ITU-SUDACAD Regional Forum

IoT for Development of Smart Sustainable Cities

Khartoum, Sudan

13-14 December 2017

Session 7

RFID & IoT

Adoption for Smart Cities

Prof. Mustapha Benjillali
INPT, Morocco
benjillali@ieee.org

Radio-Frequency Identification (RFID) technologies: opportunities and limitations

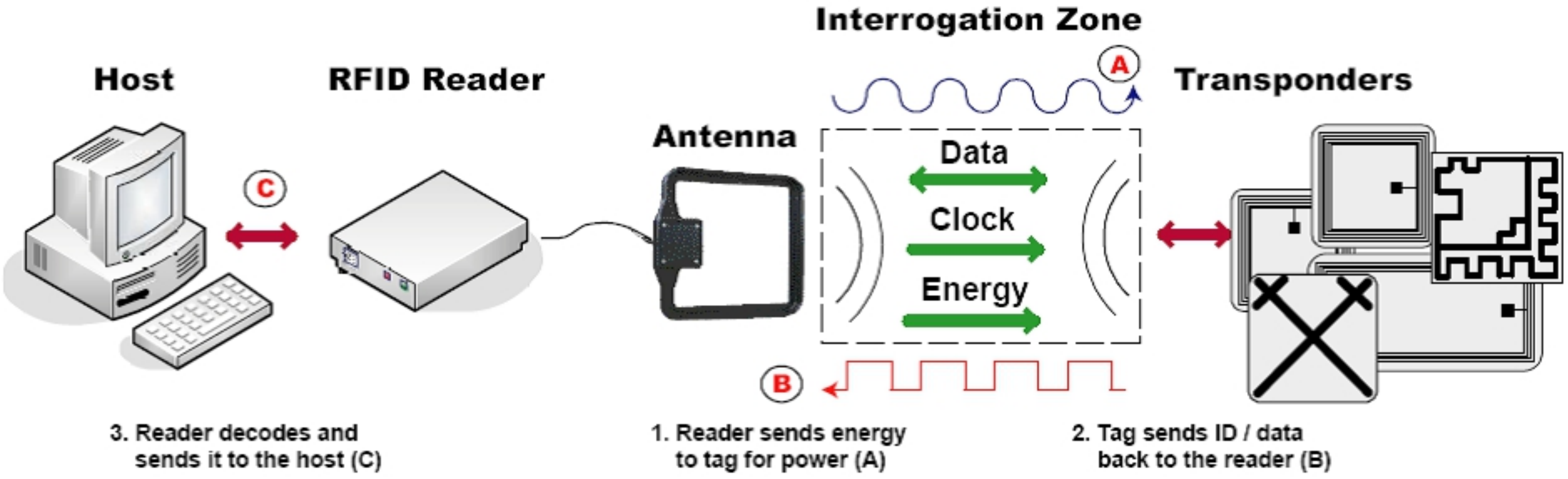
Historic development

- "Identification Friend or Foe" system (IFF) — Second World War.
- First paper related to RFID technology was the landmark paper by Harry Stockman, *"Communication by Means of Reflected Power"* in October 1948.
- The first patent on RFID was issued in 1973 for a passive radio transponder with memory.
- 1970s: First commercial RFID application — "Electronic Article Surveillance" (EAS) — Theft prevention (single bit tags).
- End 70s: applications in agriculture and animal tagging.
- 1980s: Boost to RFID technology — Norway and several US states Toll collection on roads (EZ-Pass).
- Later in 90s: Vast number of new applications *(ski passes, gasoline cards, money cards, …)*.
- 1999-2003: Auto-ID Center at MIT. Development of a global standard for item-level tagging. Result: Electronic Product Code (EPC). EPCglobal Inc. continues the work.

Ancestors

- 1973 — Mario Cardullo's patented device.
  - Passive radio transponder with 16-bit memory.
  - Basic patent covers RF, sound and light as transmission media.
  - Original business plan:
    - transportation (vehicle identification, toll system, performance monitoring, …),
    - banking (electronic check book, electronic credit card),
    - security (personnel identification, automatic gates, surveillance),
    - medical (identification, patient history, …).
- 1973 — Steven Depp, Alfred Koelle, and Robert Frayman, *Los Alamos National Laboratory*
  - Reflected power (modulated backscatter) RFID tags, both passive and semi-passive
  - Portable system operated at 915 MHz, 12-bit tags.
  - Technique used by the majority of today's UHFID and microwave RFID tags.

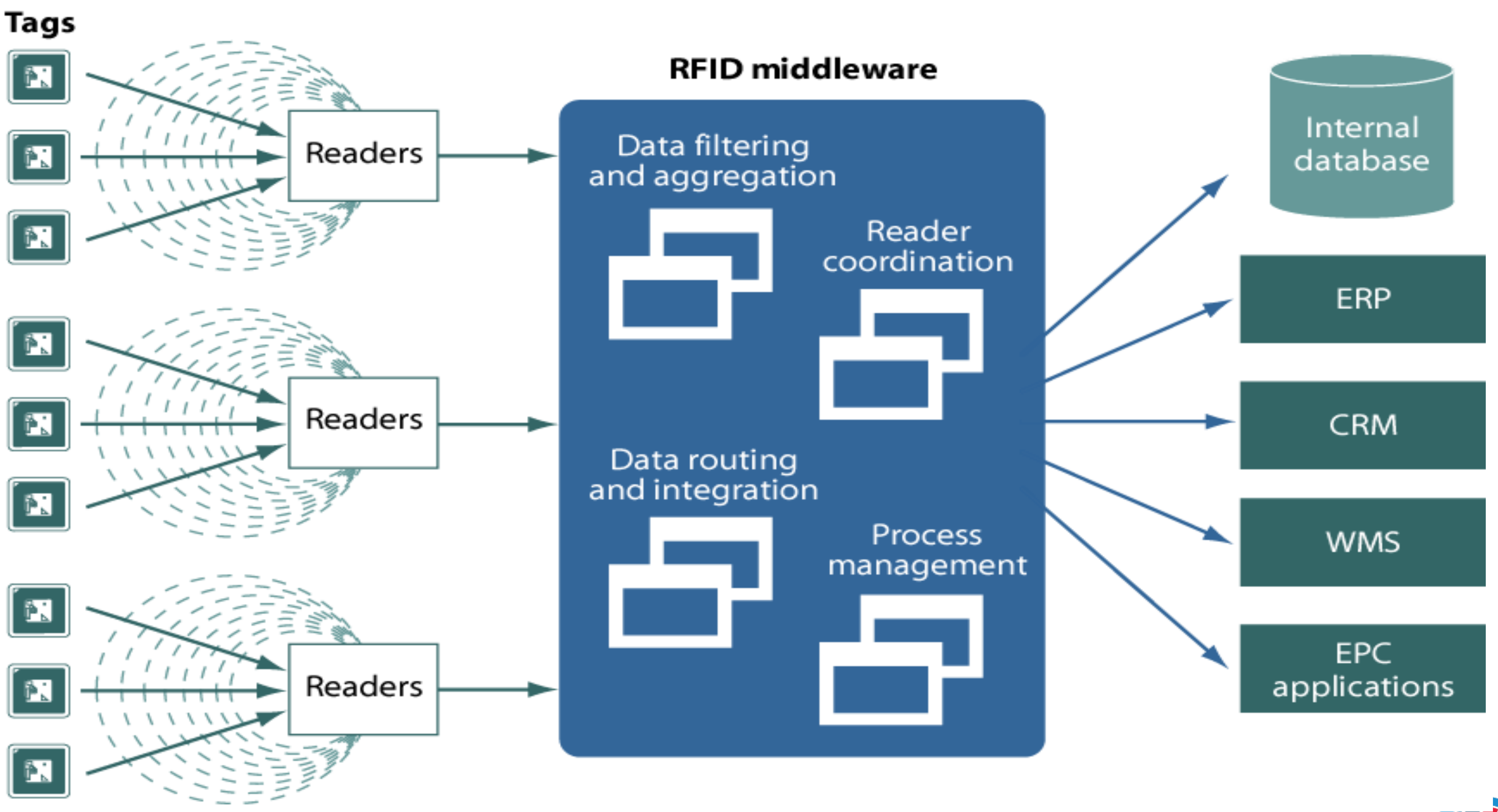
RFID Architecture



RFID system:

- Tags, or labels (attached to the objects to be identified),
- Two-way radio interrogators or readers (transceivers sending a signal to the tag and reading its response),
- Host/network (for data processing and exploitation).

