COEXISTENCE RADIO IN MASSIVE DEPLOYMENT OF IOT

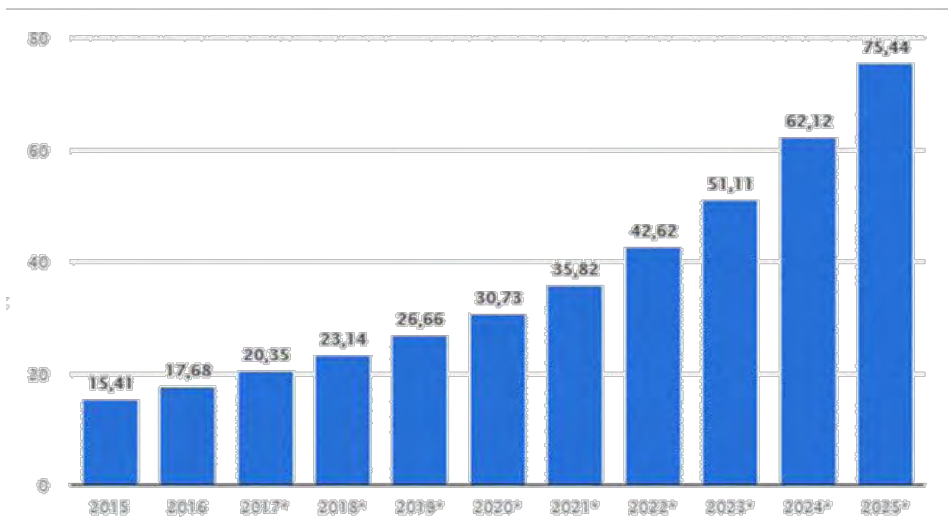BY LCIE BUREAU VERITAS

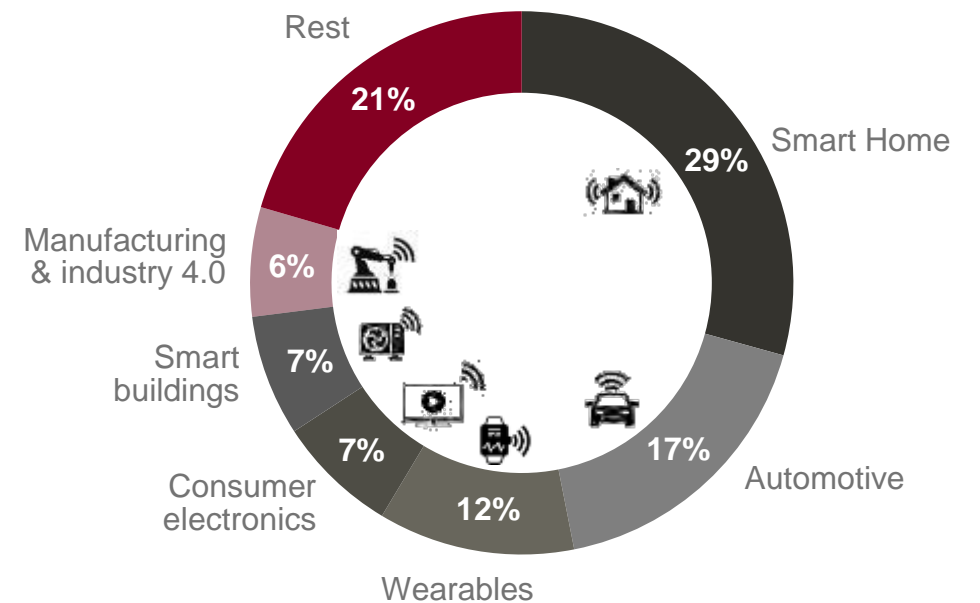# BOOM OF IOT CONNECTIONS

► **Worldwide Connections** (Billion Units)

Bar chart values:
- 2015: 15,41
- 2016: 17,68
- 2017*: 20,35
- 2018*: 23,14
- 2019*: 26,66
- 2020*: 30,73
- 2021*: 35,82
- 2022*: 42,62
- 2023*: 51,11
- 2024*: 62,12
- 2025*: 75,44

► **Global IoT connections by segment** (2020)

- Rest: 21%
- Smart Home: 29%
- Manufacturing & industry 4.0: 6%
- Smart buildings: 7%
- Consumer electronics: 7%
- Wearables: 12%
- Automotive: 17%

INDUSTRY IS EMBRACING THE INTERNET OF THINGS (IOT)

- Industry is embracing the Internet of Things (IoT)

- Large numbers of connected sensors are now being used to monitor the performance of complex physical machinery in real-time.

