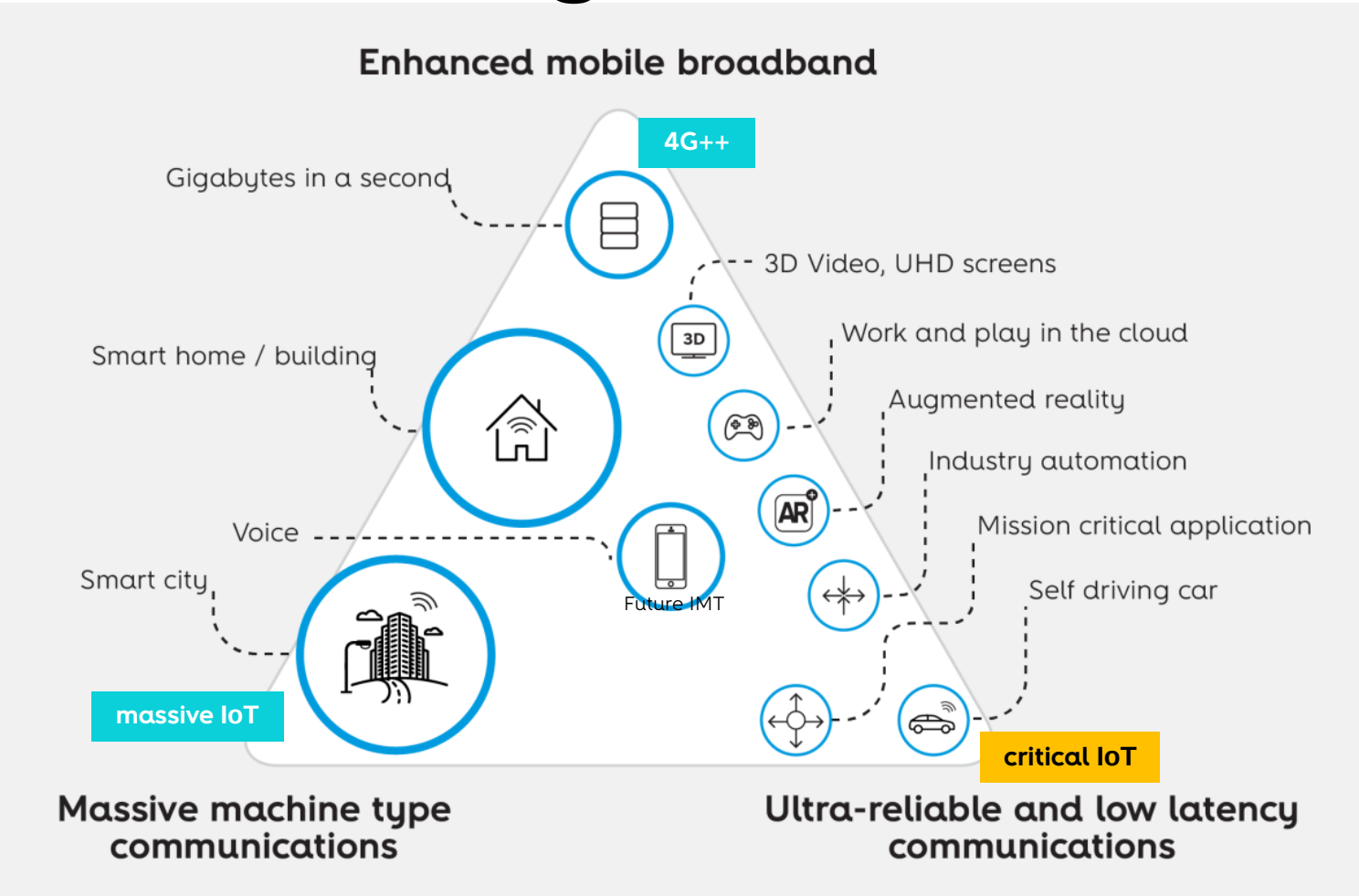
5G organization of ‘Usage Scenarios’



A trillion of devices with different needs	GB transferred in an instant	Mission-critical wireless control and automation

5G will power a **new generation of services and applications** in the areas of:

Enhanced Mobile BroadBand (eMBB)
Make it faster!

Massive Machine Type Communications (mMTC)
Make it massive!

Ultra-Reliable, Low Latency Communications (URLCC)
Make it trustable and responsive!

All with a single, unified technology

…while driving down the cost per managed bit

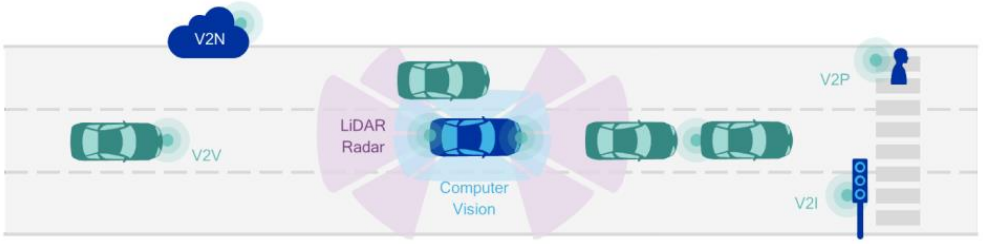
Example of verticals: 5GAA (5G Automotive Association)

http://5gaa.org/

"Develop, test and promote communications solutions, initiate their standardization and accelerate their commercial availability and global market penetration to address society's connected mobility and road safety needs with applications such as autonomous driving, ubiquitous access to services and integration into smart city and intelligent transportation"

Vehicle to anything (V2x) communications:

- Vehicle to Vehicle (V2V)
- Vehicle to Network (V2N)
- Vehicle to Infrastructure (V2I)
- Vehicle to Pedestrian (V2P)

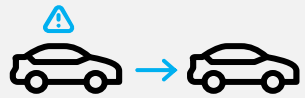


MEMBERS

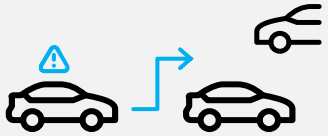
V2x Use Cases

Adapted from Qualcomm

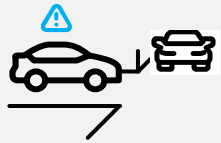
V2x enables a broad set of use cases



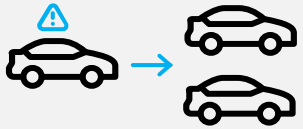
Forward collision warning



Do not pass warning (DNPW)