RFID Architecture



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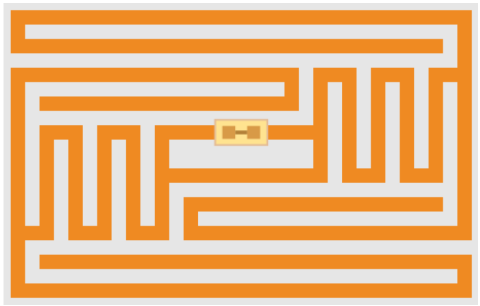
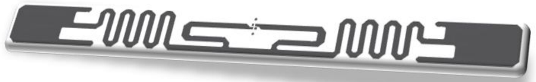
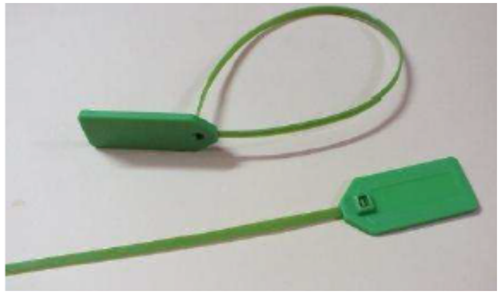
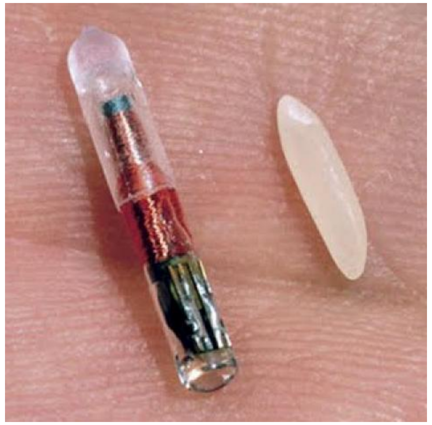
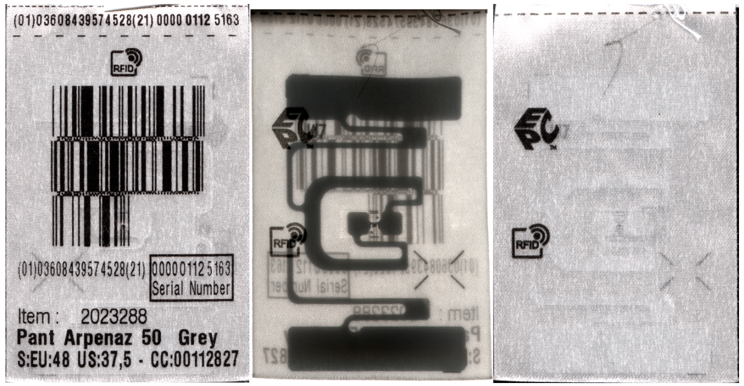
RFID Tags (1/3)











Sources: *www.perfectrfid.com and Wikimedia.*

RFID Tags (2/3)

Three types:

- Active: has an on-board battery and periodically transmits its ID signal.
- Battery-assisted passive (BAP) or semi-passive: has a small battery on board and is activated when in the presence of an RFID reader.
- Passive: cheaper and smaller because it has no battery. Uses the radio energy transmitted by the reader. Must be illuminated with a power level 1000x stronger than signal transmission *(interference and in exposure to radiation)*.

Capabilities:

- Read-only: a factory-assigned serial number that is used as a key into a database.
- Read/Write: object-specific data can be written into the tag by the system user.
  Field programmable tags may be write-once, read-multiple;
  "blank" tags may be written with an electronic product code by the user.

RFID Tags (3/3)

- Three parts:
  - Integrated circuit for storing and processing information that modulates and demodulates RF signals. The tag information is stored in a non-volatile memory, fixed or programmable logic for processing;
  - Power collector/harvester for collecting DC power from the incident reader signal;
  - Antenna for receiving and transmitting the signal.

- Capabilities:
  - RFID reader transmits an encoded radio signal to *interrogate* the tag.
  - RFID tag receives the message and then responds with its identification and other information: unique tag serial number, or product-related information *(e.g. stock number, lot/batch number, production date, …)*
  - Tags have individual serial numbers. RFID system design can discriminate among several tags within the range of the RFID reader and read them simultaneously.

RFID Readers (1/2)

Source: www.perfectrfid.com

RFID Readers (2/2)

- Three types:
  - Passive Reader Active Tag (PRAT) system has a passive reader which only receives radio signals from active tags (battery operated, transmit only). The reception range of a PRAT system reader can be adjusted from 1–2,000 feet (0–600 m,) allowing flexibility in applications such as asset protection and supervision.
  - Active Reader Passive Tag (ARPT) system has an active reader, which transmits interrogator signals and also receives authentication replies from passive tags.
  - Active Reader Active Tag (ARAT) system uses active tags awoken with an interrogator signal from the active reader. A variation of this system could also use a Battery-Assisted Passive (BAP) tag which acts like a passive tag but has a small battery to power the tag's return reporting signal.
- Capabilities:
  - Fixed readers are set up to create a specific interrogation zone which can be tightly controlled. This allows a highly defined reading area for when tags go in and out of the interrogation zone.
  - Mobile readers may be hand-held or mounted on carts or vehicles.

Operational Parameters

Frequency Ranges	LF 125 KHz	HF 13.56 MHz	UHF 868 - 915 MHz	Microwave 2.45 GHz & 5.8 GHz
Typical Max Read Range (Passive Tags)	Shortest 1”-12”	Short 2”-24”	Medium 1’-10’	Longest 1’-15’
Tag Power Source	Generally passive tags only, using inductive coupling	Generally passive tags only, using inductive or capacitive coupling	Active tags with integral battery or passive tags using capacitive storage, E-field coupling	Active tags with integral battery or passive tags using capacitive storage, E-field coupling
Data Rate	Slower	Moderate	Fast	Faster
Ability to read near metal or wet surfaces	Better	Moderate	Poor	Worse
Applications	Access Control & Security Identifying widgets through manufacturing processes or in harsh environments Ranch animal identification Employee IDs	Library books Laundry identification Access Control Employee IDs	supply chain tracking Highway toll Tags	Highway toll Tags Identification of private vehicle fleets in/out of a yard or facility Asset tracking

Source: S. Iyer, www.it.iitb.ac.in/~sri

Adoption and Applications

- Three driving factors:
  - decreased cost of equipment and tags,
  - increased performance/reliability of 99.9%,
  - stable international standard around UHF passive RFID[1]
- Institutions: Hospitals and healthcare, Libraries, Museums, Schools and Universities, Sports
- Applications:
  - Commerce *(retail, access control, advertising, promotion tracking, …)*
  - Transportation and logistics *(access management, transportation payments, toll collection and contactless payment, tracking of goods/persons/animals, waste management, timing sporting events, …)*
  - Passports
  - Infrastructure management and protection
  - Telemetry
  - Human implantation

[1] EPCglobal is a joint venture between GS1 and GS1 US, which were responsible for driving global adoption of the barcode in the 1970s and 1980s. The EPCglobal Network was developed by theAuto-ID Center.

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RFID in action

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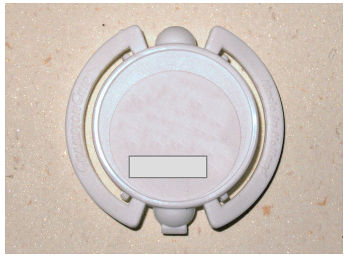

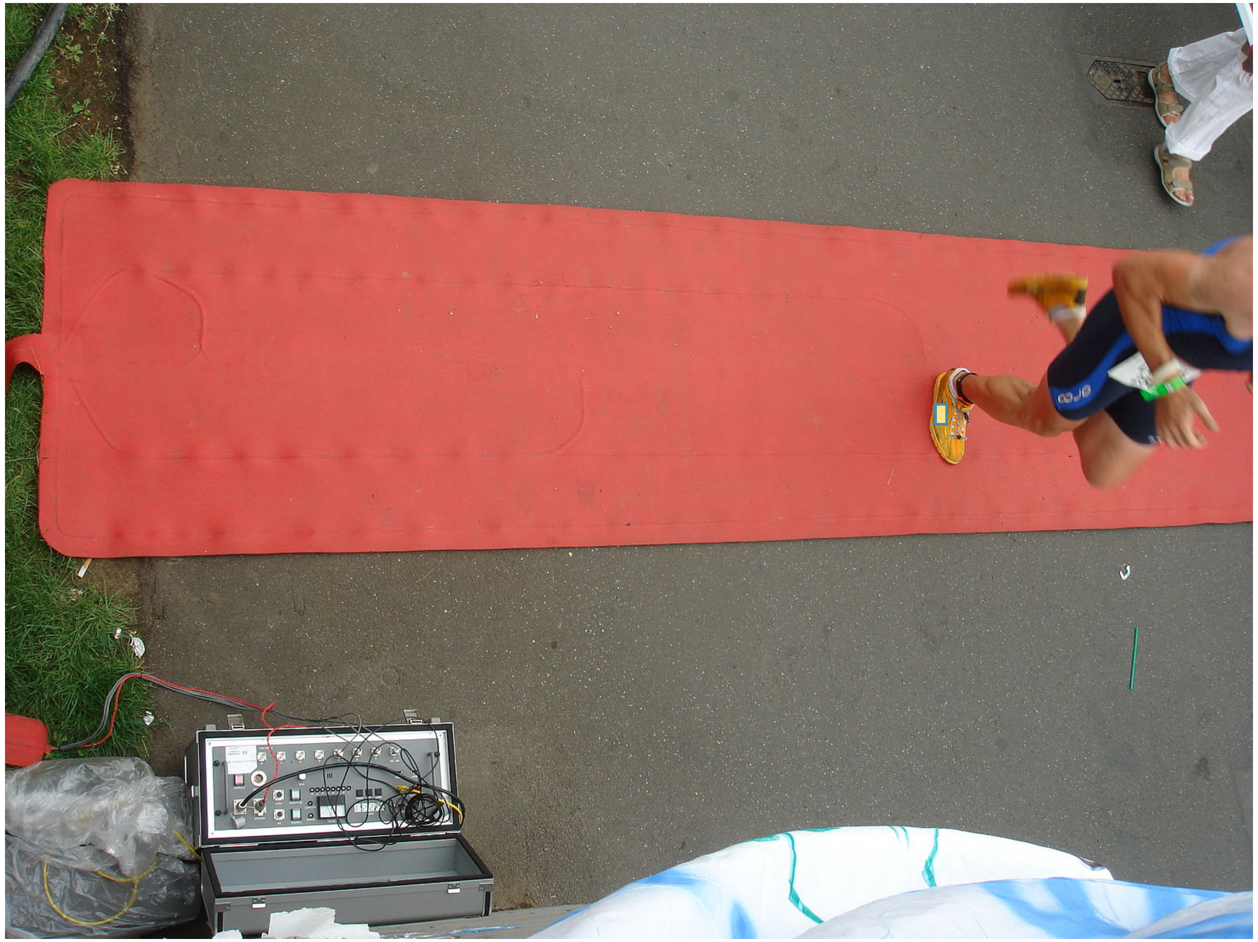

Photos credit: www.perfectrfid.com

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RFID in action

Photos credit: www.perfectrfid.com

Regulation and Standardization (1/3)

Many organizations have set standards for RFID:

- International Organization for Standardization (ISO)
- International Electrotechnical Commission(IEC)
- ASTM International
- DASH7 Alliance
- EPCglobal.
- …

Several specific industries that have set guidelines:

- Financial Services Technology Consortium (FSTC): tracking IT Assets with RFID,
- Computer Technology Industry Association (CompTIA): certifying RFID engineers,
- International Airlines Transport Association (IATA): tagging guidelines for luggage in airports.

