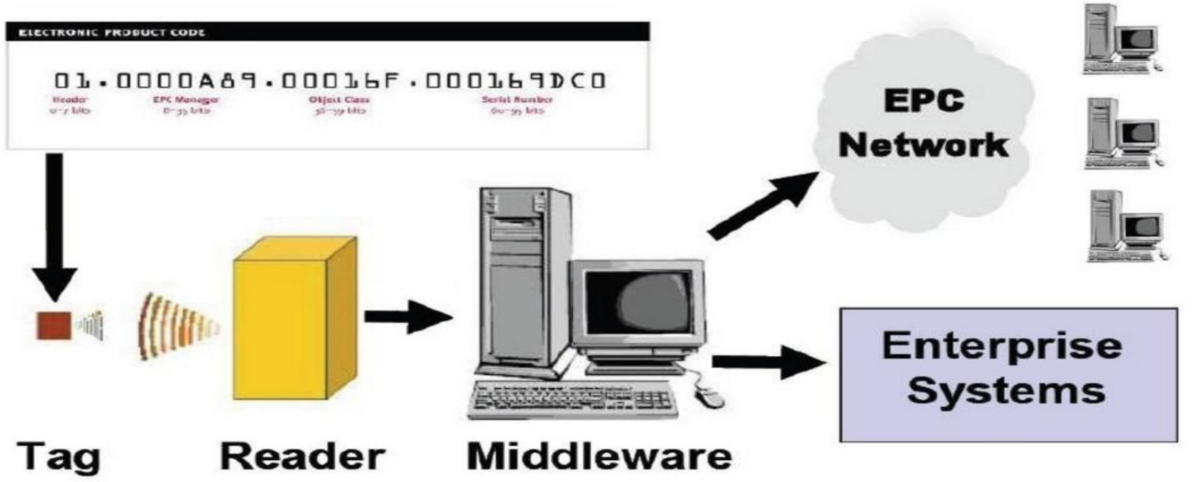
Short Range IoT Solutions

- RFID
- Bluetooth
- ZigBee
- WiFI

RFID: Radio Frequency Identification

- **Appeared first in 1945**
- **Features:**
  - Identify objects, record metadata or control individual target
  - More complex devices (e.g., readers, interrogators, beacons) usually connected to a host computer or network
  - Radio frequencies from 100 kHz to 10 GHz
- **Operations:**
  - Reading Device called Reader (connected to banckend network and communicates with tags using RF)
  - One or more tags (embedded antenna connected to chip based and attached to object)





Bluetooth

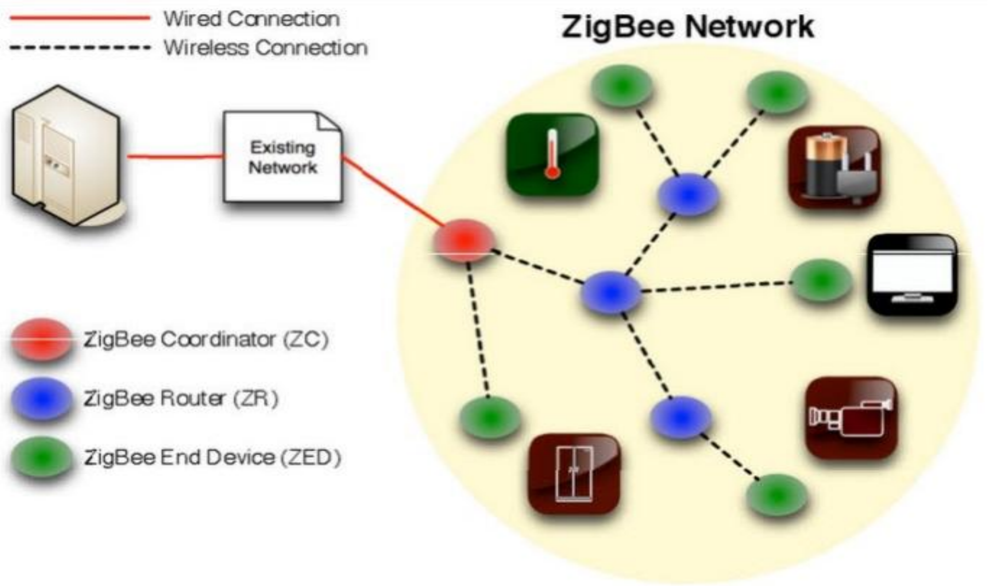
- **Features:**
  - Low Power wireless technology
  - Short range radio frequency at 2.4 GHz ISM Band
  - Wireless alternative to wires
  - Creating PANs (Personal area networks)
  - Support Data Rate of 1 Mb/s (data traffic, video traffic)
  - Uses Frequency Hopping spread Spectrum

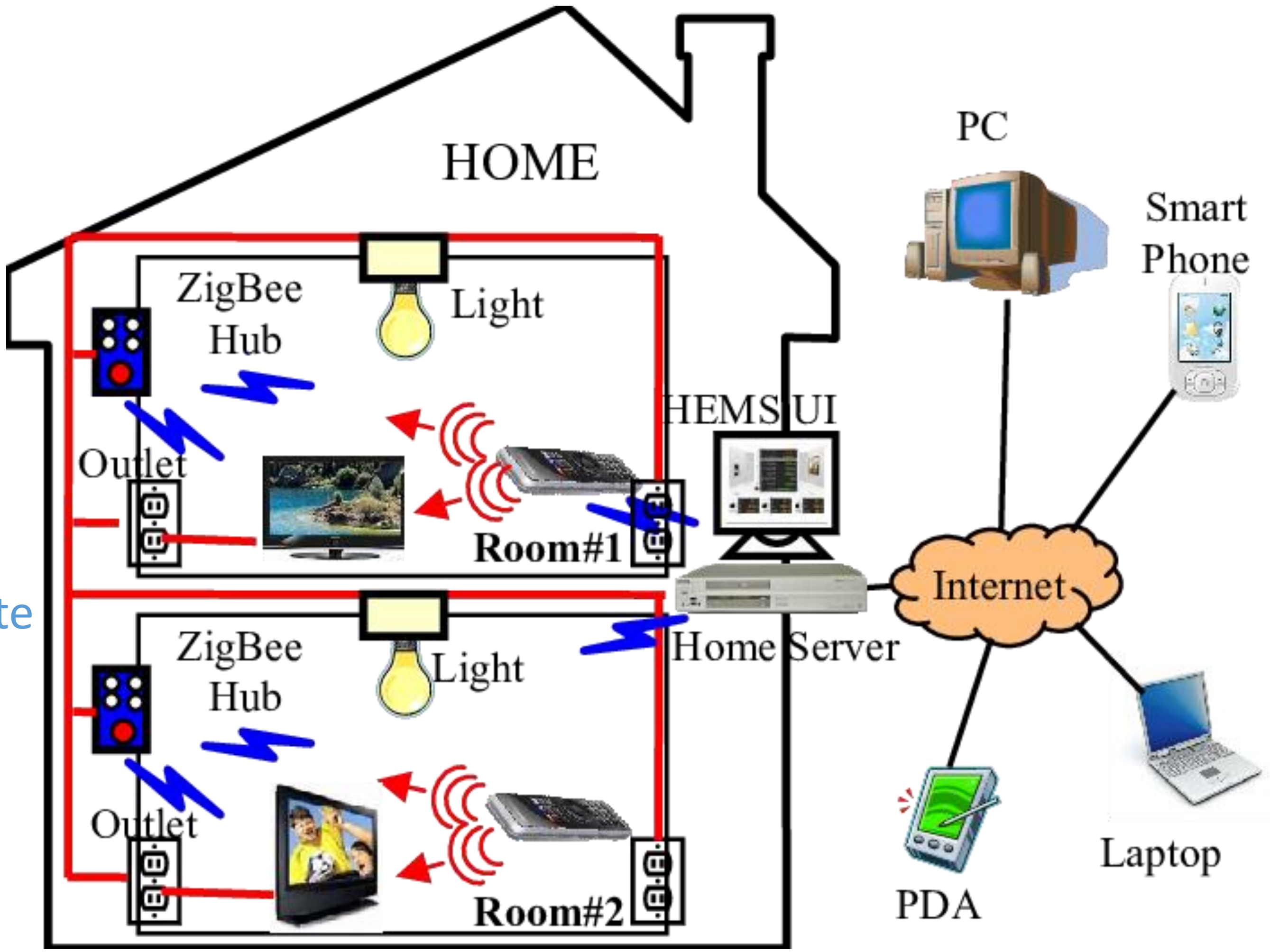
- **Bluetooth 5:**
  - 4x range, 2x speed and 8x broadcasting message capacity
  - Low latency, fast transaction (3 ms from start to finish) Data Rate 1 Mb/s: sending just small data packets

Class	Maximum Power	Range
1	100 mW (20 dBm)	100 m
2	2,5 mW (4 dBm)	10 m
3	1 mW (0 dBm)	1 m

ZigBee

- **Operations:**
  - **Coordinator**: acts as a root and bridge of the network
  - **Router**: intermediary device that permit data to pass to and through them to other devices
  - **End Device:** limited functionality to communicate with the parent nodes



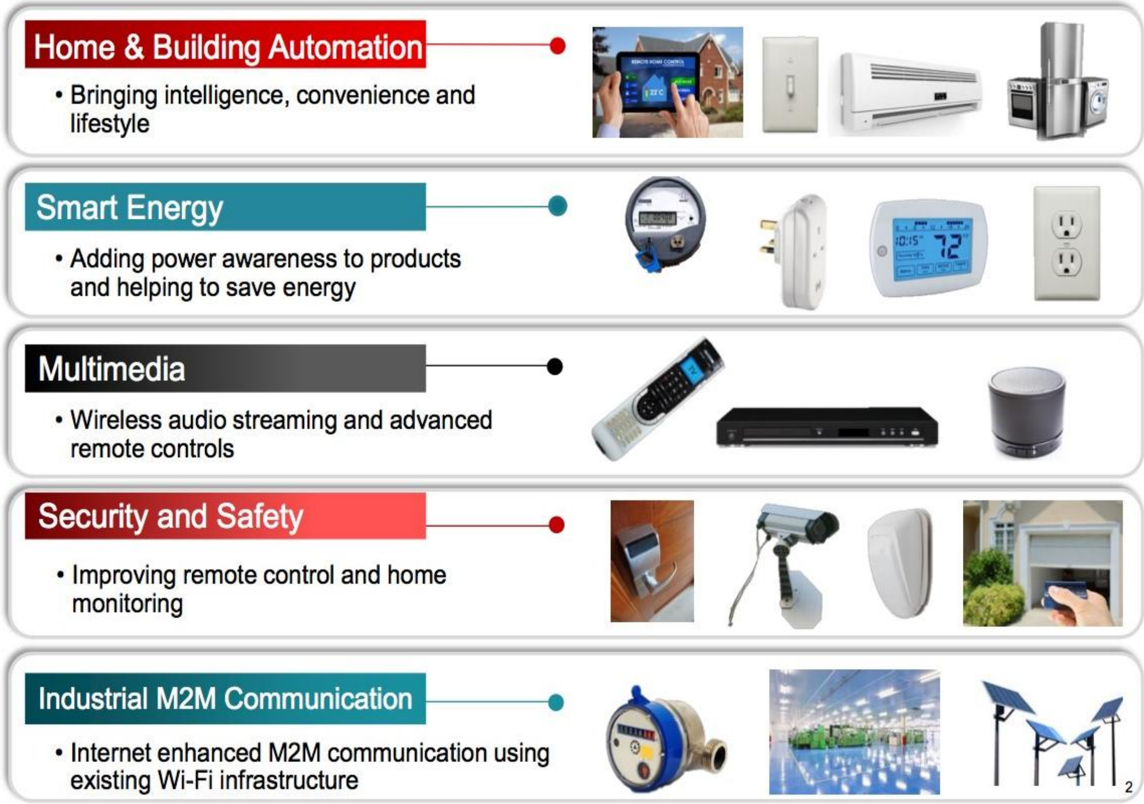


Low cost and available

WiFi

- Wireless Alternative to Wired Technologies
- Standardized as IEEE 802.11 standard for WLANs

Standard	Frequency bands	Throughput	Range
WiFi a (802.11a)	5 GHz	54 Mbit/s	10 m
WiFi B (802.11b)	2.4 GHz	11 Mbit/s	140 m
WiFi G (802.11g)	2.4 GHz	54 Mbit/s	140 m
WiFi N (802.11n)	2.4 GHz / 5 GHz	450 Mbit/s	250 m
IEEE 802.11ah	900 MHz	8 Mbit/s	100 M



