5G Standards Overview & 3GPP Tech Evolution Trends

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Agenda

1. **5G Standardisation Overview** (who, when, what)
2. **3GPP Technology Evolution Trend**
   - 3GPP Overall Timeline & Release Features
   - 3GPP Technology Roadmap

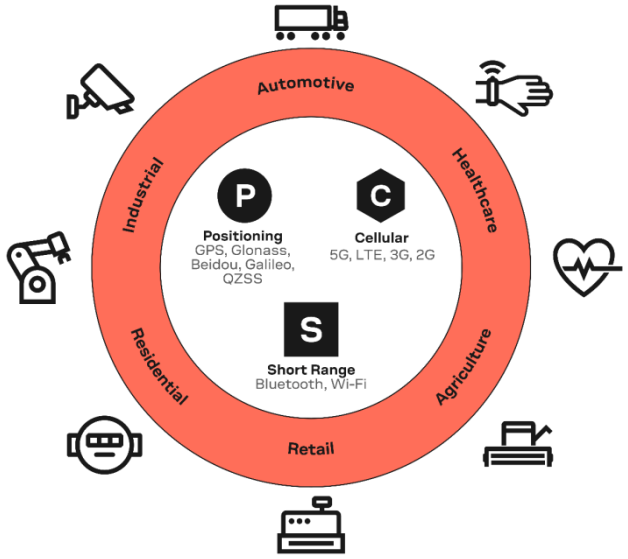
   2.1 IoT in 5G
   - NB-IoT, LTE-M Evolution into 5G
   - NR-IIoT: New Radio Industrial IoT

   2.2 5G for Automotive
   - LTE-V2X Background
   - Cellular V2X (C-V2X)

   2.3 Positioning in 5G
   - 3GPP Technology Roadmap for cellular positioning
   - 5G NR Positioning Trend
3. **Take-away**

3 Core Technologies

	Positioning	Cellular Communication	Short Range Communication
Integrated Circuits			
Modules			
Services and Solutions	CellLocate® (modem based positioning) AssistNow™ (world wide GNSS assistance service) GNSS Correction Data (for high precision)* FOTA (Firmware over the air) Lifetime Security *through Sapcorda, a JV with industry partners		



3 Core Markets Served

Automotive
Industrial
Consumer

approved Rel-15 Standalone 5G NR radio specs

June 2018 in La Jolla

5G Standardisation Overview

Who defines it and how?

ITU-R

IMT-2020
'5G' encompasses a range of features
- Ultra low latency
- High reliability
- Advanced antenna tech
- mmWave
- Massive IoT
- Spectrum flexibility

SDOs
(Standard development organizations)

3GPP

ETSI

IEEE

Etc.

Usage Scenarios

eMBB
Enhanced Mobile Broadband

uRLLC
Ultra Reliable Low Latency Communication

mMTC
Massive Machine-Type Communication

5G NR (new radio)

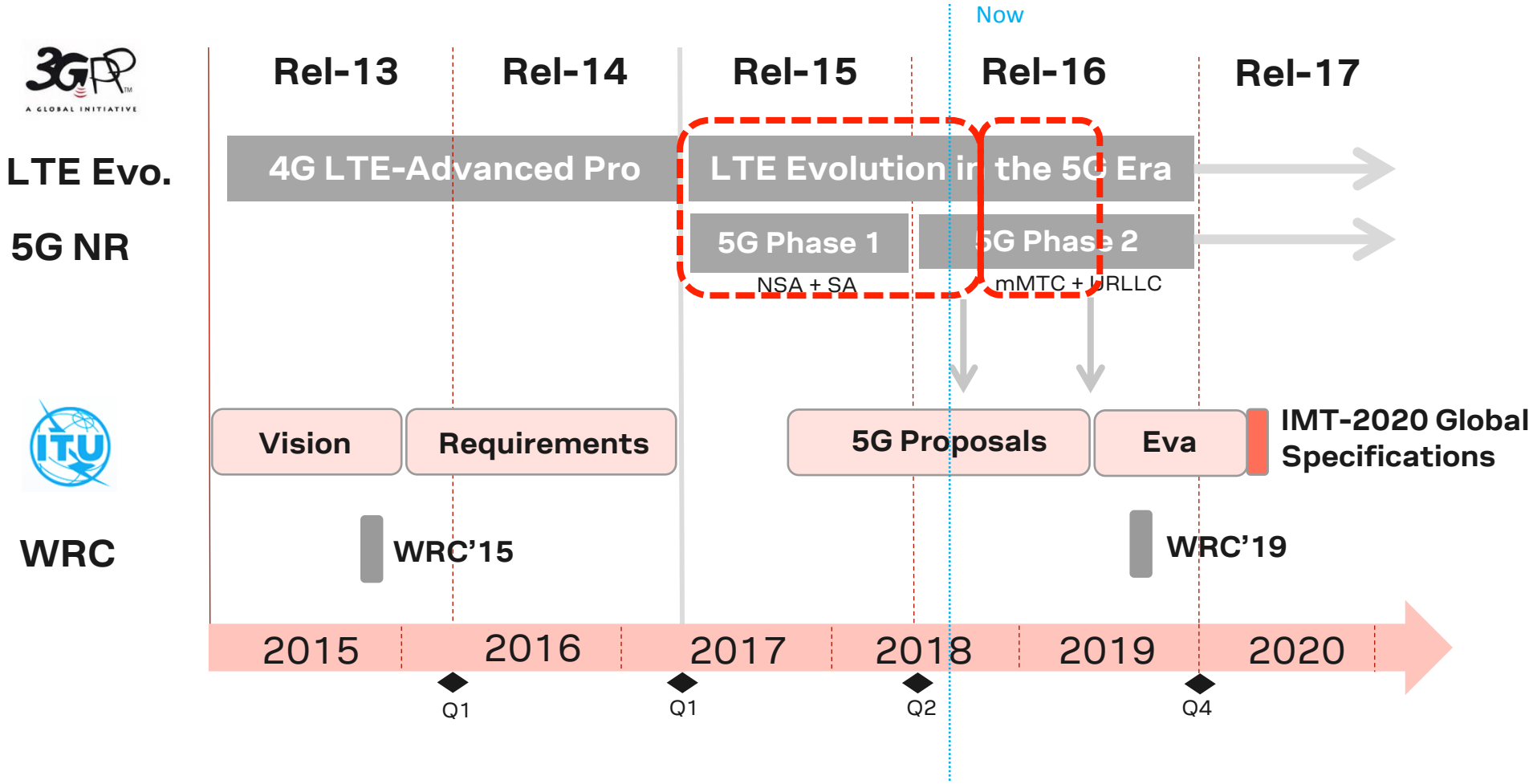
NSA (non-standalone)