Regulation and Standardization (2/3)

- Countries can set own rules for Industrial Scientific and Medical (ISM) frequency bands allocation. Not all bands available in all countries.
- Low-frequency (LowFID) [125–134.2 kHz 140–148.5 kHz] and high-frequency (HighFID) [13.56 MHz] tags can be used globally without a license.
- Ultra-high-frequency (UHFID) [865–928 MHz] tags cannot be used globally, no single global standard.
- A site license may be needed income countries. Applied for at the local authorities, and can be revoked.
- Examples of standards:
  - **ISO 11784/11785:** Animal identification.
  - **ISO/IEC 14443:** popular for HighFIDs, basis of RFID-enabled passports under ICAO 9303.
  - **ISO/IEC 15693:** popular for HighFIDs, non-contact smart payment and credit cards.
  - **ISO 18185:** industry standard for electronic seals (e-seals), tracking cargo containers at 433 MHz and 2.4 GHz.
  - **ISO 28560-2:** encoding standards and data model for libraries.
  - **EPC Gen2:** EPCglobal UHF Class 1 Generation 2.
- Other standards for conformance, performance, and interoperability tests — ensure global interoperability.

Problems and Limitations

- Propagation phenomena (Friis equation) and range;
- Access and collision (tree, memoryless, contactless, I-code, …);
- Data flooding;
- Global standardization;
- Health;
- Exploitation;
- Shielding;
- Other issues:
    - Privacy;
    - Security concerns;
    - Government control.

SWOT Matrix

Strengths	Weaknesses
• Advanced technology • Small size and easy to use *(no LOS required)* • High memory capacity • EPC (96 bits)	• Multitude of industry/application standards • Cost/unit and integration costs • Weak market understanding of the benefits
Opportunities	**Threats**
• Could replace bar code • End user demand is increasing • Huge market potential in many businesses	• Ethical threats concerning privacy • Highly fragmented competitive environment • Health concerns in some applications

Thank You

شكراً

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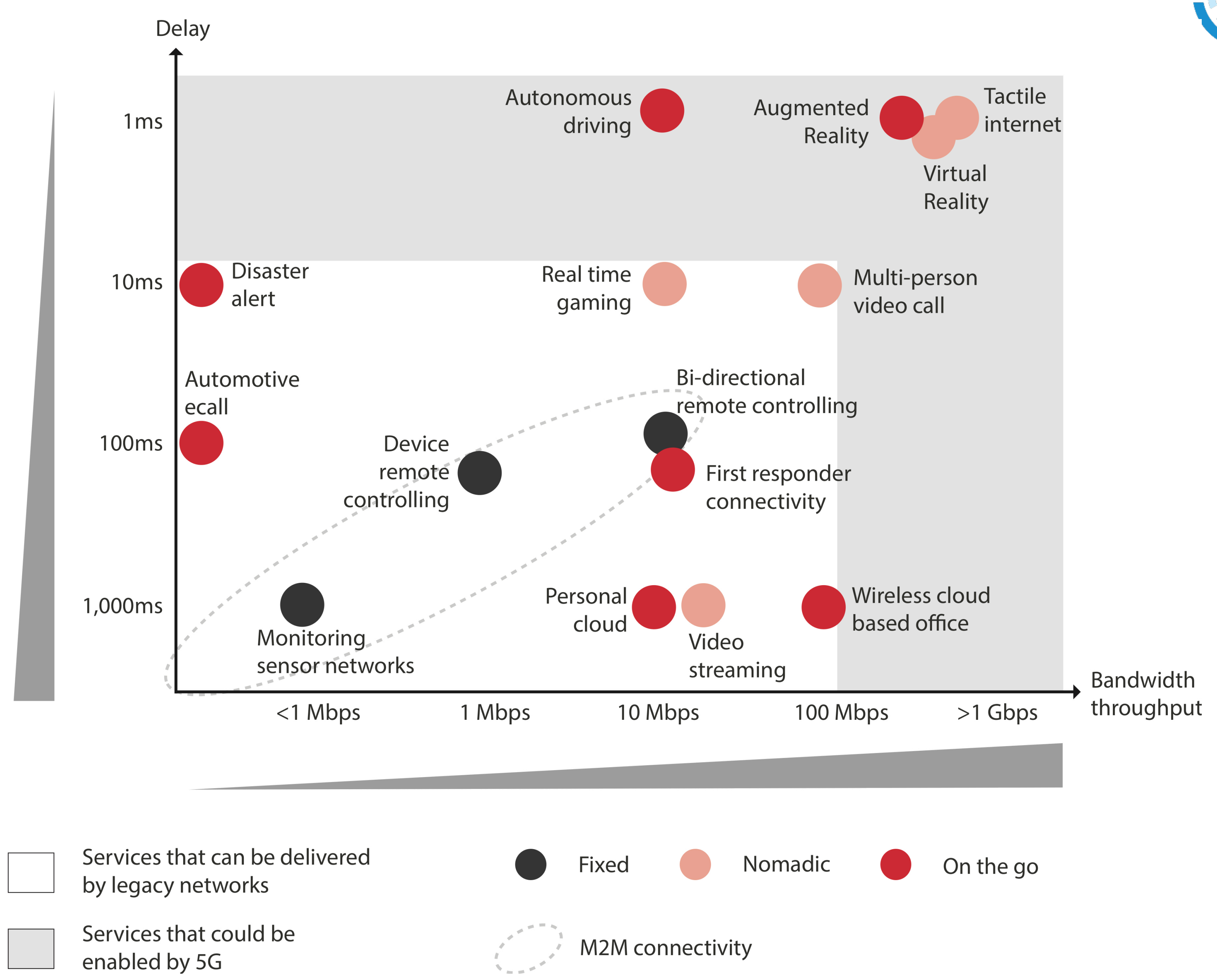
Alternative and/or complementary solutions

(5G, WSN, LPWAN, ...)



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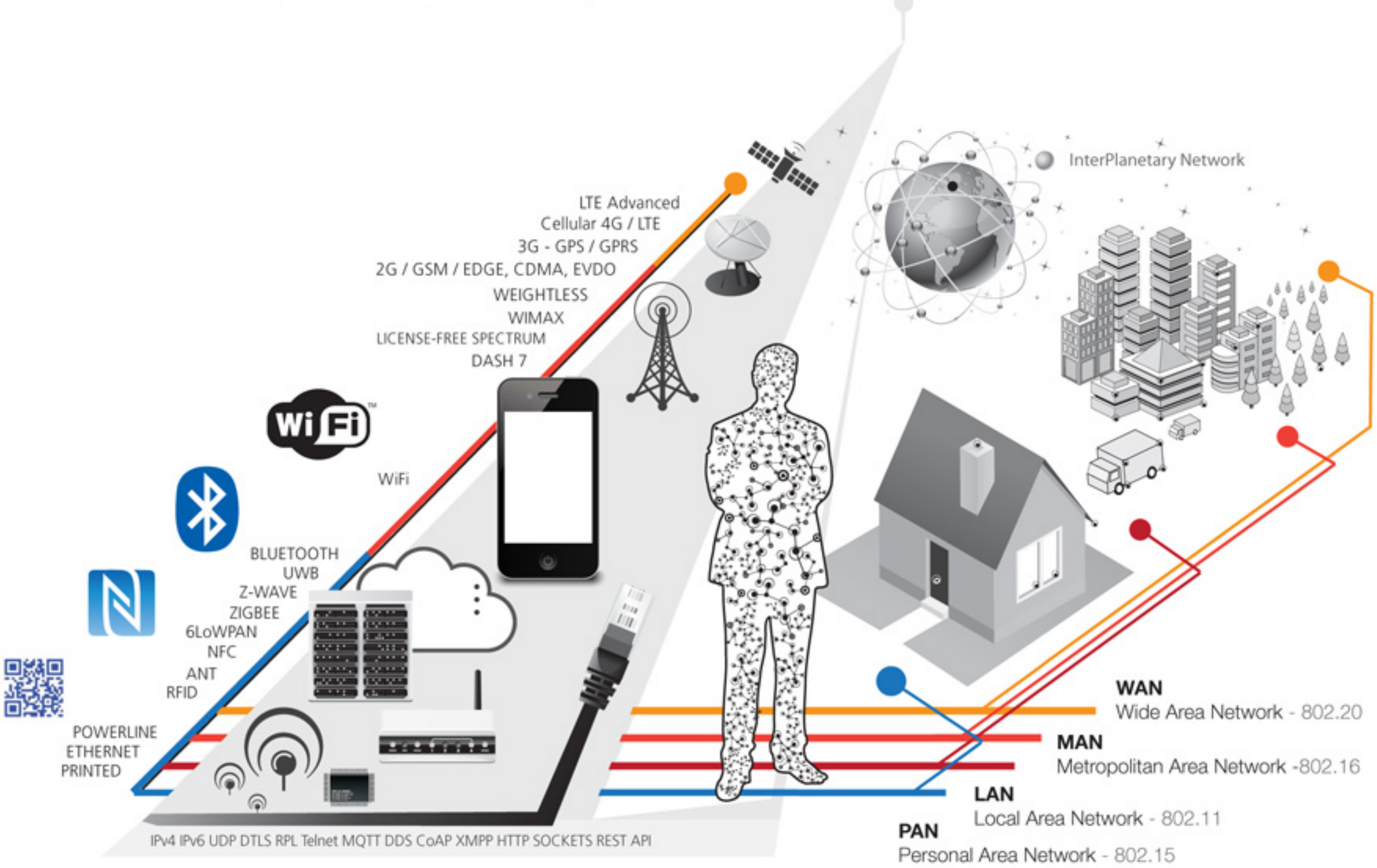