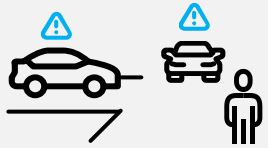
Blind intersection



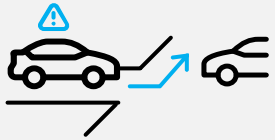
Queue warning

Cooperative adaptive cruise control & platooning

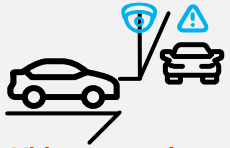
Emergency Vehicle alert



Vulnerable road user (VRU) alerts

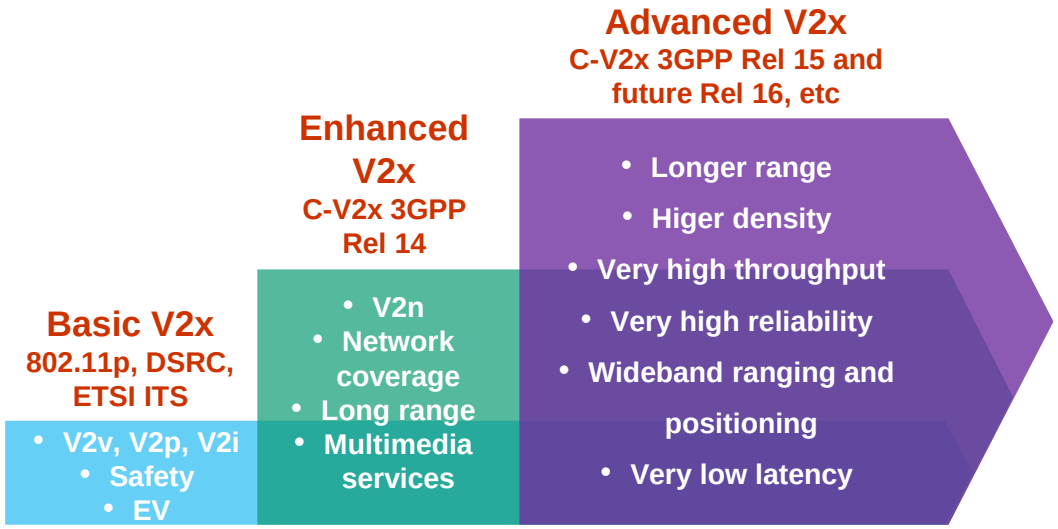


Left turn assist (LTA)



Video streaming, to look around the corner

3GPP V2x evolutionary support



Source: 5G Americas Whitepaper, "Cellular V2x Communications towards 5G", Mar'18

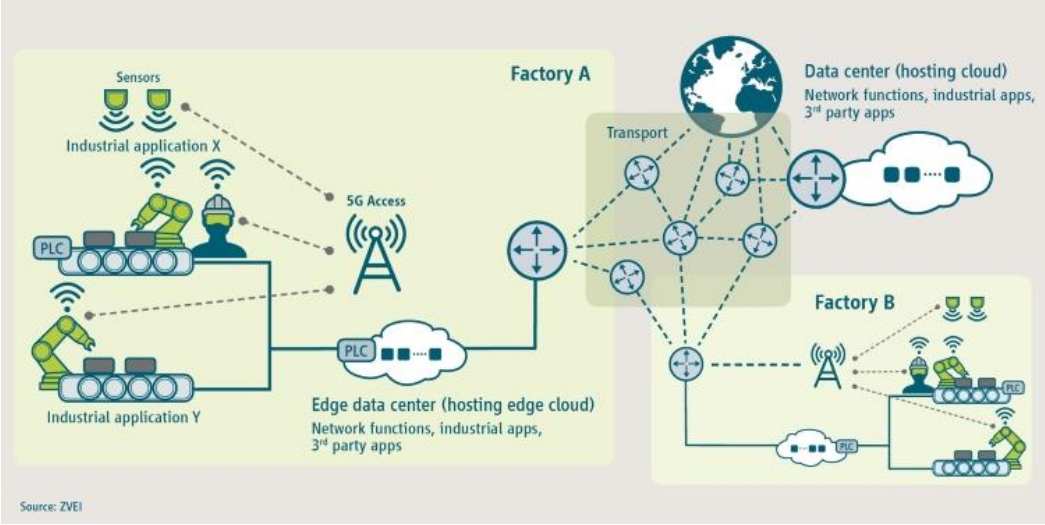
Communication scenario description	Max end-to-end latency (ms)	Reliability (%)
Information exchange between a UE supporting V2X application and a V2X Application Server	5	99.999
Cooperative driving for vehicle platooning Information exchange between a group of UEs supporting V2X application.	10	99.99
Emergency trajectory alignment between UEs supporting V2X application.	3	99.999
Sensor information sharing between UEs supporting V2X application	3	99.999

3GPP TS 22.186

Example of verticals: 5G-ACIA

https://www.5g-acia.org/

“5G-ACIA ensures the best possible applicability of 5G technology and 5G networks for the manufacturing and process industries by addressing, discussing and evaluating relevant technical, regulatory and business aspects.”



Source: 5G-ACIA, “5G for Connected Industries and Automation”, Whitepaper, Apr’18