WiFi HaLow

A new low-power, long-range version of Wi-Fi that bolsters IoT connections

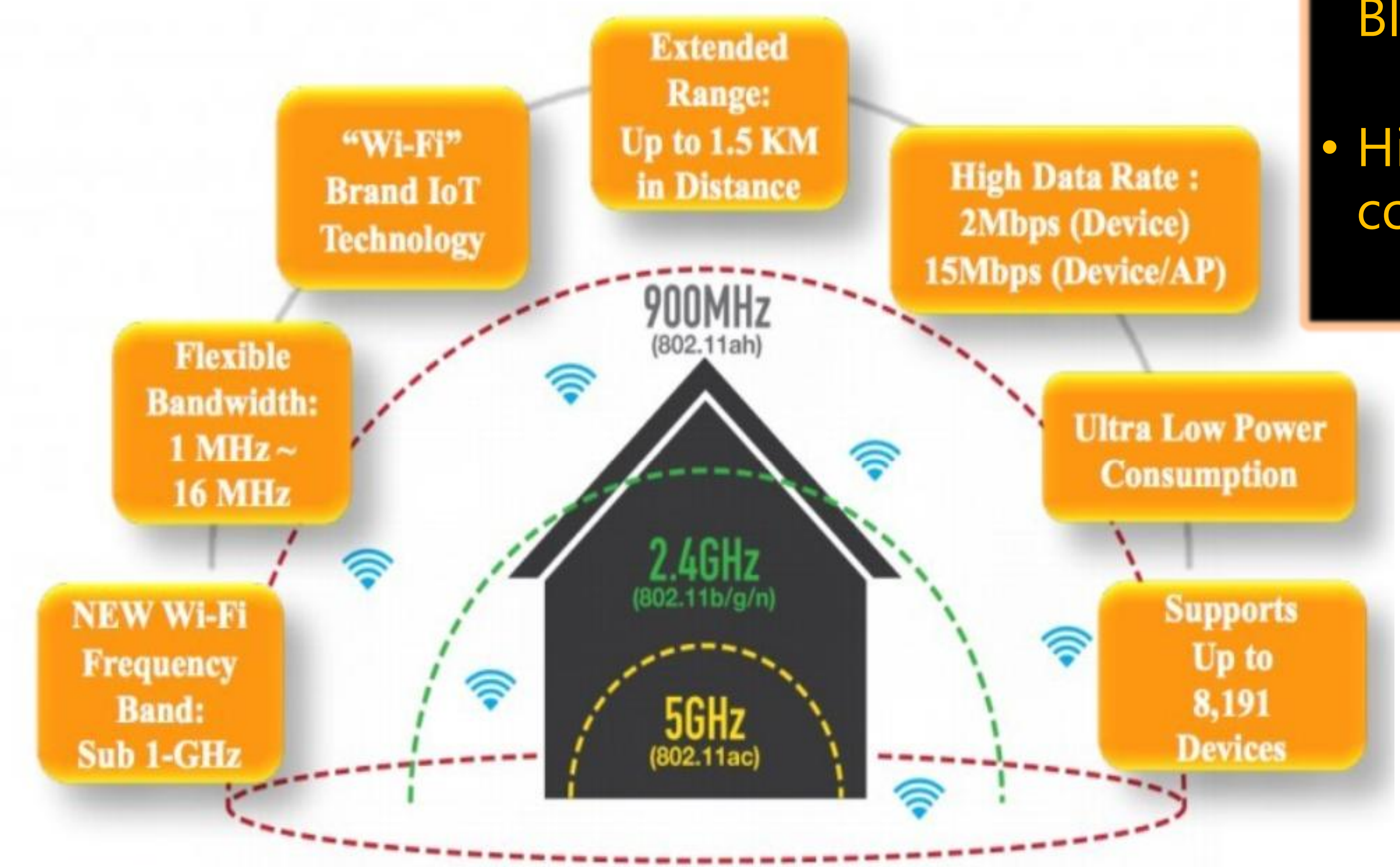
Wi-Fi HaLow is based on the **IEEE 802.11ah** specification

Wi-Fi HaLow will operate in the unlicensed wireless spectrum in the 900MHz band

Its range will be nearly double today's available Wi-Fi (1 kilometer)

- More flexible
- The protocol's low power consumption competes with Bluetooth
- Higher data rates and wider coverage range

WiFi HaLow



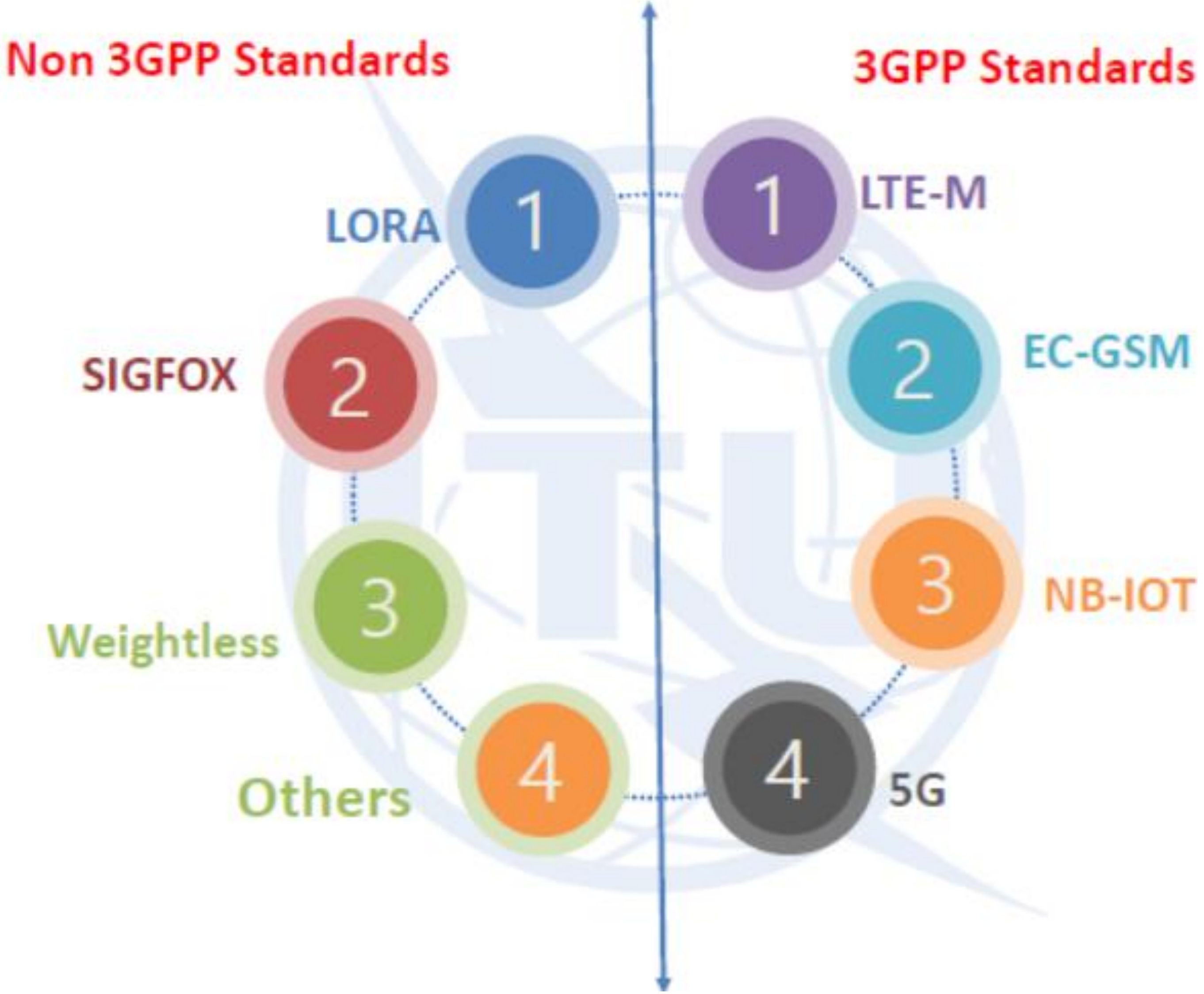
- More flexible
- The protocol's low power consumption competes with Bluetooth
- Higher data rates and wider coverage range

Picture Source: Newracom

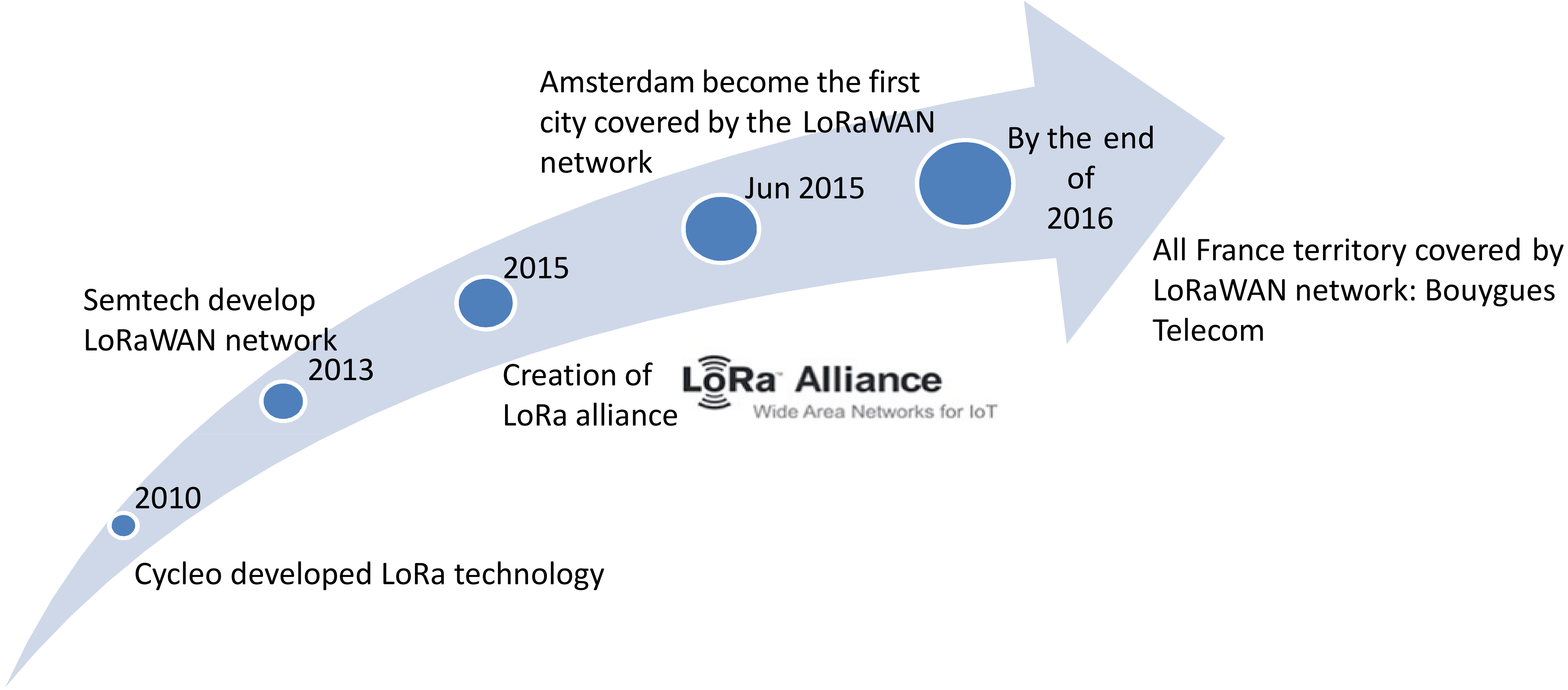
Long Range IoT Solutions

- Non 3GPP
- 3GPP

IoT Long Range Technical Solutions



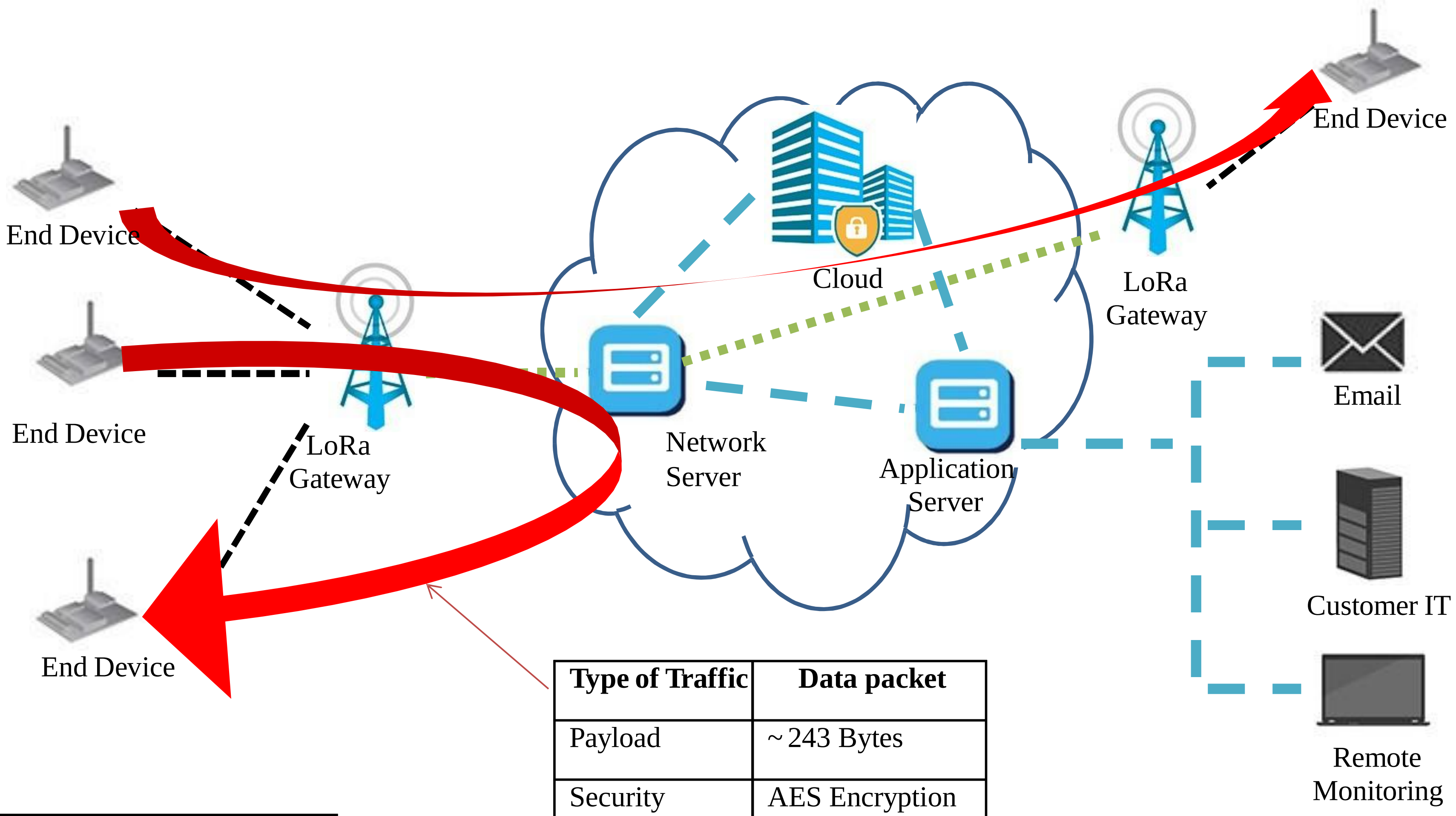
LORA


Amsterdam become the first city covered by the LoRaWAN network
By the end of 2016
Jun 2015
All France territory covered by LoRaWAN network: Bouygues Telecom
2015
Semtech develop LoRaWAN network
2013
Creation of LoRa alliance
LoRa Alliance
Wide Area Networks for IoT
2010
Cycleo developed LoRa technology