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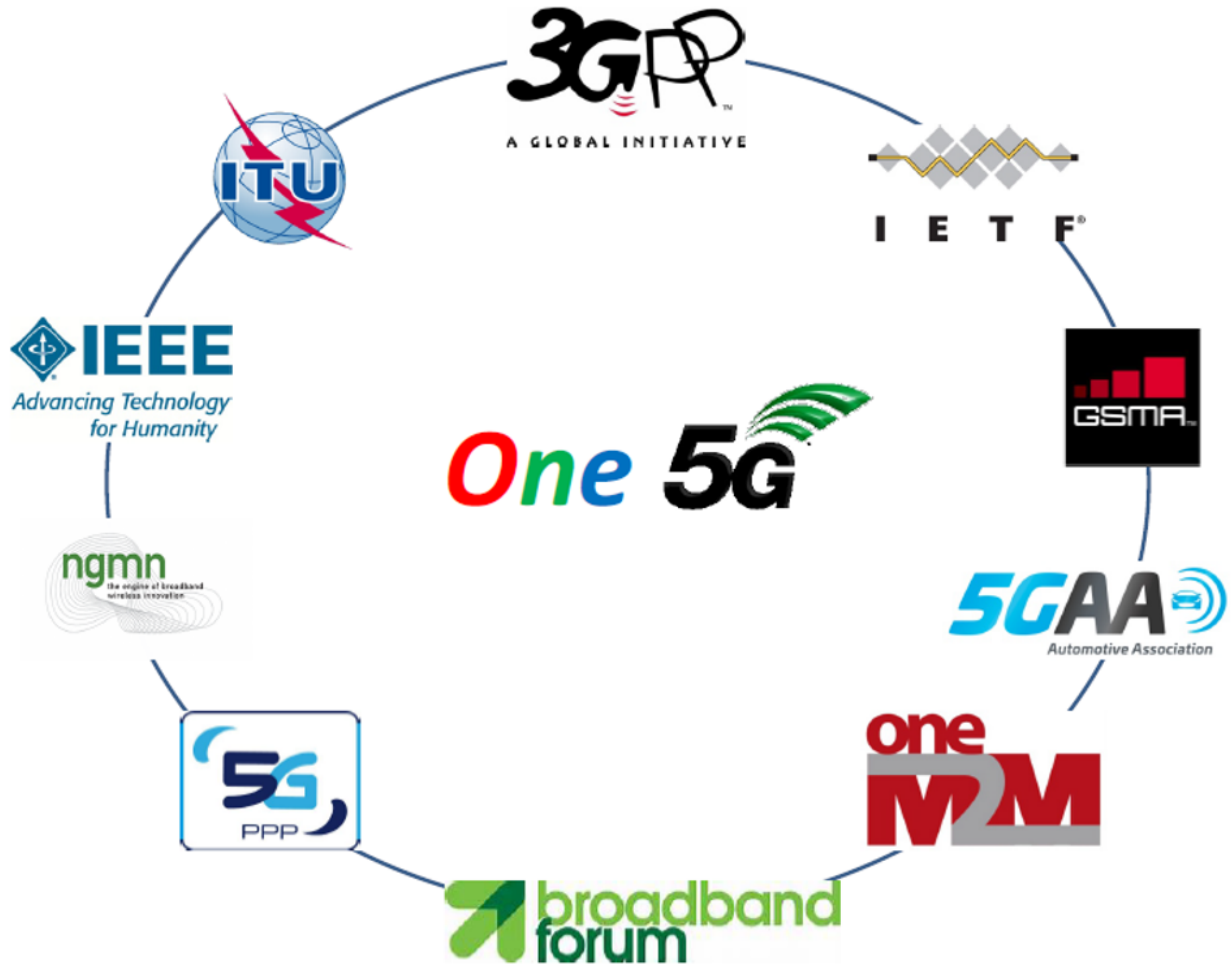
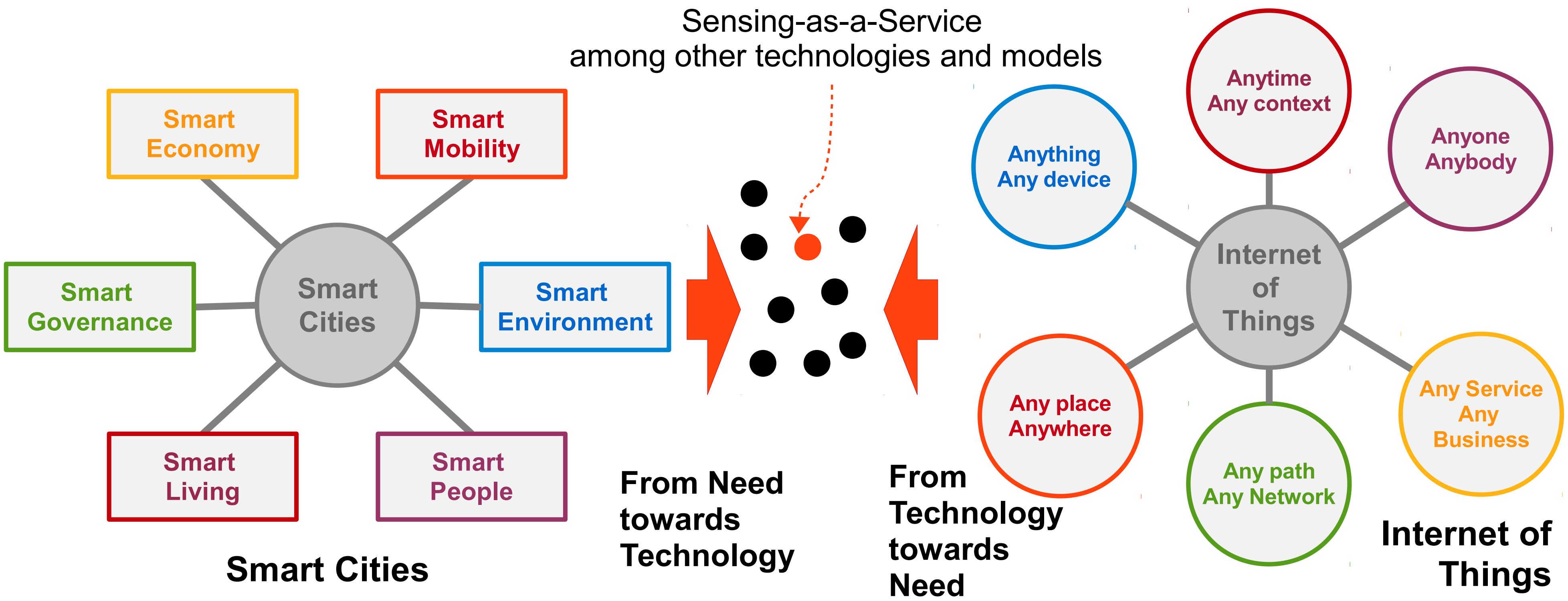
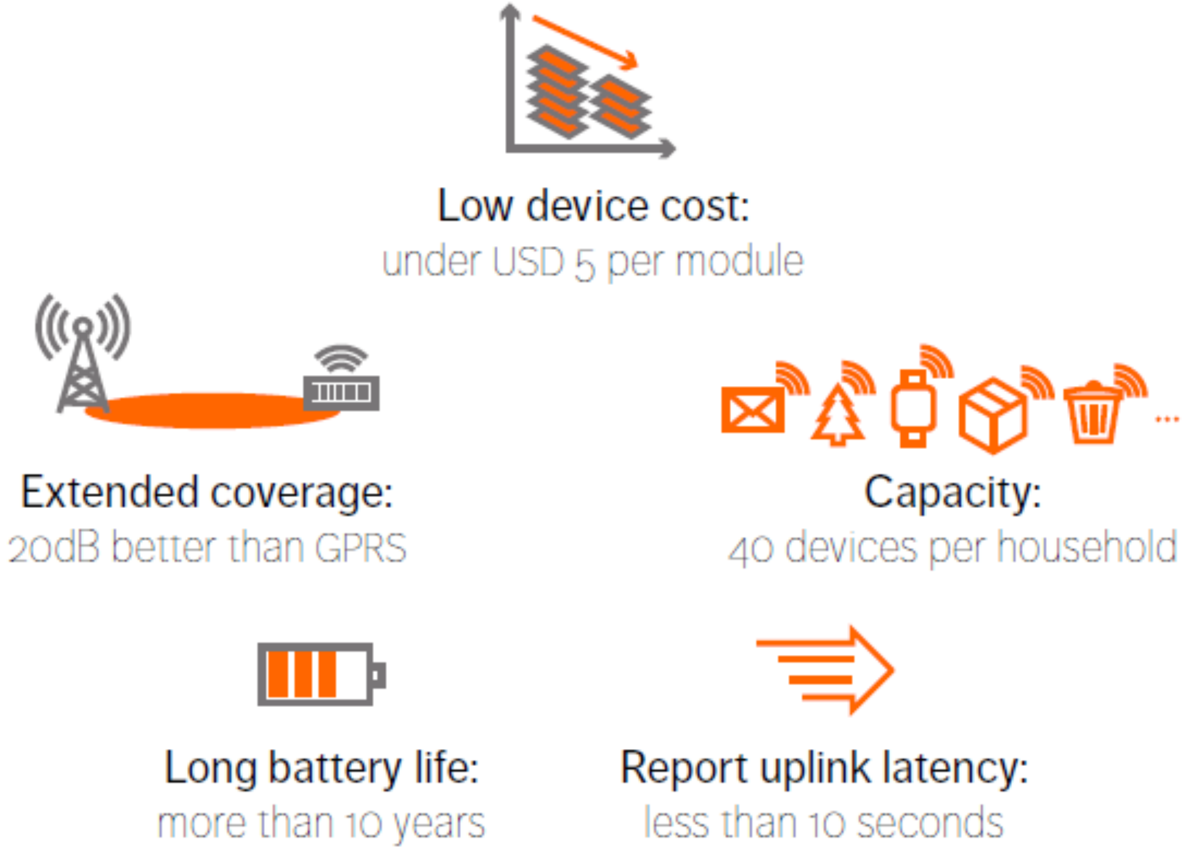

One 5G
3GPP
A GLOBAL INITIATIVE
IETF
GSMA
5GAA
Automotive Association
oneM2M
broadband forum
5G PPP
ngmn
IEEE
Advancing Technology for Humanity
ITU



Source: *C. Perera et al., "Sensing as a Service Model for Smart Cities Supported by Internet of Things", Trans. Emerging Tel. Tech.* 2014, **00**:1-12.