SA (stand-alone)

'5G LTE'

5G Timeline

5G = 5G NR + LTE Evolution



Overview of LTE Categories (From Cat-NB1 to Cat-19)

R13 NB-IoT: Cat-NB1 →
R14 NB-IoT: Cat-NB2 →
R13 LTE-M: Cat-M1 →
R14 LTE-M: Cat-M2 →

Downlink					Uplink				
DL Cat	Max DL Mbps	Max DL BW (MHz)	Max DL MIMO	Max DL QAM	UL Cat	Max UL Mbps	Max UL BW (MHz)	Max UL MIMO	Max UL QAM
NB1	0.027	0.2	-	4 (QPSK)	NB1	0.0625	0.2	-	4 (QPSK)
NB2	0.08*	0.2	-	4(QPSK)	NB2	0.105*	0.2	-	4 (QPSK)
M1	1**	1.4	-	16	M1	1**	1.4	-	16
M2	4**	5	-	16	M2	7**	5	-	16
0	1	20	-	64	0	1	20	-	16
1bis	1	20	-	64	1bis	1	20	-	16
1	10	20	-	64	1	5	20	-	16
2	50	20	2	64	2	25	20	-	16
3	100	20	2	64	3	50	20	-	16
4	150	20	2	64	4	50	20	-	16
5	300	20	4	64	5	75	20	-	64
6	300	2*20	2 or 4	64	6	50	20	-	16
7					7	100	2*20	1 or 2	16
8	3000	5*20	8	64	8	1500	5*20	4	64
9	450	3*20	2 or 4	64	9	50	20	-	16
10					10	100	2*20	1 or 2	16
11	600	4*20	2 or 4	64 or 256	11	50	20	-	16
12					12	100	2*20	1 or 2	16
13	400	2*20	2 or 4	256	13	150	2*20	1 or 2	64
14	4000	5*20	8	256	14	10000	32*20	4	64
15	800	5*20	2 or 4	64 or 256	15	225	3*20	1 or 2	64
16	1000	5*20	2 or 4	64 or 256	16	300	4*20	1 or 2	64
17	25000	32*20	8	256					
18	1200	6*20	2 or 4, [8]	64 or 256					
19	1600	8*20	2 or 4, [8]	64 or 256					

*: based on 1HARQ
**: based on FD-FDD

3GPP Rel-8
3GPP Rel-10
3GPP Rel-11
3GPP Rel-12
3GPP Rel-13
3GPP Rel-14

Per 3GPP TS 36.306

UE Categories in 5G NR?

NR UE Categories (on-going)

- Discussions are on-going in 3GPP
- **5G UE will not signal UE categories anymore explicitly to the network**
- Definition will be in the spec but just **for marketing concept**
- Likely KPI to define UE categories: peak data rate, reflecting the best achievable data rate among the operation modes supported by the UE
- 5G NR spectrum allocations are unclear in certain regions (impact data rate)

New 3GPP 5G NR Operating Bands

Different requirements, RF specifications for different frequency ranges (FR)

FR1 (<6GHz)

NR operating band	Uplink (UL) operating band BS receive / UE transmit F_{UL_low} – F_{UL_high}	Downlink (DL) operating band BS transmit / UE receive F_{DL_low} – F_{DL_high}	Duplex Mode
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n50	1432 MHz – 1517 MHz	1432 MHz – 1517 MHz	TDD
n51	1427 MHz – 1432 MHz	1427 MHz – 1432 MHz	TDD
n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD
n70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD
n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
n74	1427 MHz – 1470 MHz	1475 MHz – 1518 MHz	FDD
n75	N/A	1432 MHz – 1517 MHz	SDL
n76	N/A	1427 MHz – 1432 MHz	SDL
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n83	703 MHz – 748 MHz	N/A	SUL
n84	1920 MHz – 1980 MHz	N/A	SUL

FR2 (24.25GHz – 52.6GHz)

n257	26500 MHz	–	29500 MHz	26500 MHz	–	29500 MHz	**TDD**
n258	24250 MHz	–	27500 MHz	24250 MHz	–	27500 MHz	TDD
n260	37000 MHz	–	40000 MHz	37000 MHz	–	40000 MHz	TDD

FR1: 26 new NR bands (450MHz-6000MHz)

