

Emerging communication technologies enabling the Internet of Things (IoT)

AK EMARIEVBE

PRODUCT MANAGER

Mobile Radio Communication Testers

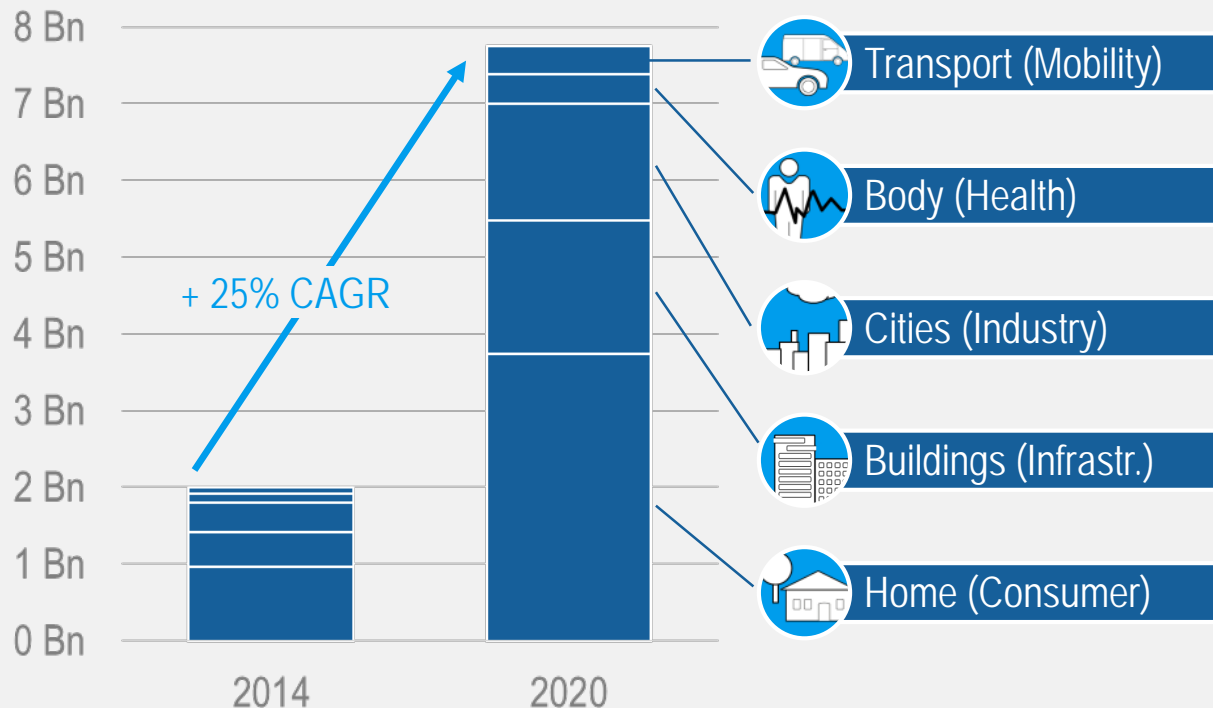
Smart Testing
for a smart world



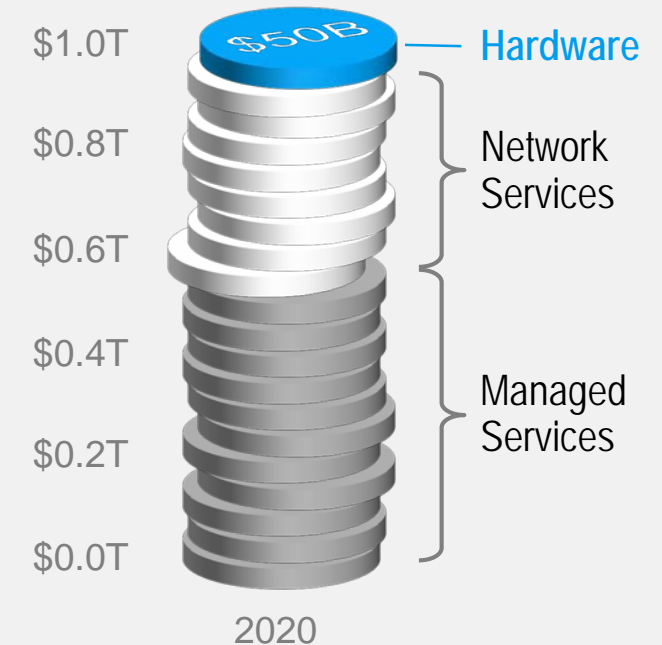
IoT the Trillion Dollar Opportunity for the industry

M2M Communication Modules are just an enabler of the IoT

Number of shipped Internet of Things connected Devices



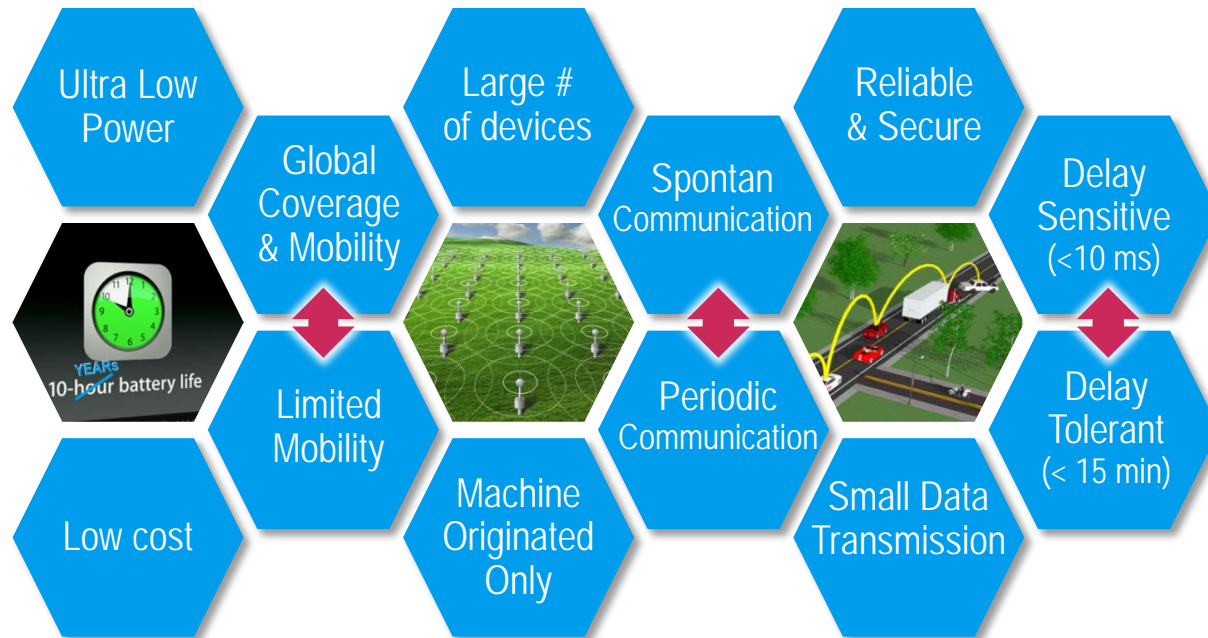
Revenue Opportunities



Source Habor Research IoT market forecast <https://s3.amazonaws.com/postscapes/IoT-Harbor-Postscapes-Infographic.pdf>

Machines are different!

