

5G Automotive



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FACTORIES OF THE FUTURE

- 1 Time-critical process control
- 2 Non time-critical factory automation
- 3 Remote control
- 4 Intra/Inter-enterprise communication
- 5 Connected goods

ENERGY

- 1 Grid access
- 2 Grid backhaul
- 3 Grid backbone

e-HEALTH

- 1 Assets and interventions management in Hospital
- 2 Robotics
- 3 Remote monitoring
- 4 Smarter medication

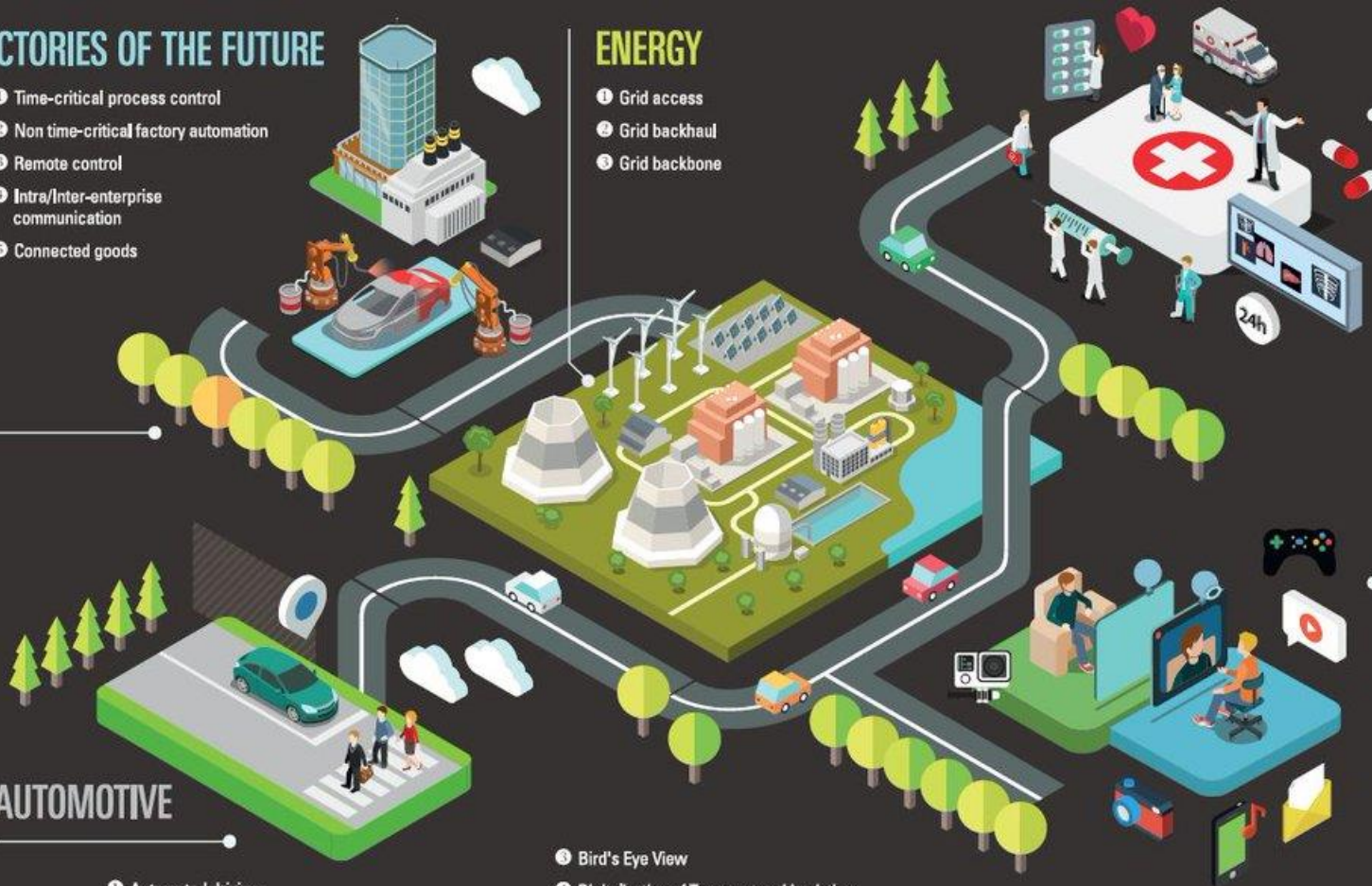
MEDIA & ENTERTAINMENT

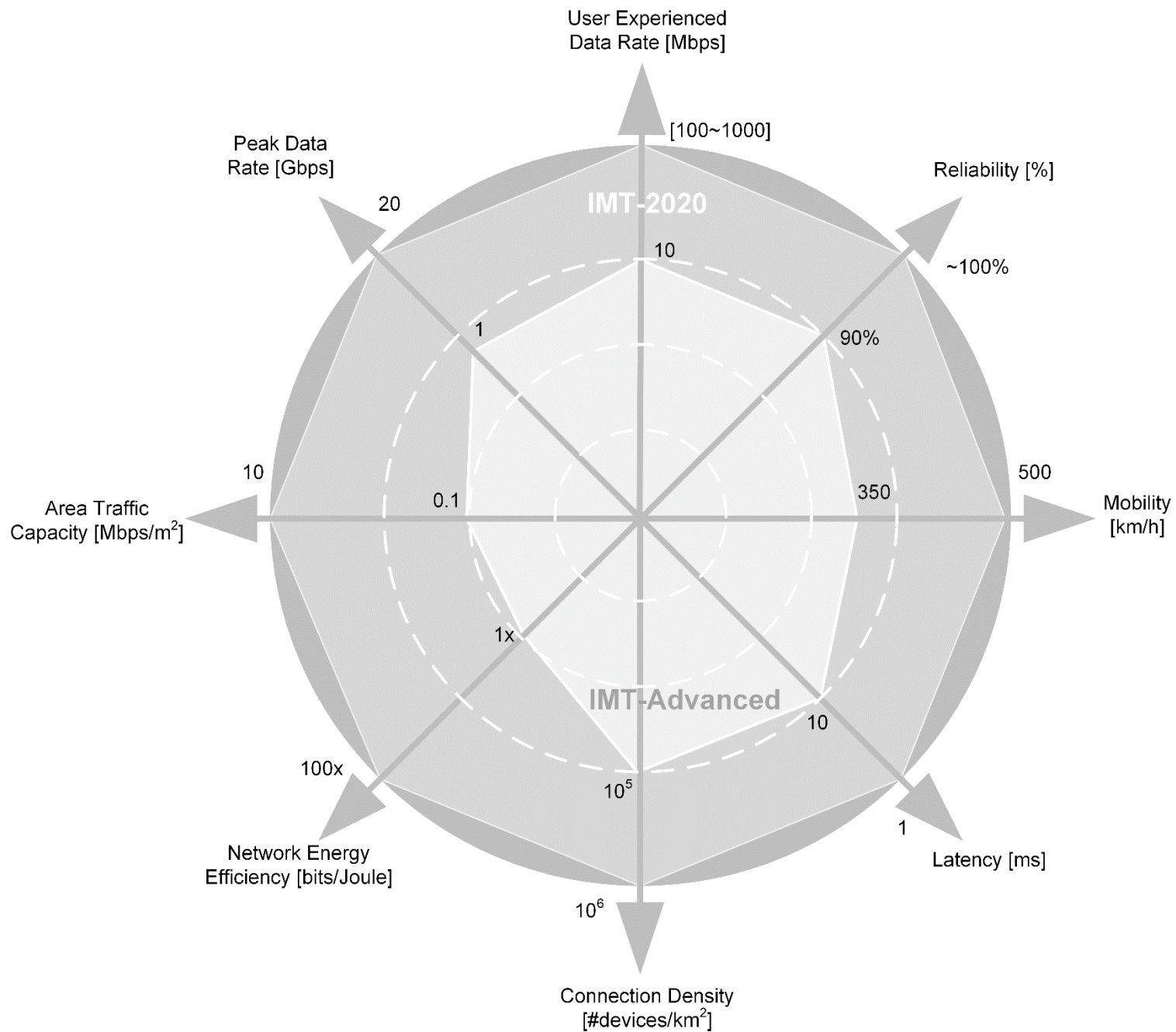
- 1 Ultra High Fidelity Media
- 2 On-site Live Event Experience
- 3 User/Machine Generated Content
- 4 Immersive and Integrated Media
- 5 Cooperative Media Production
- 6 Collaborative Gaming

AUTOMOTIVE

- 1 Automated driving
- 2 Share My View

- 3 Bird's Eye View
- 4 Digitalization of Transport and Logistics
- 5 Information Society on the road