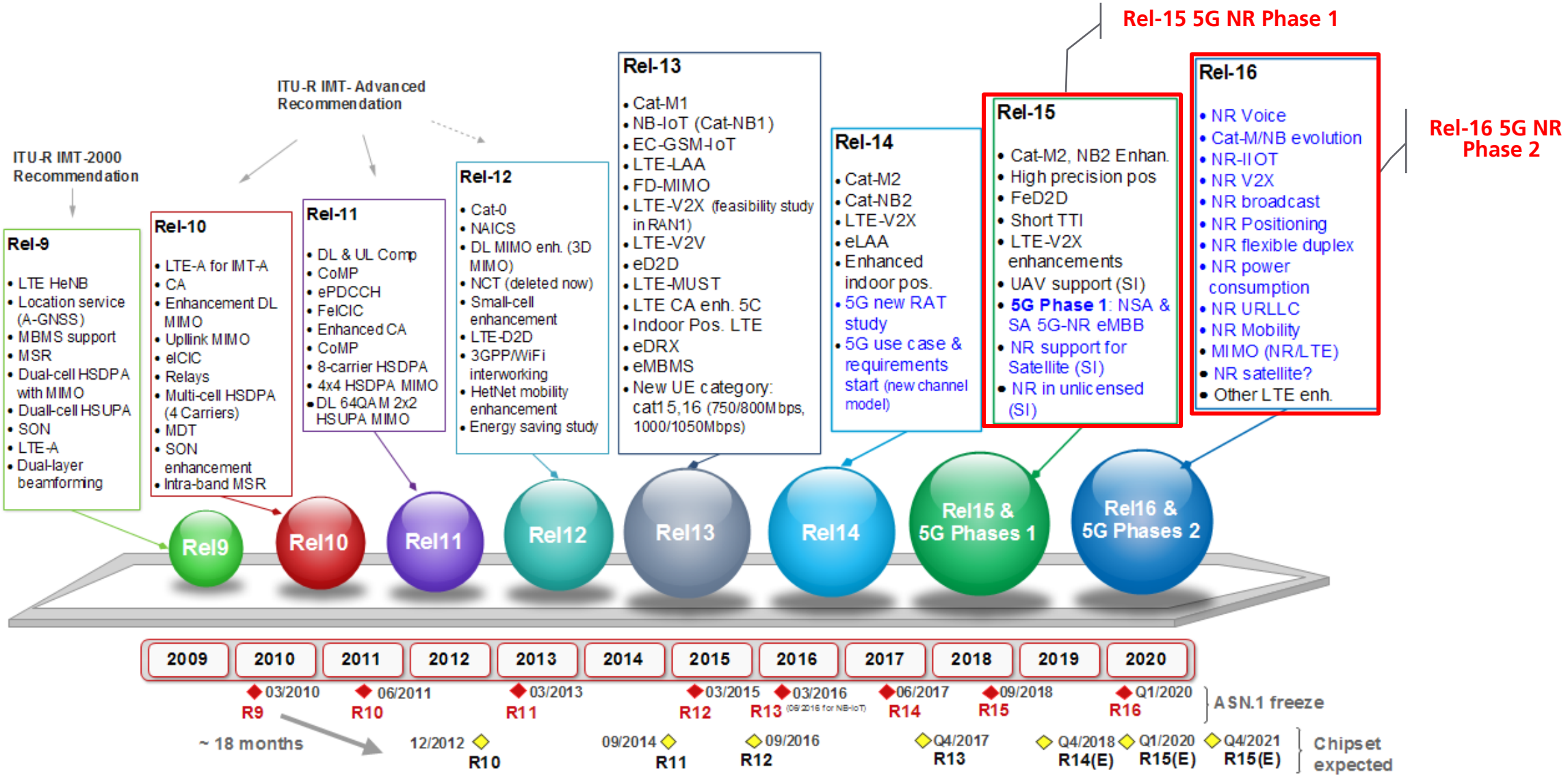
- <1GHz: 600MHz, 700MHz
- <3GHz: LTE band re-farming
- 3 – 6GHz: highest global interest bands:
  n77 & n78 (3.3-4.2GHz)
  (100MHz BW)

FR2: 3 new NR bands (24.5 – 52.6GHz)

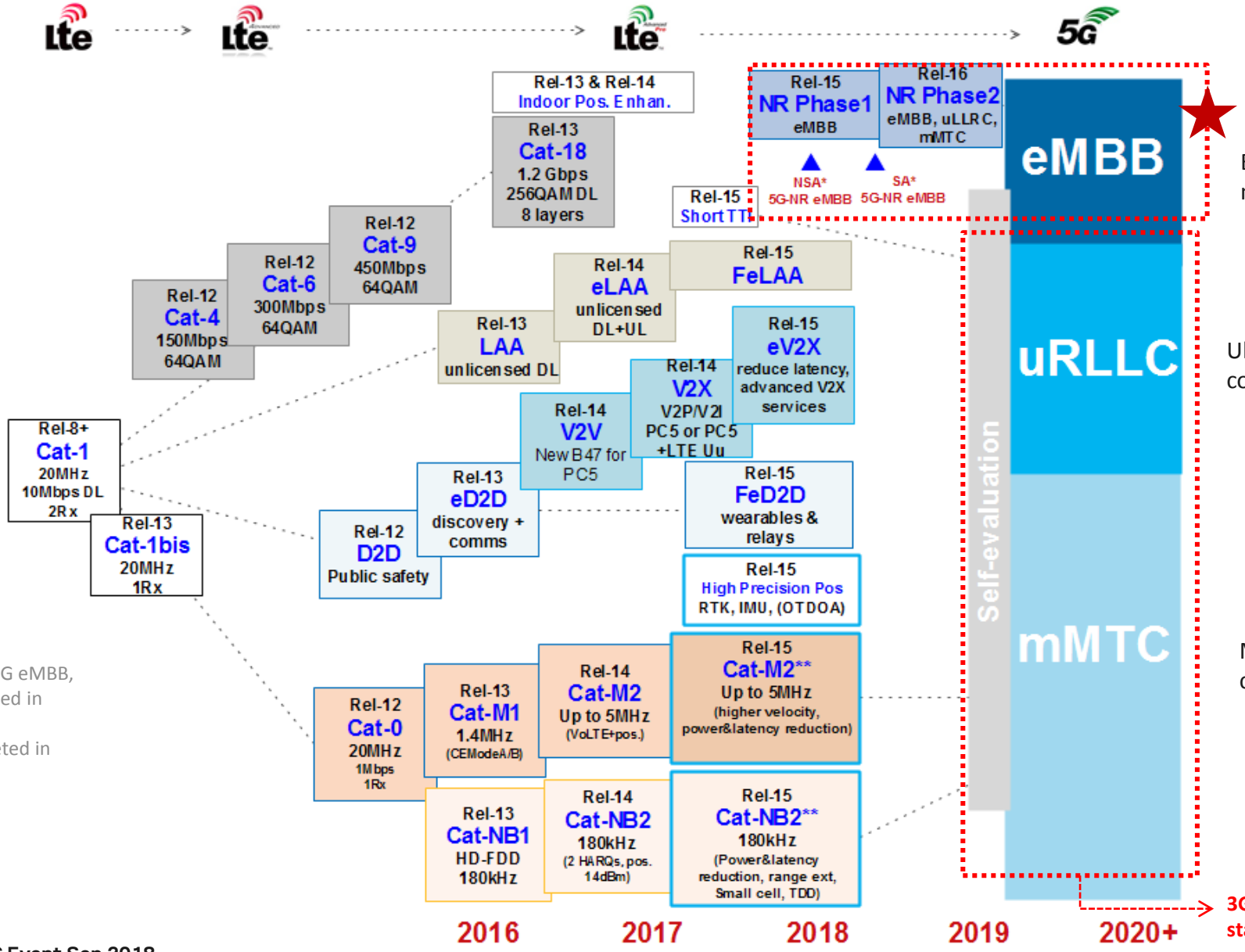
- Suitable for hotspot coverage , high capacity
- Highest interest
  n257 & n258 (24.25-29.5GHz)
  (400MHz BW)