Diverse communication requirements



M2M Communication has become vital in several industries

Wearables



Smart Homes



Smart Cities



Healthcare



Automotive



Smart Buildings



Asset Tracking



Retail



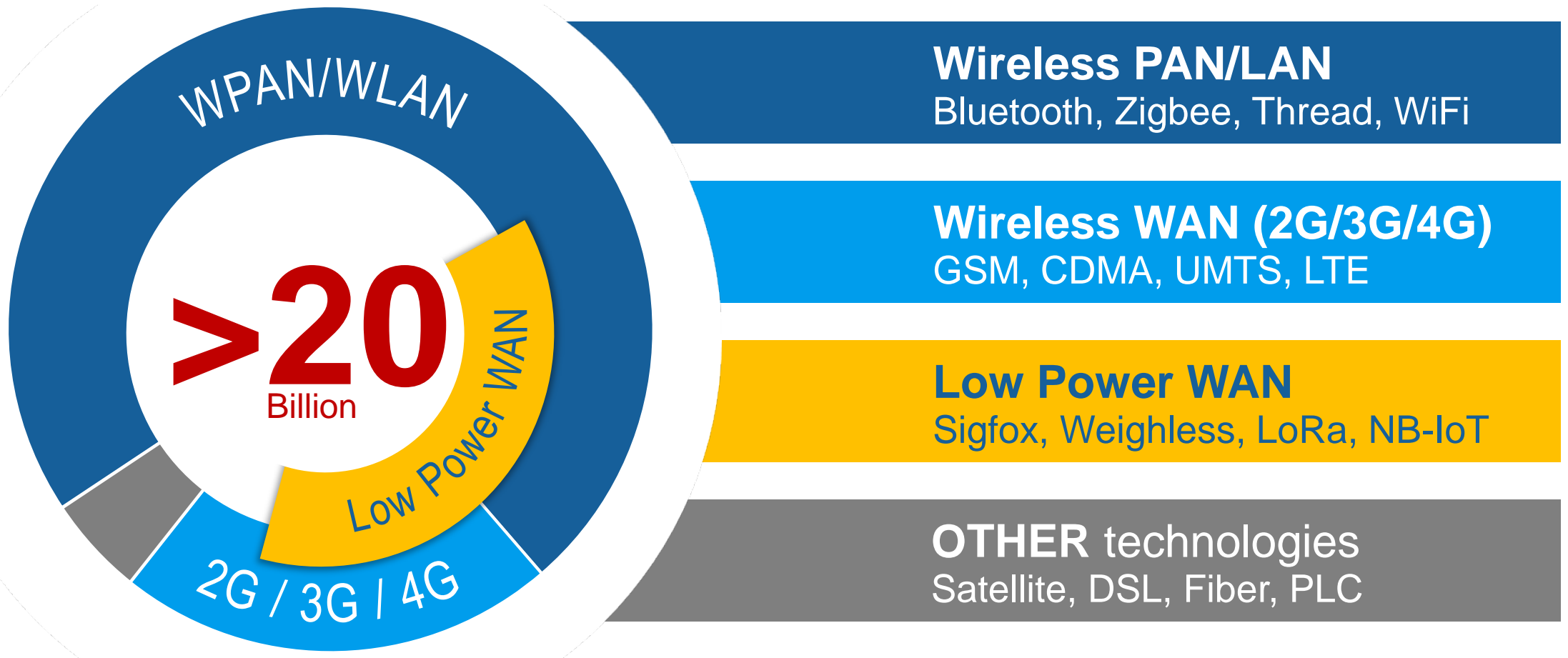
Agriculture



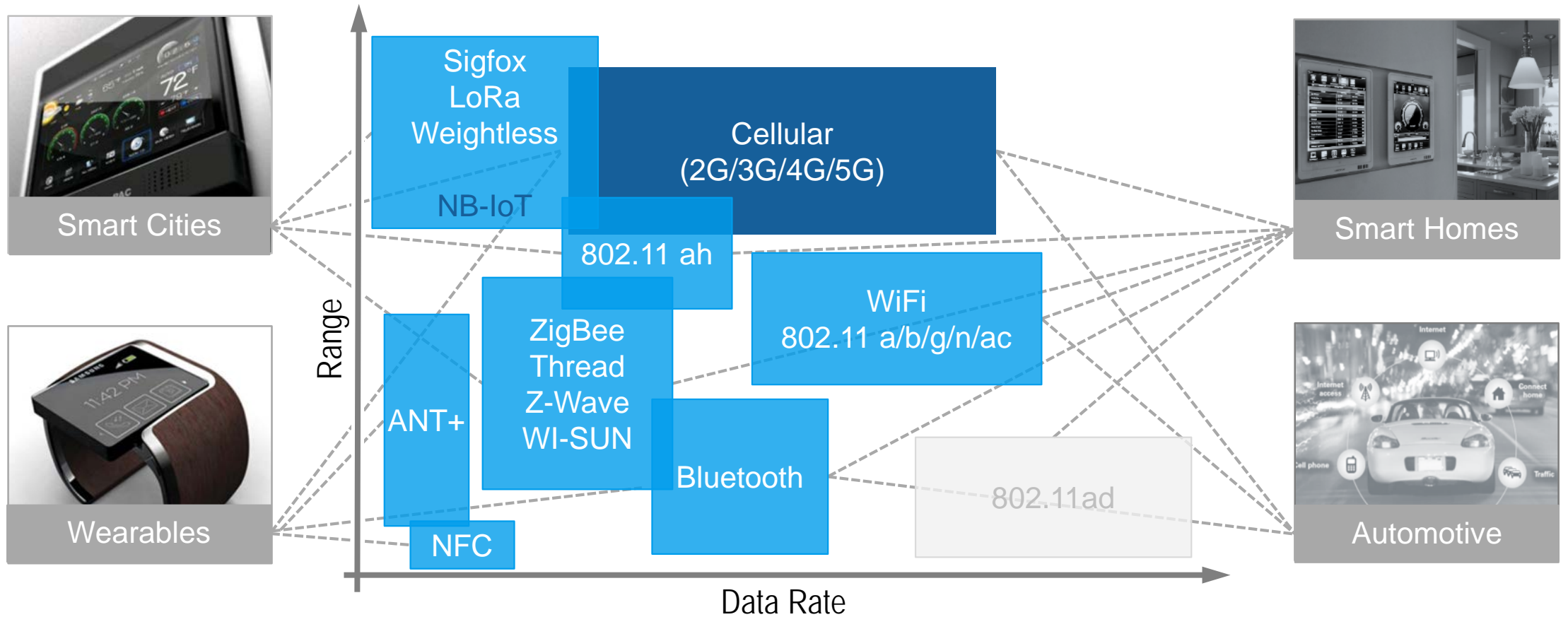
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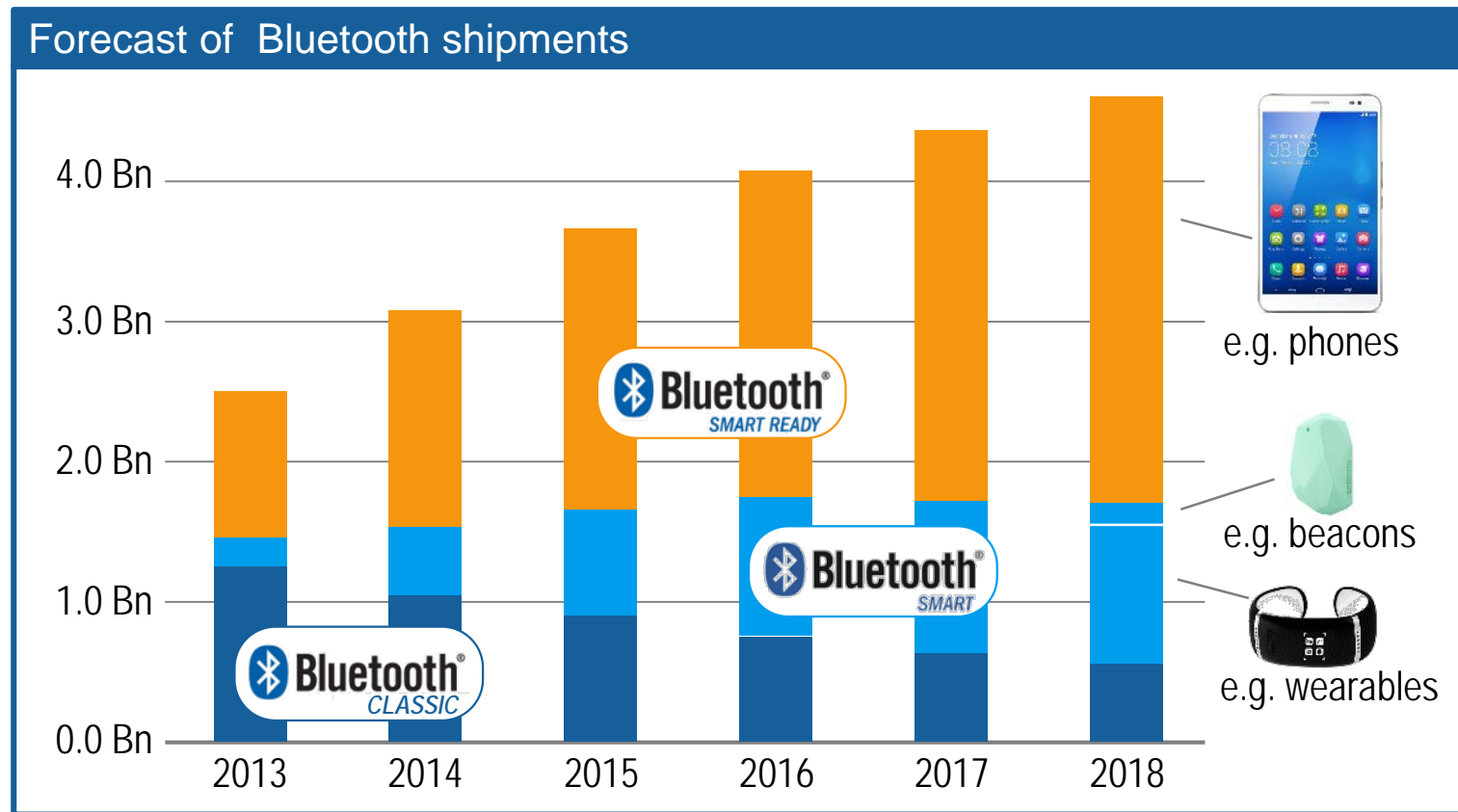
A bunch of communication technologies connecting Billions of Devices to the Internet of Things (IoT)