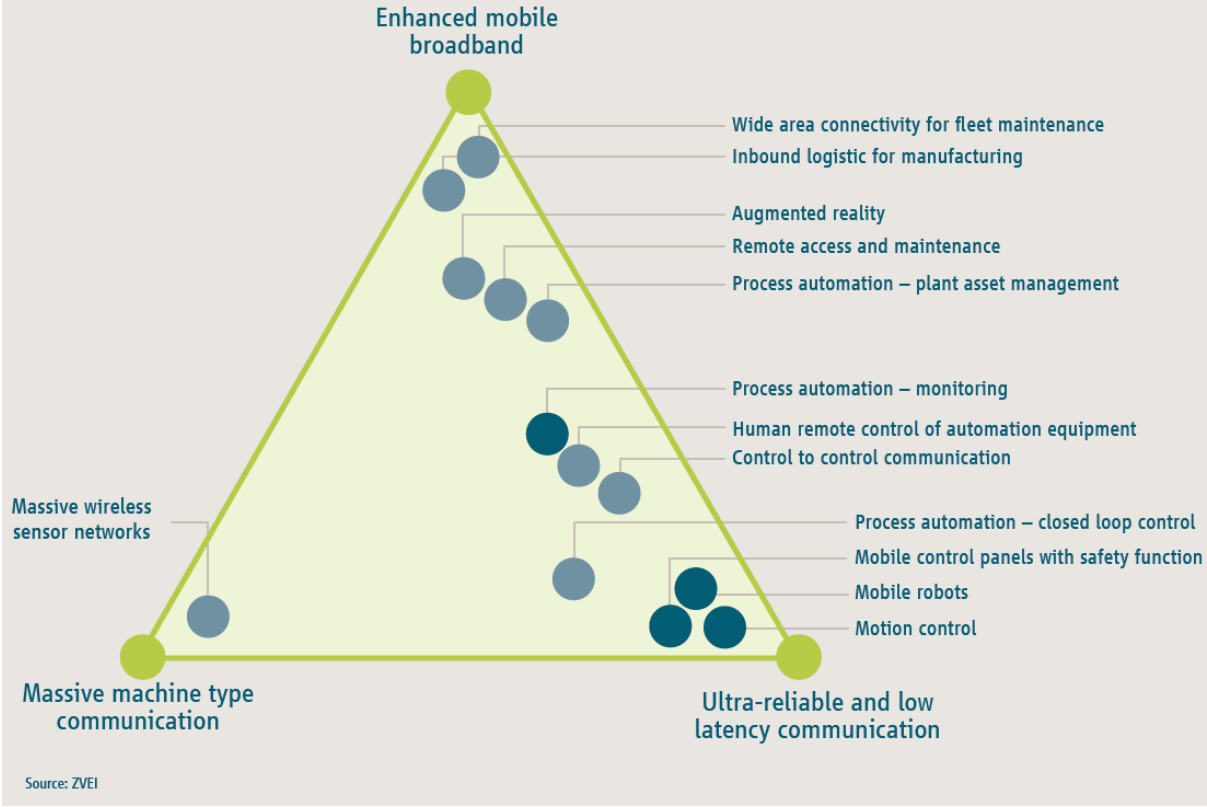
5G ACIA

5G Alliance for Connected Industries and Automation

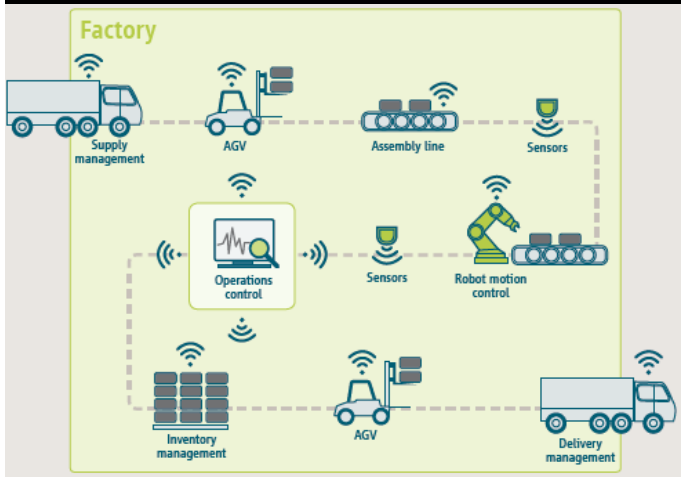
Industry use cases

- **5G in the private domain**

Overview of selected industrial use cases and arrangement according to their basic service requirements (5G-ACIA)



Exemplary application areas of 5G in the factory of the future (5G-ACIA)



Selected use cases requirements (5G-ACIA)

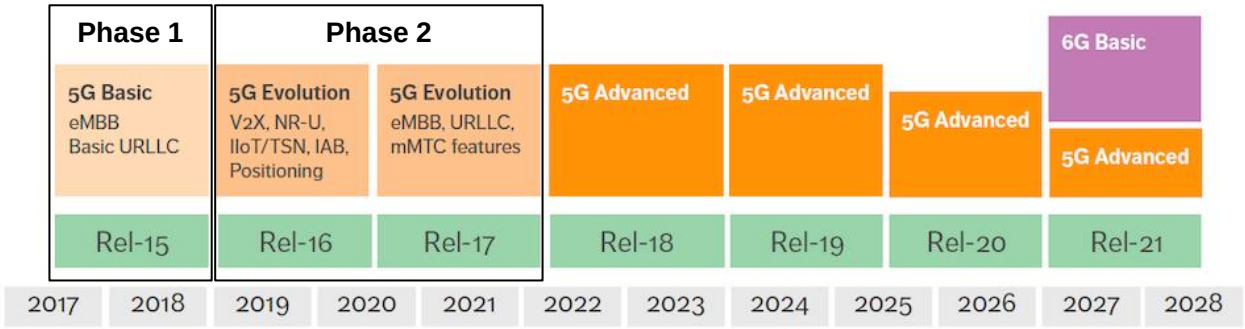
Use case (high level)		Availability	Cycle time	Typical payload size	# of devices	Typical service area
Motion control	Printing machine	>99.9999%	< 2 ms	20 bytes	>100	100 m x 100 m x 30 m
	Machine tool	>99.9999%	< 0.5 ms	50 bytes	~20	15 m x 15 m x 3 m
	Packaging machine	>99.9999%	< 1 ms	40 bytes	~50	10 m x 5 m x 3 m
Mobile robots	Cooperative motion control	>99.9999%	1 ms	40-250 bytes	100	< 1 km²
	Video-operated remote control	>99.9999%	10 – 100 ms	15 – 150 kbytes	100	< 1 km²
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	10000 devices per km²	