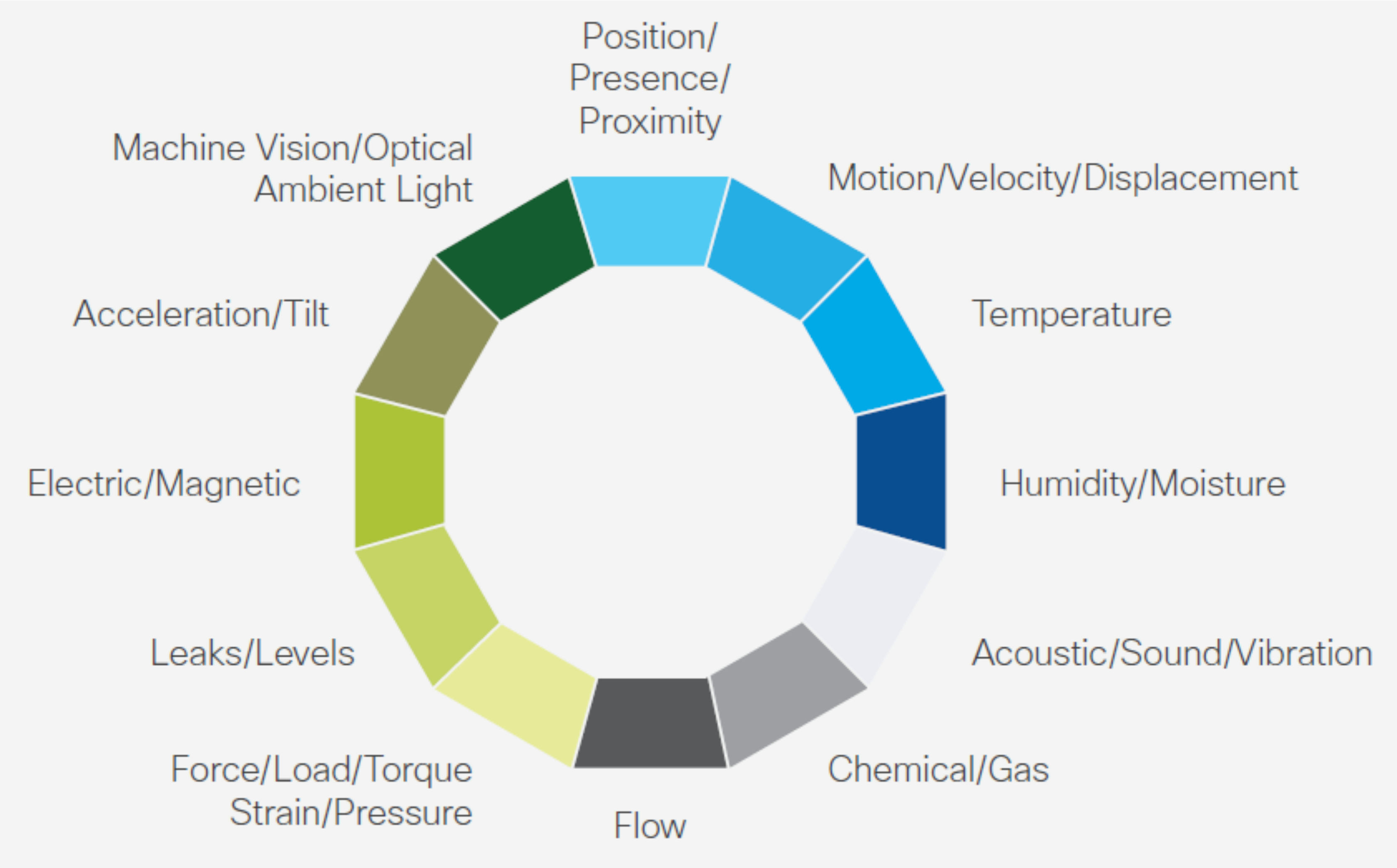
Sensing and Access/Network Requirements

- Enablers (mmWave, OWC, …)
- Bottleneck (bandwidth, power, weight, …)
- Evolution (2G, 3G, LTE, NB-IoT…) vs. Revolution (5G, molecular comms., …)



Source: Ericsson, Apr. 2016

Sensor families



Source: [3] Harnessing the Internet of Things for Global Development, ITU & Cisco

Sensor categories

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Highest Cost

	Functionality	Sensor Type
$150-$1000+	• Long-term install/deployment • Industrial scale deployment • Extreme accuracy/precision • Typically large enterprises • Ease of solution interoperability	• Chemical/Gas • Electrical/Capacitive • Pressure/Load/Weight • Proximity/Position
$50-$150	• Residential/commercial • Advanced development kits • Consumer-based support • Cloud partnership capability • Fast deployment • Medium infrastructure required • Low-Medium accuracy/Precision	• Water Treatment/Flow • Weather/Temperature • Motion/Velocity • Acoustic/Sound/Vibration • Light/Imaging • Proximity/Position • Flex/Force/Strain
$0 - $50	• Single function • DIY/Prototyping often needed • Limited without other hardware • Requires basic equipment • Geared towards amateurs • Singular functionality • No infrastructure required	• Water Treatment/Flow • Weather/Temperature • Motion/Velocity • Acoustic/Sound/Vibration • Light/Imaging

Lowest Cost

Source: [3] Harnessing the Internet of Things for Global Development, ITU & Cisco

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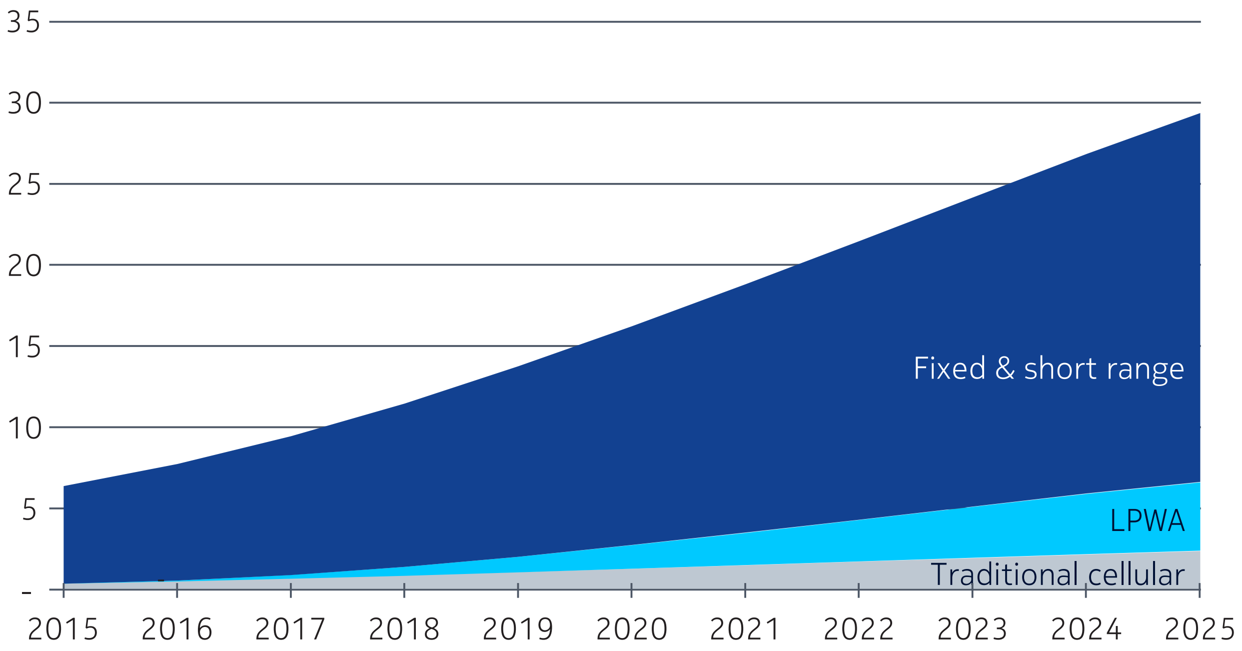
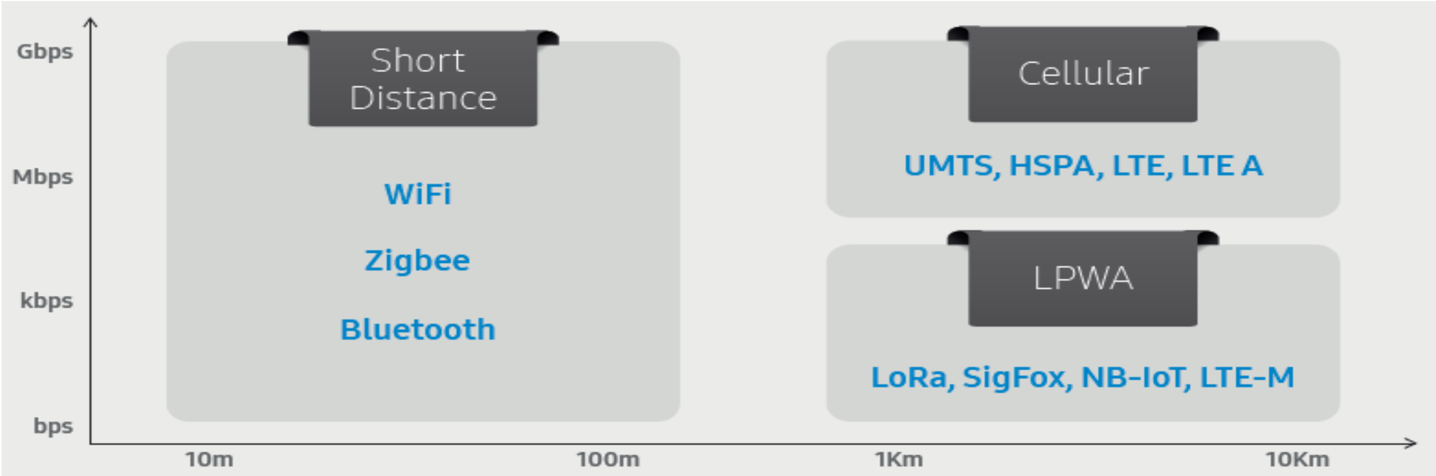