The majority of devices building the Internet of Things will use wireless technologies in un-licensed frequency bands



Bluetooth will dominate the IoT market for Wearables with BLE and will enter the smart home market with Smart Mesh in 2016



Source: ABI Research

While the power-efficiency of Bluetooth Smart makes it perfect for devices needing to run off a tiny battery for long periods, the magic of Bluetooth Smart is its ability to work with an application on the smartphone or tablet.

With introducing Bluetooth Smart Mesh the smart home/building market should be addressed as well. Smart Mesh enables smart locks, lights, HVAC systems, and even appliances work together to deliver a seamless smart home

For 2016 the Bluetooth SIG focuses on enhancements for the Internet of Things (IoT)

Mesh

building meshed network
using relay nodes



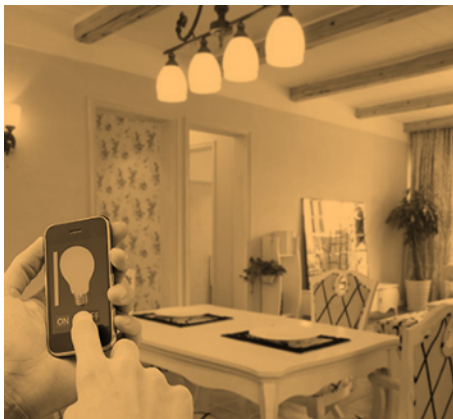
Speed

100% improvement for
low latency applications



Gateway

Connecting devices
directly to the cloud



Range

4x range to cover a
smart home or office

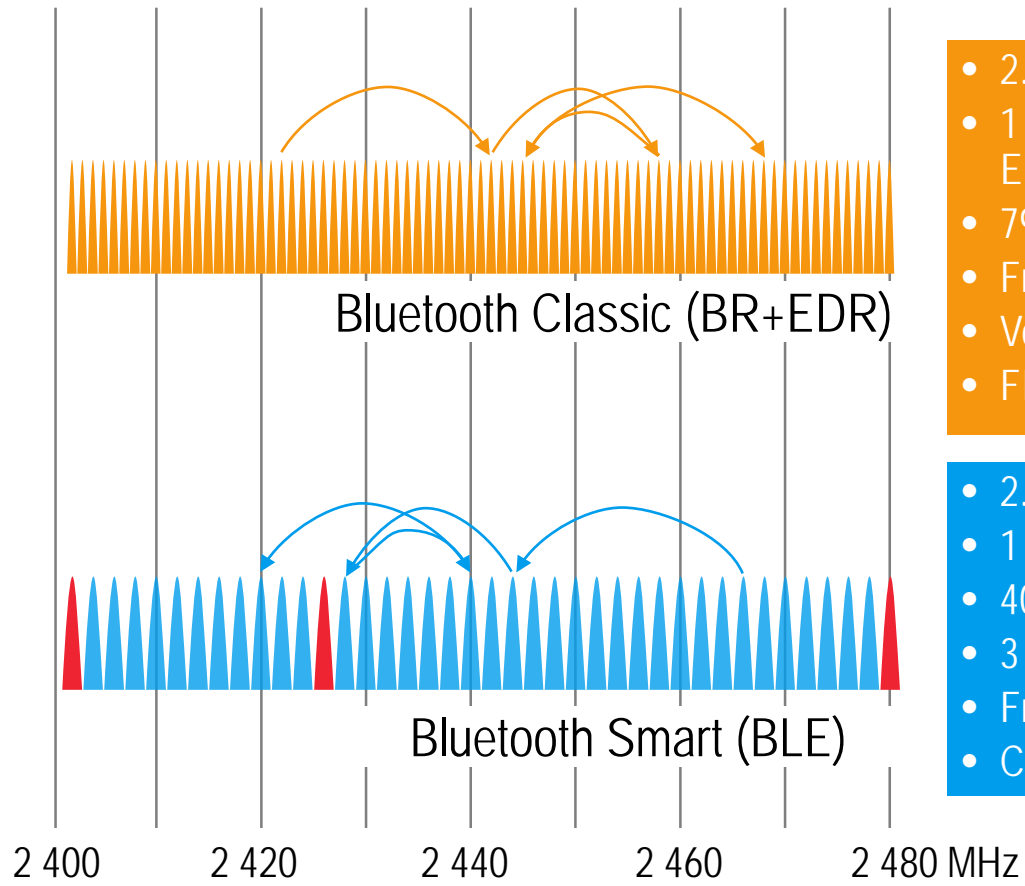


Direction

Extended capabilities of