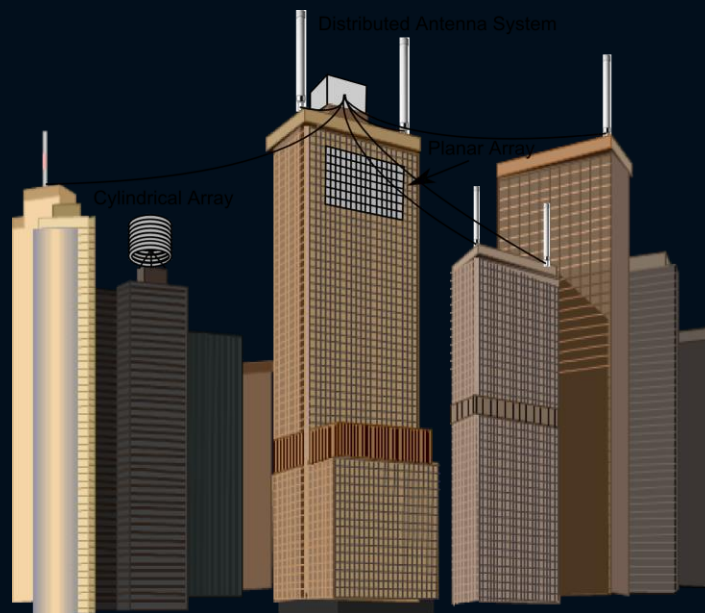
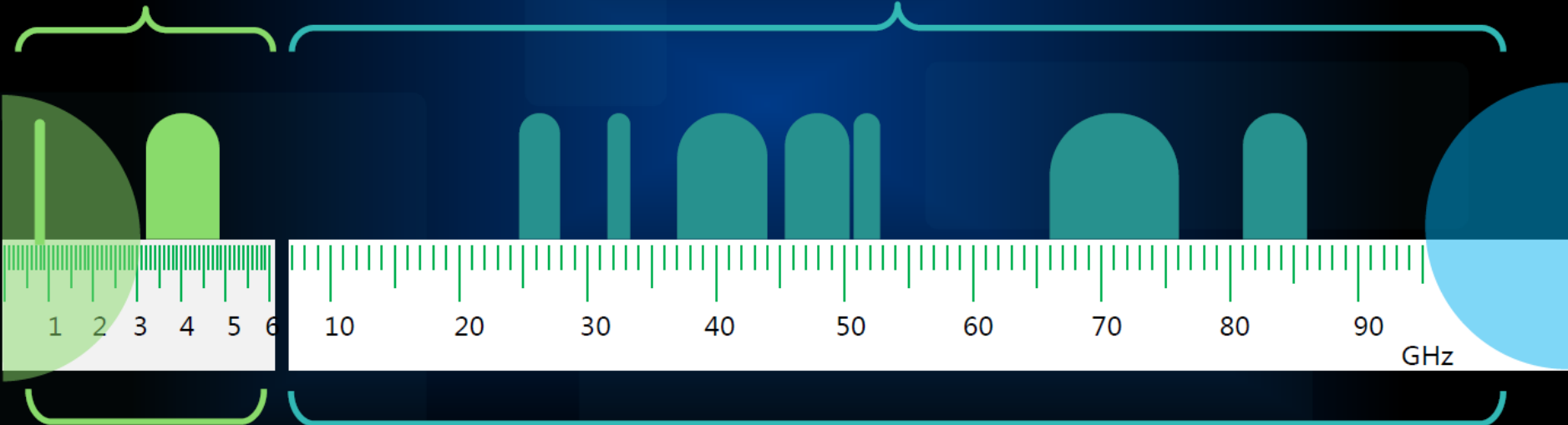