35
30
25
20
15
10
5
-
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Fixed & short range
LPWA
Traditional cellular


Gbps
Mbps
kbps
bps
10m
100m
1Km
10Km
Short Distance
WiFi
Zigbee
Bluetooth
Cellular
UMTS, HSPA, LTE, LTE A
LPWA
LoRa, SigFox, NB-IoT, LTE-M

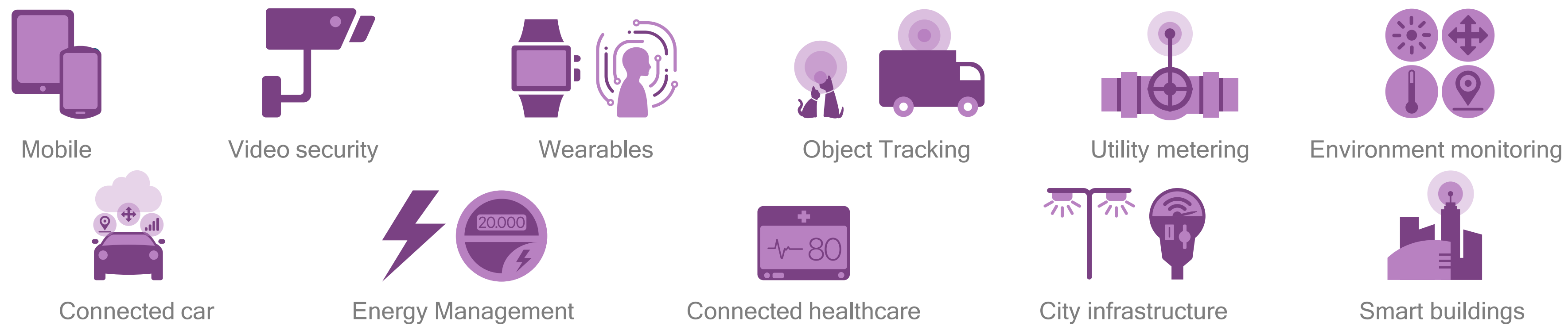
Scaling up in performance and mobility

Scaling down in complexity and power

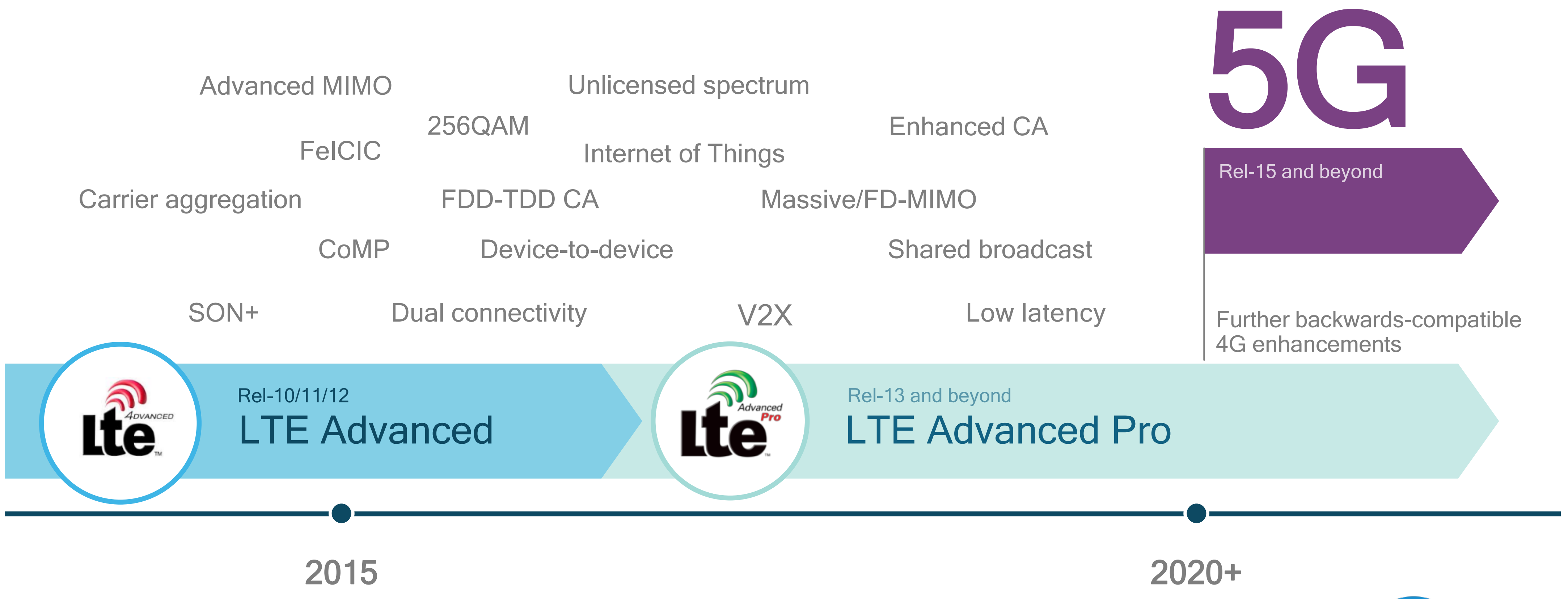
LTE Advanced	LTE Cat-1	eMTC (Cat-M1)	NB-IOT (Cat-M2)
>10 Mbps	Up to 10 Mbps	Up to 1 Mbps	10s of kbps to 100s of kbps
n x 20 MHz	20 MHz	1.4 MHz narrowband	180 kHz narrowband

LTE Advanced (Today+)

LTE IoT (Release 13+)



Source: Qualcomm, Jun. 2016



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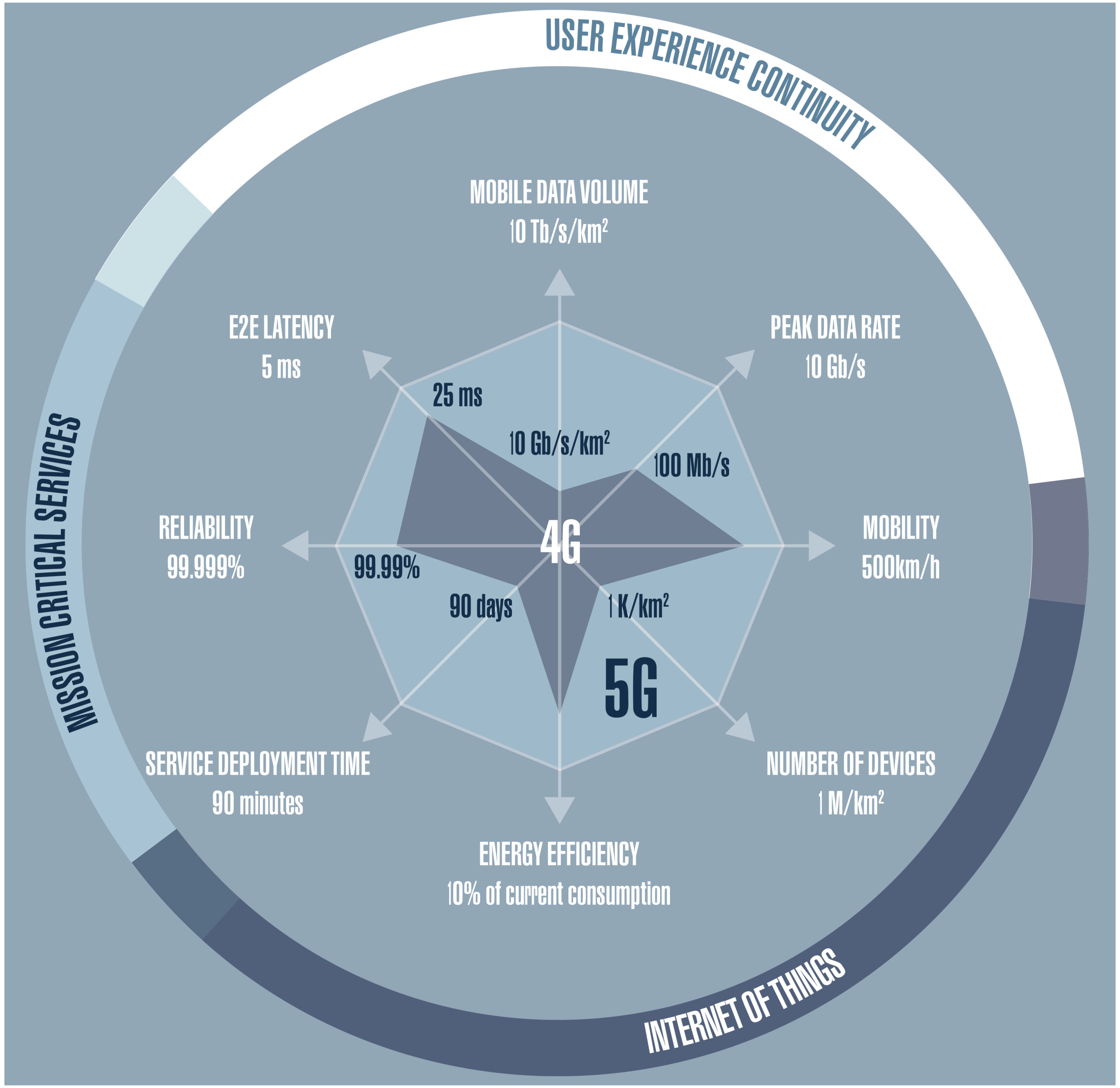

Source: 5GPPP.