beacons for positioning

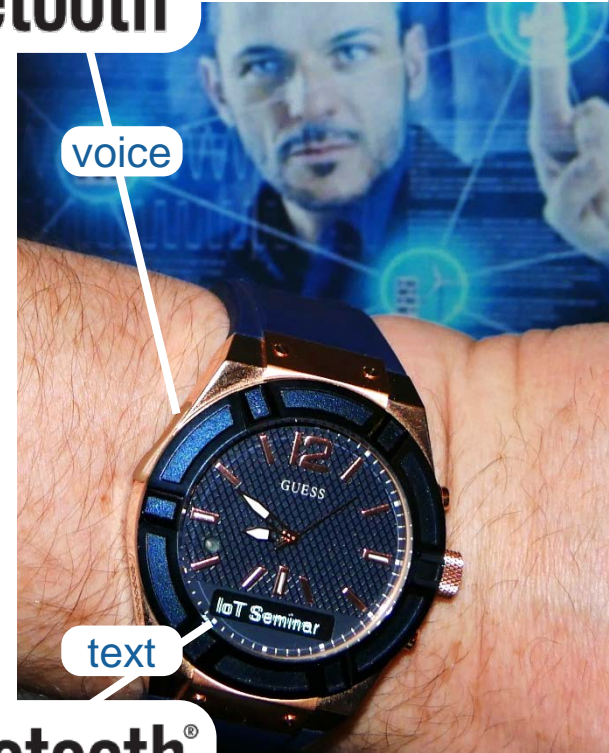


Bluetooth Classic and Bluetooth Smart

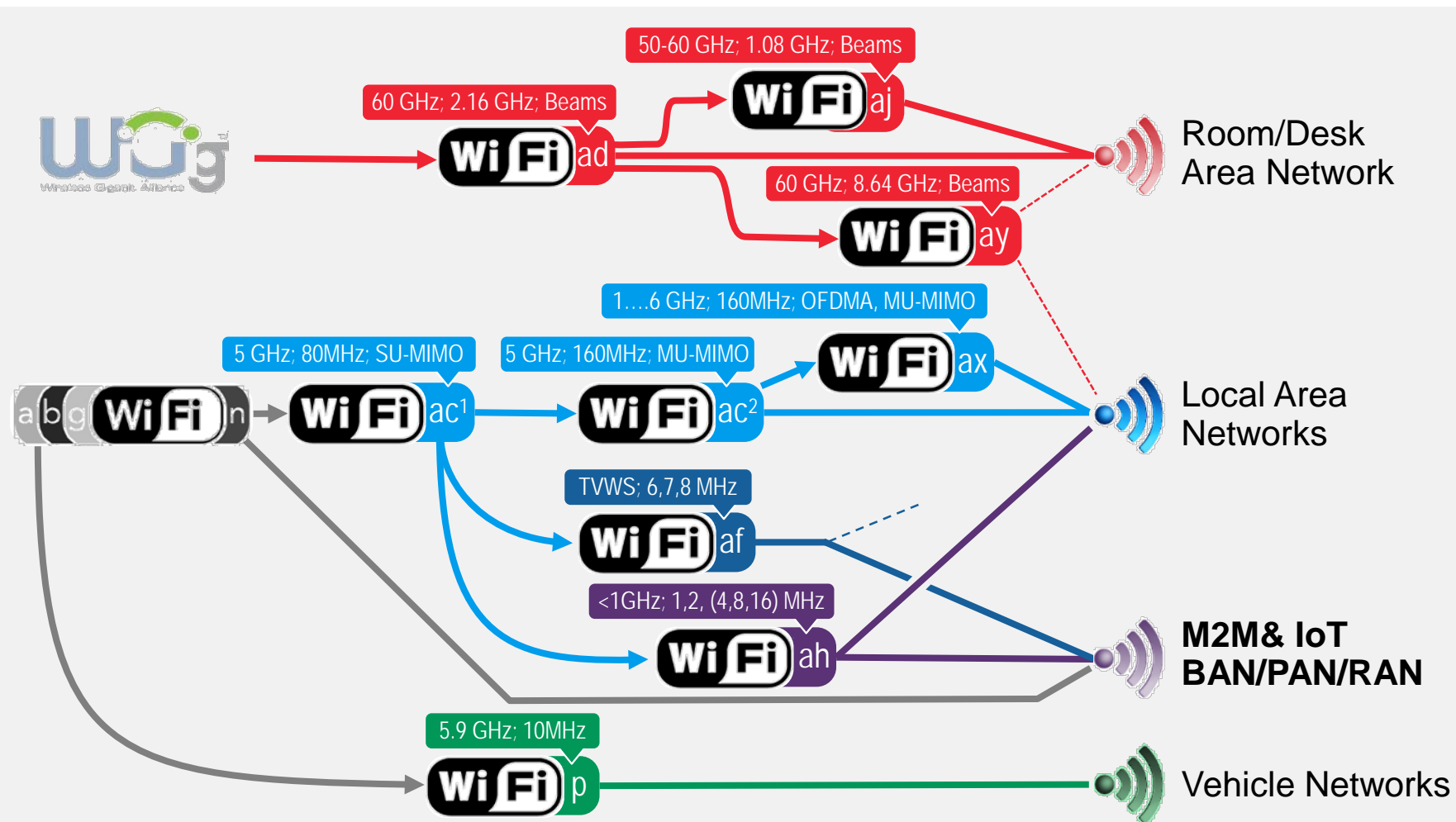


- 2.4 GHz ISM band
- 1 Msymbol/s using GFSK modulation
EDR: Data modulation $\pi/4$ -DQPSK / 8DPSK
- 79 Channels on 1 MHz spacing
- Frequency Hopping (1600 hops/s)
- Voice support
- FEC

- 2.4 GHz ISM band
- 1 Msymbol/s using GFSK modulation
- 40 Channels on 2 MHz spacing
- 3 advertising channel
- Frequency Hopping (37 channel)
- CRC

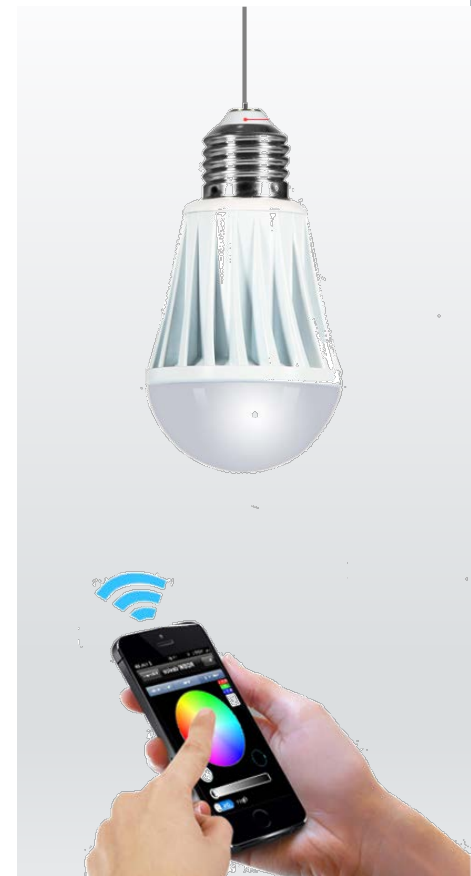


Wi-Fi adoption beyond Local Area Networks



Wi-Fi is used for several IoT applications, especially in smart home and smart office environment today

	802.11a	802.11b	802.11g	802.11n
Frequency	5 GHz	2.4 GHz	2.4 GHz	2.4/5GHz
Channel bandwidth	20 MHz	20 MHz	20 MHz	20 MHz, 40 MHz
Spatial streams	1	1	1	1,2,3,4
Max. Data rate	54 Mbps	11 Mbps	54 Mbps	600 Mbps
MAC	CSMA/CA	CSMA/CA	CSMA/CA	CSMA/CA
System	OFDM	DSSS	OFDM, DSSS	OFDM, OFDMA
Duplex	TDD	TDD	TDD	TDD
Max. Power (typ.)	1 W (100 mW)	1 W (100 mW)	1 W (100 mW)	1 W (100 mW)
Modulation	BPSK, QPSK, 16QAM, 64QAM	CCK	CCK, BPSK, QPSK, 16QAM, 64QAM	BPSK, QPSK, 16QAM, 64QAM