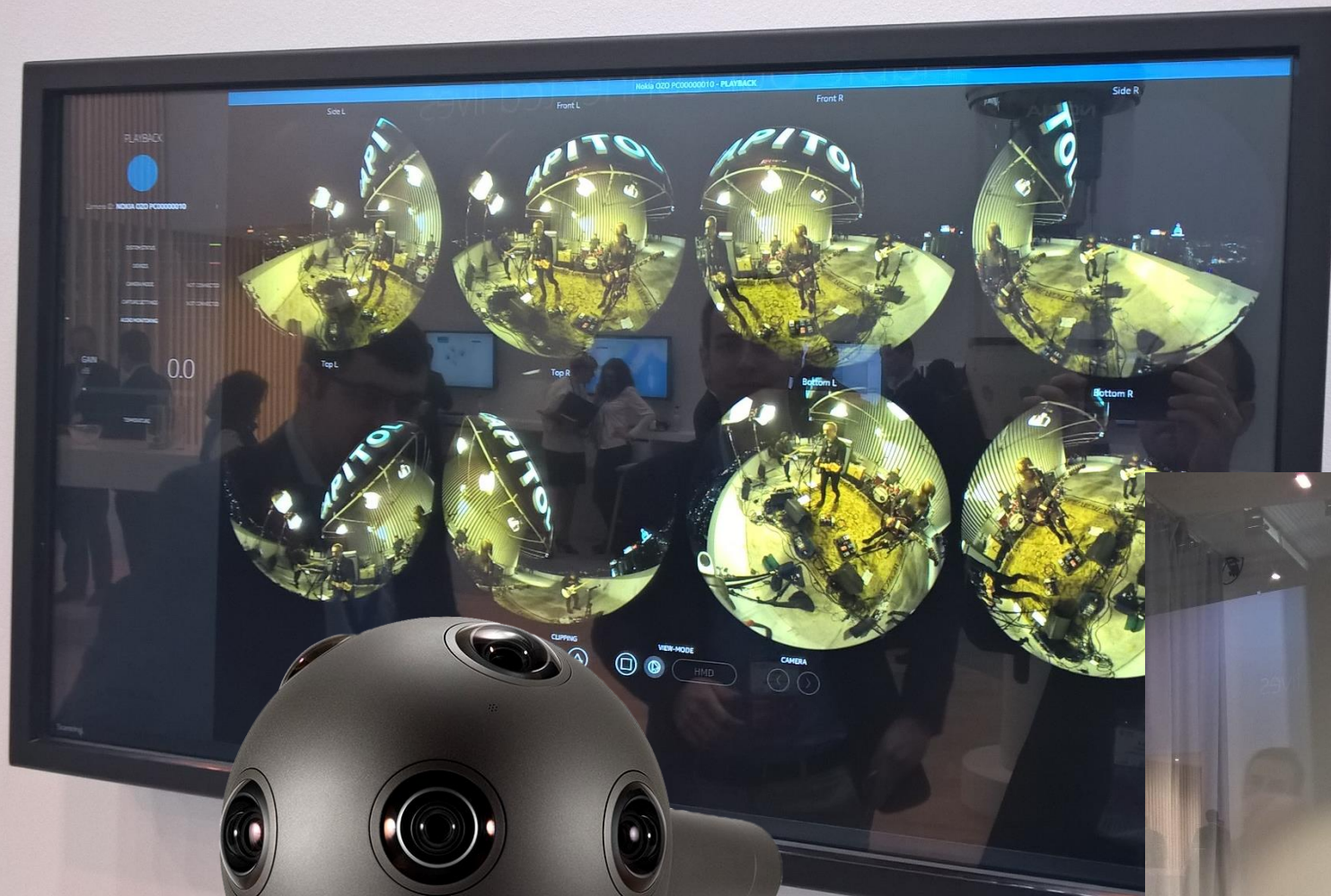
WRC-15

470MHz-6GHz
(below 6GHz)

WRC-19

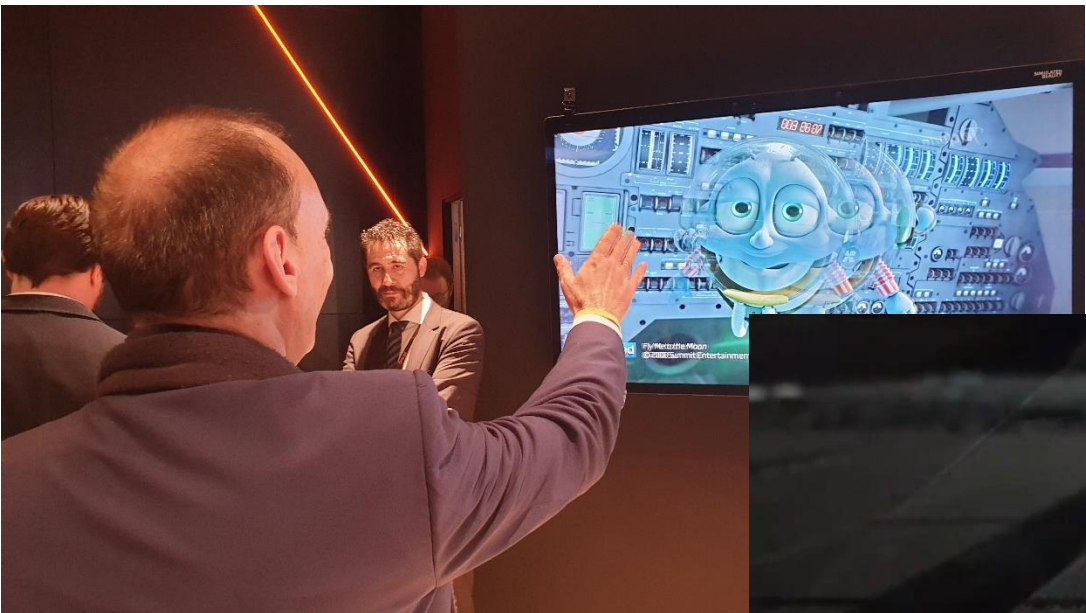
24.25-86GHz
(above 6GHz)