3GPP TS 36.101

3GPP Overall Timeline & Release Features



3GPP Technology Roadmap



3GPP 5G Phase 1 Priority

Enhanced mobile broadband, high-mobility

Ultra reliable and low latency communications

Massive machine type communications

3GPP 5G 2nd Priority, started in H2'2018

*NSA: Non-Standalone 5G eMBB, accelerated and completed in Dec'17(core)
*SA: Standalone, completed in June'18

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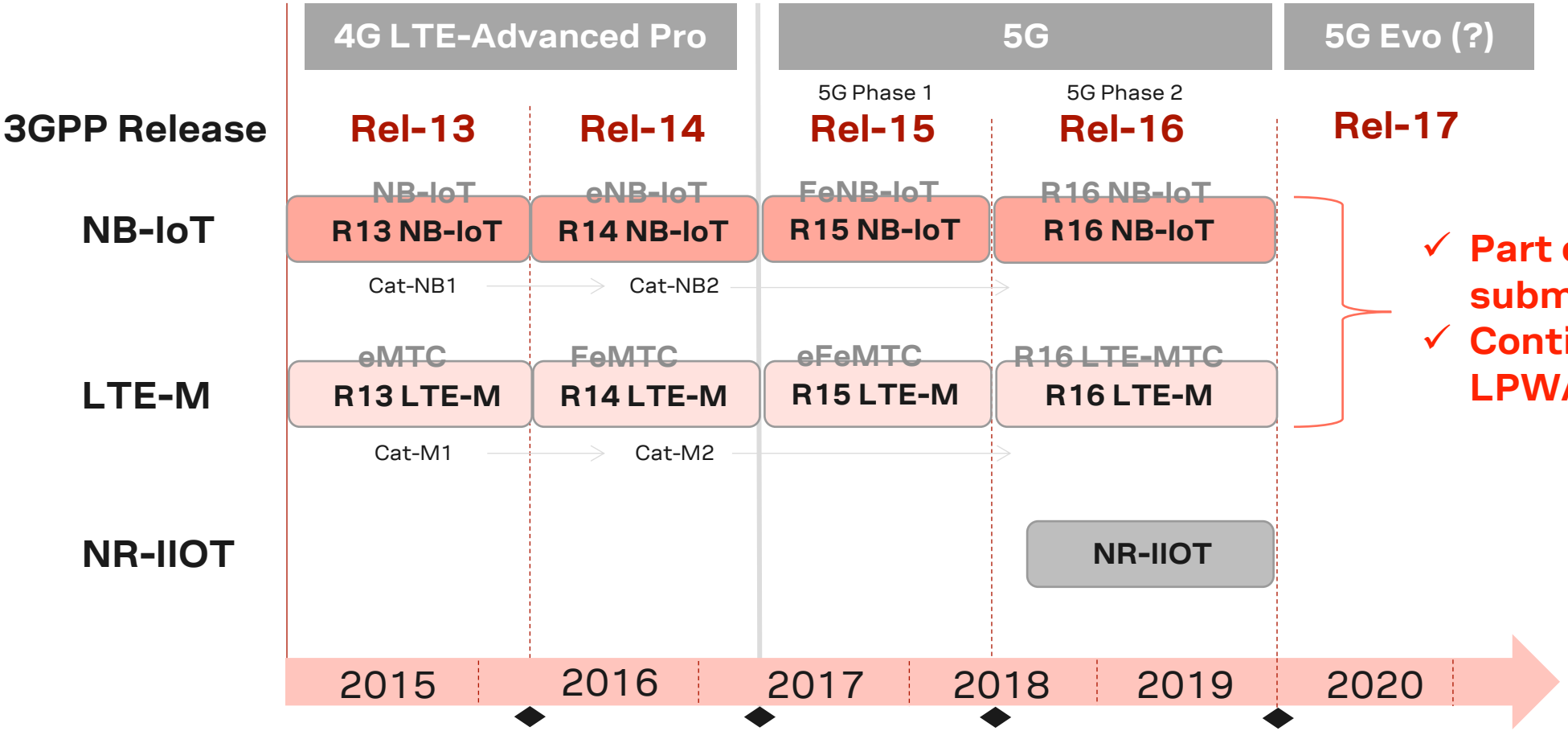
IoT in 5G