LORA - Features

- **LoRaWAN is a Low Power Wide Area Network**
- **Modulation:** a version of Chirp Spread Spectrum (CSS) with a typical channel bandwidth of 125KHz
- **High Sensitivity:** End Nodes: Up to -137 dBm, Gateways: up to -142 dBm
- **Long range:** up to 15 Km
- **Strong indoor penetration:** With High Spreading Factor, Up to 20dB penetration (deep indoor)
- **Robust** Occupies the entire bandwidth of the channel to broadcast a signal, making it robust to channel noise
- **Resistant to Doppler effect multi-path and signal weakening.**

LORA - Architecture



Type of Traffic	Data packet
Payload	~ 243 Bytes
Security	AES Encryption

Modulation	LoRa RF (Spread Spectrum)
Range	~ 15 Km
Throughput	~ 50 Kbps

LORA – Device Classes

Classes	Description	Intended Use	Consumption	Examples of Services
A (« all »)	Listens only after end device transmission	Modules with no latency constraint	The most economic communication Class energetically.. Supported by all modules. Adapted to battery powered modules	• Fire Detection • Earthquake Early Detection
B (« beacon »)	The module listens at a regularly adjustable frequency	Modules with latency constraints for the reception of messages of a few seconds	Consumption optimized. Adapted to battery powered modules	• Smart metering • Temperature rise
C (« continuous »)	Module always listening	Modules with a strong reception latency constraint (less than one second)	Adapted to modules on the grid or with no power constraints	• Fleet management • Real Time Traffic Management

Any LoRa object can transmit and receive data

Sigfox – Development

2012
Launch of the Sigfox network

2013
First fundraising of Sigfox company to cover France

2014
All France territory is covered by Sigfox network

Mar 2016
San-Francisco become the first US. State covered by Sigfox

2017
42 countries, 1000 customers

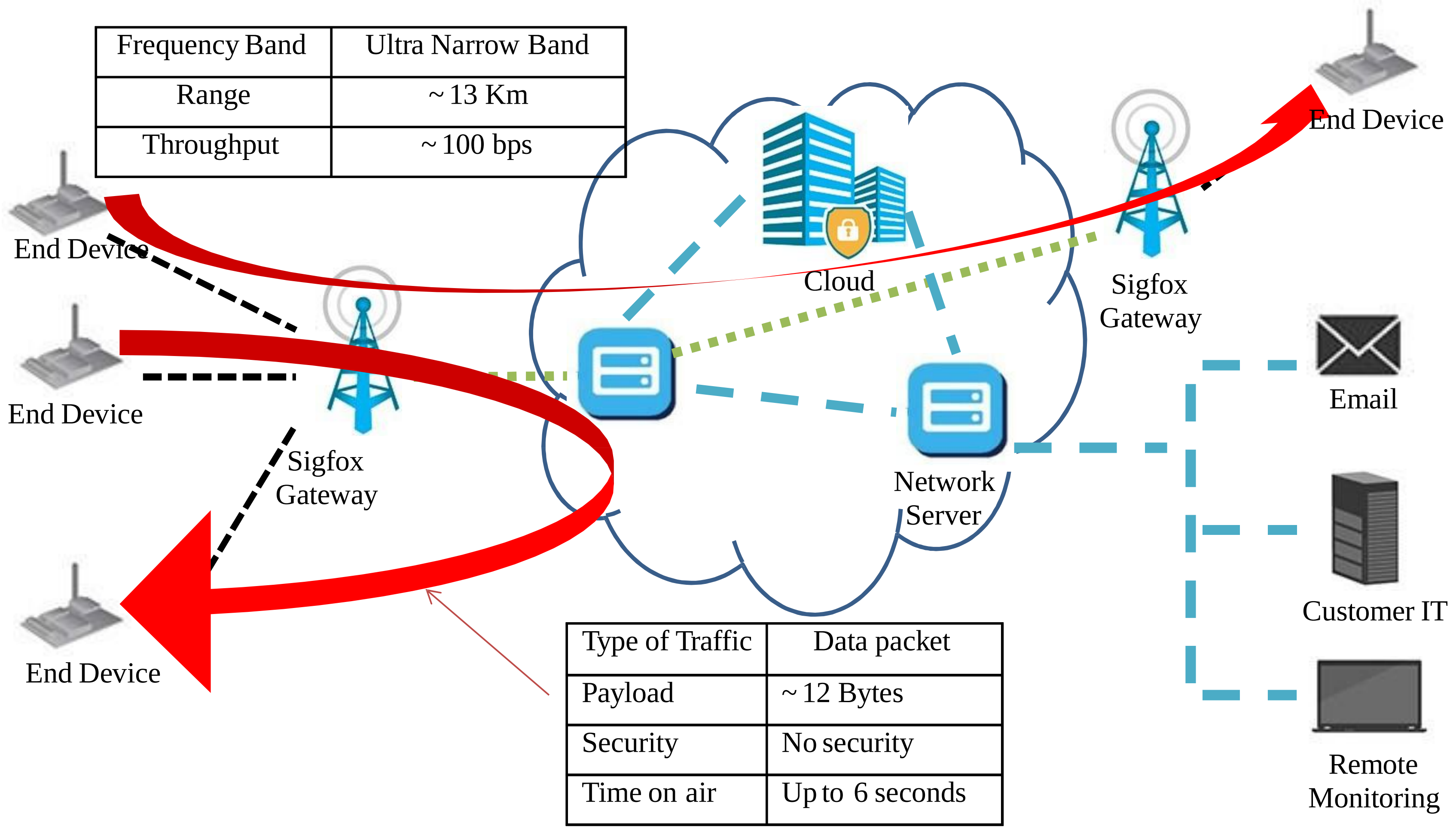
60 countries covered by the end of 2018

Sigfox – Overview

- First LPWAN Technology (BPSK based transmission)
- The physical layer based on an Ultra-Narrow band wireless modulation
- Proprietary system
- Low throughput (~100 bps)
- Low power
- Extended range (up to 50 km)
- 140 messages/day/device
- Subscription-based model
- Cloud platform with Sigfox –defined API for server access
- Roaming capability
- Takes very narrow parts of spectrum and changes the phase of the carrier radio wave to encode the data

Sigfox - Architecture

Frequency Band	Ultra Narrow Band
Range	~ 13 Km
Throughput	~ 100 bps



Type of Traffic	Data packet
Payload	~ 12 Bytes
Security	No security
Time on air	Up to 6 seconds

Weightless - Overview

WEIGHTLESS™

- Low cost technology to be readily integrated into machines
- Operates in an unlicensed environment where the interference caused by others cannot be predicted and must be avoided or overcome.
- Ability to operate effectively in unlicensed spectrum and is optimized for M2M.
- Ability to handle large numbers of terminals efficiently.

Frequency Band	Narrow Band
Range	~ 13 Km
Throughput	~ 10 Mbps

Type of Traffic	Data packet
Payload	~ 200 Bytes
Security	AES Encryption

Weightless – Development

- 2012 — Starts specification
- Creation of Weightless Special Interest Group
- 2014 — White Space spectrum is coming - ratified in USA Q3 2012, UK expected Q2 2014
- First version released
- First Weightless-N network deployed in London

Weightless – Versions

	Weightless-N	**Weightless-P**	**Weightless-W**
Communication	1-way	2-ways	2-ways
Range	5Km+	2Km+	5Km+
Battery life	10 years	3-8 years	3-5 years
Terminal cost	Very low	Low	Low-medium
Network cost	Very low	Medium	Medium
Data Rate	Up to 10 Mbps	Up to 100 Kbps	Up to 200 Kbps

RPMA – Overview

- **Random Phase Multiple Access (RPMA) technology is a low-power, wide-area channel access method used exclusively for machine-to-machine (M2M) communication**
  - Uses the popular 2.4 GHz band
  - Offer extreme coverage and High capacity
  - Allows handover (channel change) with Excellent link capacity

- **RPMA is a Direct Sequence Spread Spectrum (DSSS) using**
- Convolutional channel coding, gold codes for spreading
- 1 MHz bandwidth
- TDD frame with power control in both open and Closed Loop Power Control

TDD frame

RPMA – Development

2008	September 2015	2016	2017
RPMA was developed by On-Ramp Wireless to provide connectivity to oil and gas actors	it was renamed Ingenu, and targets to extend its technology to the IoT and M2M market	RPMA was implemented in many places Austin, Dallas/Ft. worth, Hostton,TX,Phenix,AZ, ….	RPMA will be introduced in many others countries: Los Angeles, San Franscisco-West Bay,CA,Washington,DC, Baltimore,MD, Kanasas City

EnOcean

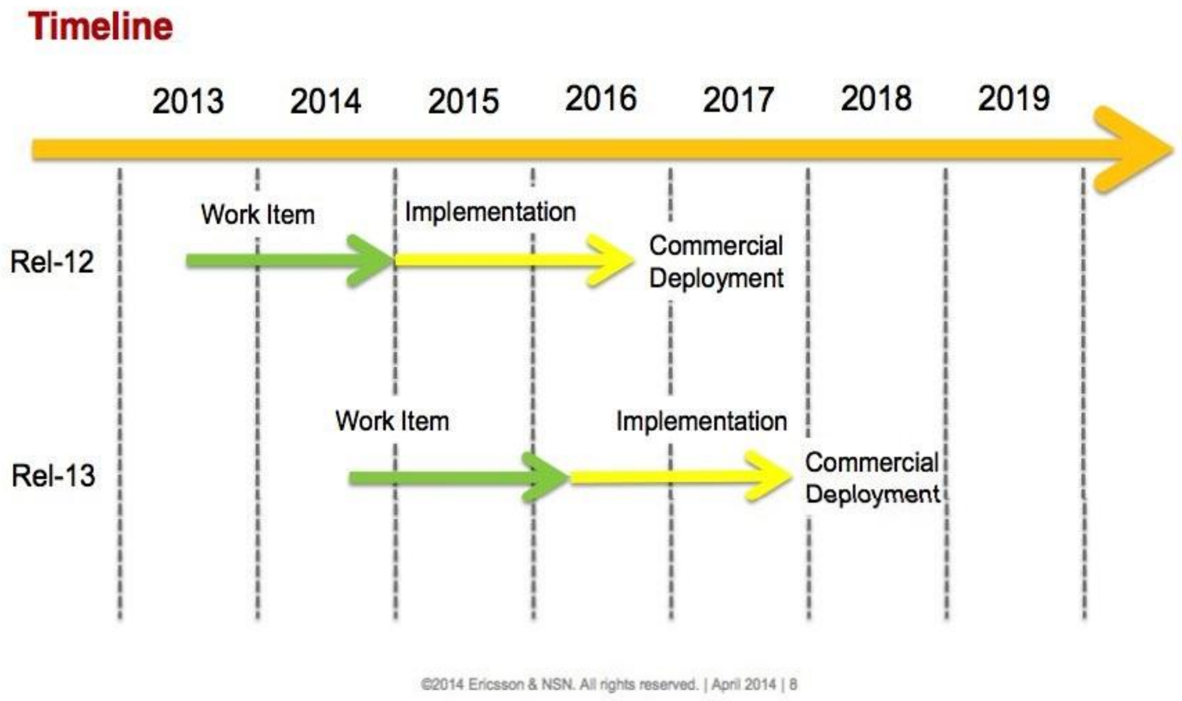
- **Ultra low power radio technology based on miniaturized power converters**
  - Power is generated by harvesting energy from motion, light or temperature (e.g. pressure on a switch or by photovoltaic cell)
  - These power sources are sufficient to power each module to transmit wirelessly and have battery-free information.
- **Frequencies:**
  - 868 MHz for Europe and 315 MHz for the USA
- **EnOcean Alliance**
  - By 2014 = more than 300 members (Texas, Leviton, Osram, Sauter, Somfy, Wago, Yamaha ...)