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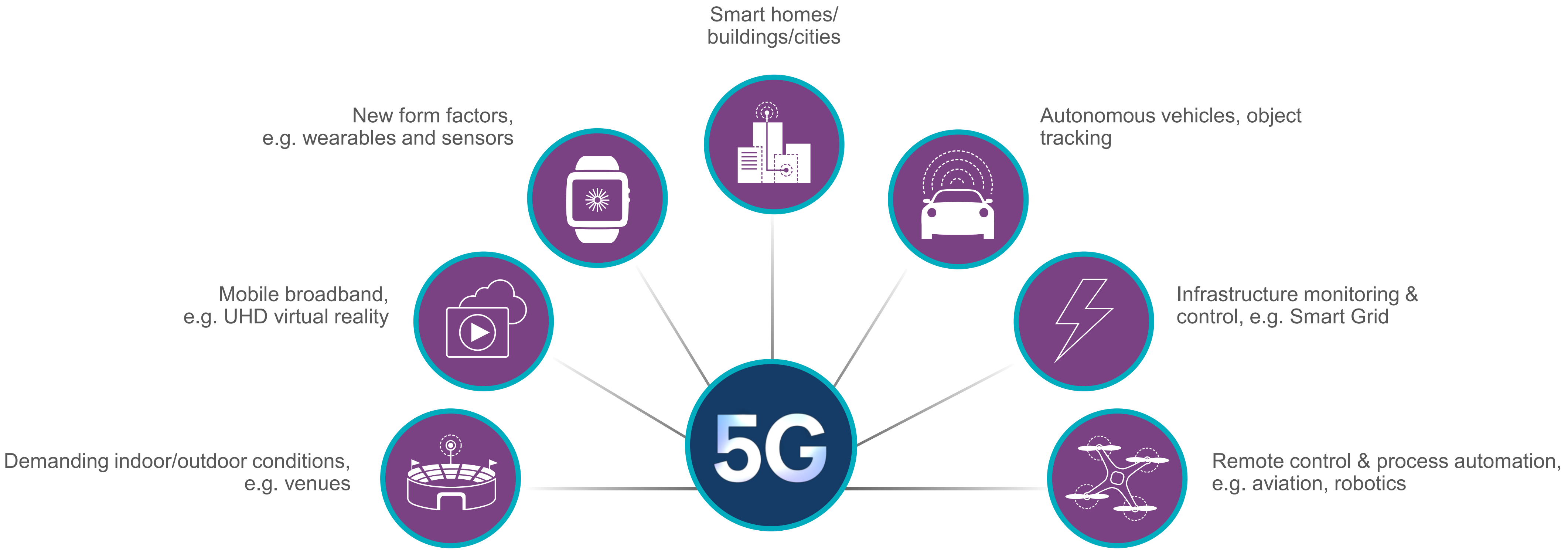

Enhanced Mobile Broadband

Faster, more uniform user experiences

Wide Area Internet of Things

More efficient, lower cost communications with deeper coverage

Higher-Reliability Control

Lower latency and higher reliability

Source: Qualcomm, Jun. 2016

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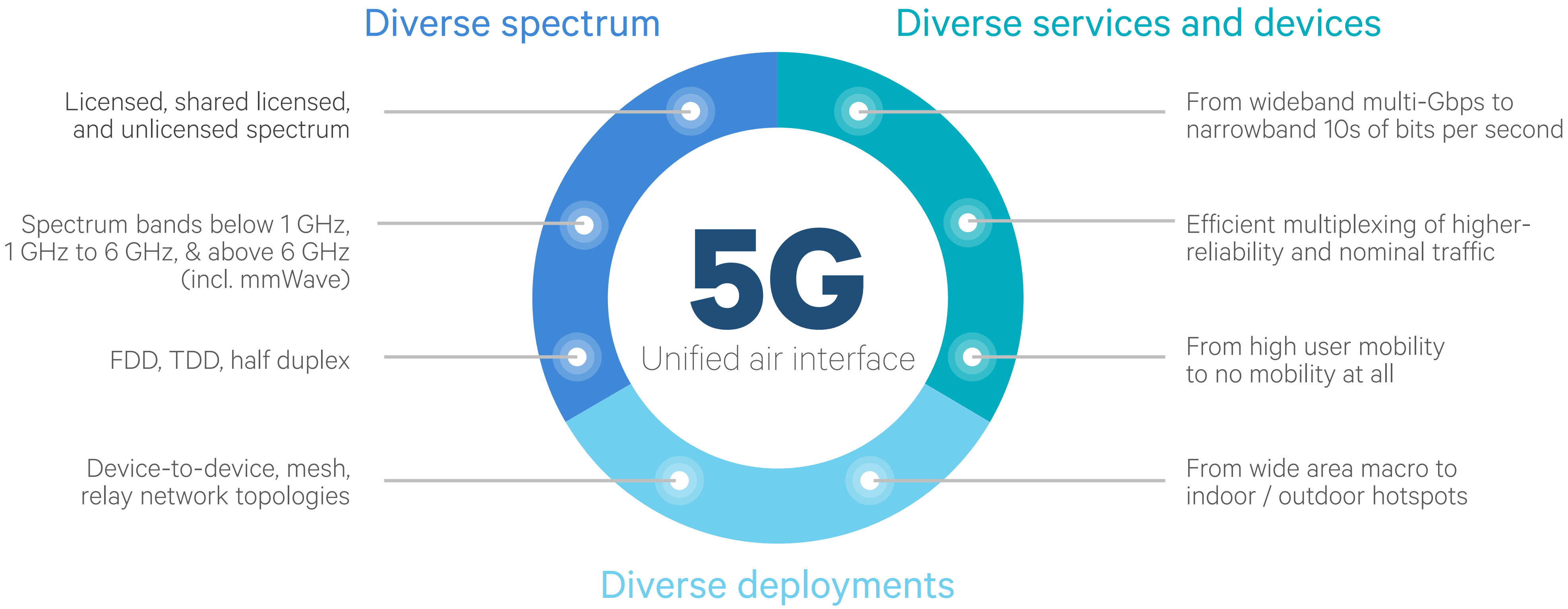

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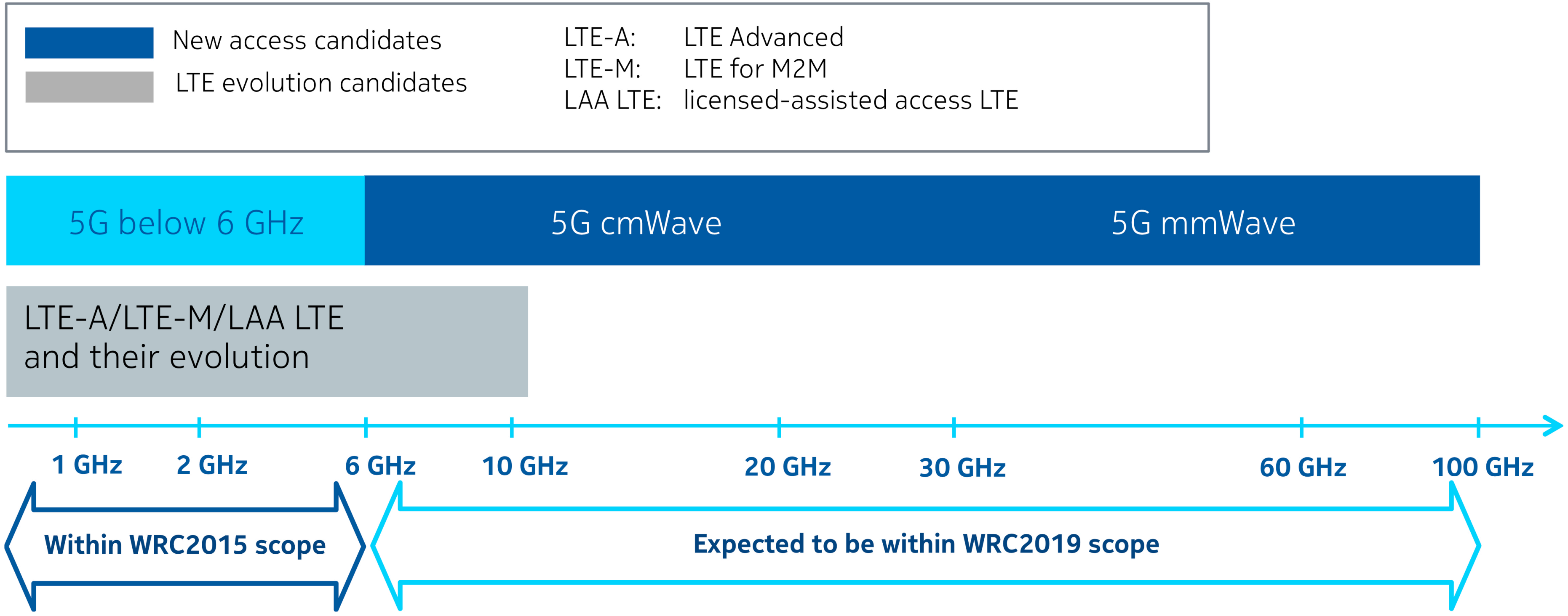
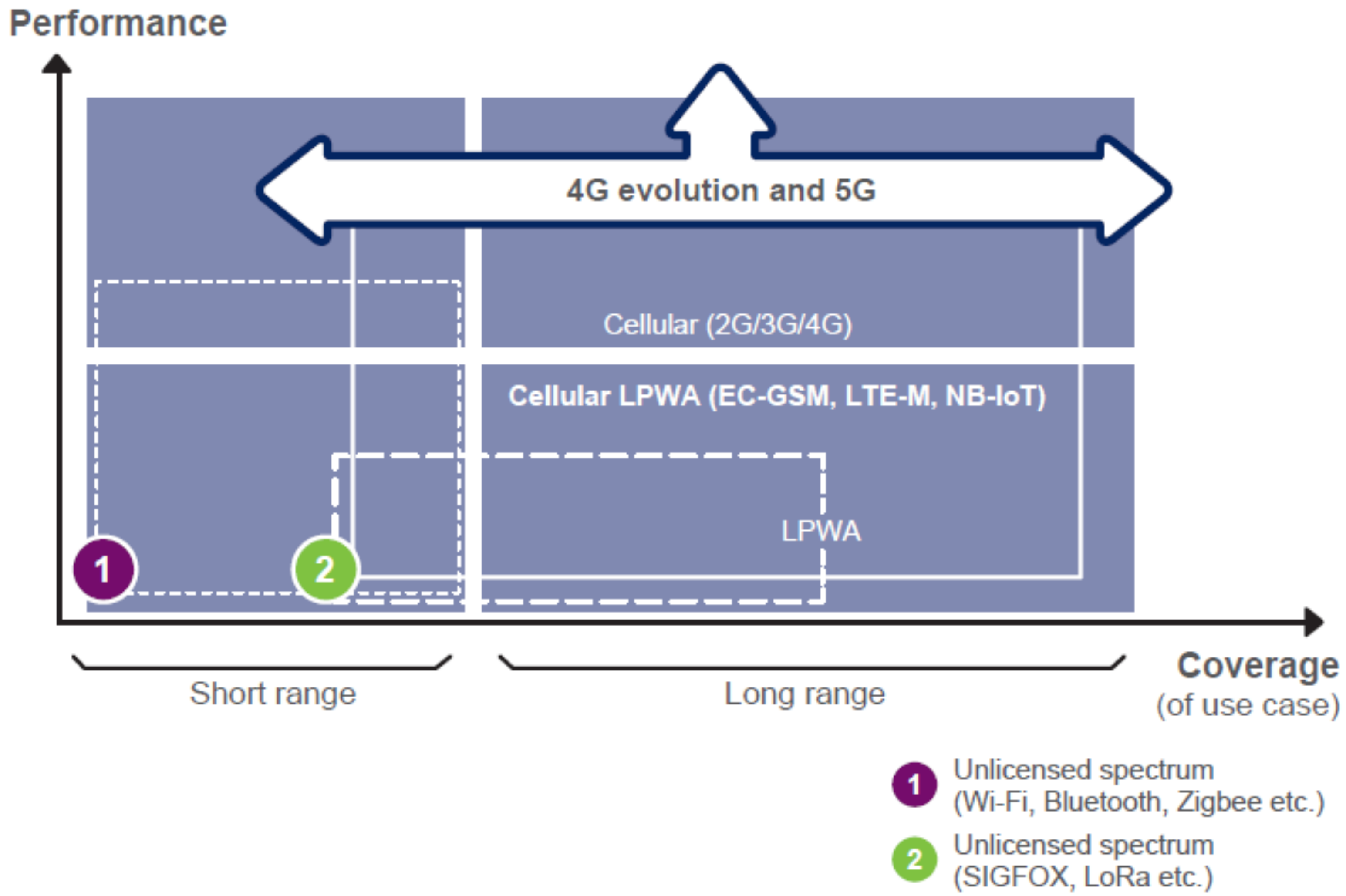