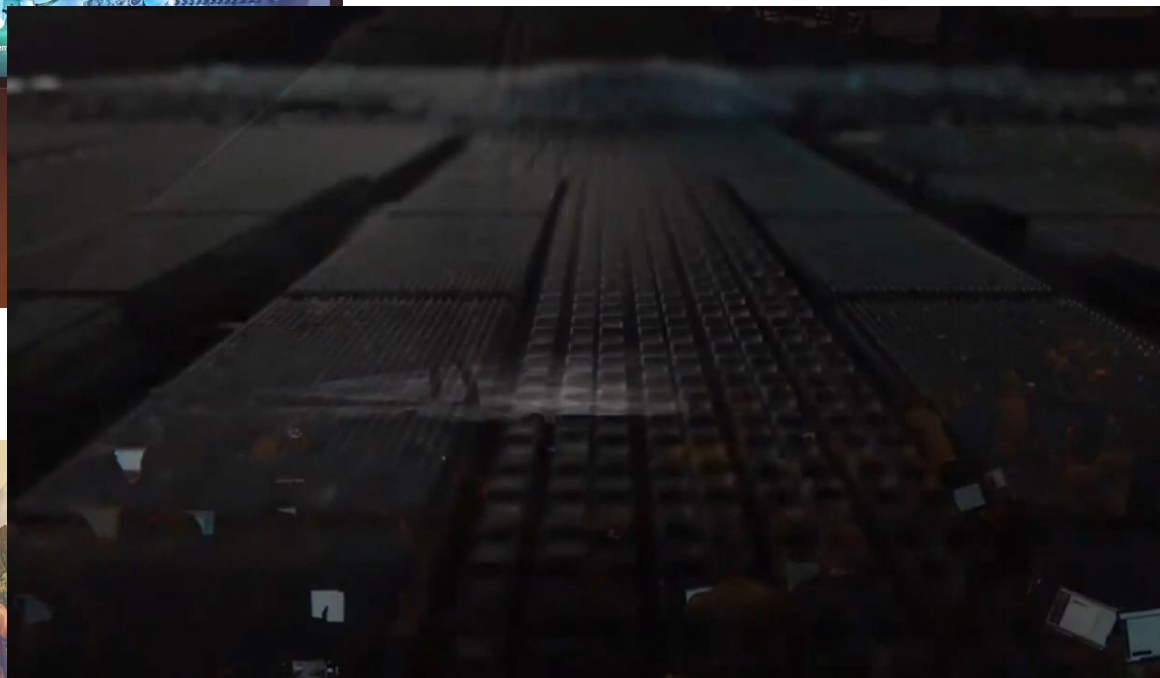


8 Gbps





3 Gbps (2 x 4K)



50 Mbps <16ms RTT

100 Mbps



holoportation

<http://research.microsoft.com/holoportation>

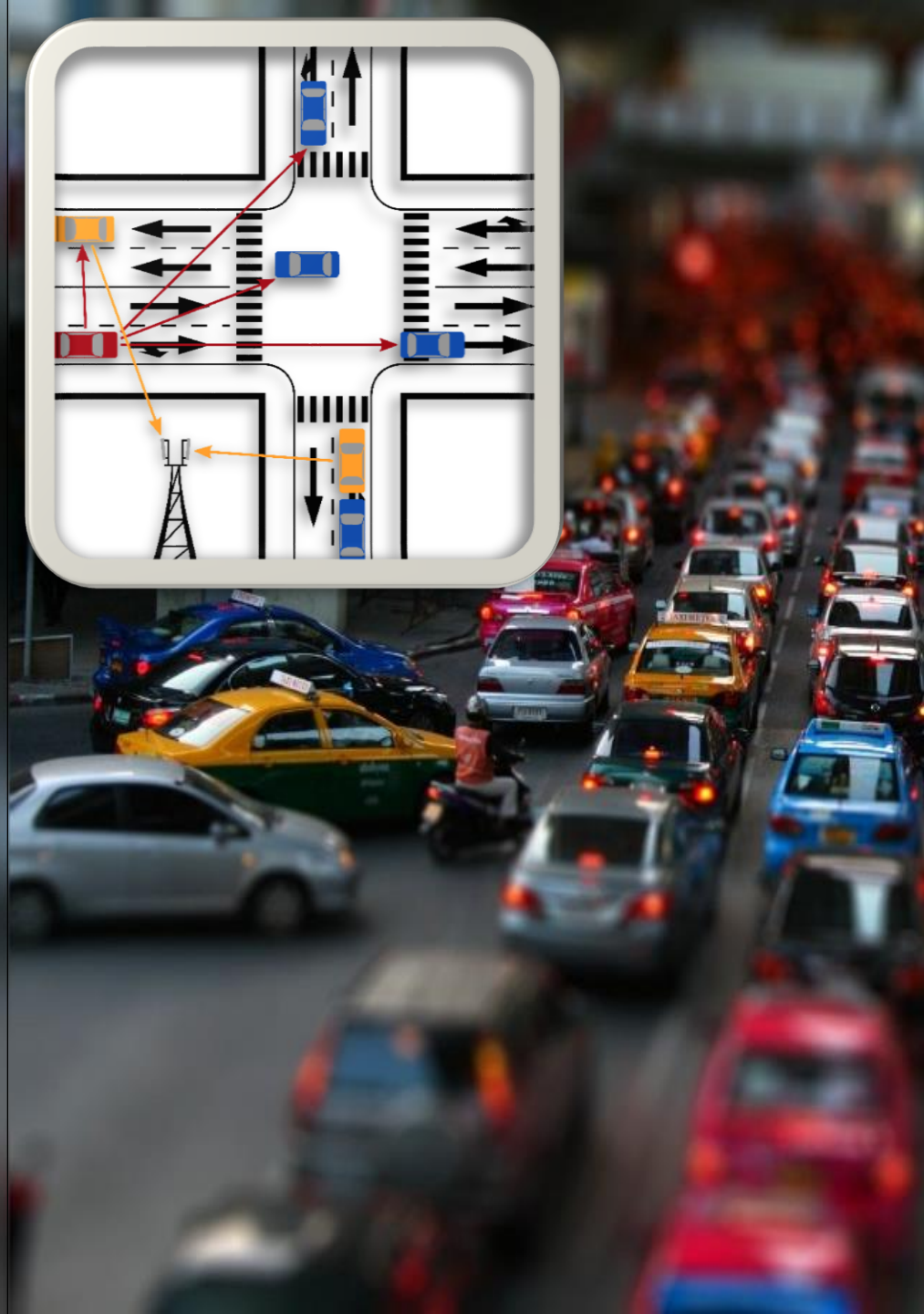
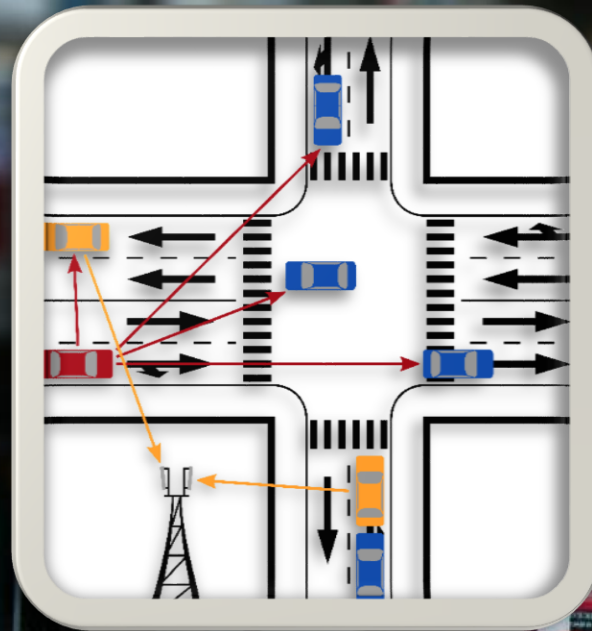
Interactive 3D Technologies

<http://research.microsoft.com/groups/i3d>

Microsoft Research

Automotive

- V2V Communications
- IEEE 802.11p standard, WiFi variant
- Vehicles communicate to each other
 - Burst traffic every 10-100 ms
- USA regulation already started in January 2017 → proposal for rule making → mandatory by 2025