NB-IoT, LTE-M Evolution into 5G

NB-IoT and LTE-M, including their evolutions, are expected to be the vital 5G components to address LPWA use cases in the 5G era

IMT-2020 5G mMTC requirements:

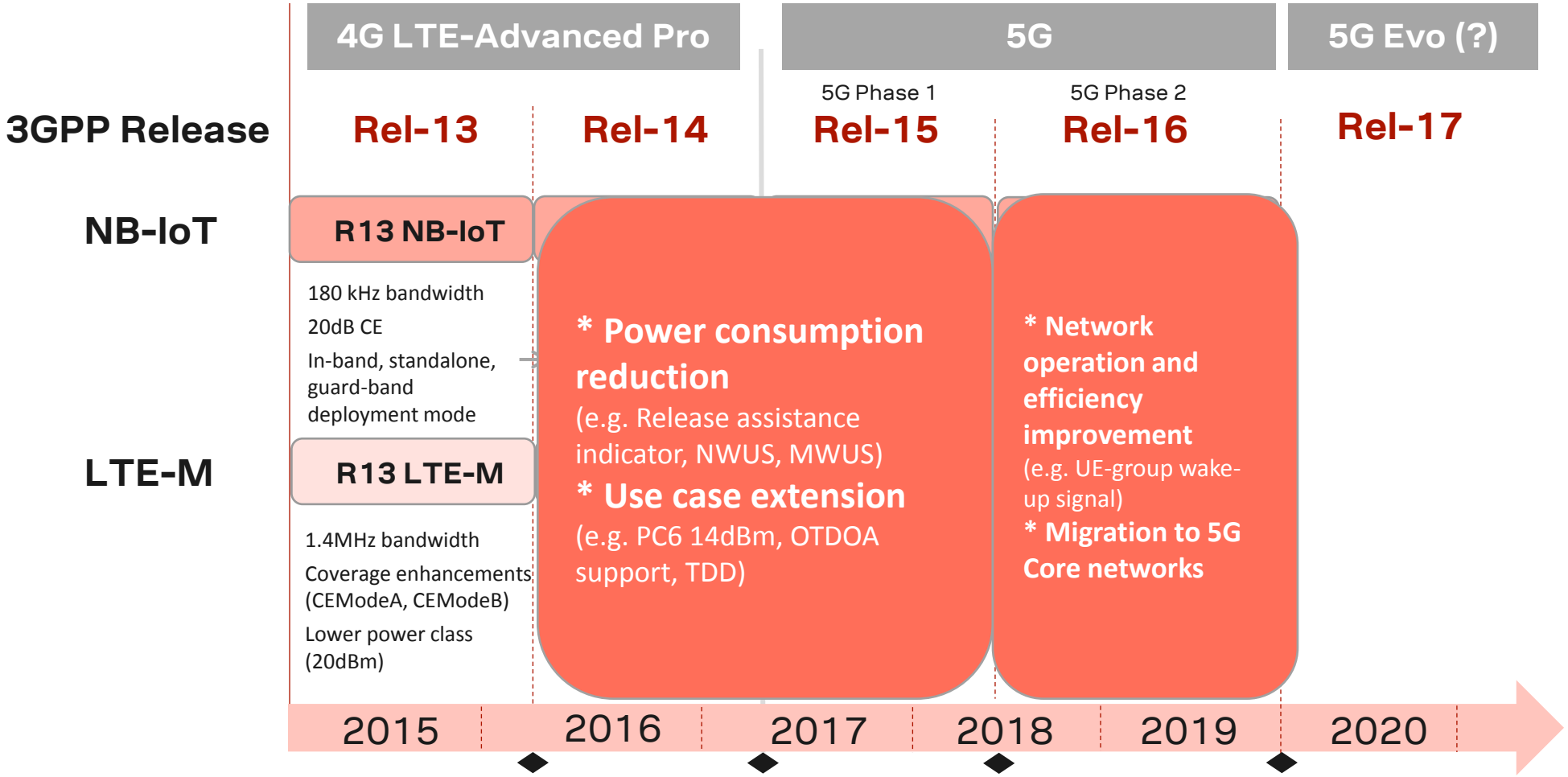
- 20dB CE
- 1M devices per km^2
- >=10 Years lifetime