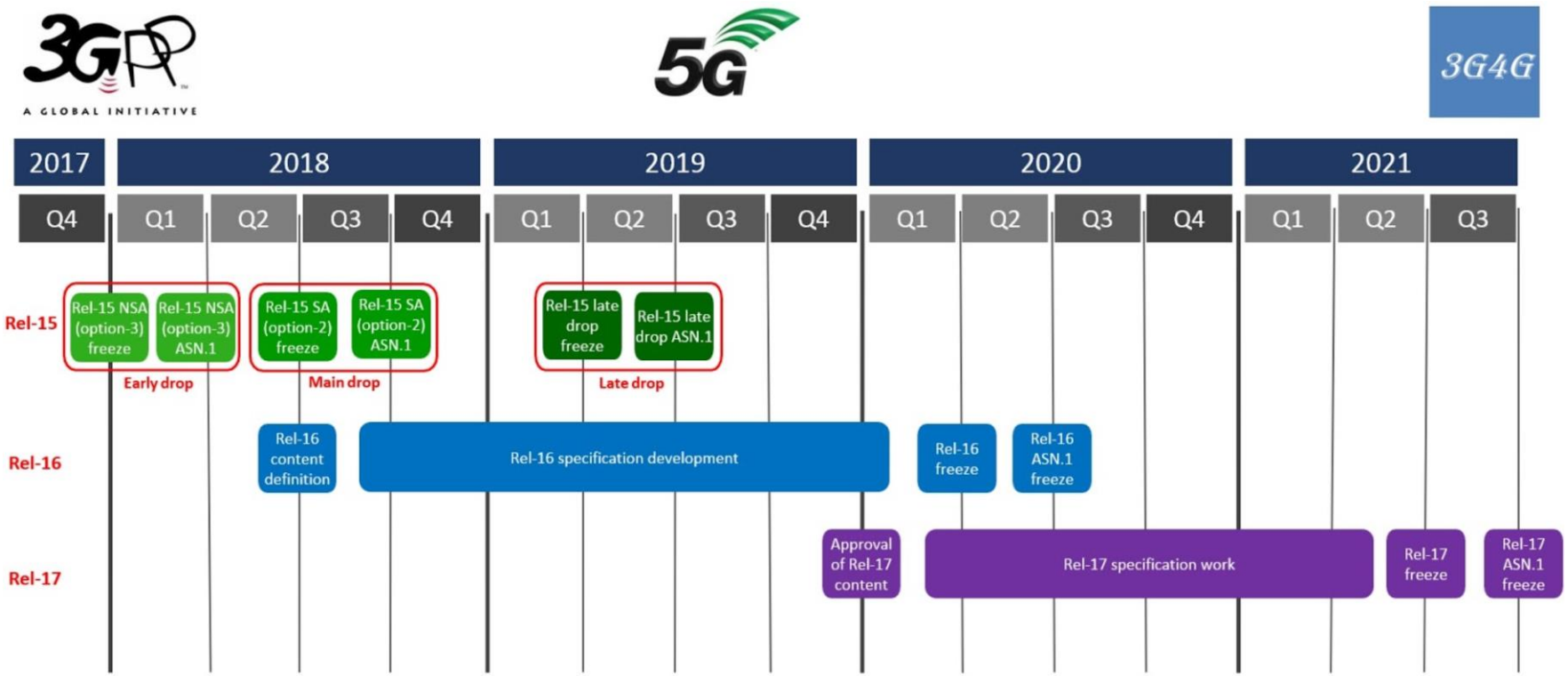
Service unavailability <31,5s / Year

Cycle time shall be measured from command execution to feedback received ➔ 5G latency < half the cycle time

Pictures from: 5G-ACIA, "5G for Connected Industries and Automation", Whitepaper, Apr'18

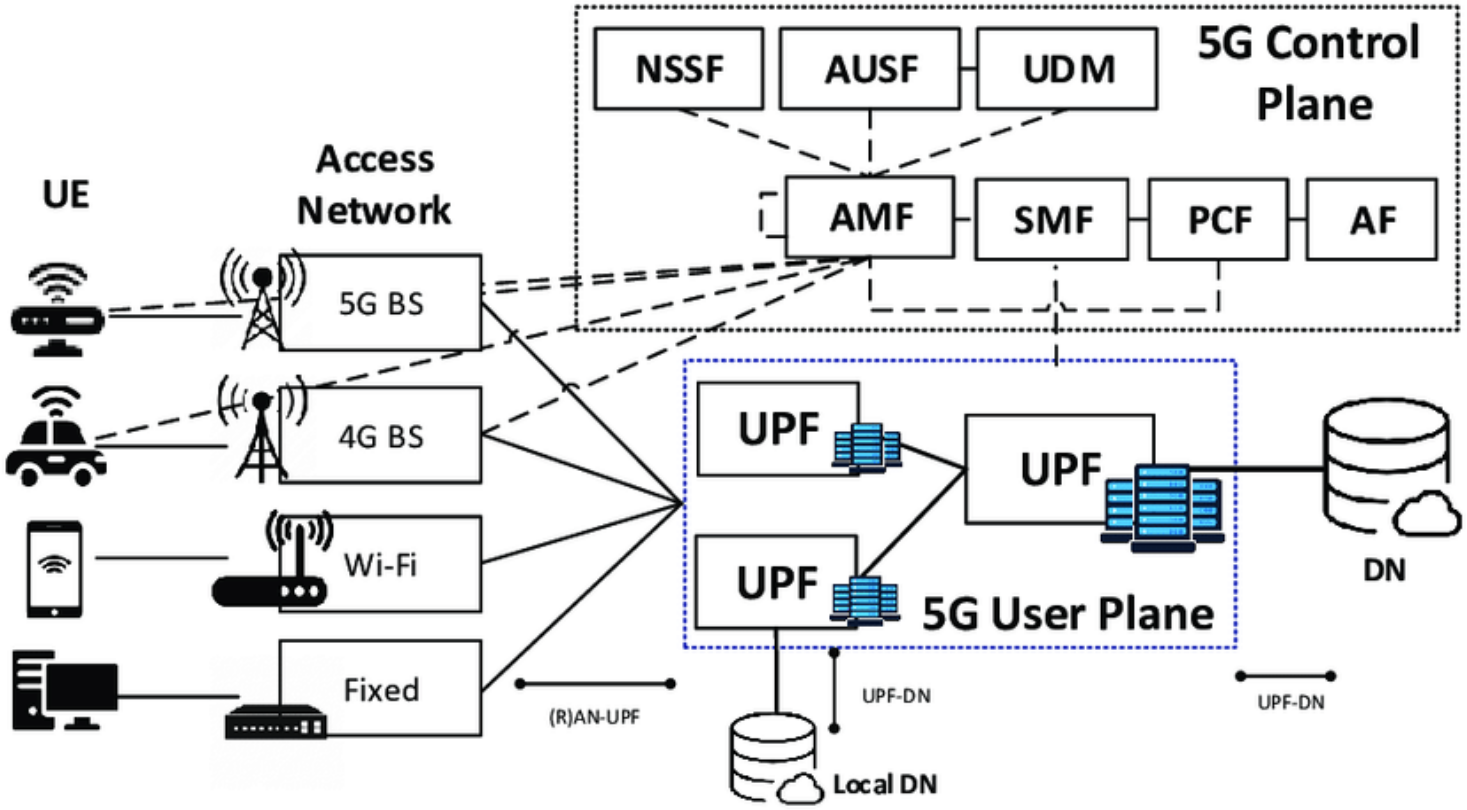
5G roadmap





Designed by 3G4G, based on roadmap from 3GPP, July 2019

5G System



5G System:

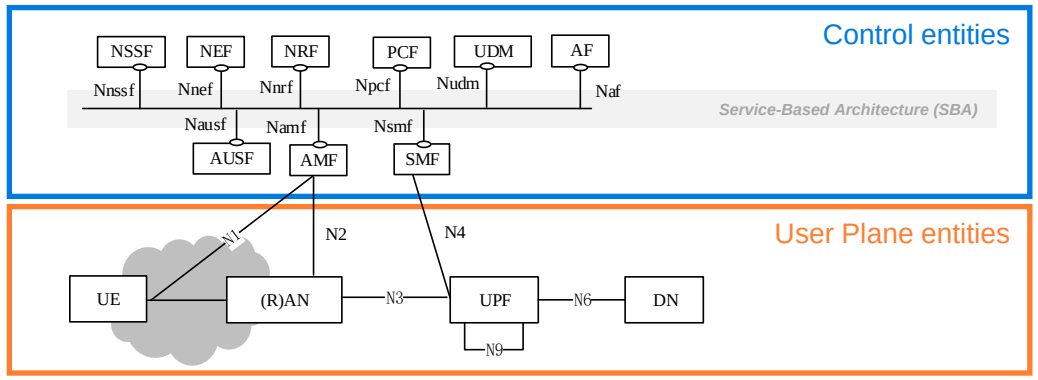
1. UEs
2. 5G RAN
3. 5G Core

Control and user planes separation

Microservices (5G Core)

Multi-access

5G System arch. and functional modules (parcial)



3GPP TS 23.501 V0.3.1 (2017-03)

- **Separate the User Plane (UP) functions from the Control Plane (CP) functions**
- **Modularize the function design**, e.g. to enable flexible and efficient network slicing
- **Define procedures** (i.e. the set of interactions between network functions) **as services**
- Enable each Network Function to interact with other NF directly if required (**direct interaction**)
- **Minimize dependencies between the Access Network (AN) and the Core Network (CN)**
- Support a **unified authentication framework**
- Support **"stateless" NFs**, where the "compute" resource is decoupled from the "storage" resource
- Support **capability exposure**
- Support **concurrent access to local and centralized services**. To support low latency services and access to local data networks, **UP functions can be deployed close to the Access Network**

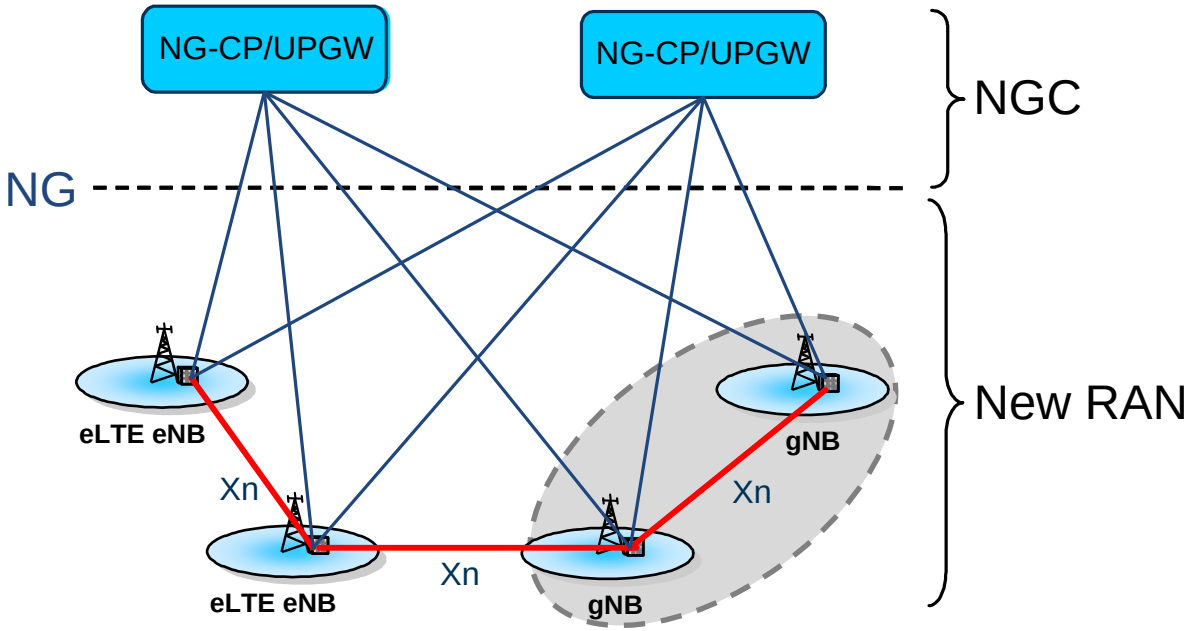
1. Network Slice Selection Function (NSSF)
2. Network Exposure Function (NEF)
3. NF Repository Function (NRF)
4. Policy Control Function (PCF)
5. Unified Data Management (UDM)
6. Application Function (AF)

7. Authentication Server Function (AUSF)
8. Access and Mobility Management Function (AMF)
9. Session Management Function (SMF)

10. Unified Data Repository (UDR)
11. Unstructured Data Storage Function (UDSF)
12. 5G-Equipment Identity Register (5G-EIR)
13. Security Edge Protection Proxy (SEPP)
14. Network Data Analytics Function (NWDAF)

1. User Equipment (UE)
2. (Radio) Access Network ((R)AN)
3. User Plane Function (UPF)
4. Data Network (DN)

5G: a New Radio is required



NGC: Next Generation Core
NG-CP: *Next Generation Control Plane*
UPGW: *User Plane GateWay*