- EU in March 13 2019 goes into the same direction



INTERNET









C-V2X Standard

Some facts

- eCall is mandatory in new cars in EU by April 2018
- More than 800 operators have full road coverage worldwide
- C-V2X technology is available in Release 14 since June 2017
- 273 billion euros is the potential revenue of connected vehicle market
- Qualcomm chipset 9150 is available in production
- USA and EU are defining their technology priorities in parallel



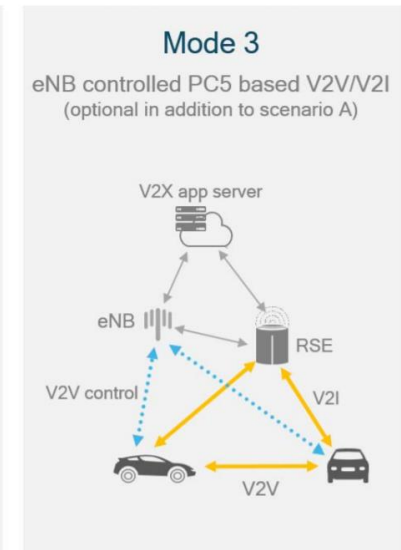
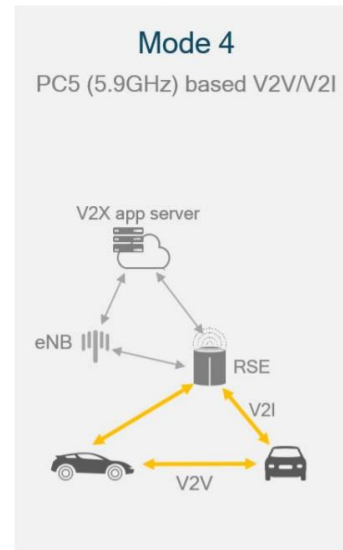
C-V2X Release 14 in short