- ✓ **Part of IMT-2020 submission**
- ✓ **Continue to address LPWA use cases**

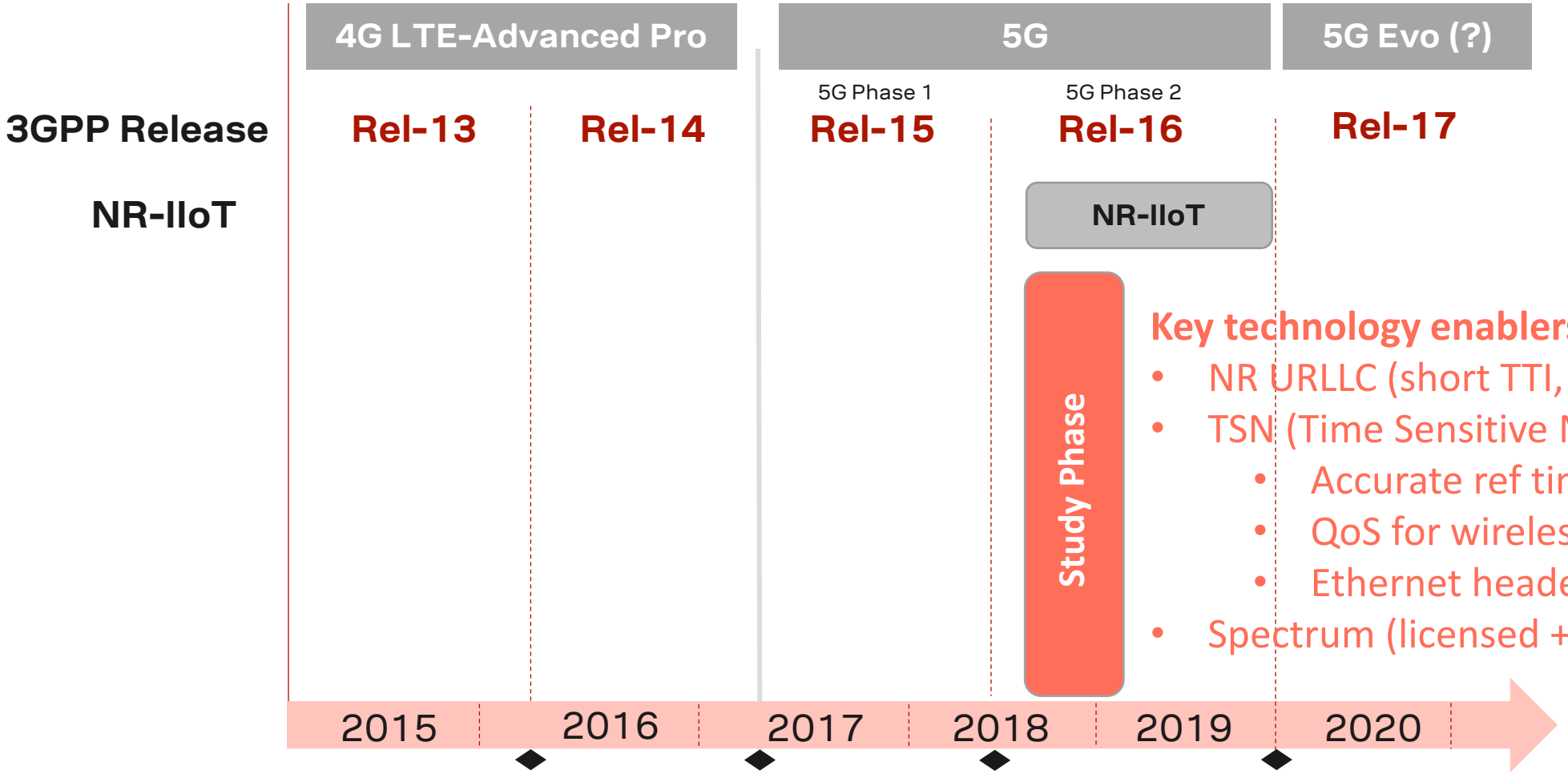
NB-IoT, LTE-M Evolution into 5G

NB-IoT and LTE-M, including their evolutions, are expected to be the vital 5G components to address LPWA use cases in the 5G era



NR-IIoT: New Radio Industrial IoT

To address IIoT use cases: factory automation, transport industry, electrical power distribution



Key technology enablers:

- NR URLLC (short TTI, reliability)
- TSN (Time Sensitive Networking)
  - Accurate ref timing
  - QoS for wireless Ethernet
  - Ethernet header compression
- Spectrum (licensed + unlicensed)

Industrial Automation Perf. Requirements for 5G

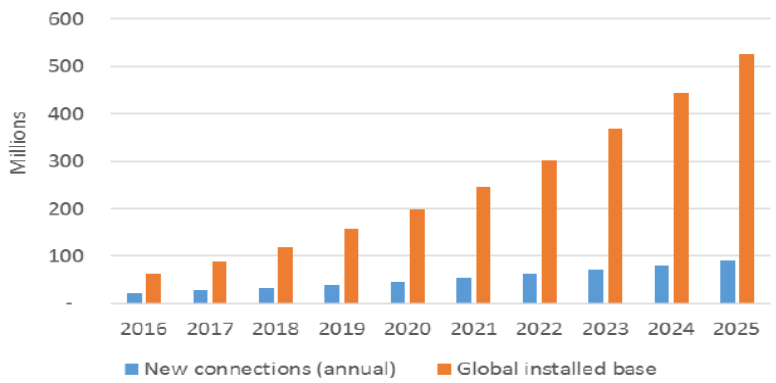
Use Case		Availability	Cycle Time	Typical Payload Size	# of Devices	Typical Service Area
Motion control	Printing machine	>99.9999%	< 2 ms	20 bytes	> 100	100 m x 100 m x 30 m
	Machine tool	>99.9999%	< 0.5 ms	50 bytes	~20	15 m x 15 m x 3 m
	Packaging machine	>99.9999%	< 1 ms	40 bytes	~50	10 m x 5 m x 3 m
Mobile robots	Cooperative motion control	>99.9999%	1 ms	40-250 bytes	100	< 1 km^2
	Video-operated remote control	>99.9999%	10-100 ms	15-150 kbytes	100	< 1 km^2
Mobile control panels with safety functions	Assembly robots or milling machines	>99.9999%	4-8 ms	40-250 bytes	4	10 m x 10 m
	Mobile cranes	>99.9999%	12 ms	40-250 bytes	2	40 m x 60 m
Process automation (process monitoring)		>99.99%	> 50 ms	Varies	10,000 devices per km^2	

Source: 3GPP, 22.804

5G for Automotive

LTE-V2X Background

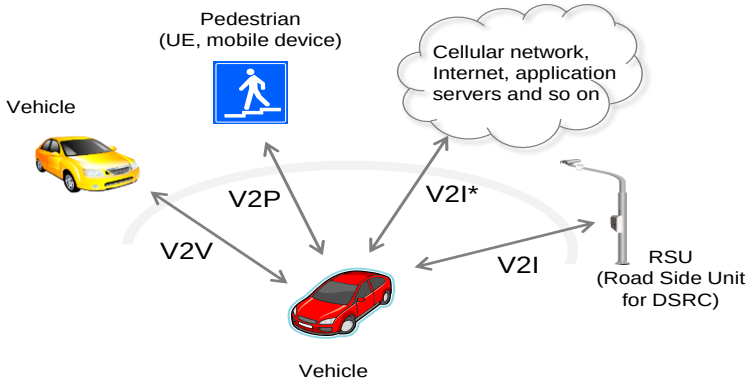
- Technology base: LTE, LTE-D2D
- V2X Candidate solutions: IEEE 802.11p/DSRC, LTE-V2X
- 3GPP is expanding LTE into automotive verticals
- GSA forecasts by 2025, annual sales of new connections for connected cars will reach 91 million units/year, with global installed base approaching 527 million