ZWave

- Low power radio protocol
- Home automation (lighting, heating, ...) applications
- Low-throughput: 9 and 40 kbps
- Battery-operated or electrically powered
- Frequency range: 868 MHz in Europe, 908 MHz in the US
- Range: about 50 m (more outdoor, less indoor)
- Mesh architecture possible to increase the coverage
- Access method type CSMA / CA
- **Z-Wave Alliance:** more than 100 manufacturers

LTE-M - Overview

- Evolution of LTE optimized for IoT
- Low power consumption and autonomous
- Easy Deployment
- Interoperability with existing LTE networks
- Coverage upto 11 Km
- Max Throughput ≤ 1 Mbps



- ✓ First released in Rel.1 in 2 Q4 2014
- ✓ Optimization in Rel.13
- ✓ Specifications completed in Q1 2016
- ✓ Available since 2017

LTE to LTE-M

3GPP Releases	8 (Cat.4)	8 (Cat. 1)	12 (Cat.0) LTE-M	13 (Cat. 1,4 MHz) LTE-M
Downlink peak rate (Mbps)	150	10	1	1
Uplink peak rate (Mbps)	50	5	1	1
Number of antennas (MIMO)	2	2	1	1
Duplex Mode	Full	Full	Half	Half
UE receive bandwidth (MHz)	20	20	20	1.4
UE Transmit power (dBm)	23	23	23	20

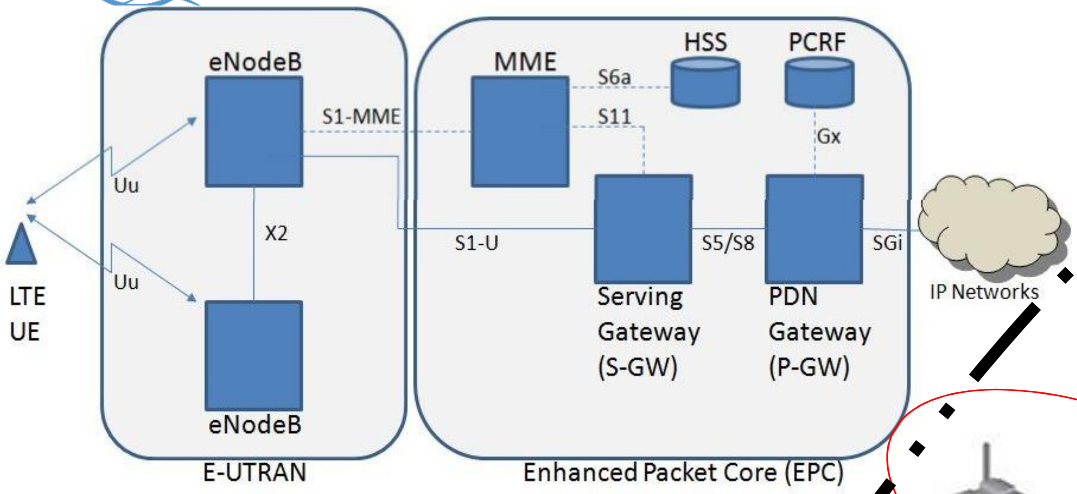
Release 12

- New category of UE ("Cat-0"): lower complexity and low cost devices
- Half duplex FDD operation allowed
- Single receiver
- Lower data rate requirement (Max: 1 Mbps)

Release 13

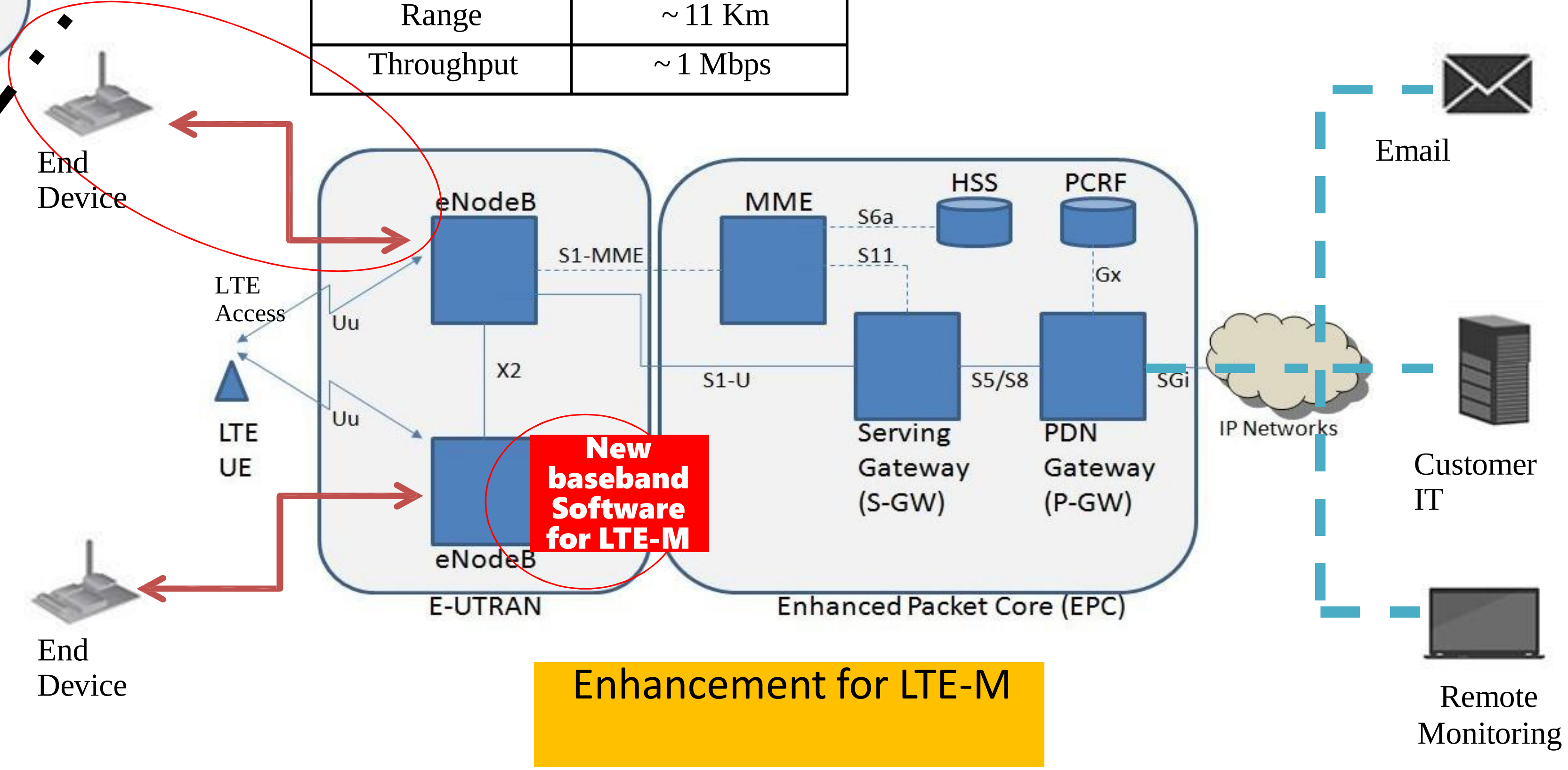
- Reduced receive bandwidth to 1.4 MHz
- Lower device power class of 20 dBm
- 15dB additional link budget: better coverage
- More energy efficient because of its extended discontinuous repetition cycle (eDRX)

LTE to LTE-M - Architecture



Present LTE Architecture

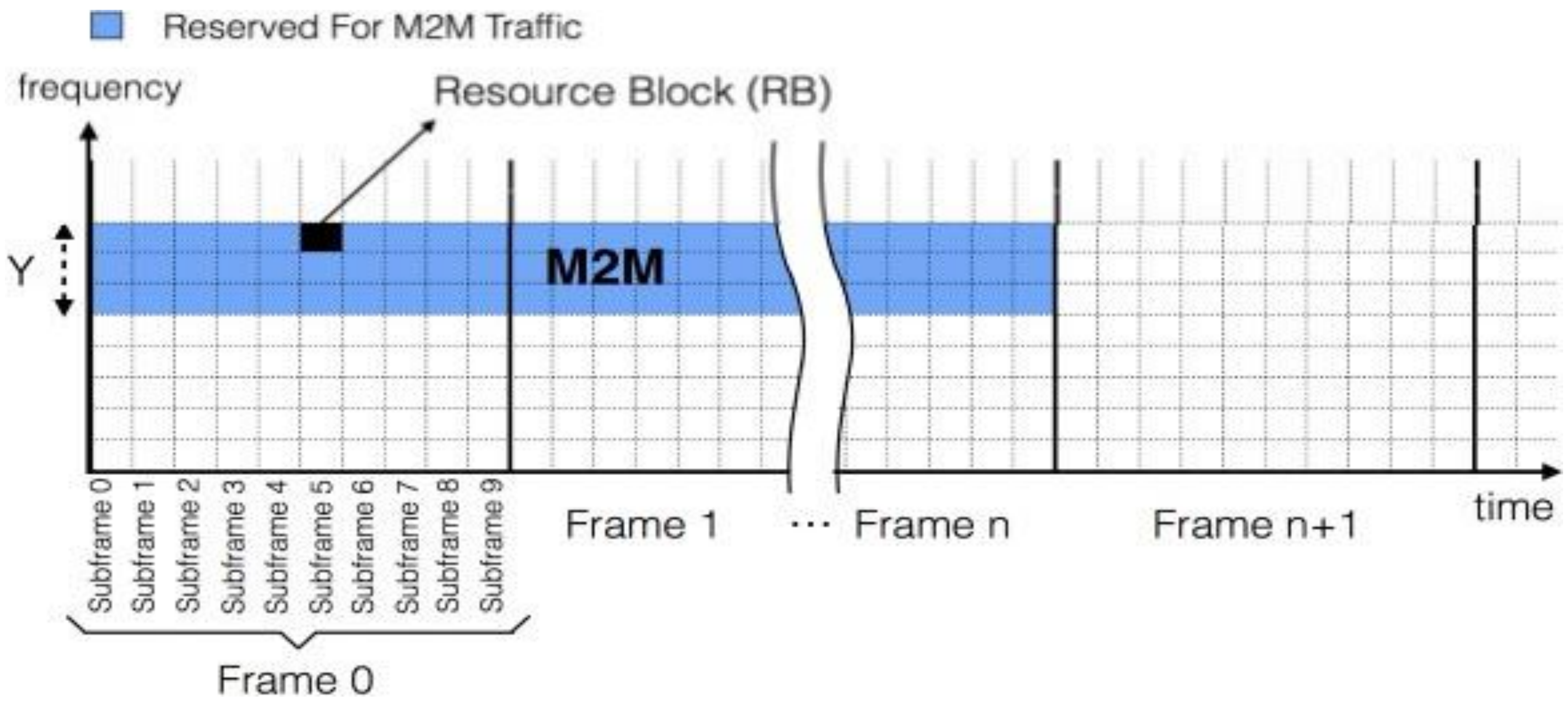
Frequency Band	Narrow Band
Access	LTE-M
Range	~ 11 Km
Throughput	~ 1 Mbps



Enhancement for LTE-M

LTE-M

- Licensed Spectrum
- Frequency Bands: 700-900 MHz for LTE
- Some resource blocks are allocated to IoT on LTE bands



NB-IoT

- April 2014 — Narrowband proposal to Connected Living
- May 2014 — 3GPP 'Cellular IoT' Study Item
- March 2015 — GSMA Mobile IoT created
- August 2015 — 3GPP alignment on single standard
- November 2015 — 1st ive pre-standard NB-IOT message NB-IoT
- Jun 2015 — Full 3GPP Standard Released
- 2017+ — Commercial rollout