- Analysis of the resulting data can be used **to optimize production and perform predictive maintenance**, increasing efficiency and generating insights that can be used to develop new processes.

- As industry players start to realize the benefits of connecting Industrial IoT connections will overtake consumer IoT connections in 2023

- The industrial segment will account for just over half of all IoT connections in 2025 as IoT solutions are deployed within enterprises and vertical-specific applications, such as manufacturing and energy management.
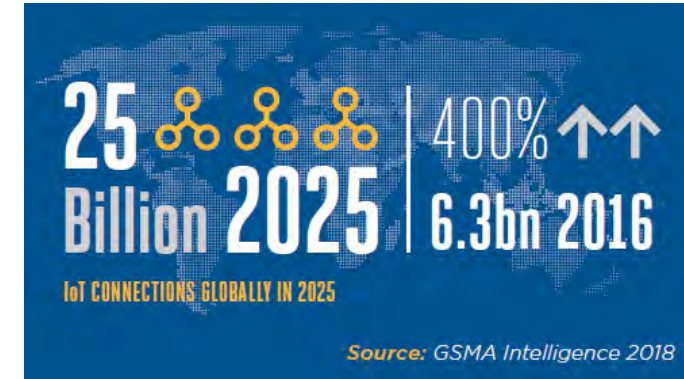
WIRELESS SOLUTIONS – SHORT-RANGE SOLUTIONS

Short-range IoT connectivity solutions transfer data over small physical distances, with the distance between the 'thing' that collects data and the gateway that processes it (or sends it over the internet to another platform) usually less than 150 meters.

Solution	Frequency	Max. Range	Max. Throughput	Latency	Topology	Power Consumption	Use
Wi-Fi HaLow (IEEE 802.11ah)	Various (sub-1 GHz)	1 km	40 Mbps	100 ms	Mesh	Low	Smart lighting, smart HVAC, security systems
Bluetooth Low Energy	2.4 GHz	100 m	2 Mbps	6 ms	Point-to-point	Low	Mobile phones, gaming, wearables
Z-Wave	800-900 MHz	100 m	100 kbps	N/A	Mesh	Low	Smart lighting, thermostats, locks, sensors
Zigbee	2.4 GHz	100 m	250 kbps	10 ms	Mesh	Low	Lighting controls, smoke and CO_2 detectors
NFC	13.56 MHz	10 cm	424 kbps	100 ms	Point-to-point	Low	Commerce, smart-phone automation

WIRELESS SOLUTIONS – LONG-RANGE SOLUTIONS (CELLULAR)

- Cellular provides solutions for IoT solutions that require long-distance data transfers combined with low latency. While cellular is clearly capable of sending high quantities of data, especially for standards such as 4G, the hardware costs, maintenance expenses, monthly costs for rates and data plans, and the power consumption of older LTE releases will be too high for many IoT applications.

- However, cellular standards in more recent releases, especially LTE Cat-0, 1, M1, NB1, can provide the low power, low throughput, wireless technology required by many modern IoT applications (lower prices charged by mobile network operators for these standards are an advantage over regular cellular standards).

Solution	Frequency	Max. Range	Max. Throughput	Latency	Topology	Power Consumption	Use
GSM/ GPRS / Edge			384 kbps	0.15–1 s		High	
UMTS/ HSPA			10 Mbps	0.2–0.4 s		High	Smart metering, asset tracking, sensors
LTE CAT 1			10 Mbps	0.05–0.1 s		Medium	
LTE CAT 0	Various (Depending on region)	Up to 100 km	1 Mbps	N/A	Star	Medium	
EC-GSM-IoT			2 Mbps	0.7–2 s		Medium	
LTE Cat NB1 (NB-IoT)			250 kbps	1.6–10 s		Low	Health monitoring, smart cities, sensors
LTE Cat M1 (eMTC)			1 Mbps	10–15 ms		Low	

WIRELESS SOLUTIONS – LONG-RANGE SOLUTIONS (LPWA)

2 sub-terms:

- Low Power (LP) means that the hardware power consumption is generally very low and therefore can operate on small, inexpensive batteries for several years.

- Wide Area Network (WAN) indicates that the connectivity solution can bridge an operating range that is typically more than 10 km in urban areas. It is important to understand that LPWAN (not a connectivity standard, but rather an umbrella term encompassing various implementations and protocols that share common connectivity characteristics).