Direct Communications

- Referred to as PC5
- Use ITS 5.9 spectrum
- No SIM is required
- Anonymous communications
- GPS for synchronization
- Can use 10 MHz for basic services or up to 70
- Mode 3 or mode 4

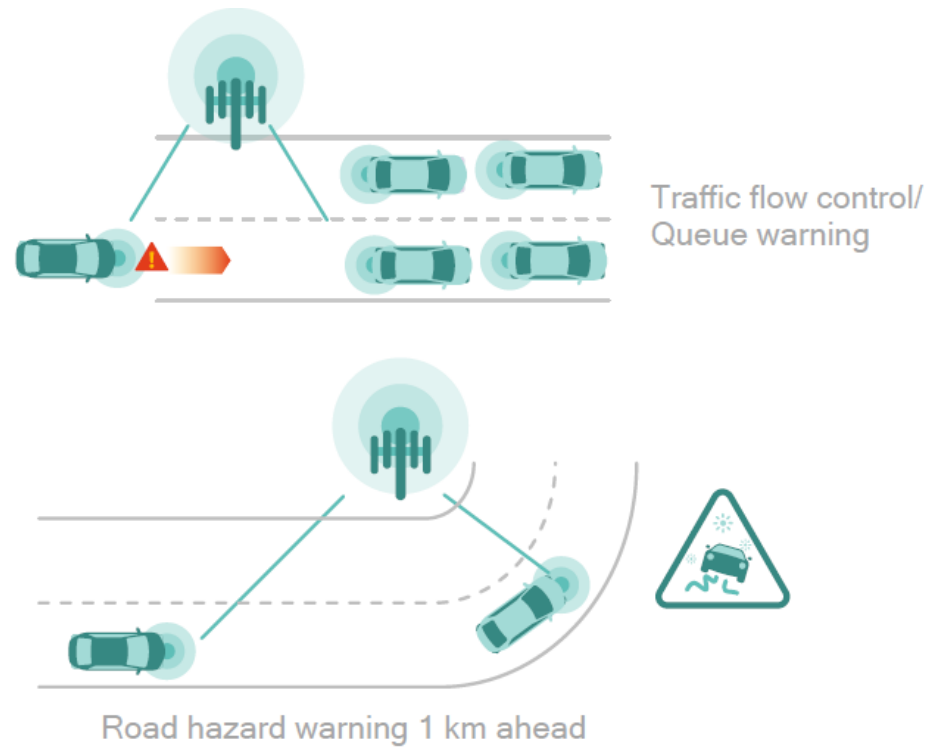
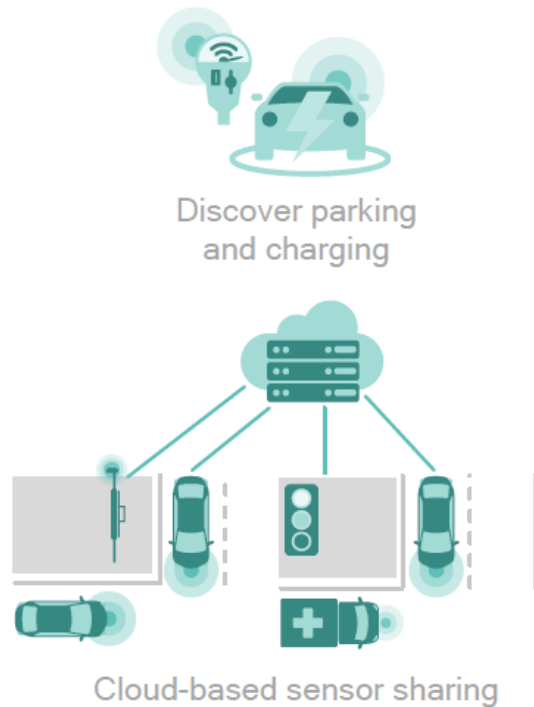
Network Communications

- LTE
- Use any licensed spectrum
- SIM required since the network is used



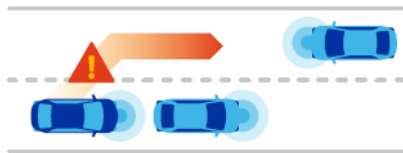
Network Communications

For latency tolerant use cases

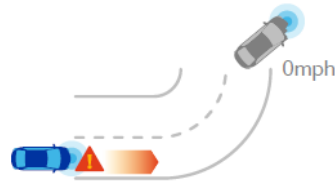


Direct Communications

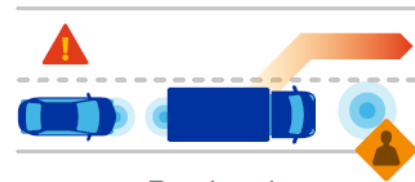
For active safety and low latency use cases