Wi-Fi HaLow

"New technology will extend Wi-Fi® solutions for the Internet of Things" Wi-Fi Alliance (Jan.2016)

Long range
operation

Low power
consumption

Large number
of devices per
access point

High throughput
compared to
e.g. ZigBee

Greenfield
operation

Sensor Networks



Home Security



Wearables



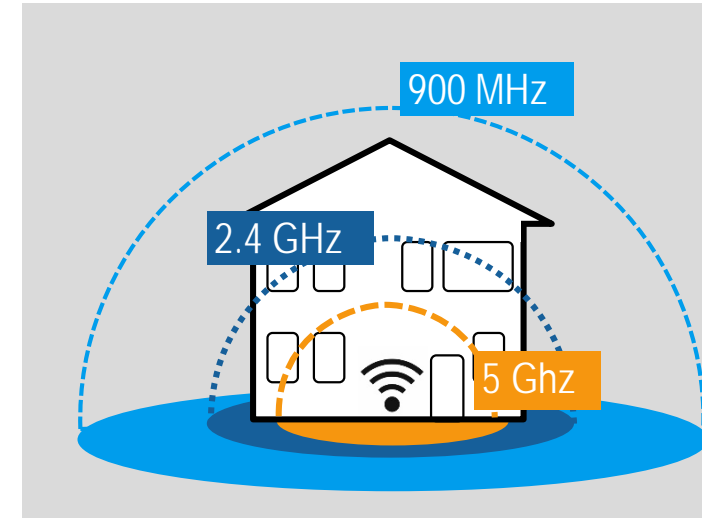
Range extension



Smart Metering



Support of 1 & 2 MHz channels is mandatory



802.11ah in a nutshell - Wi-Fi *HaLow*

scalable - long range - low power network

802.11ah PHY Layer

- Operates in sub 1 GHz license-exempt bands
- Essentially 10-times down-clocked version of 802.11ac (max. data rate 340 Mbps)
- Defines 2 MHz, 4 MHz, 8 MHz, and 16 MHz channels and a **1 MHz channel for extended coverage**
- For ≥ 2 MHz modes, the PHY layer is exactly designed based on 10 times down-clocking of 802.11ac's PHY layer: techniques like OFDM, MIMO, DL MU-MIMO, MCSs have been adopted
- 1 MHz channel supports additional scheme for extend transmission range by 2x symbol repetition (MCS10)

802.11ah MAC Layer

- Support large number of stations (8191) by introducing an hierarchical AID structure
- Power saving mode optimized for a large number of stations in power saving mode
- Improved channel access mechanisms by introducing Target Wakeup Times (TWT) and restricted access windows (RAW)
- Throughput enhancements by reducing protocol overhead



802.15.4 – for smart home , smart buildings and more



THREAD



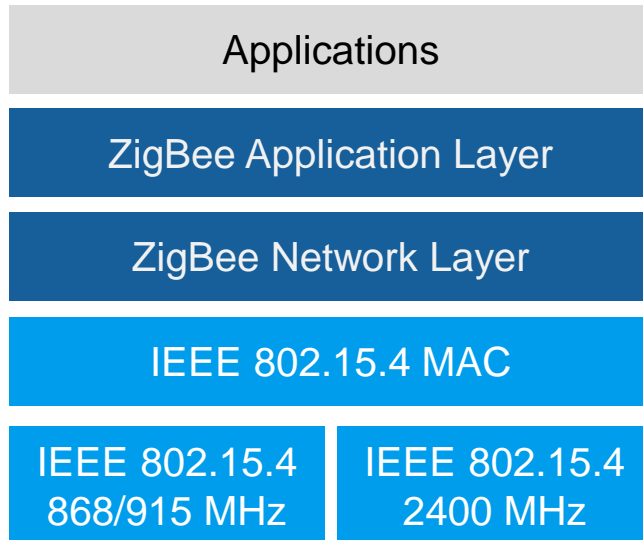
WirelessHART

ZigBee - Protocol	Protocol (e.g. CoAP)	ISA Protocol	HART: Protocol
ZigBee - Transport	UDP/TCP	UDP	HART: TCP like
ZigBee - Networking	6LoWPAN, DTLS, Distance Vector Routing	6LoWPAN	HART Addressing/Routing
802.15.4 MAC	802.15.4 MAC	Upper data link ISA100 802.15.4 MAC	HART TDMA - hopping
IEEE 802.15.4 2.4 GHz ♦ O-QPSK	IEEE 802.15.4 2.4 GHz ♦ O-QPSK	IEEE 802.15.4 2.4 GHz ♦ O-QPSK	IEEE 802.15.4 2.4 GHz ♦ O-QPSK

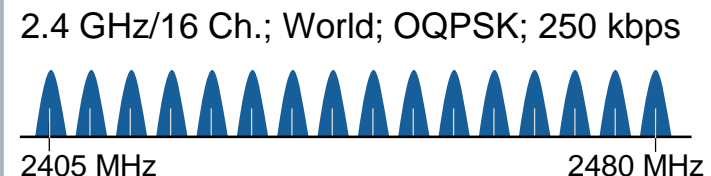
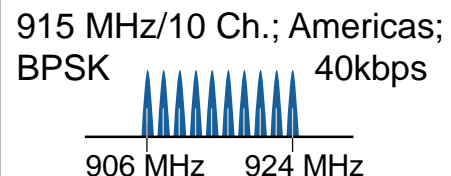
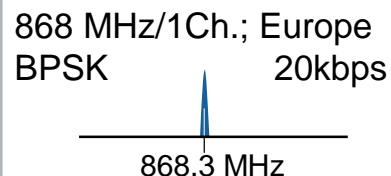
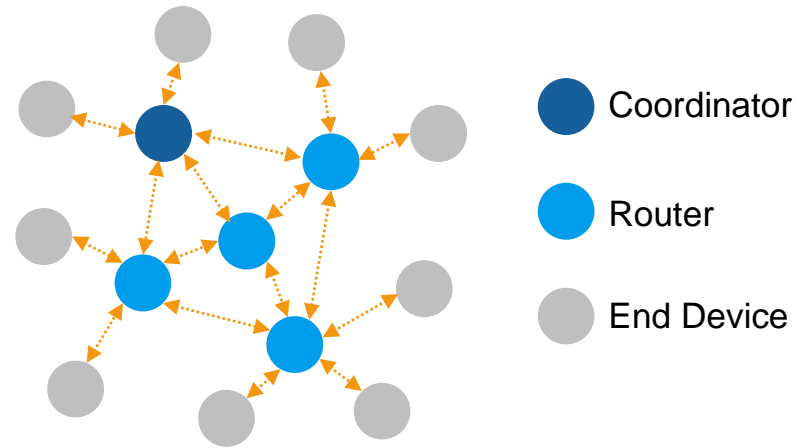