A GLOBAL INITIATIVE

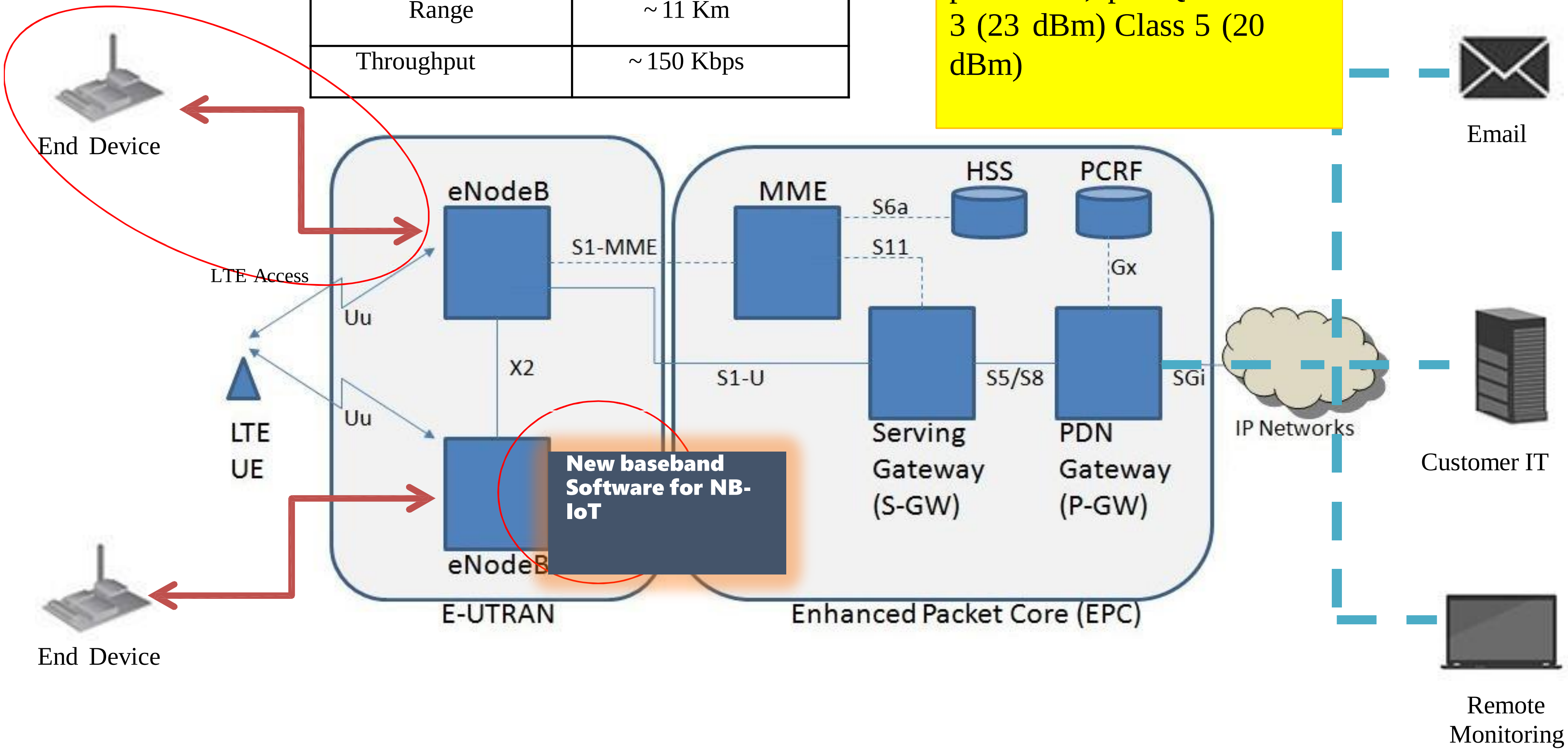
NB-IoT

- **Uses LTE design extensively** e.g. DL: FDMA, UL: SC-FDMA
- **Lower cost** than eMTC (Narrow band: supports 180 KHz channel)
- **Extended coverage:** 164 dB maximum coupling loss or link budget (at least for standalone) in comparison to GPRS link budget of 144dB and LTE of 142.7 dB
- **Low Receiver sensitivity** = -141 dBm
- **Long battery life**: 10 years with 5 Watt Hour battery (depending on traffic and coverage needs)
- **Support for massive number of devices**: at least 50.000 per cell
- **3 modes of operation:**
  - **Stand-alone**: *stand-alone carrier, e.g. spectrum currently used by GERAN (GSM Edge Radio Access Network) systems as a replacement of one or more GSM carriers*
  - **Guard band:** *unused resource blocks within a LTE carrier's guard-band*
  - **In-band:** *resource blocks within a normal LTE carrier*

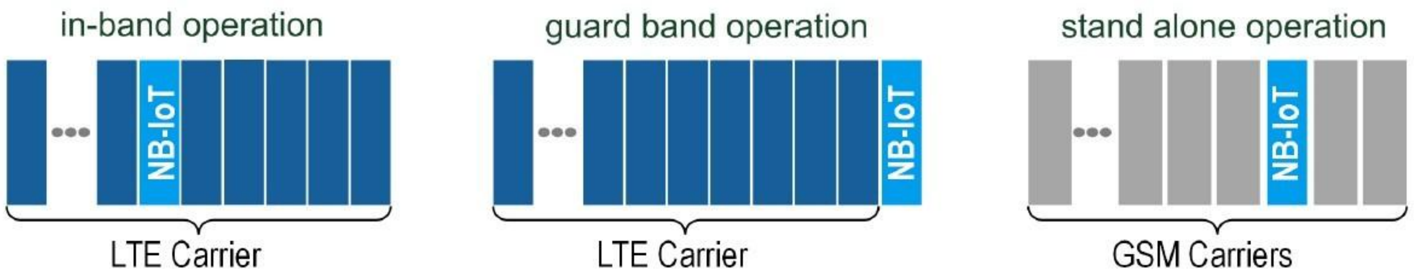
NB-IoT - Architecture

Frequency Band	Ultra Narrow Band
Range	~ 11 Km
Throughput	~ 150 Kbps

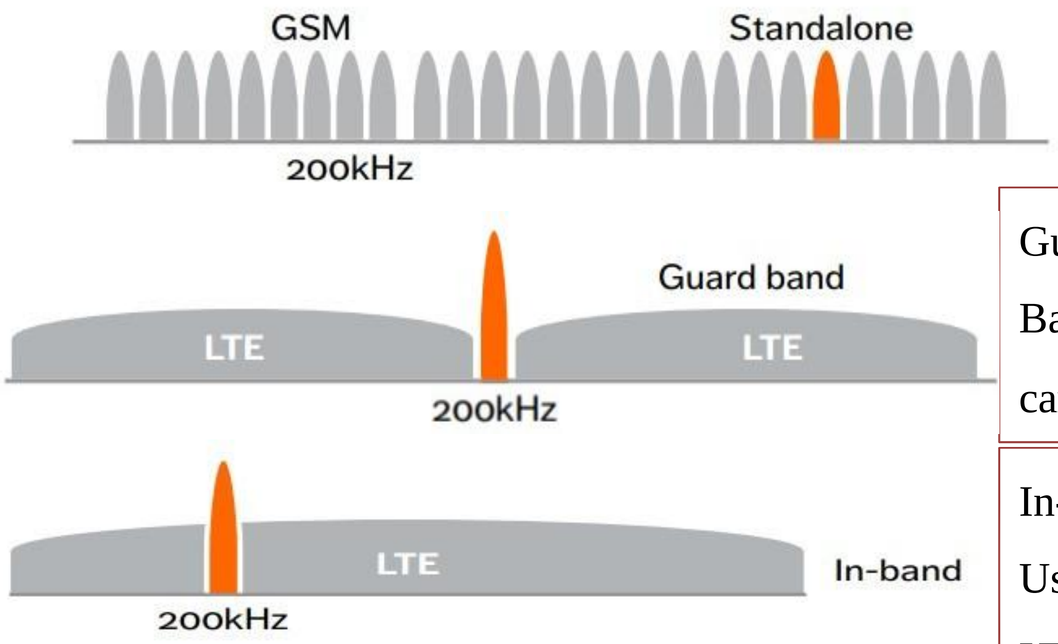
HD-FDD
p/2 BPSK, p/4 QPSK Class 3 (23 dBm) Class 5 (20 dBm)



NB-IoT – Spectrum & Access



Designed with a number of deployment options for licensed GSM , WCDMA or LTE spectrum to achieve efficiency



Stand-alone operation

Dedicated spectrum.

Ex.: By re-farming GSM channels

Guard band operation

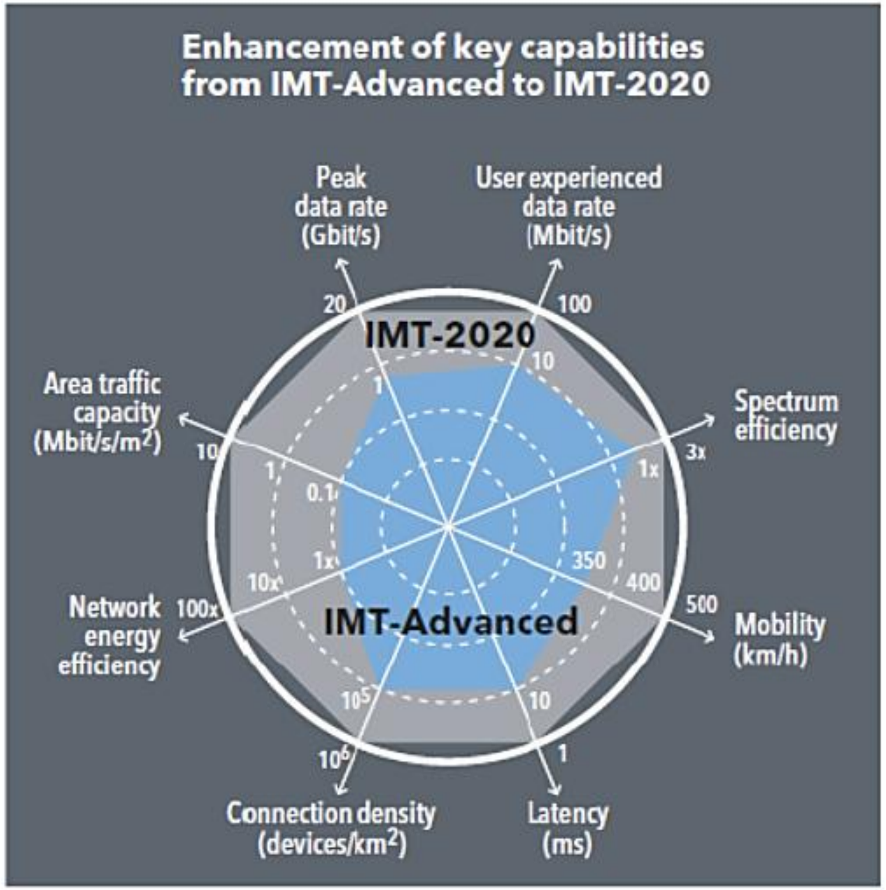
Based on the unused RB within a LTE carrier's guard-band