Solution	Frequency	Max. Range	Max. Throughput	Encryption	Topology	Power Consumption	Use
LoRaWAN	Various (sub-1 GHz)	15 km	50 kbps	128-bit AES	Star on star	Very low	Logistics, utilities, smart cities, industrial IoT
Sigfox	900 MHz	50 km	10 kbps	N/A	Star	Very low	Asset tracking, mHealth, remote monitoring
Weightless (W,N,P)	Various (sub-1 GHz)	5 km	10 Mbps (W)	128/256-bit AES	Star	Very low	Smart metering, asset tracking, smart cars
Ingenu	Various (sub-1 GHz)	500 km	38 kbps	128-bit AES	Star	Very low	Agriculture precision, smart grid, asset tracking

WIRELESS COEXISTENCE

➜ **Key factor affecting a wireless device's performance** is the limited amount of RF spectrum available, which can result in potential competition among wireless technologies for simultaneous access to the same spectrum.

- Because conflicts among wireless signals can be expected, most wireless communication technologies incorporate methods to manage these conflicts and minimize disruptions in the shared wireless environment.

➜ Selection of RF wireless operating frequency and modulation:

- Should take into account other RF wireless technologies and users that might be expected to be in the vicinity of the wireless device system.

- These other wireless systems can pose risks that could result in device signal loss or delay that should be considered in the risk management process.

➜ To address this issue, many recommendations and studies are published

INTERFERENCE AND COEXISTENCE CONCERNS FOR WIRELESS

Traditional concern for radio frequency (RF) communication systems is the presence of other unwanted communication or RF signals either in-band or near-band (typically categorized as adjacent bands).

In a licensed frequency band, all signals other than the licensed user of the spectrum are considered **interference (or RF noise).**

When the spectrum is shared, the nature of interference is not as clear.

EXAMPLES OF COEXISTENCE RADIO

1. **Wireless coexistence in the 2.4 GHz** radio band of the main wireless technologies that are using these bands: IEEE Std. 802.15.4, IEEE Std. 802.11 (Wi-Fi), and Bluetooth Smart.

2. **ECC Report 302** studied the coexistence scenarios between WAS/RLAN (within the band 5925-6425) MHz and the incumbent usages:

Fixed Service (FS), Fixed-Satellite Service (FSS), Radio astronomy (RAS) and Ultra Wideband (ÚWB), as well as Road Intelligent Transport Systems (ITS) and Communication Based Train Control (CBTC).

The studies considered various WAS/RLAN scenarios with power up to 1 W e.i.r.p., indoor and outdoor devices, and also scenarios that assumed indoor only usage. Guidance is provided in ECC Report 302.

3. **ECC Report 207** - Adjacent band co-existence of SRDs in the band 863-870 MHz with LTE below 862 MHz

➔ Possible interference from LTE UE into SRDs (distance<10m)

➔ Blocking effect improvement of SRD receivers (categories as defined in ETSI EN 300 220)

➔LTE unwanted emissions falling into the band of SRDs

4. **Indoor Coexistence Analysis Among 5G New Radio, LTE-A and NB-IoT in the 700 MHz Band**

WIRELESS COEXISTENCE IN THE 2.4 GHZ BAND

- **IEEE Std. 802.15.4** is designed to ensure a reliable co-existence with other 2.4 GHz wireless technologies and provides mechanisms that improve or enhance this co-existence. These mechanisms can be found **in Annex E of the IEEE 802.15.4 specification.**

- Tests described aim is to determine the effects of coexistence in the 2.4 GHz radio band of the main wireless technologies that are using these bands: IEEE Std. 802.15.4, IEEE Std. 802.11 (Wi-Fi), and Bluetooth Smart.

➔ **Main purpose of the tests:** determine the performance of an IEEE Std. 802.15.4 radio when operating with Wi-Fi static and dynamic interference, BLE interference, or combined Wi-Fi and BLE interference.

➔ The test results determine the best and worst case scenarios when different wireless technologies coexist.

WIRELESS COEXISTENCE IN THE 2.4 GHZ BAND

➔ IEEE 802.11 traffic is affecting not only the overlapping channels but also adjacent channels of the overlapping channels, as can be seen in Figure 24 (for 802.15.4 channel 20 - 2.450 GHz and 802.11 channel 11 – 2.462 GHz), but the impact is weaker.