Source: GSA

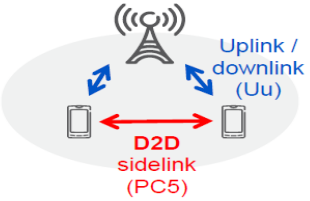
Types of V2X:

- V2V: vehicle to vehicle
- V2P: vehicle to pedestrian (e.g. handheld terminal carried by a pedestrian, cyclist, driver or passenger)
- V2I: vehicle to infrastructure application, where infrastructure is RSU (Roadside Unit)
- V2N: vehicle to network

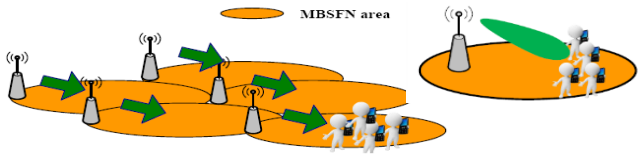


Enablers (3GPP technologies):

- ProSe or D2D communications
- MBMS & SC-PTM: provide efficient delivery of broadcast, multicast or unicast services, to be used in: group call session, live TV broadcasting, public warning message delivery etc.
- Non-3GPP technologies enablers: DSRC and 802.11p



ProSe, D2D

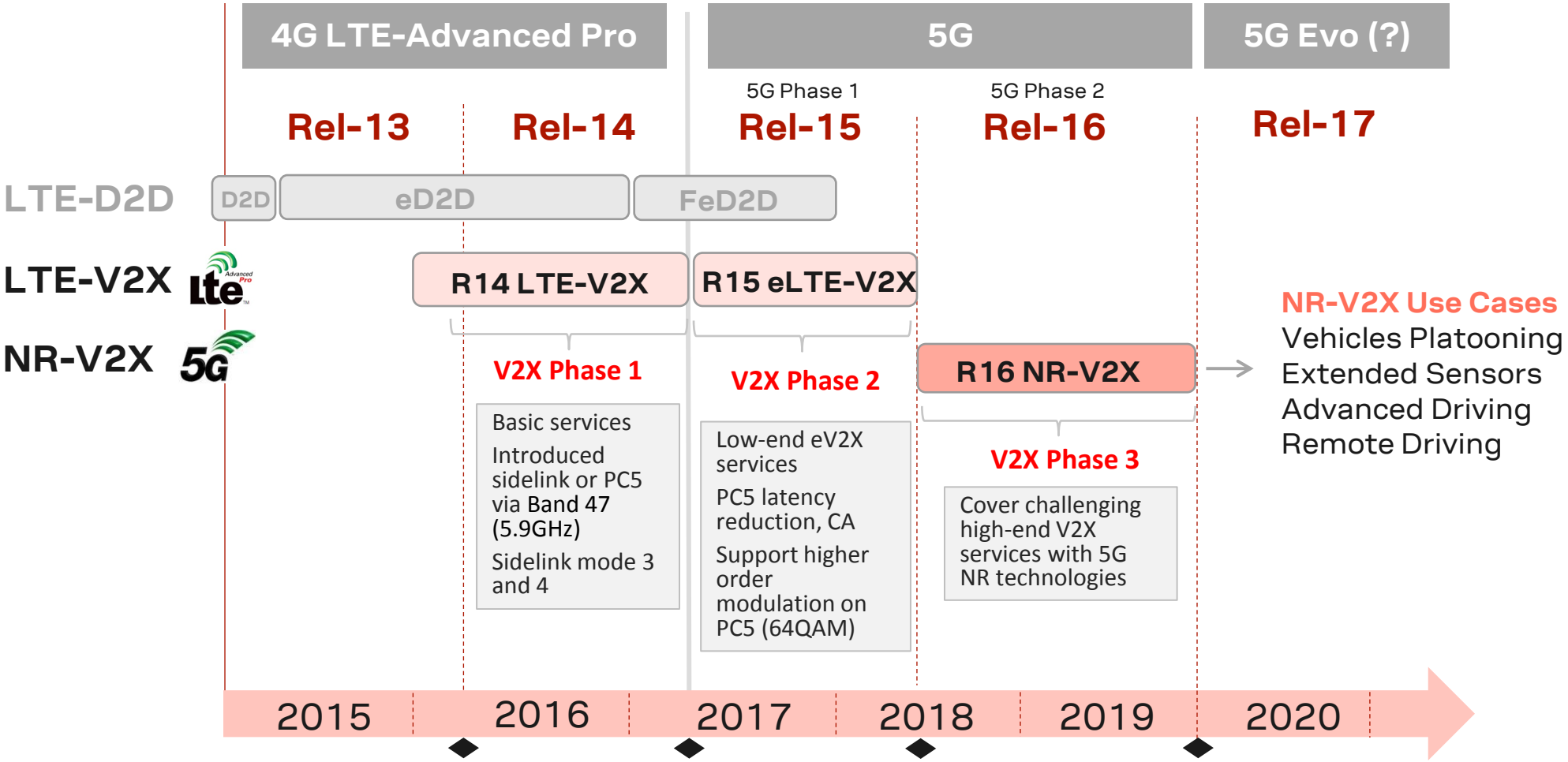


MBSFN & SC-PTM

802.11p/DSRC

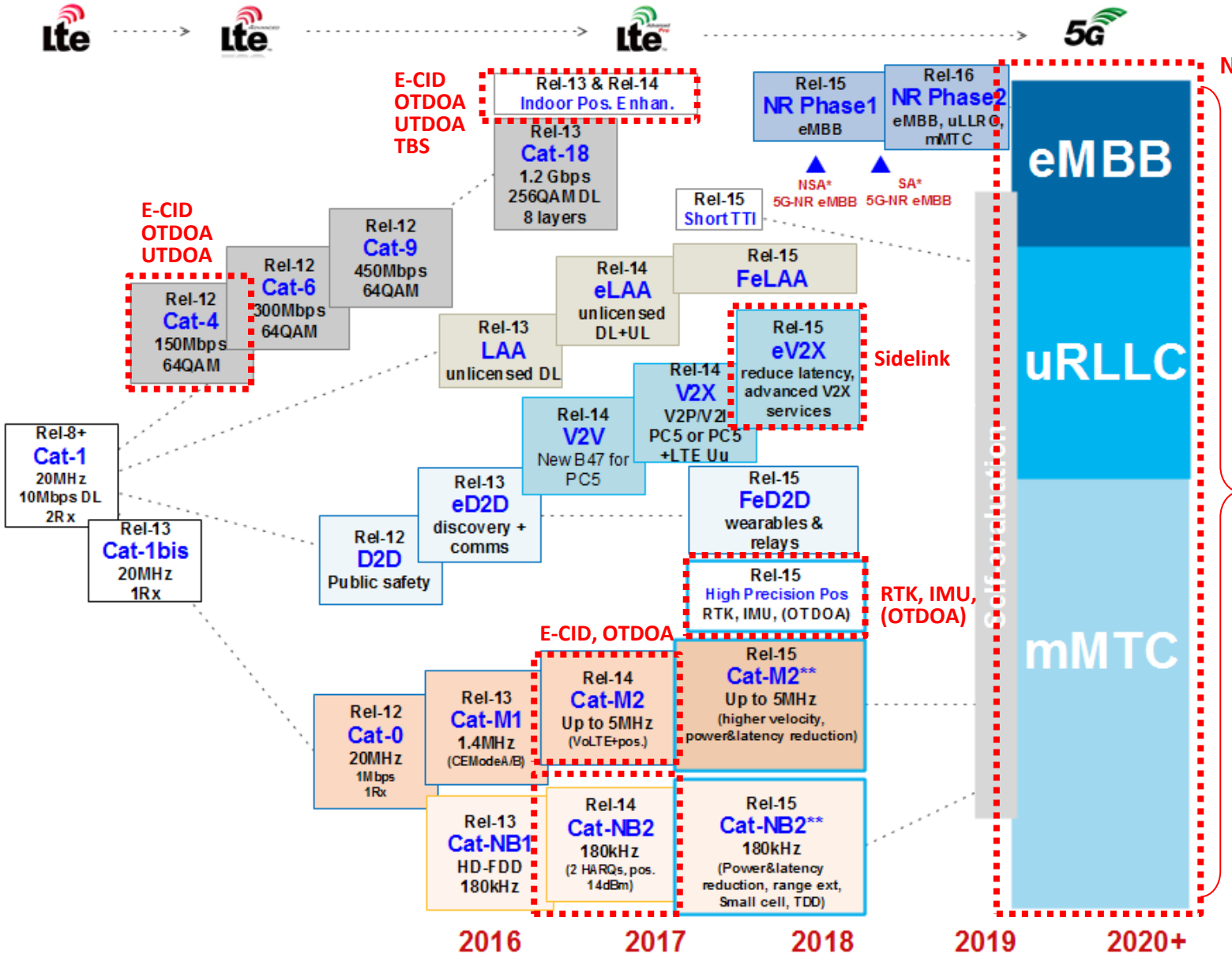
Cellular V2X (C-V2X)

Evolve from LTE-V2X to NR-V2X



Positioning in 5G

3GPP Technology Roadmap – Highlighting Cellular Positioning



Observations

- Since 3GPP Rel-11, OTDOA & E-CID have been the flagship cellular positioning technologies
- Additional D2D based ranging solutions are gaining momentum in V2X use cases

Looking forward, 5G cellular positioning will evolve based on existing E-CID, OTDOA, UTDOA or D2D positioning solutions

In addition, leveraging RAN-independent technologies, incl.: GNSS, RTK, IMU, Wi-Fi, TBS, Bluetooth, towards hybrid solutions, to cover a wider range of use cases

5G NR Positioning Trend

Overview of 5G NR Positioning in 3GPP