ZigBee Technology Facts

Reliable, Low Power, Cost Effective



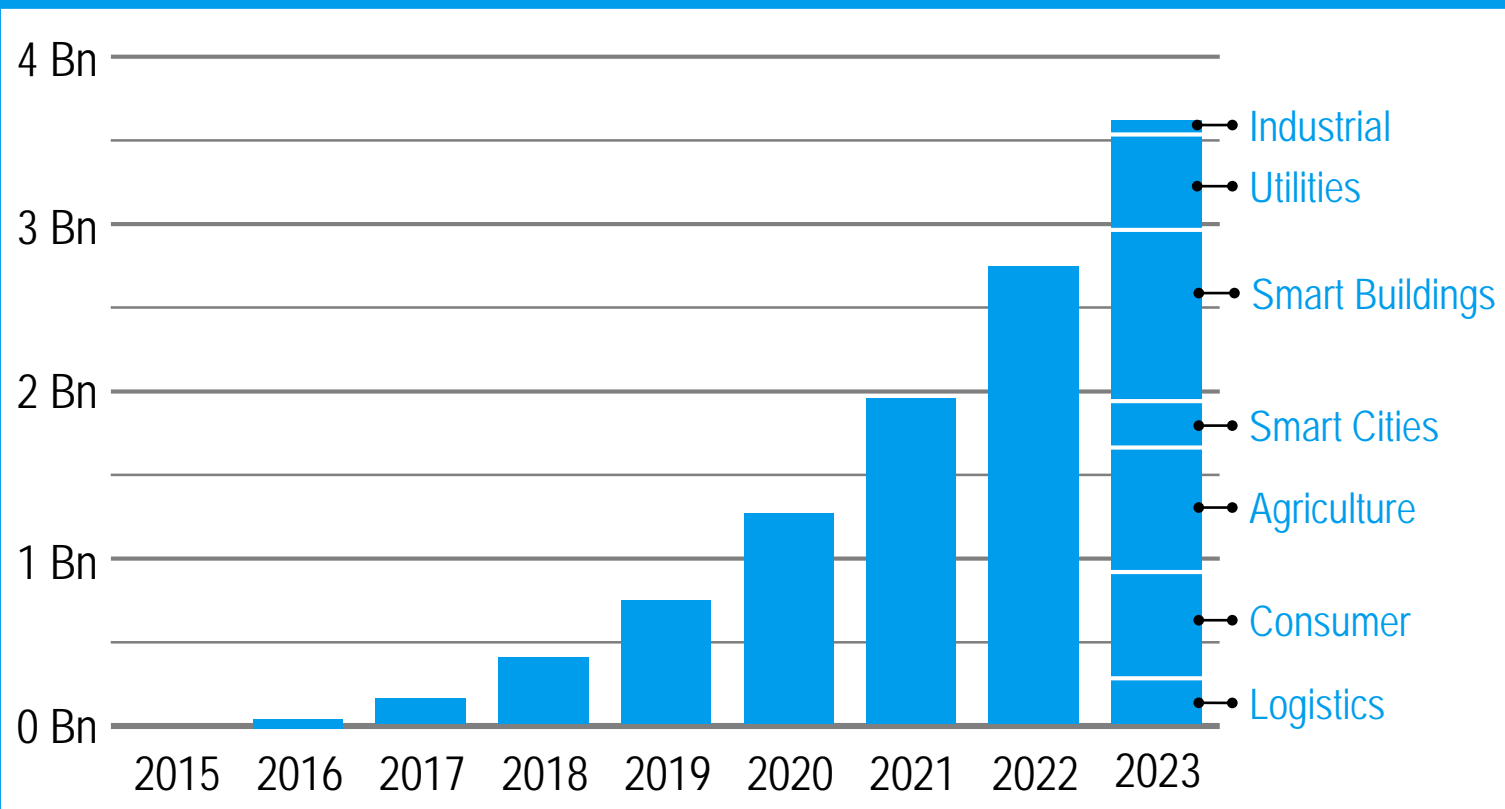
Meshed Network of thousands of devices



Low Power Wide Area Networks:

Low cost, battery powered devices and strong propagation

Forecast of Low Power WAN connected Devices



Source: Analysys Mason 2015



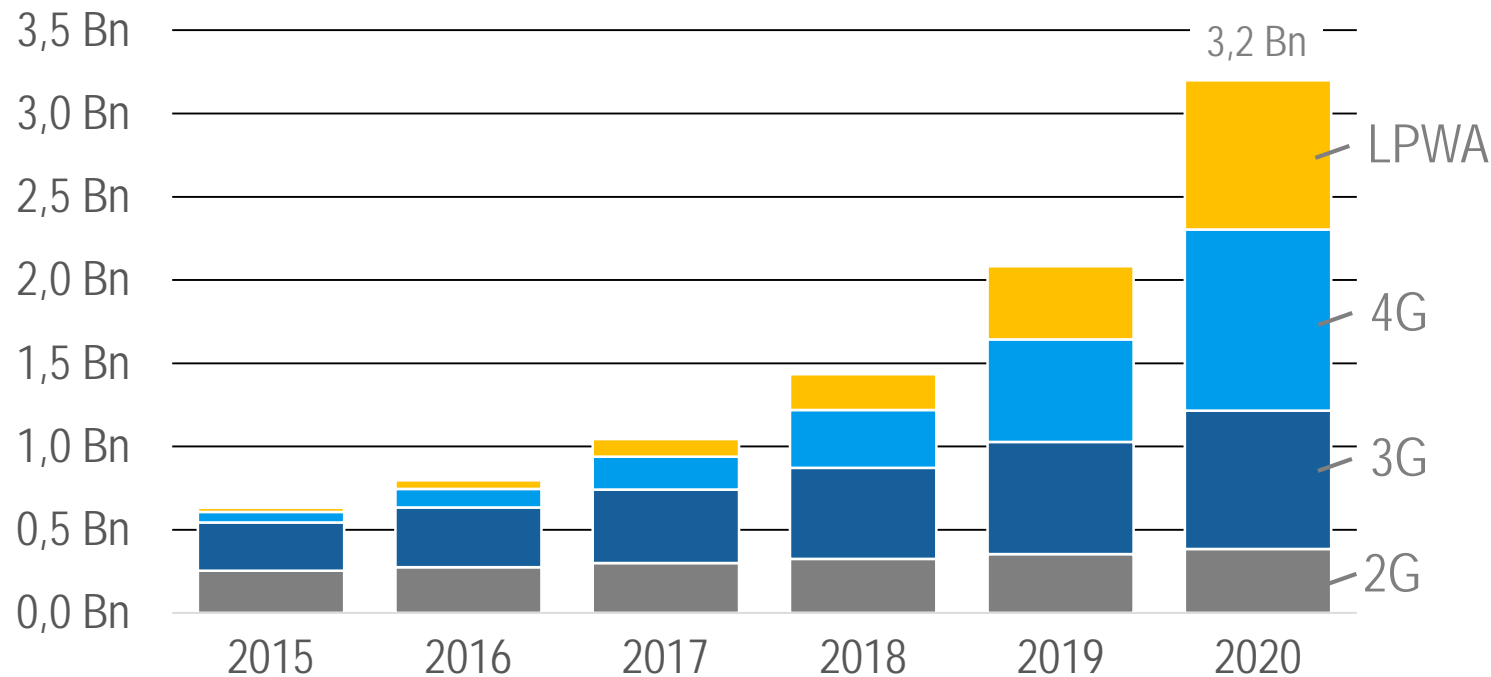
The new kids on the block – LP-WAN (unlicensed)



	Sigfox	LoRa	Weightless-N	RPMA	
Frequency Bands	868 MHz (ETSI) 915 MHz (FCC) 2 400 MHz	868 MHz (ETSI) 915 MHz (FCC)	868 MHz (ETSI) 915 MHz (FCC)	2 400 MHz	
Technology	Ultra Narrow Band DBPSK/2GSK	FM chirped spread spectrum	Ultra Narrow Band DBPSK	Random Phase Multiple Access	
Single channel	100 Hz/ 600 Hz	125/250/500 kHz	200 Hz	1 MHz	
Driver	Sigfox	Semtech	nWave	Ingenu	
Signal Range	621 miles	12.4 miles	2KM	300 square miles	
Data Rates (UL/DL)	100bps	50Kpbs	~2.5kbps – 16Mbps	624 kbit/s / 156 kbits/s	

Move to LTE in order to ensure long-term availability and to address more IoT applications with LTE-M & NB-IOT