• For the adjacent channels of the overlapping channels significant PERs are obtained for throughputs higher than 35 Mbps (at 25 mW TX power).

• All of the overlapping 802.15.4 channels (channels 21, 22, 23, and 24 in this test) with the 802.11 channel (channel 11 in this test) are affected similarly (relatively close PER values for every overlapping channel for each separate Wi-Fi throughput).

• By reducing the 802.11 router's output power by 25 times from 14 dBm (25 mW) to 0 dBm
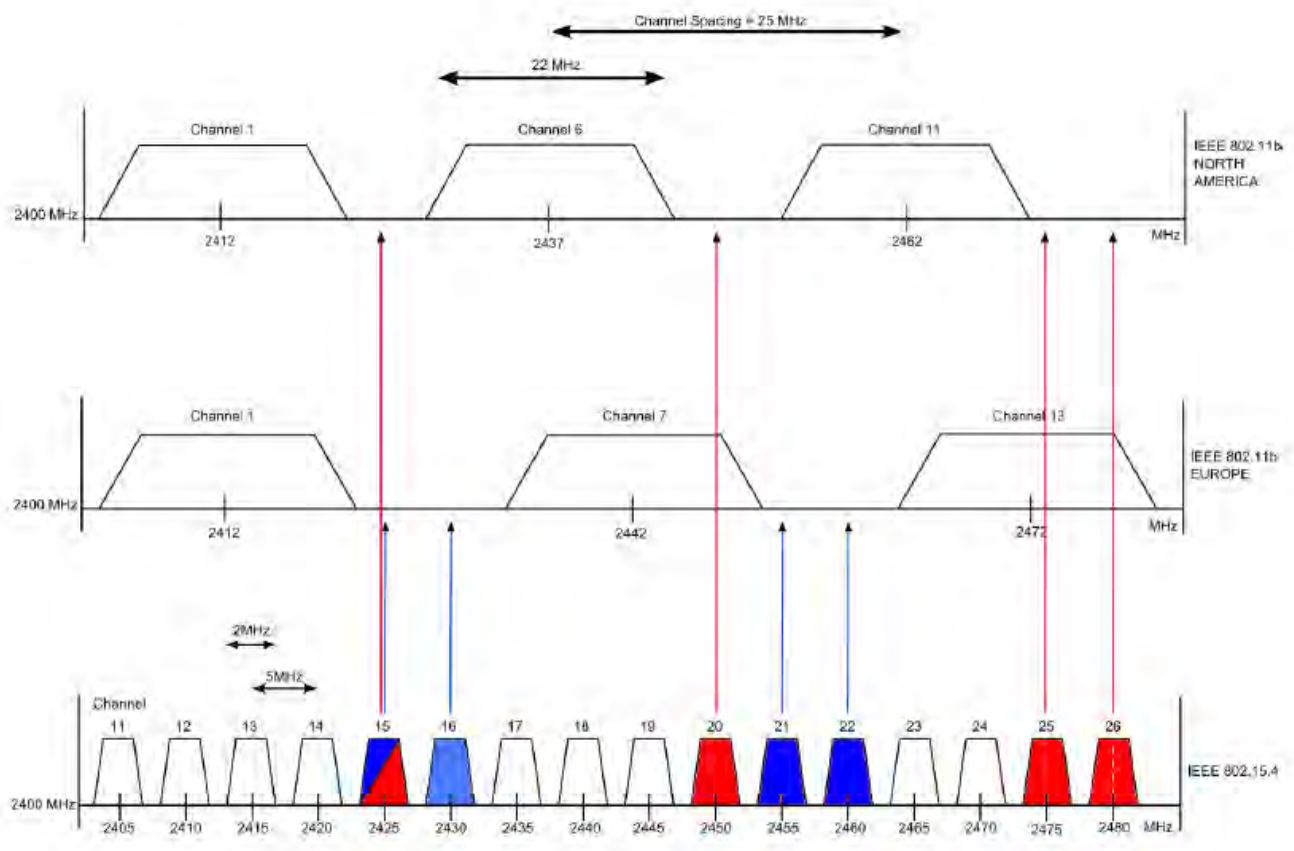
WIRELESS COEXISTENCE DEFINITION

- IEEEE Std. 802.15.4 defines 16 channels. The first channel is channel 11 (with a central frequency of 2405 MHz) and the last channel is 26 (with a central frequency of 2480 MHz). Each channel has a 2 MHz bandwidth and a 5 MHz channel spacing

- IEEE Std. 802.11 defines a total of 14 channels however in contrast with IEEE 802.15.4, the channel usage depends on the regulatory domain. IEEE Std. 802.11b recommends the use of non-overlapping channels 1, 6, and 11 for North America and channels 1, 7, and 13 for Europe. Also, (North America channels 13 and 14 are not used).