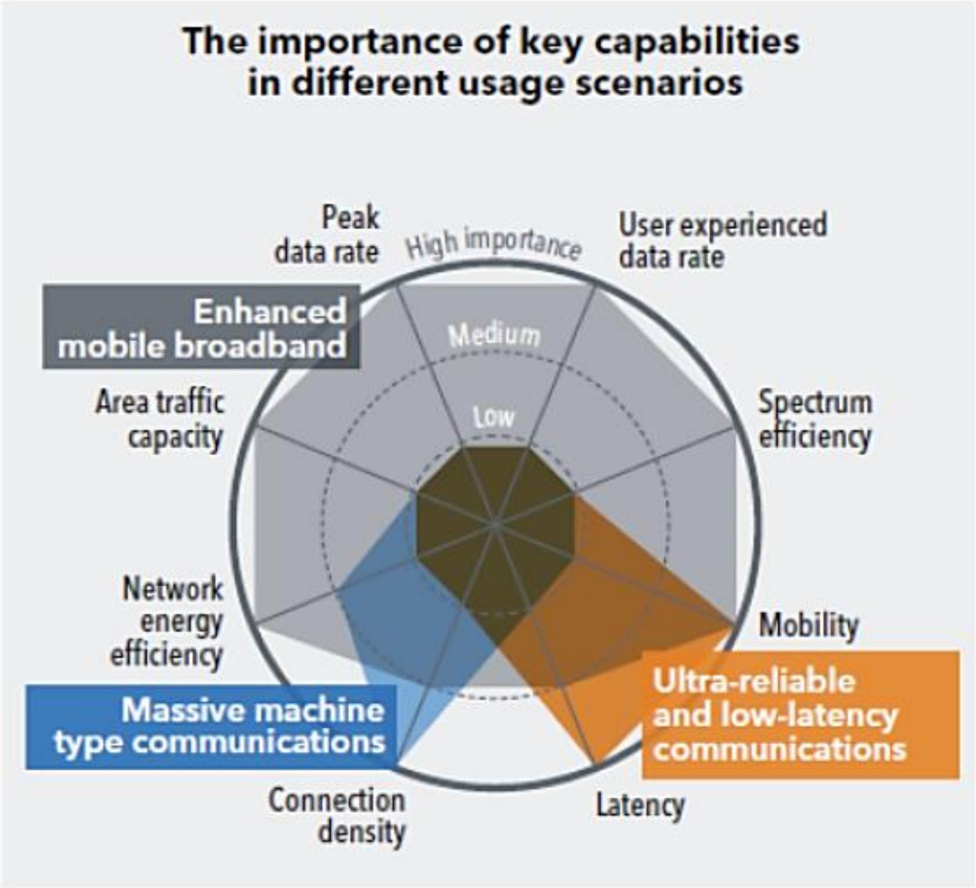
In-band operation

Using resource blocks within a normal LTE carrier

IMT 2020 (5G) Supporting IoT

IMT

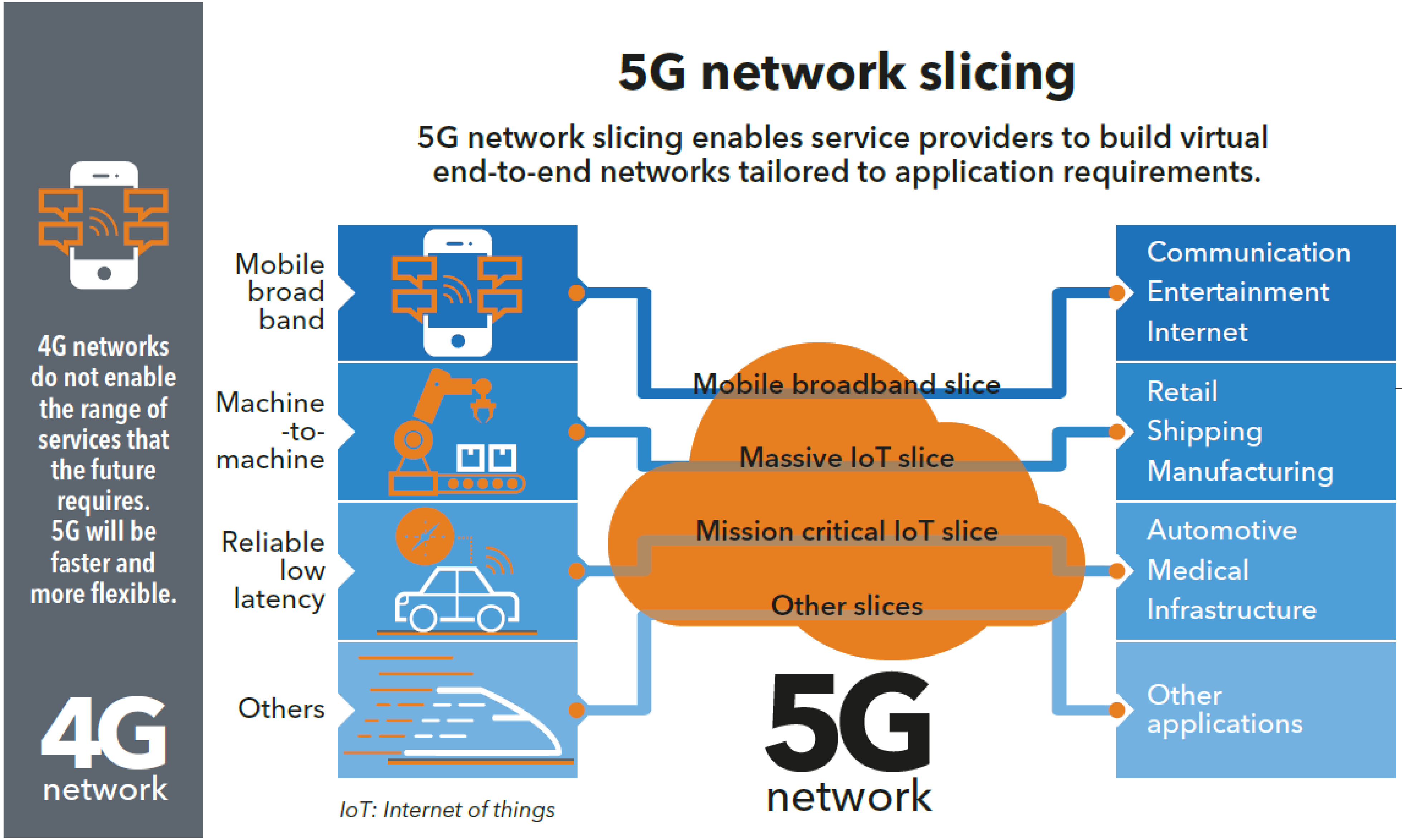




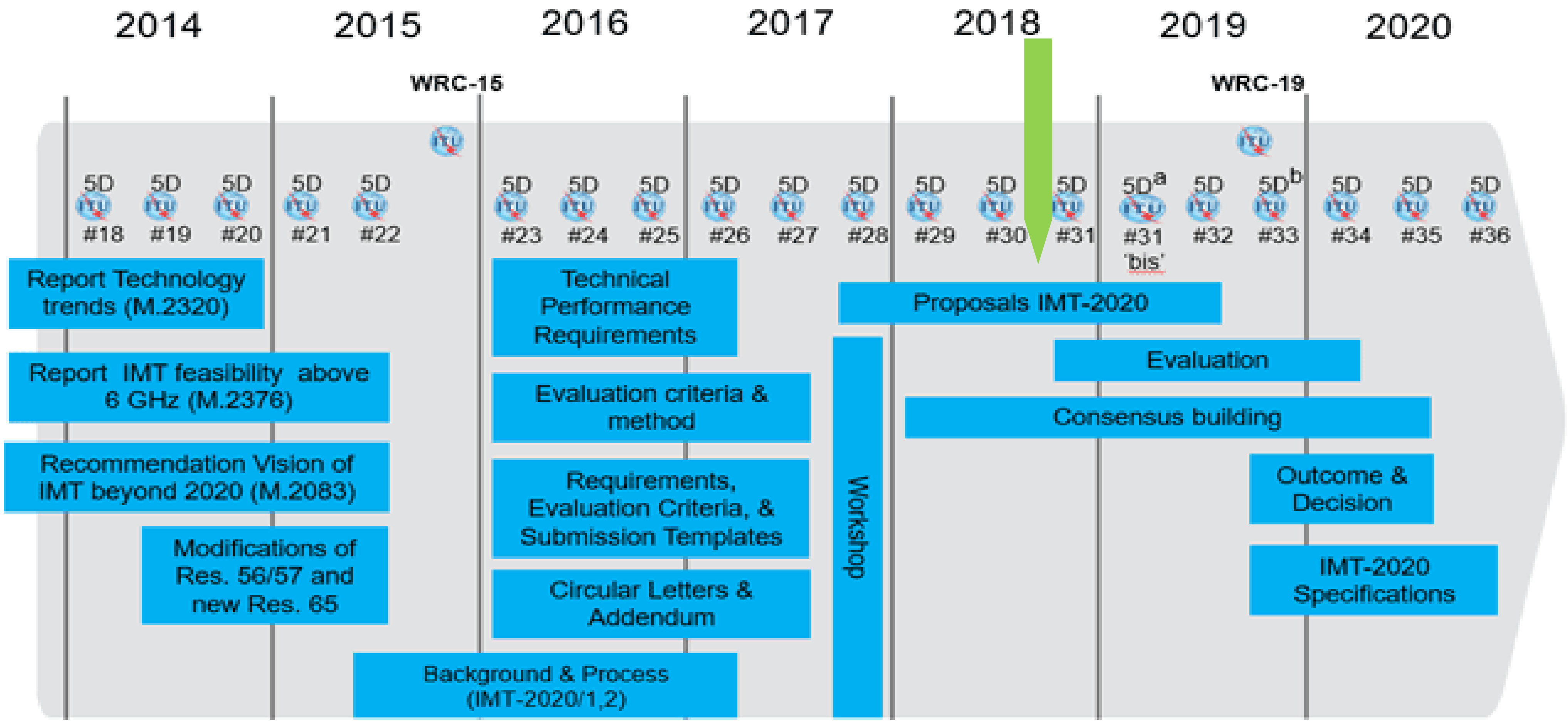
The values in the figures above are targets for research and investigation for IMT-2020 and may be revised in the light of future studies. Further information is available in the IMT-2020 Vision ***(Recommendation ITU-R M.2083)***

IMT-2020 (5G) Network slicing to Supports IoT

Source: Forging paths to IMT-2020 (5G), Stephen M. Blust, Chairman, ITU Radiocommunication Sector (ITU–R) Working Party 5D, Sergio Buonomo, Counsellor, ITU–R Study Group 5, ITU News, 02/2017



IMT-2020 (5G) – Detailed Timeline and Process in ITU

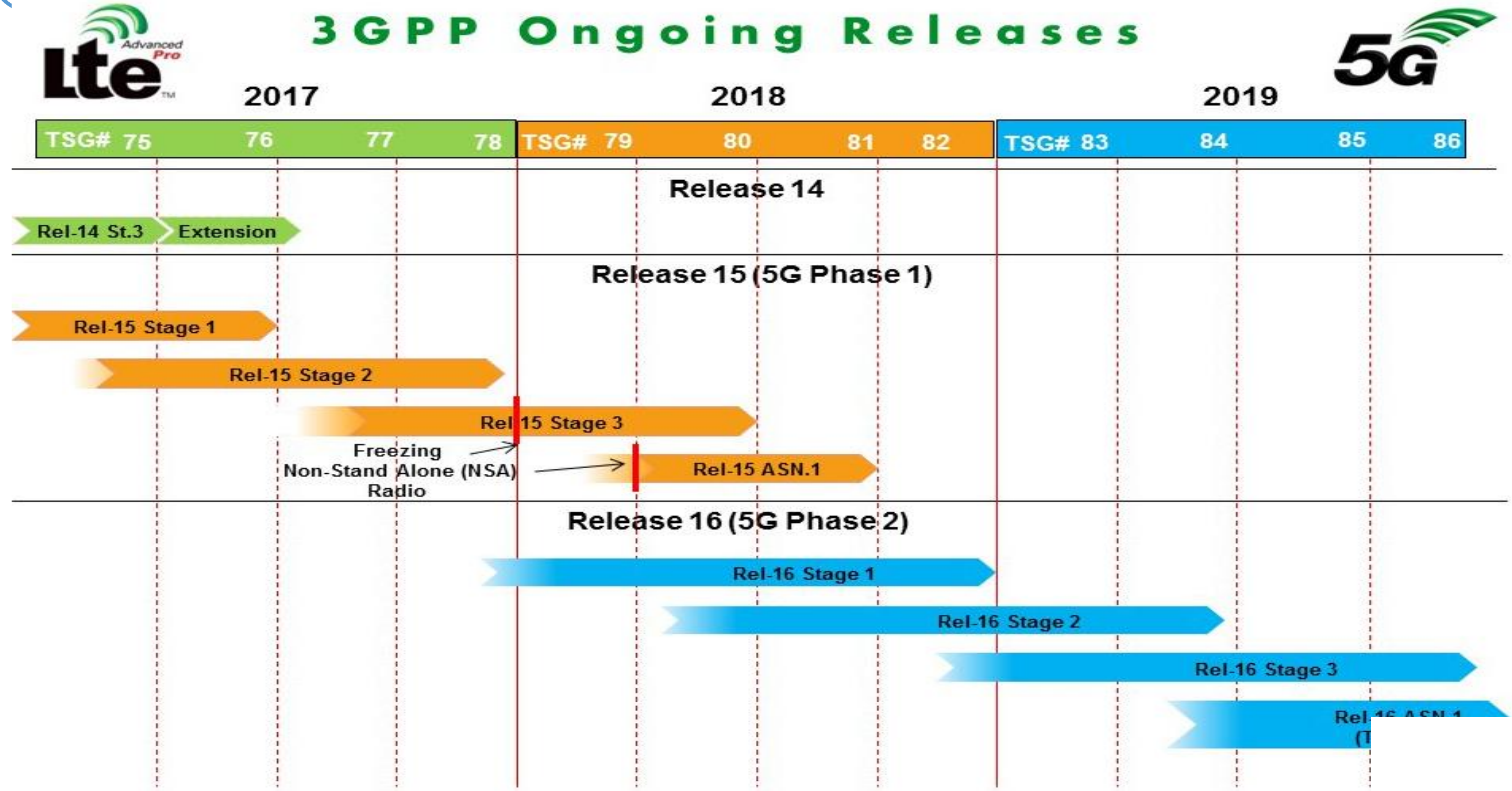


(a) – five day meeting, (b) – focus meeting on Evaluation (Technology)

Note: While not expected to change, details may be adjusted if warranted.

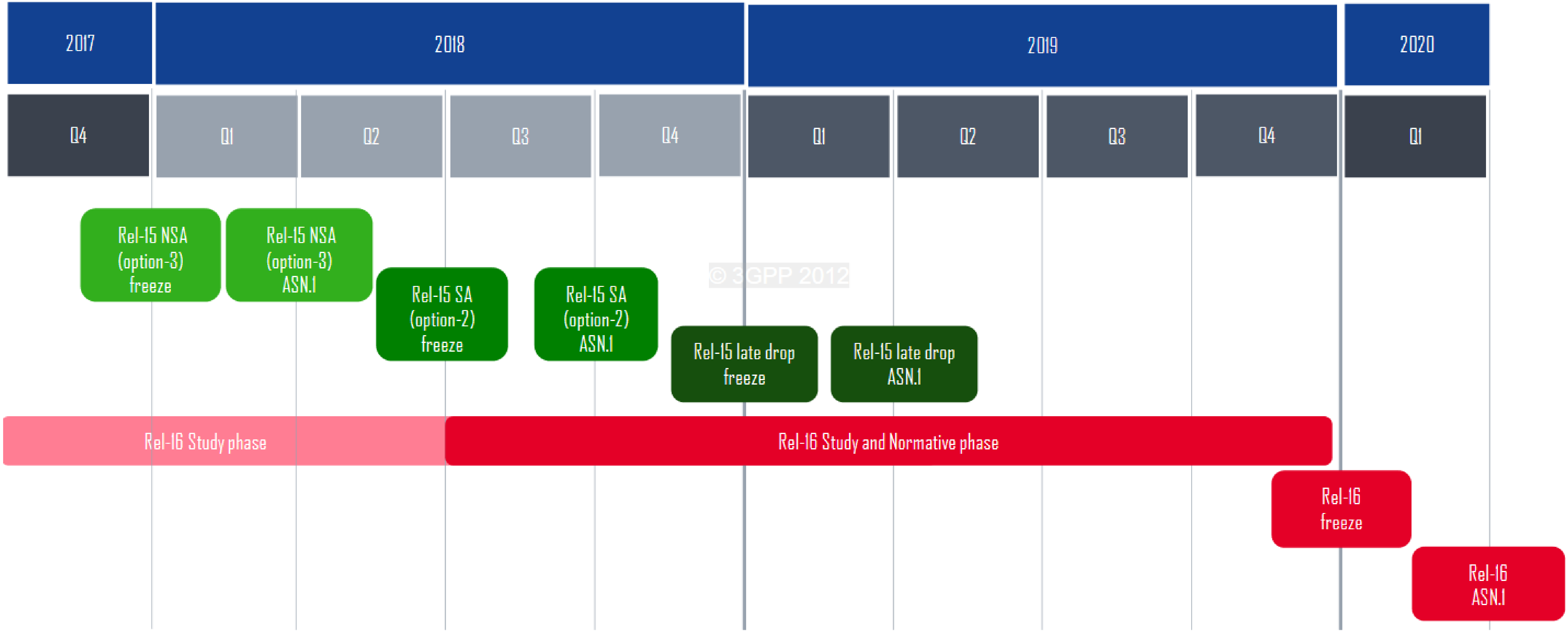
Source: https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Pages/default.aspx