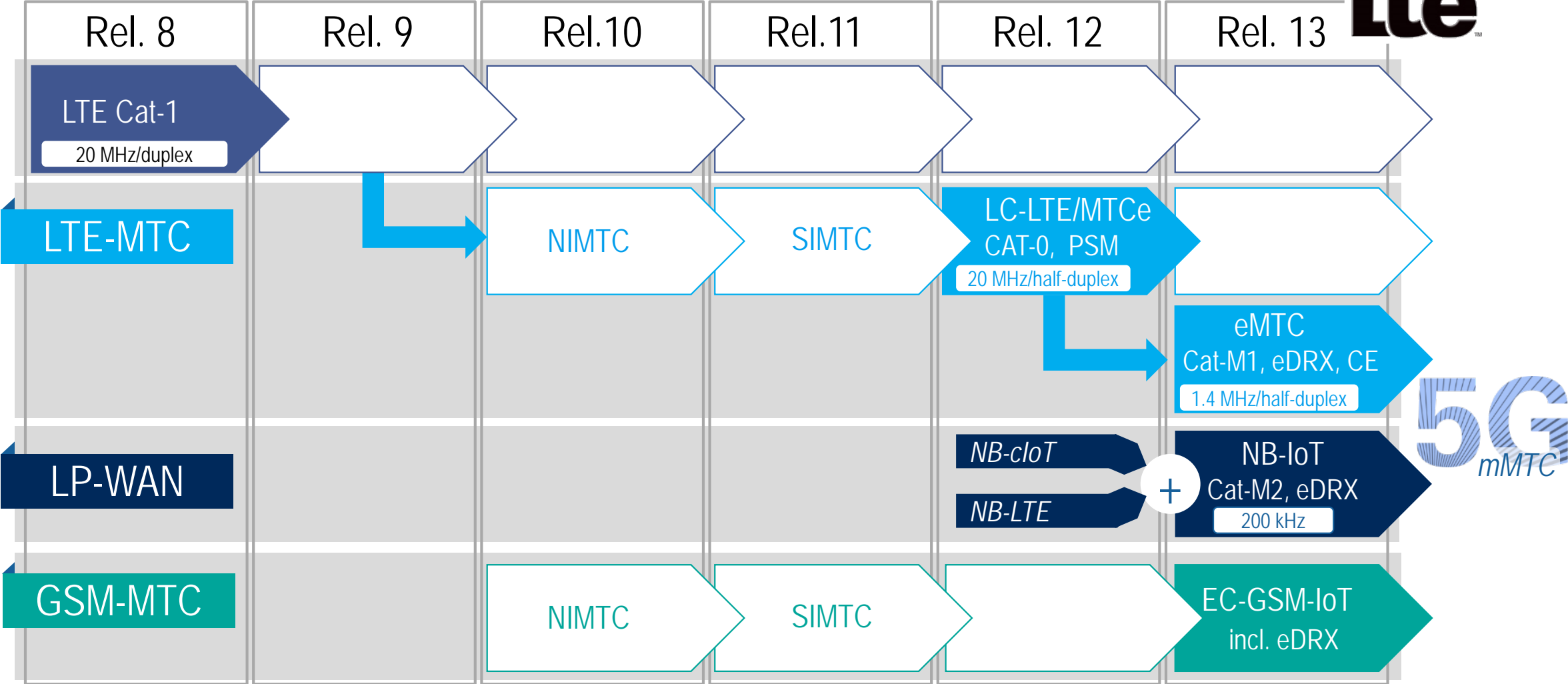
Number of cellular M2M Connections



Source Cisco VNI Mobile 2016

- I Cellular M2M connectivity still dominated by 2/3G technologies
- I Increasing global 4G coverage makes LTE to an attractive alternative to 2G/3G especially considering the long term perspective of 2G networks.
- I Availability of M2M optimized LTE only chipsets
- I LTE-M and NB-IOT opens opportunities in new markets

3GPP IoT standardization on the way to 5G



Rel. 12: New Category 0 –for low complexity UEs

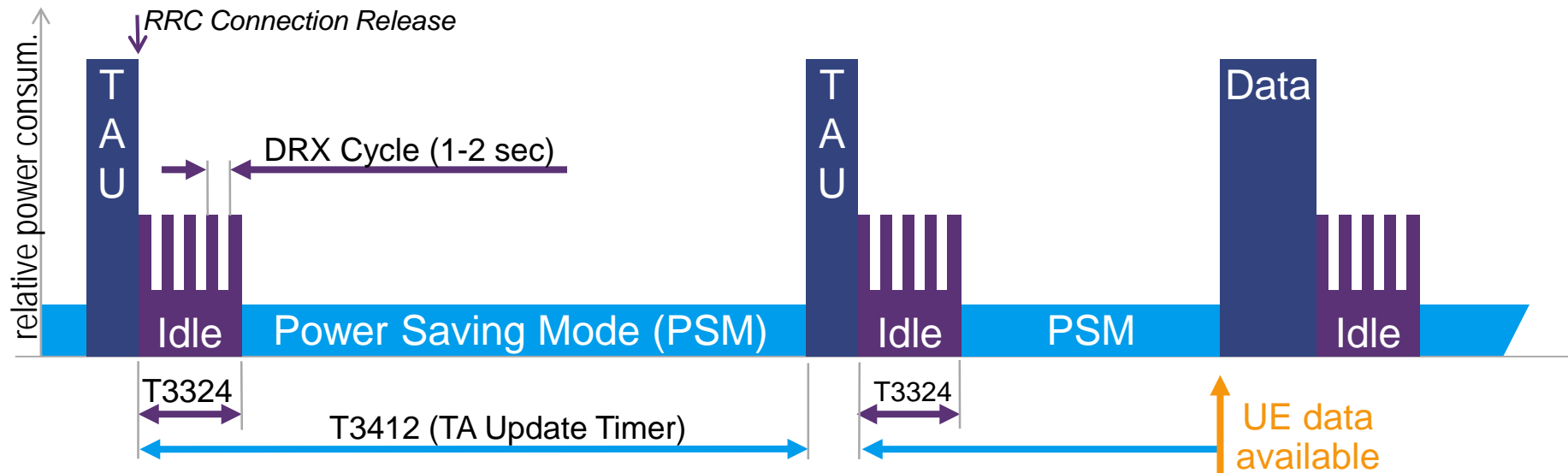
	Cat 1 (Rel-8)	Cat-0 (Rel-12)*
Downlink Peak Rate	10 Mbps	1 Mbps
Uplink Peak Rate	5 Mbps	1 Mbps
UE RF Chains	2	1
Duplex Mode	Full duplex	Half duplex (opt)
UE Receiver bandwidth	20 MHz	20 MHz
Max UE Transmit Power	23 dBm	23 dBm
# soft channel bits	250 368	25 344
max TBS for PMCH	10 296	4 584
MIMO Layer	1	1
Highest DL Modulation	64QAM	64QAM
Highest UL Modulation	16QAM	16QAM

- Peak rate reduction to 1Mbps in DL and UL
- One Rx/Tx antenna only (single RF Chain)
- New half-duplex (HD) FDD operation (type B**) with adapted guard period
- 1 oscillator
- Reduced maximum TBS for PMCH
- Reduced number of soft buffer bits
- No support of 64 QAM UL



Rel. 12: Power saving mode for UE that can accept long latency for terminating data

PSM Mode: UE remains registered with the network and there is **no need to re-attach or re-establish PDN connections** – saves power, but UE isn't reachable in PSM Node



UE request an Active Time value (T3324) during every Attach / TAU Request.
Network confirms usage of PSM by allocating an Active Time value to the UE

Rel.13: NB-IoT – even more ‚streamlined‘ than cat-M1

Objectives

- Improved indoor coverage: extended coverage of 20 dB
- Support of massive number of low throughput devices
e.g. 40 MTC devices per household
- Reduced complexity
- Things that cost less than a 2G device
- Improved power efficiency: more than 10 years battery life time
- Relaxed Delay characteristics: ~10 sec.