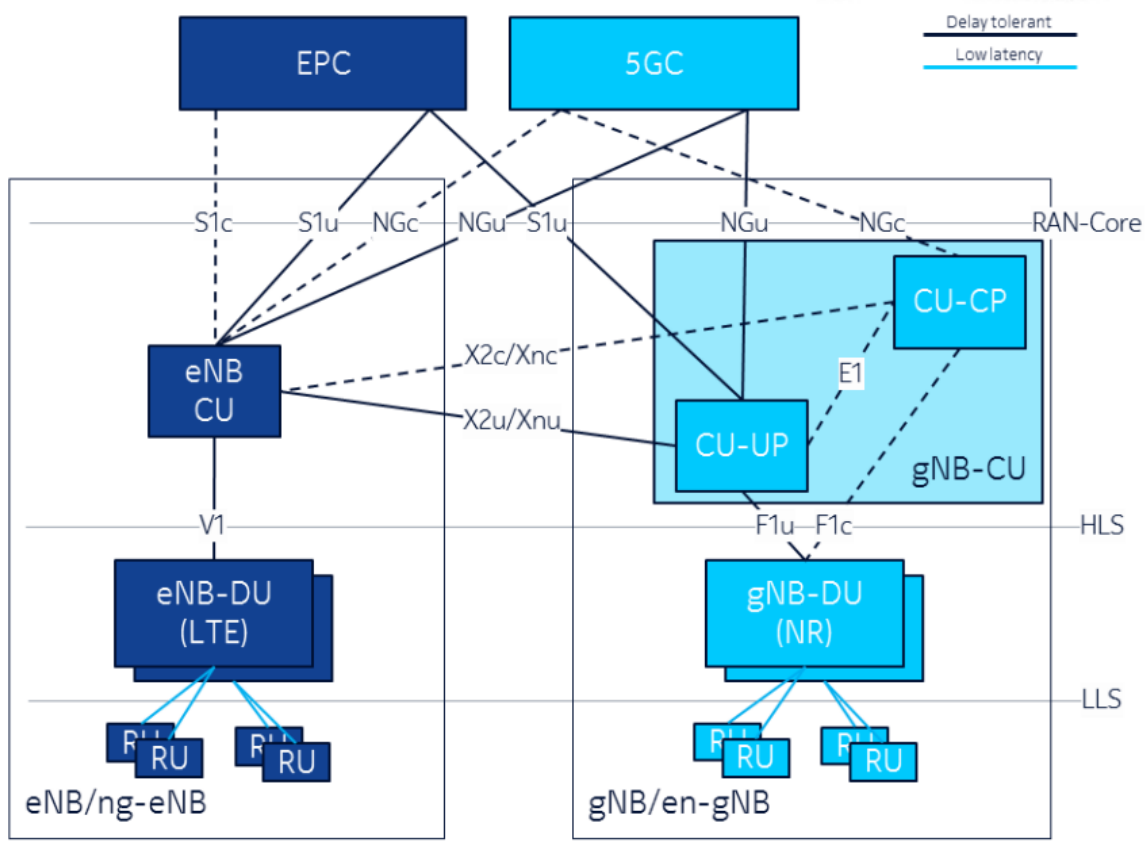
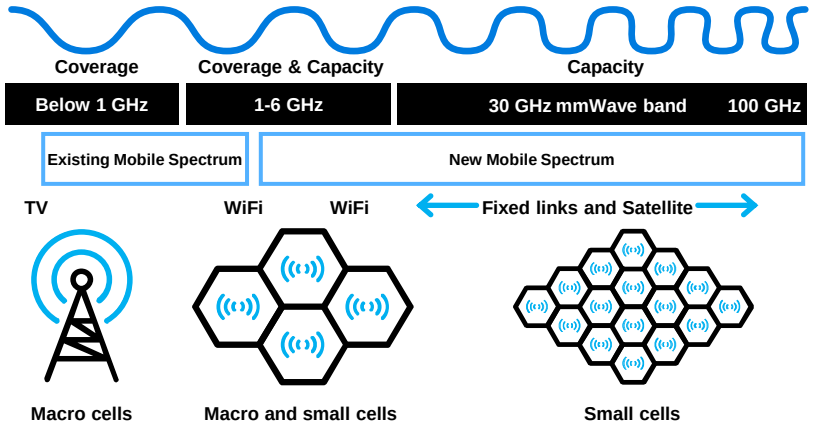
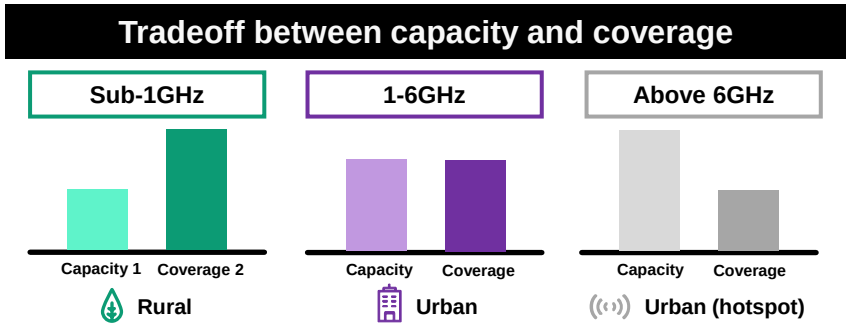
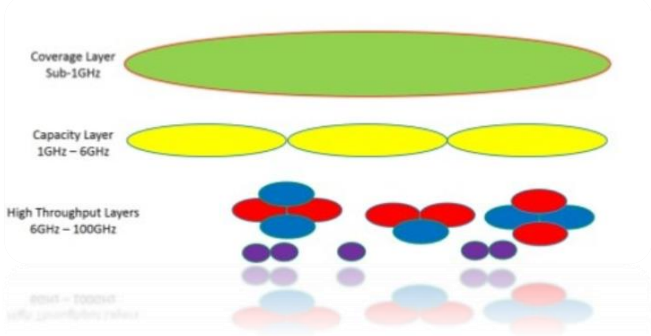


Figure 3: Overall RAN architecture

Larger spectrum usage to cover all applications



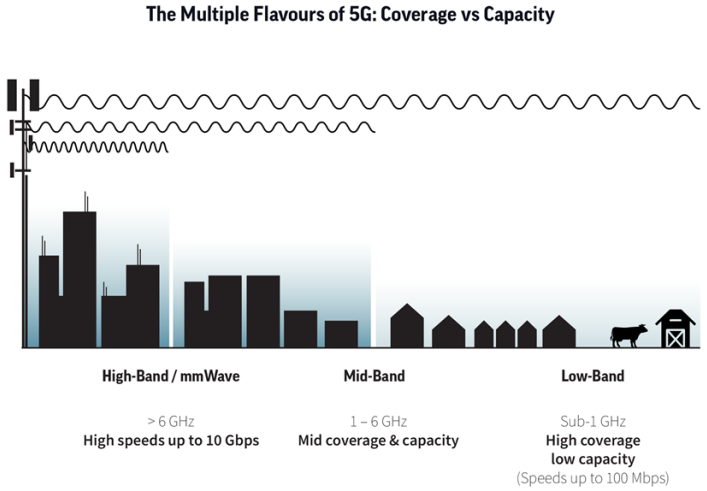




Universal coverage (10's of Mb/s) of reliable connectivity

Urban coverage with dense small cells (1-3 Gb/s) e.g. mobile Gb/s society, smart cities, option for connected highways

Hot spots coverage (up to 10 Gb/s) e.g. fixed wireless access, railway stations, sport events, smart factories,