- IEEE Std. 802.15.4 is designed to ensure a reliable co-existence with other 2.4 GHz wireless technologies and provides mechanisms that improve or enhance this co-existence. These mechanisms can be found in Annex E of the IEEE 802.15.4 specification.

WIRELESS COEXISTENCE IN THE 2.4 GHZ BAND

The following figure demonstrates that for both North America and Europe you can choose up to four 802.15.4 channels that are not overlapping the Wi-Fi channels. *(Source Wireless Coexistence in the 2.4 GHz Band, Application Note, Rev. 0, 09/2015)*

IEEE 802.15.4 channel vs. non-overlapping IEEE 802.11b channels (US, Europe)

WIRELESS COEXISTENCE IN THE 2.4 GHZ BAND

Coexistence among wireless technologies is dependent on three main factors:

• **Frequency**

• **Time**

• **Space**

If one (at least) of these three factors can be controlled, then coexistence can be achieved by:

• **Frequency separation between networks' operating channels**

• **Low occupancy of the channel**

• **Setting convenient distances between networks**

- However in real world deployment none of these three main factors can be fully controlled and therefore the interference will always exist.

- The objective is to achieve an acceptable level of performance of services delivered by the coexisting wireless technologies.

LAB TESTS: IEEE 802.15.4 – IEEE 802.11N COEXISTENCE

The test results determine the best and worst case scenarios when different wireless technologies coexist.

These tests will enable you to:

• Setup different wireless networks that may coexist

• Understand the effects of mutual interference

• Learn which channels are recommended for use and which are not

• Ensure proper distances between and correct placement of wireless networks.

CONCLUSIONS OF THOSE TESTS

➔ The IEEE 802.11 traffic is affecting not only the overlapping channels but also adjacent channels of the overlapping channels, (for 802.15.4 channel 20 - 2.450 GHz and 802.11 channel 11 – 2.462 GHz), but the impact is weaker.

• For the adjacent channels of the overlapping channels significant are obtained for throughputs higher than 35 Mbps (at 25 mW TX power).

• All of the overlapping 802.15.4 channels (channels 21, 22, 23, and 24 in this test) with the 802.11 channel (channel 11 in this test) are affected similarly.

• By reducing the 802.11 router's output power by 25 times from 14 dBm (25 mW) to 0 dBm (1 mW), the PER has been significantly reduced.

• It can be seen that for the overlapping channels, at throughputs equal or less than 15 Mbps, the PER is negligible and at about 20 Mbps the PER is very small. The neighboring adjacent channels are noticeably affected only when the throughput is over 30 Mbps.

(Source Wireless Coexistence in the 2.4 GHz Band, Application Note, Rev. 0, 09/2015)

TECHNICAL PARAMETERS FOR ARTICLE 3.2 OF DIRECTIVE 2014/53/EU

Harmonised Standards : not intended to specify how products are designed but how they respond in the presence of various external stimuli, simulating other spectrum users and interference, i.e. the EUT can be regarded as a "black box".

Transmitter parameters under article 3.2 of Directive2014/53/EU:

- *Transmitter power limits*
- *Transmitter power accuracy*
- *Spectrum mask*
- *Transmitter frequency stability*
- *Transmitter intermodulation attenuation*
- *Transmitter unwanted emissions in the spurious domain*
- *Transmitter time domain characteristics*
- *Transmitter transients*

TECHNICAL PARAMETERS FOR ARTICLE 3.2 OF DIRECTIVE 2014/53/EU

Receiver parameters under article 3.2

- Receiver sensitivity

- Receiver co-channel rejection

- Receiver Selectivity
- Single signal selectivity
- Receiver spurious response rejection
  Receiver multiple signal selectivity (blocking, intermodulation, Receiver adjacent signal selectivity…)
- Other receiver effects

- Other receiver effects
- Receiver dynamic range
- Reciprocal mixing
- Desensitization

- Receiver unwanted emissions in the spurious domain

➔ **EMC standards also cover coexistence radio through many specifications: IEC 60601-1-2 Medical, risks analysis, IEC 62657-2, ANSI C63.27 + AAMI TIR 69**

THANK YOU