Smart Parking



Smart Bike



Smart Suitcase



Sensor Networks



Agriculture Sensor



Rel 13: Narrowband-IoT (standardization ongoing)

The Uplink and Downlink total transmission bandwidth is 180 kHz

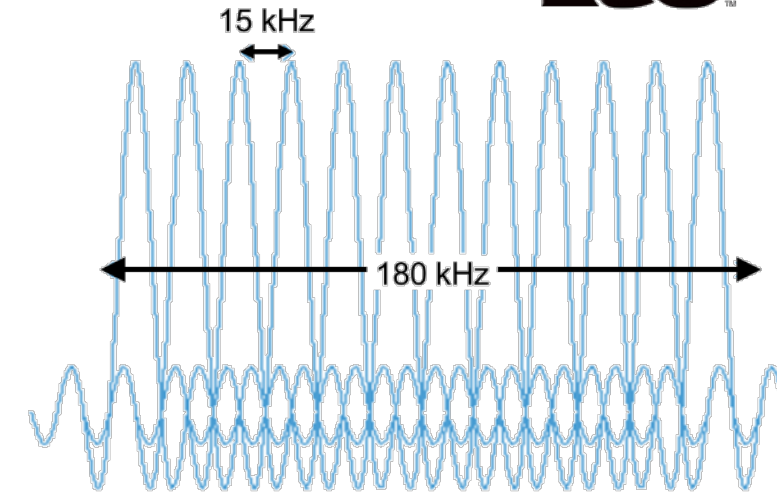
Downlink: OFDM with 15 kHz sub-carrier spacing

Same subcarrier spacing, OFDM symbol duration, slot format, slot duration, and subframe duration as LTE

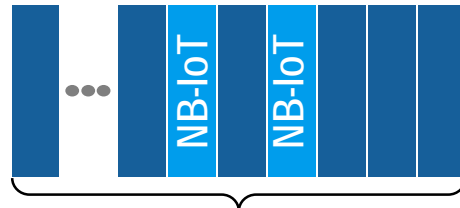
Uplink: SC-FDMA with 3.75 kHz and 15 kHz for single-tone transmissions and optional multi-tone transmissions with 15 kHz subcarrier spacing

Only FDD in half-duplex mode (analog to UE cat.0 half-duplex TypeB),

Only mobility in IDLE mode is supported



In-Band Operation



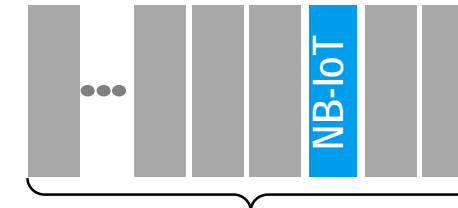
LTE Carrier

Guard-band Operation



LTE Carrier

Standalone operation



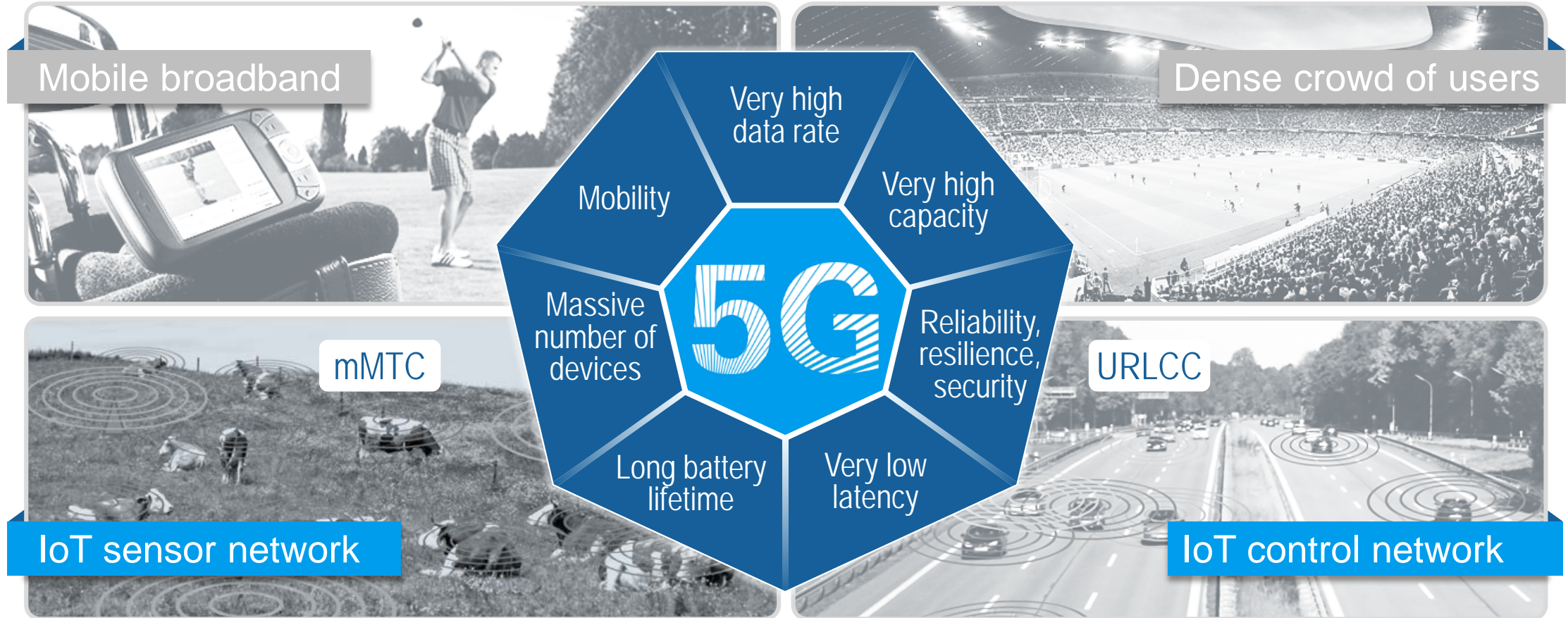
e.g. GSM Carriers

MTC features like Power Save Mode (PSM), extended DRX (eDRX) cycle are valid

A handfull 3GPP offerings to adress the growing IoT market

	LTE-Cat 1	LTE-Cat 0	LTE-Cat M 1	NB-IoT	EC-GSM-IoT
Deployment	In-band LTE	In-Band LTE	In-band LTE	In-Band LTE Guard-Band LTE Standalone	In-band GSM
Downlink	OFDMA [15 kHz]	OFDMA [15 KHz]	OFDMA [15 kHz]	OFDMA [15kHz]	TDMA/FDMA
Uplink	SC-FDMA [15 kHz]	SC-FDMA [15 kHz]	SC-FDMA [15 kHz]	Single Tone [15/3.75 kHz]	TDMA/FDMA
Peak Rate	DL:10 Mbps UL: 5 Mbps	DL: 1 Mbps UL: 1 Mbps	DL: 1 Mbps UL: 1 Mbps	UL: 250 kbps DL: 20 kbps	UL: 70/240 kbps DL: 70/240 kbps
UE receiver BW	20 MHz	20 MHz	1.4 MHz	200 kHz	200 kHz
Duplex Mode	Full-Duplex	Half-Duplex	Half-Duplex	Half-Duplex	Half-Duplex
Max UE transmit power	23 dBm	23 dBm	23 or 20 dBm	23 dBm	33 dBm or 23 dBm
Power saving	PSM, eDRX	PSM, eDRX	PSM, eDRX	PSM, eDRX	PSM, eDRX

5G Networks will enable the Internet of Things of the future





ROHDE & SCHWARZ