5G and 3GPP Releases evolution



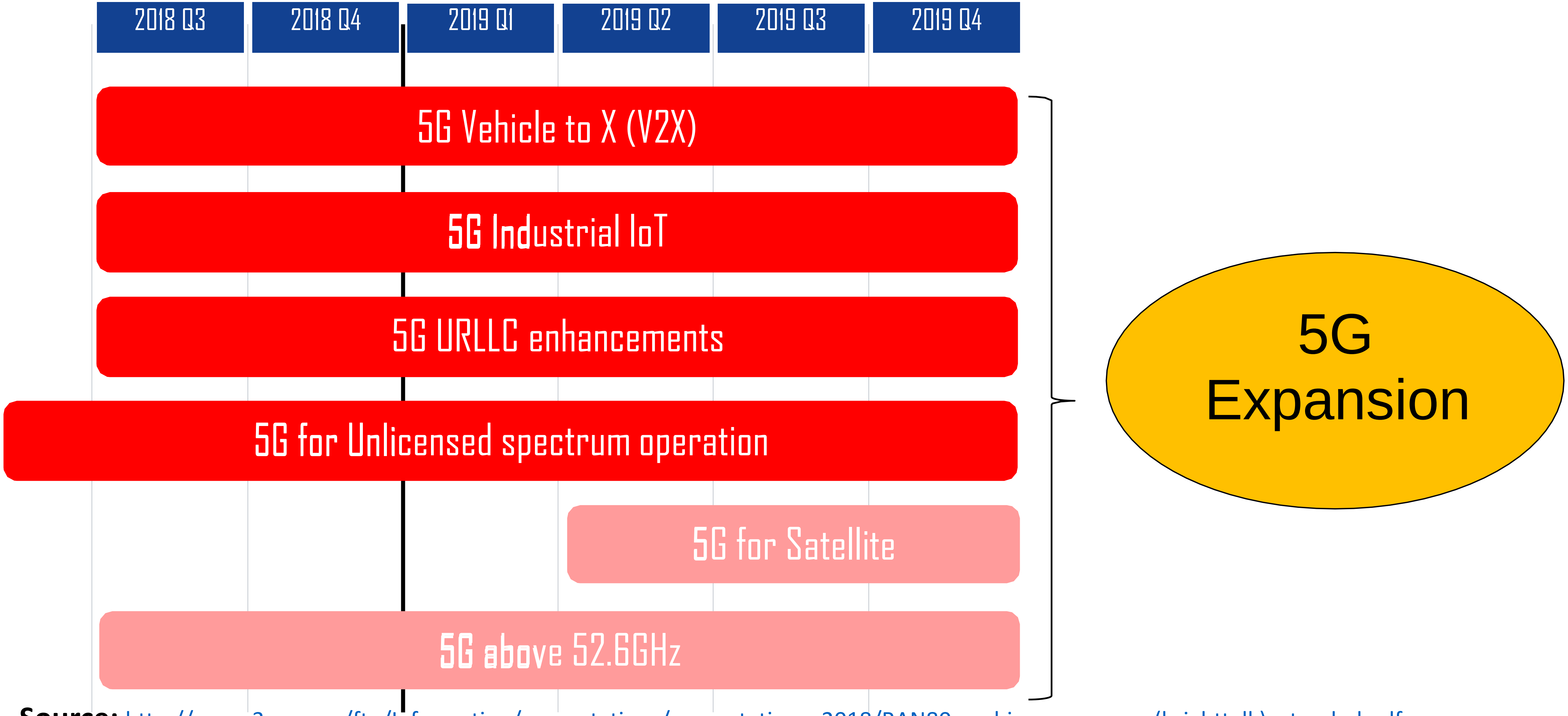
Source: http://www.3gpp.org/images/articleimages/ongoing_releases_900px.JPG

3GPP Release 16 - Timeline



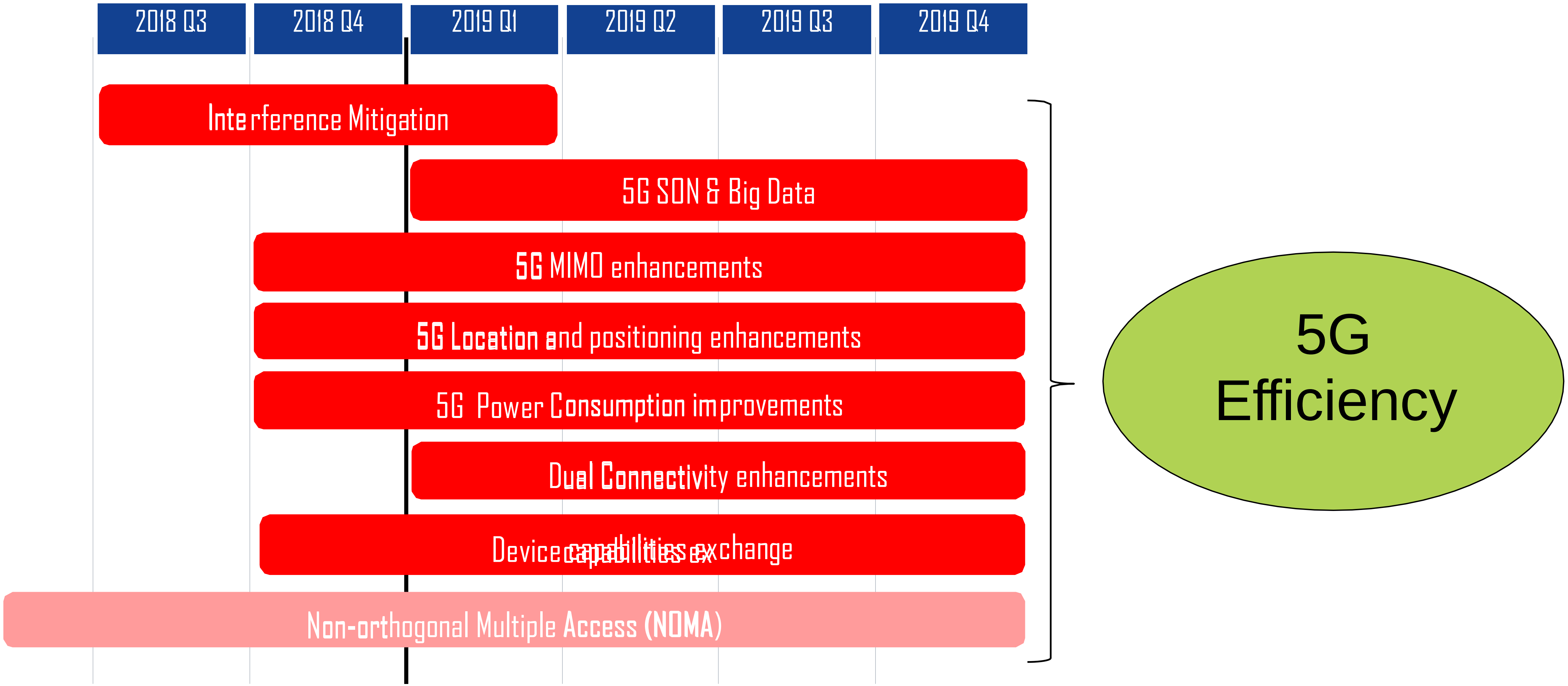
Source: http://www.3gpp.org/ftp/Information/presentations/presentations_2018/RAN80_webinar_summary(brighttalk)extended.pdf

3GPP Release 16 – 5G expansion



Source: http://www.3gpp.org/ftp/Information/presentations/presentations_2018/RAN80_webinar_summary(brighttalk)extended.pdf

3GPP Release 16 – 5G Efficiency



Source: http://www.3gpp.org/ftp/Information/presentations/presentations_2018/RAN80_webinar_summary(brighttalk)extended.pdf

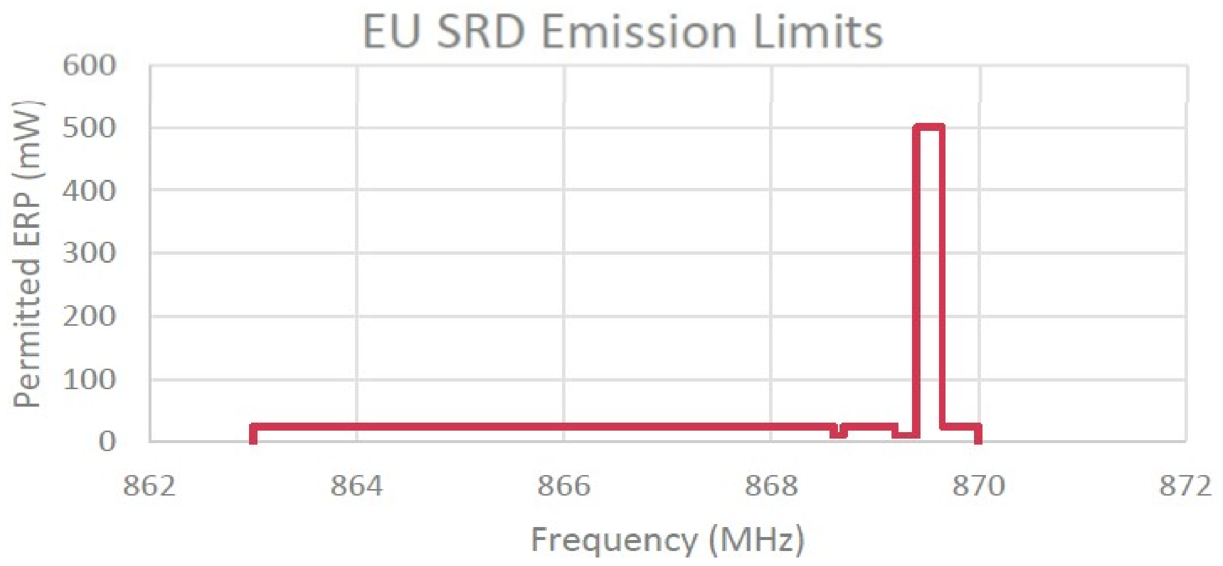
Examples from of current IoT Market

- Regulation
- Pricing
- Future analysis and issues

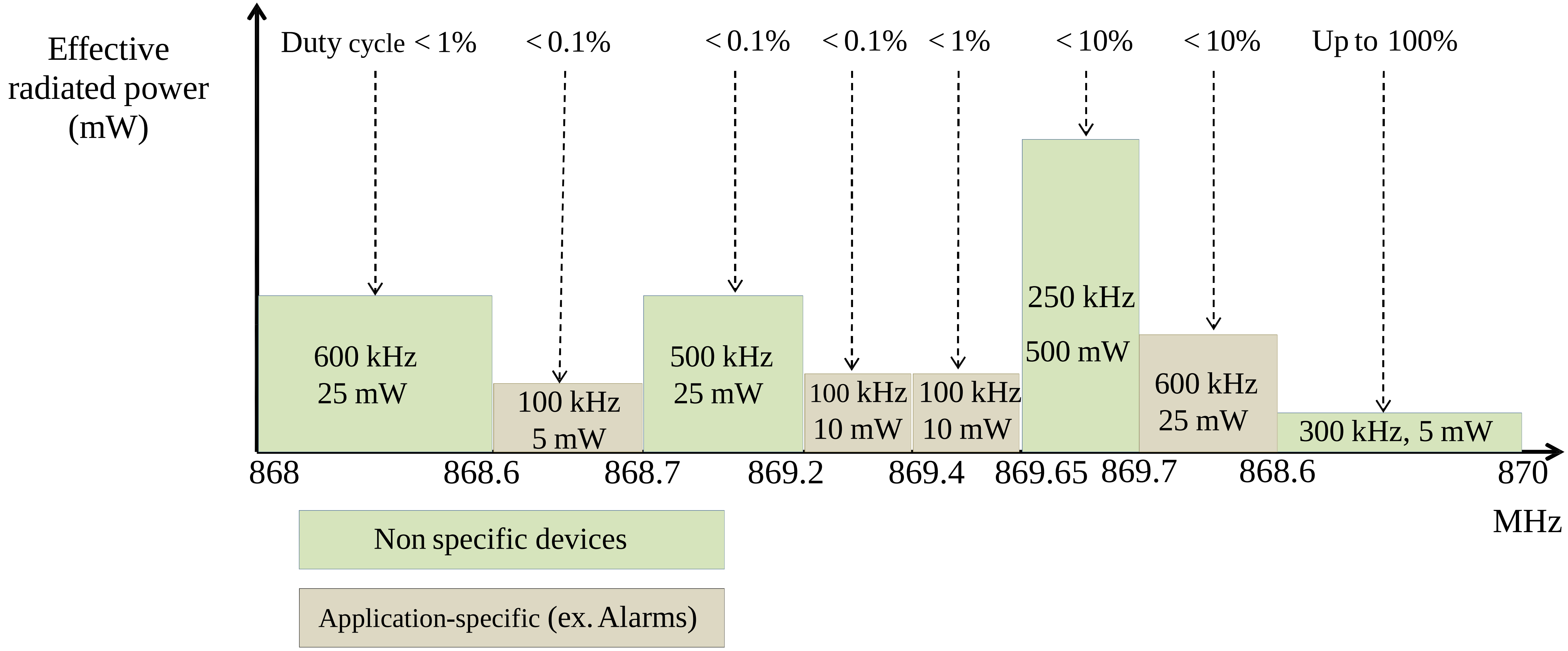
Regulations: Example

ARCEP- France

Link	Activity rate	Power
DL	10%	25 mW
UL	1%	500 mW



Regulations: Example Tunisia



ISM 868MHz Band Plan Tunisia

Infrastructure Capex Estimates: 5G Example

CAPEX for scenario 1 – **Large dense city**

Item	Value
Total CAPEX (USD millions)	55.5
Number of small cell sites	1 027
Cost per square km (USD millions)	3.7
CAPEX per site (USD thousands)	**54.1**