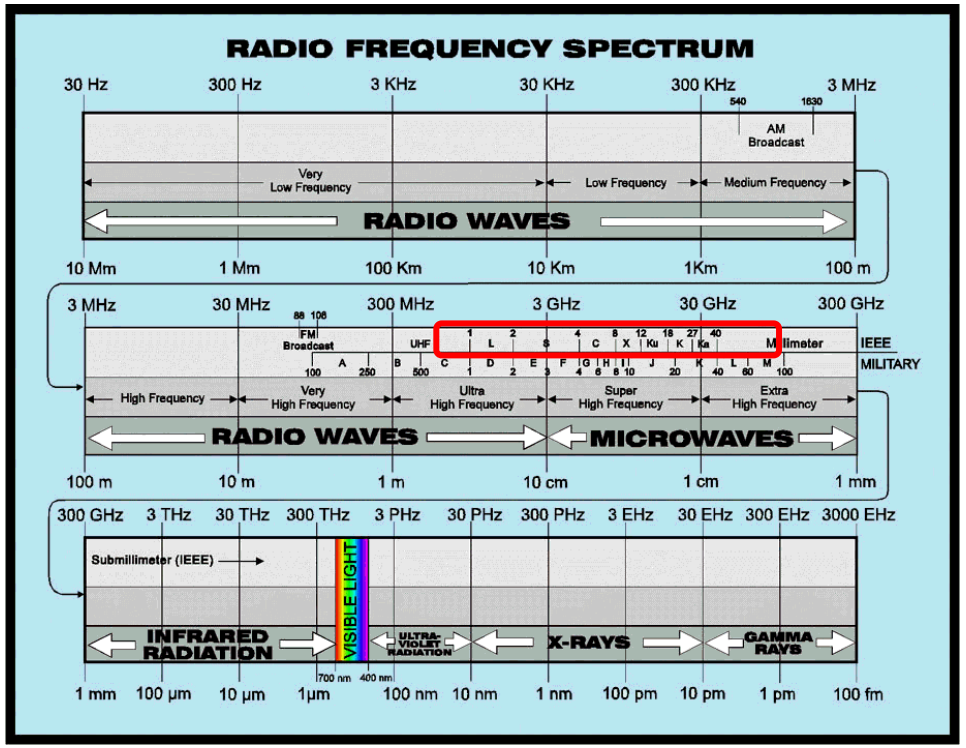


5G-NR to operate on a larger spectrum range

- Expanding to lower freqs. for coverage and penetration
- Expanding to higher freqs. for capacity and low latency

5G Spectrum

http://donsnotes.com/tech/em-spectrum.html



RADIO SPECTRUM POLICY GROUP, "STRATEGIC ROADMAP TOWARDS 5G FOR EUROPE"
"Opinion on spectrum related aspects for next-generation wireless systems (5G)", Nov/16

http://rspg-spectrum.eu/wp-content/uploads/2013/05/RPSG16-032-Opinion_5G.pdf

- **<1GHz (e.g. 700MHz)**
  to "enable nationwide and indoor 5G coverage" — < 1GHz
- **3400-3800 MHz GHz**
  - **>100MHz (400MHz) of continuous spectrum**
  to "put Europe at the forefront of the 5G deployment" — > 1GHz < 6GHz
- **24.25-27.5 GHz**
  "pioneer band for earlier implementation in Europe"
- **31.8-33.4 GHz**
  "looks a promising band which could be made available" — > 6GHz
- **40.5-43.5 GHz**
  "is a viable option for 5G in the longer term"

IMT frequencies usage between 24.25 and 86GHz will be analysed at the ITU-T WRC'19 (Nov/19)

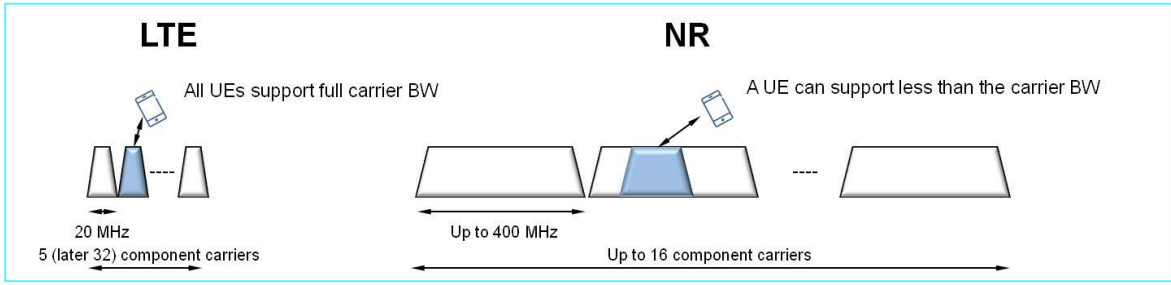
	Quantidade de frequência adquerida						
	Dense Air	Dixarobil	MEO	NOS	NOWO	VODAFONE	TOTAL
700 MHz	0	0	10 MHz	20 MHz	0	20 MHz	**50 MHz**
900 MHz	0	10 MHz	4 MHz	4 MHz			**18 MHz**
1800 MHz	0	10 MHz	0	0	20 MHz	0	**30 MHz**
2,1 GHz	0	0	0	10 MHz	0	0	**10 MHz**
2,6 GHz	0	35 MHz	0	0	10 MHz	0	**45 MHz**
3,6 GHz	40 MHz	40 MHz	90 MHz	100 MHz	40 MHz	90 MHz	**400 MHz**
Total	**40 MHz**	**95 MHz**	**104 MHz**	**134 MHz**	**70 MHz**	**110 MHz**	**553 MHz**

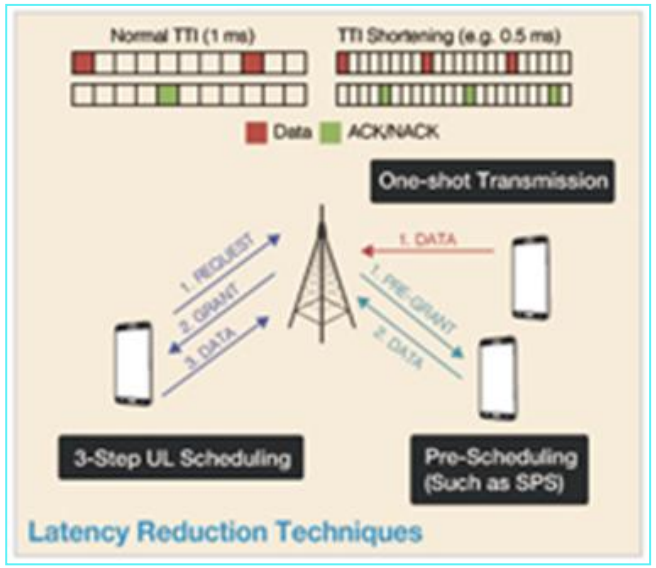
2021 PT Auction results

5G-NR main characteristics

Workshop on 3GPP submission towards IMT-2020, Brussels, October 24/25, 2018
"NR Physical Layer Design: Physical layer structure, numerology and frame structure"
Havish Koorapaty 3GPP TSG RAN WG1 vice-chairman (Ericsson)