- **Requirements** - 3GPP identified high-level 5G NR potential positioning requirements (incl. highly accurate positioning, hybrid positioning)
- **Use cases** – study on 5G positioning use cases covers diverse use case and scenarios (IoT, V2X, Industry 4.0, emergency services, Aerials, Location based Services)
- **Next**: New 5G NR Positioning Study to start in Rel-16 (Oct'2018)
- Some potential NR positioning benefits: wider bandwidths expect to provide better ToA resolution, massive antenna systems, beam angles and ToA triangulation, flexible NR network architecture; RTK for precise positioning

Take-away

- Transition to 5G is an **evolution**, but could also **transfer** verticals
- 5G NR is designed for long term **coexistence** with 4G LTE
- 5G systems evolution direction: **connecting verticals**; need more inputs from verticals, more **collaboration**
- Existing **LPWA** (LTE-M and NB-IoT) solutions are 5G ready and will be forward-compatible with 5G core networks
- **NB-IoT and LTE-M**, including their evolutions, are expected to be the vital 5G components to address LPWA use cases in the 5G era
- **NR-IIoT** to address IIoT use cases: factory automation; leveraging NR URLLC and TSN
- 5G UE will not signal **UE categories** anymore explicitly to the network, definition however will be in the spec for marketing concept
- **NR-V2X** to address advanced V2X use cases
- NR Positioning: highly accurate positioning (**centimetre**), hybrid positioning

CONNECTING THE DIGITAL WORLD

Thank you!

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