Source: Nokia Networks.



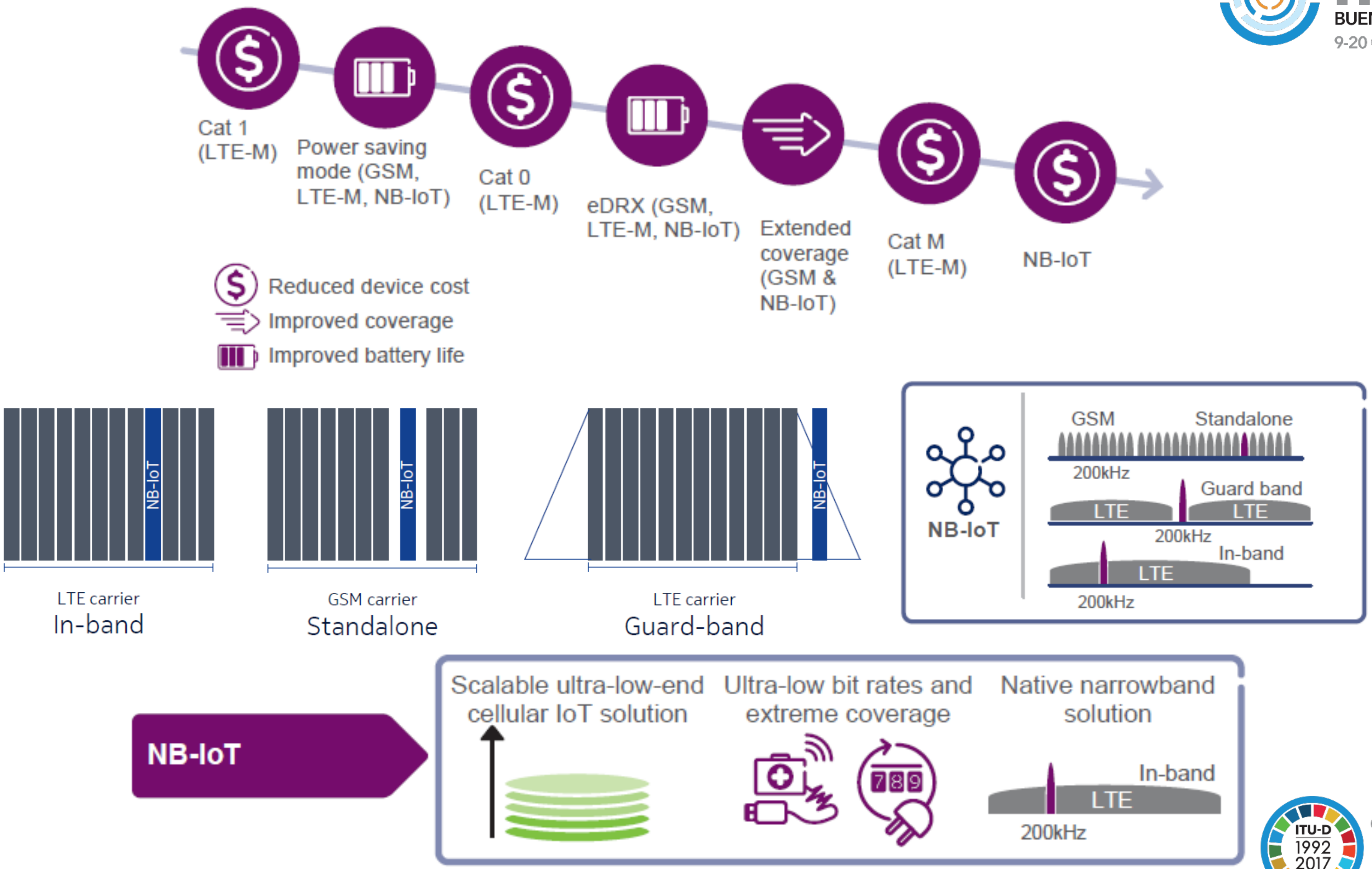
Source: Ericsson, Jan. 2016

	Wireless-			Wireline
	Personal Area Networks (WPAN)	Local Area Networks (WLAN)	Wide Area Networks (WWAN)	
	ANT+, Bluetooth, 4.0 LE RFID, NFC 802.11.4, ZigBee	Wi-Fi	LoRa, Weightless, Dash 7 WiMax, 2G, 3G 4G/LTE, Satellite	Copper/DSL Coaxial Fiber
Range short to long				
Bandwidth narrow to broad				
Battery Life short to long				

Source: [3] Harnessing the Internet of Things for Global Development, ITU & Cisco

	LPWA (Low Power Wide Area)					
	Cellular IoT (3GPP Standard-based)				Non-Cellular IoT	
	LTE-M			NB-IoT (Rel.13)	LoRa	SigFox
	Cat 1 (Rel.8)	Cat 0 (Rel.12)	Cat M (Rel.12)			
Coverage*	Same as LTE coverage (Cat-M : Deeper Penetration)			+ 20dB than LTE (<22km)	<14km	<17km
Spectrum	LTE In-band Only			LTE In-band Guard band Standalone	Un-licensed Band	
Signal BW	20 MHz	1.4 MHz	1.08 MHz	180 kHz	125 kHz	0.1 kHz
Data Rate	10Mbps	1Mbps	1Mbps	200kbps	10kbps	100bps
Battery Life	10years			10years	10years	

	LoRa	GSM (Rel.8)	EC-GSM-IoT (Rel.13)	LTE (Rel.8)	eMTC (Rel.13)	NB-IoT (Rel.13)
LTE user equipment category	N/A	N/A	N/A	Cat.1	Cat.M1	Cat.NB1
Range Max. coupling loss	<15km 155dB	<35km 144dB	<35km 164dB	<100km 144dB	<100km 156dB	<35km 164dB
Spectrum	Unlicensed <1GHz	Licensed GSM bands	Licensed GSM bands	Licensed LTE bands In-band	Licensed LTE bands in-band	Licensed LTE in-band guard-band stand-alone
Bandwidth	<500kHz	200kHz	200kHz	LTE carrier bandwidth (1.4 – 20MHz)	1.08MHz (1.4MHz carrier bandwidth)	180kHz (200kHz carrier bandwidth)
Max. data rate*	<50kbps (DL/UL)	<500kbps (DL/UL)	<140kbps (DL/UL)	<10Mbps(DL) <5Mbps(UL)	<1Mbps (DL/UL)	< 170kbps (DL) < 250kbps (UL)



Source: Ericsson, Jan. 2016

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SUDATEL TELECOMMUNICATIONS ACADEMY

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