- **Operation from low to very high bands: 0.4 – 100Ghz**
  - Including standalone operation in unlicensed bands
- **Up to 400 MHz component-carrier bandwidth (20 MHz for LTE)**
  - Up to 100MHz in <6GHz
  - Up to 400MHz in >6GHz
- **Up to 16 component carriers**
- **Set of different numerologies for optimal operation in different frequency ranges**
- **Native support for Low Latency**
  - Shortened *Transmission Time Interval* (TTI)
- **Native support for Ultra Reliability (Multiple diversity mechanisms)**
- **Flexible and modular RAN architecture: split fronthaul, split control- and user-plane**
- **Support for devices connecting directly, with no network (D2D, V2X)**
- **Native end-to-end support for Network Slicing**
- **New channel coding**
  - LDPC for data channel, Polar coding for control channel





http://developer.samsung.com/sd2_images/progra m/content/mtech_5g09.jpg (adapted)

4G/LTE:
- **Turbo codes** for **data** channels
- **TBCCs** (Tail-Biting Convolutional Codes) for **control** channels

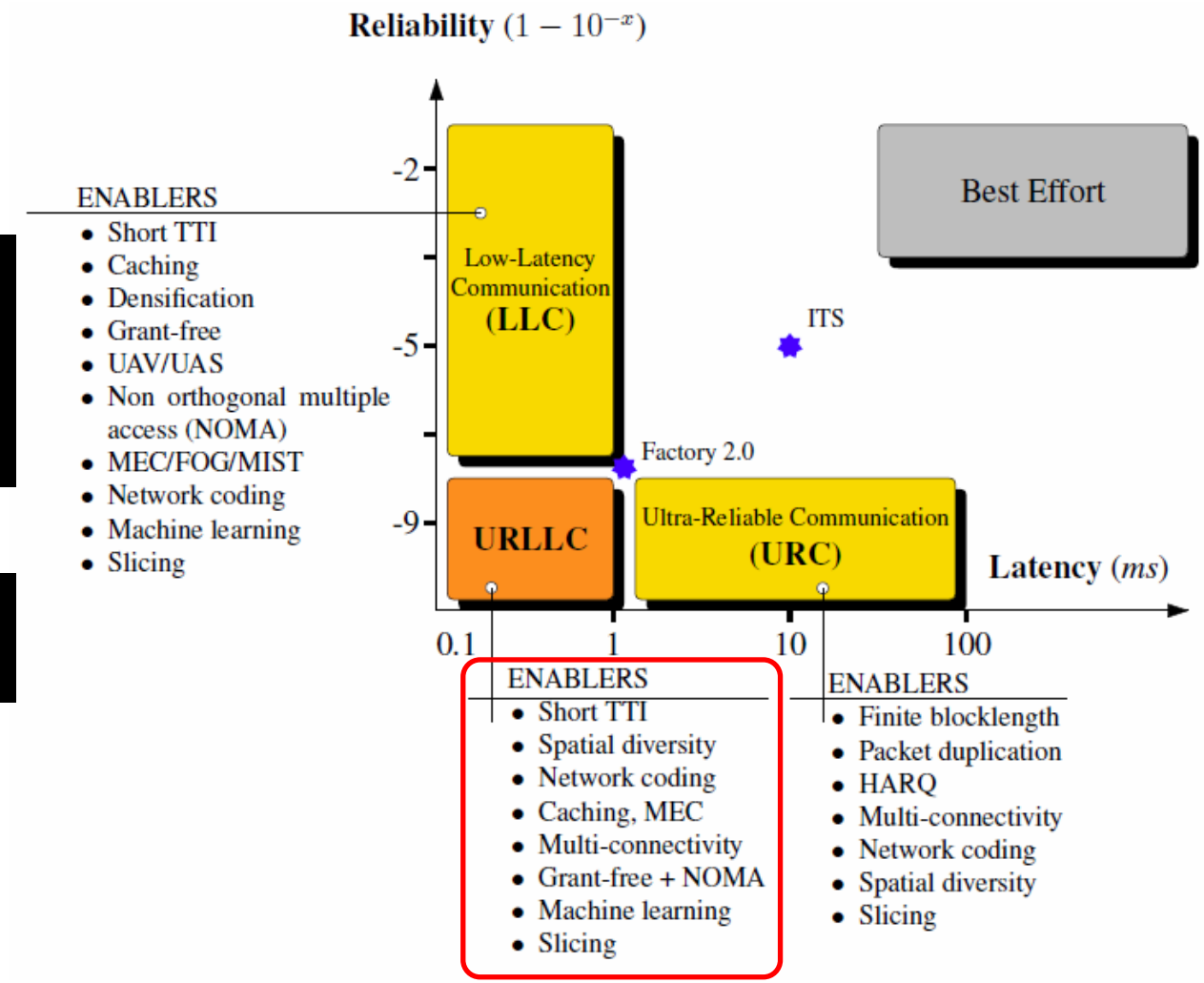
LDPC (*Low-Density Parity-Check*):
- **Improved performance**: block error rate (BLER) around or below 10^{-5} for all code sizes and code rates
- Reduced decoding complexity and **improved decoding latency** (lower overall latency)
- Better **area throughput efficiency** and **higher peak throughput**

URLLC: The Ultra Reliability versus Low Latency challenge

Answering two conflicting requirements:
- **Low latency and ultra-high reliability**

Release 16 objective:
- **0.5-1ms one-way latency**
- **Reliability of up to 99.9999%**

Retransmissions (e.g. HARQ) and packet duplications in time (e.g. PDCP duplications) are useless, considering the low latency budget



"Ultra-Reliable and Low-Latency Wireless Communication: Tail, Risk and Scale"
Mehdi Bennis, Senior Member IEEE, M'erouane Debbah, Fellow IEEE, and H. Vincent Poor, Fellow IEEE