CAPEX for scenario 2 – **Small less dense city**

Item	Value
Total CAPEX (USD millions)	6.8
Number of small cell sites	116
Cost per square km (USD millions)	2.3
CapEx per site (USD thousands)	**58.6**

Small cell distance	Scenario 1	Scenario 2
RAN equipment (antenna, street cabinet, base station electronics, battery backup and network maintenance modules)	25%	24%
Implementation costs (design and planning costs, site upgrade costs, permit costs and civils costs to lay street cabinets)	50%	46%
Fibre (provision of 144 fibre along the route of activated street assets)	25%	30%
MER (single rack and termination equipment)	<0.1%	<0.1%

Source: ITU https://www.itu.int/en/ITU-D/Documents/ITU_5G_REPORT-2018.pdf

Chipset Costs

LoRAWAN	NB-IoT	LTE-M
1. MICROCHIP **Interface**: UART **Stack / MAC**: LoRaWAN **Stack implementation**: Microchip proprietary **Price**: **$14.27 @ single unit** **$10.90 @ 1000 units** **2. MULTITECH** **Interface**: UART **Stack / MAC**: LoRaWAN **Stack implementation**: MultiTech proprietary (XBEE compatible) **Price**: ~**$30 @ single unit**	**1. NB-IoT Quectel BC95** **3GPP Rel-13** **Interfaces** SIM/USIM 1 **Transmission** 100bps **Price: $ 40,00** **2. Digi XBee Cellular NB-IOT** **Up to ~60Kbps Downlink, 25Kbps Uplink** 1 antenna design, 200 mW (23 dBm) Band 20 (800MHz) Band 8 (900MHz **$30-60 Single unit** **3. Quectel Module** **GSM/GPRS/UMTS/HSPA/NB-IoT** **$ 68,00Single unit**	**Digi International XBee™ Cellular LTE-M Embedded Modem** 200mW (23dBm) Tx power 3.0V to 4.3V supply voltage Up to 384kbps RF throughput Up to 1Mbps DL or UL speed **NB-IoT Ready with a future over-the-air update** **$ 69Single unit**



Source: ITU IoT Planning workshop Bandung 2018

Market solution Pricing: NB-IoT Example

Deutsche Telekom

2017

- The NB-IoT access entry package is available from **EUR 199** Includes a ***6-month activation of up to 25 SIM-cards with 500 KB per SIM pooled in Germany's NB-IoT network***. As a further optional add-on – a private APN with IPsec-key encryption is available.
- The NB-IoT Access & Cloud of Things entry package is available from **EUR 299** and additionally includes direct access to Deutsche Telekom's Cloud of Things platform for device and data management.

https://www.telekom.com/en/media/media-information/archive/first-narrowband-iot-service-packages-launched-in-germany-497494

IN 2018

- Europe's first data flat rate for the Internet of Things with joint offering by Deutsche Telekom and 1NCE, designed especially for business customers. It provides connectivity for devices using low data volumes in the Internet of Things (or IoT). The prepaid rates can now be booked from the 1NCE webshop.
- For a one-off price of **10 Euros**, customers receive a industrial IoT eSIM card with a data volume of **500 MB** and **250 SMS** messaging for use in the Internet of Things.

https://www.telekom.com/en/media/media-information/archive/pay-once-use-over-ten-years-533898

Market Pricing: LoraWan Example

2017

Price Plan	Data Allowance* (Frequency of communication)	Monthly Flat Rate (VAT Excluded)	Examples of Services	Note
Band IoT 35	100KB	KRW 350	Metering and monitoring services (e.g. Advanced Metering Infrastructure (AMI), environmental monitoring, water leakage monitoring, etc.)	- Discount benefits for long-term contracts: Ranging from a 5% discount for two-year contracts to a 20% discount for 5 year-contracts - Multi-line discount: Ranging from a 2% discount for those using 500 lines to a 10% discount to those who use 10,000 lines
Band IoT 50	500KB	KRW 500		
Band IoT 70	3MB	KRW 700	Tracking services (e.g. locating tracking For people/things, asset management, etc.)	
Band IoT 100	10MB	KRW 1,000		
Band IoT 150	50MB	KRW 1,500	Control service (e.g. safety management, lighting control, shared parking, etc.)	
Band IoT 200	100MB	KRW 2,000		

**Data usage exceeding the data allotment provided will be charged at KRW 0.005 per 0.5KB.*

https://www.capacitymedia.com/articles/3567404/SK-Telecom-announces-prices-for-internet-of-things-service

Market Pricing: Sigfox Example

Network subscription charges: S$1 per device per month, which comes with a data plan for up to 140 messages per day.

Qualified channel partners who commit to volume can ultimately enjoy subscription charges from as low as **S$1 per device per year**.

https://www.unabiz.com/unabiz-announces-iot-connectivity-from-1-per-year/

Market Pricing: LTE-M Example

LTE-M

One rate - unlimited data for $30/year*

LTE-M provides nationwide, carrier grade security with optimized features designed specifically for IoT applications. *Price is exclusive of taxes and fees. Terms and Conditions provided in frequently asked questions below.

LTE-M Button

Starting at

34.99 per device

The AT&T LTE-M Button is a programmable button using the AT&T nationwide LTE-M network and will be supported by AWS IoT 1-click. Price includes up to 1500 clicks or 36 months, whichever comes first. Price is exclusive of taxes and fees. Terms and conditions may apply.

Market Pricing: Outcome Based Pricing

Source: GSMA Intelligence

Examples of OBP in three sectors

Sector – IoT application	Utility-based pricing	Outcome-based pricing
Industrial predictive maintenance	Enterprise pays for real-time, secure, high-bandwidth connectivity.	Using equipment behaviour patterns, a jointly determined outcome could be the number of successful field engineer visits.
Automotive usage-based insurance risk management	Enterprise pays for real time and roaming connectivity.	Using insights from aggregated driving behaviour, an insurance company can develop an average risk score that allows it to more accurately detect insurance fraud.
Utilities critical infrastructure monitoring	Enterprise pays for private networks to collect equipment data from low-power sensors.	The supplier is paid if the utility achieves x% reduction in unscheduled grid blackouts.

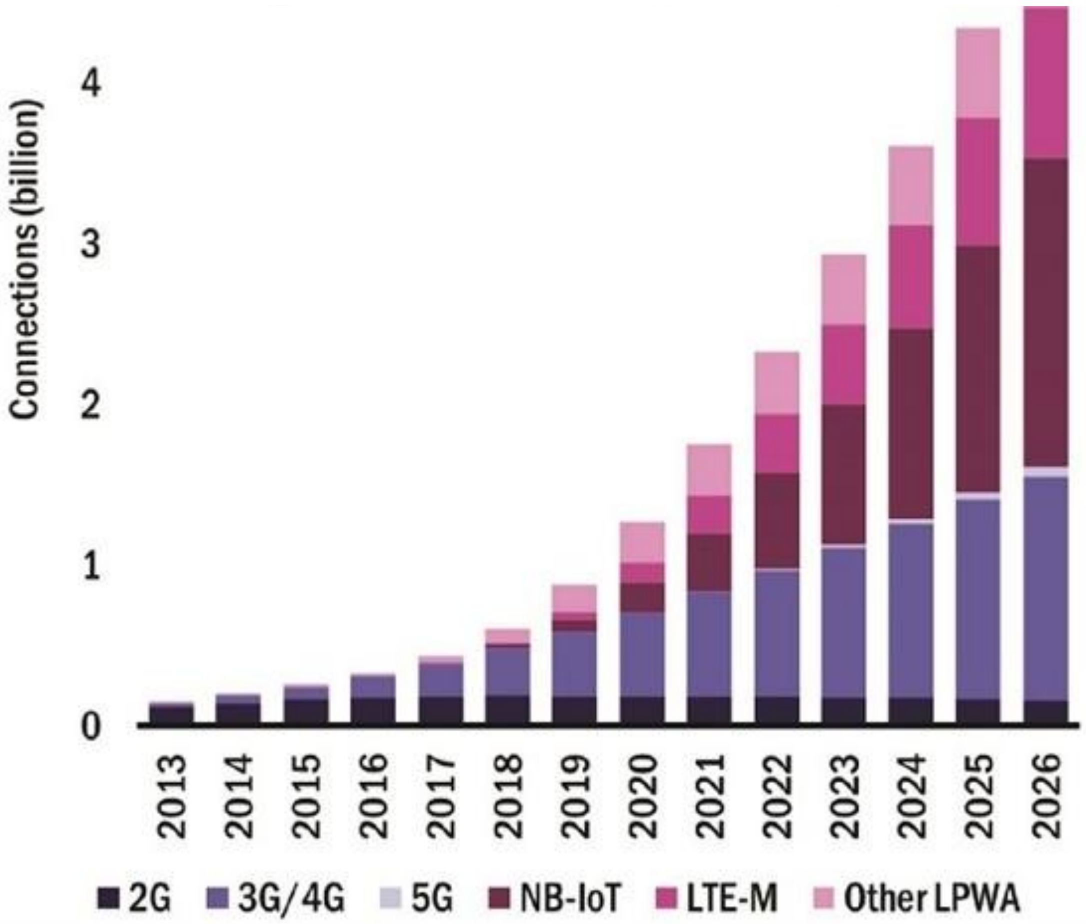
OBP differs from traditional pricing:

instead of charging by traffic/volume or number of devices, it sets pricing for enterprise clients based on achieving jointly determined outcomes.

OBP attempts to drive service providers to deliver on results but also encourages sharing of the investment burden between enterprises and service providers.

Some Facts and forecasts

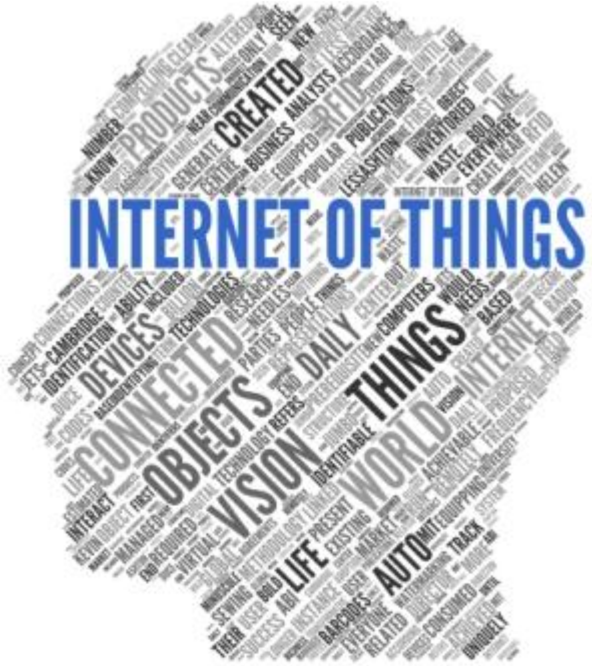
- **Analysys Mason:**
  - 3G and 4G will capture a 27% market share in 2026
  - 5G will constitute just over 1% of the total connections in 2026, but this will be the average across all application groups. For automotive and embedded SIMs specifically, 5G will have a 4% share of the total connections.



NB-IoT will be the dominant network for IoT in 2026 (Analysys Mason)

Future Issues of IoT

- Data Ownership
- Rights around derivative use of data
- Dynamic decision rights (change in consent)
- Consumer awareness
- Privacy rights
- Cybersecurity
- Liability (decision made by AI: health, transportation)
- curacy
- Public profit sharing
- Preventing oligopolies (Large tech companies taking over)
- Fairness (Some may not be able to afford)
- Disposal of electronic waste



Source: Dr. Shoumen Datta of Massachusetts Institute of Technology (MIT)

I Thank U

"Committed to connecting the WORLD"