Do not pass
warning (DNPW)



Blind curve/
Local hazard warning



Road works
warning



Intersection movement assist
(IMA) at a blind intersection



Vulnerable road user (VRU)
alerts at a blind intersection



Left turn
assist (LTA)

C-V2X Release 14 better link budget than IEEE 802.11p

Transmission time
Longer transmit time leads to better energy per bit



Waveform
SC-FDM has better transmission efficiency



Channel coding
Gains from turbo coding and retransmission

Energy per bit is accumulated over a longer period of time for C-V2X

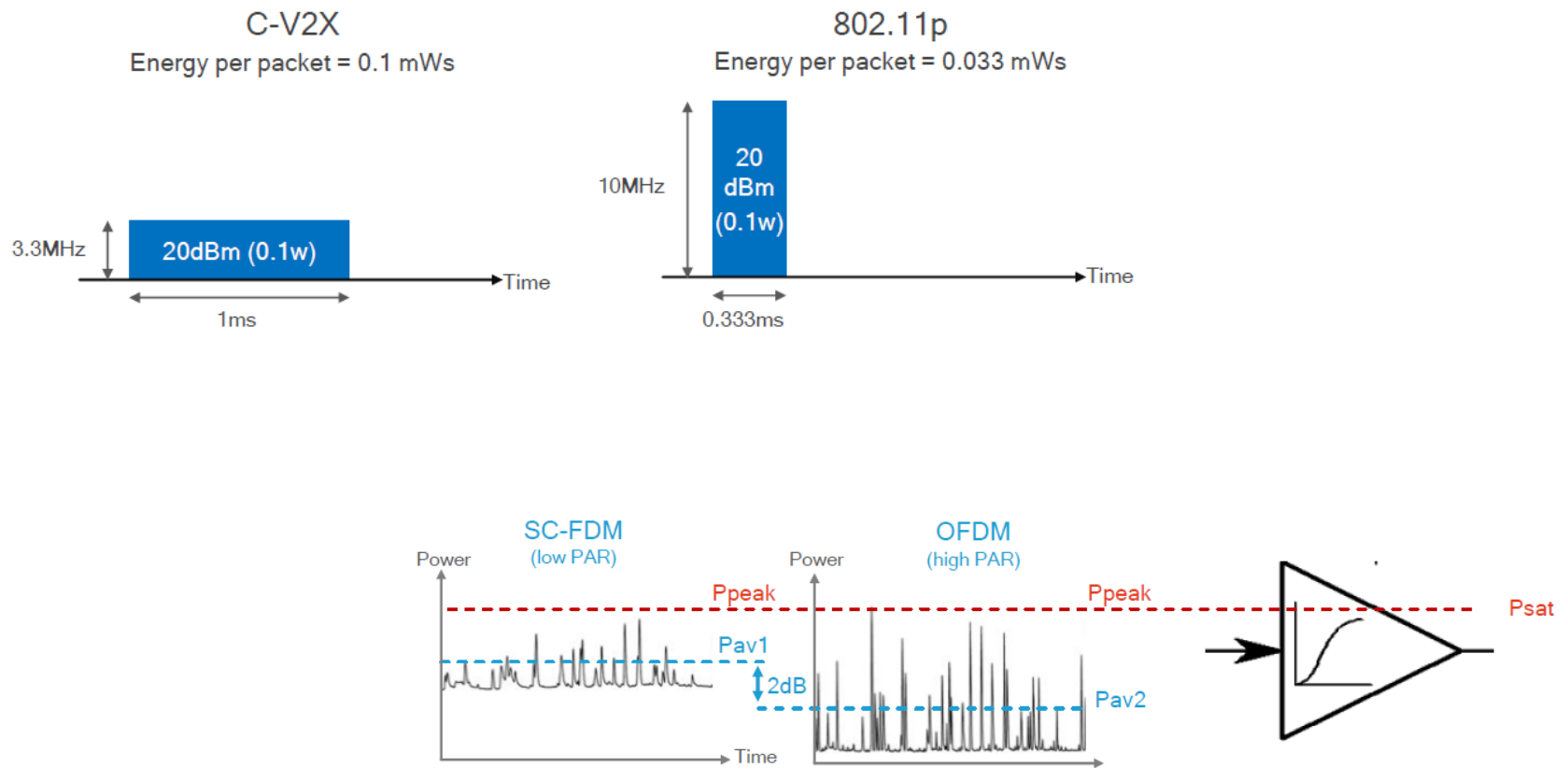
SC-FDM allows for more transmit power than OFDM for the same power amplifier

Coding gain from turbo codes and HARQ retransmission lead to longer range

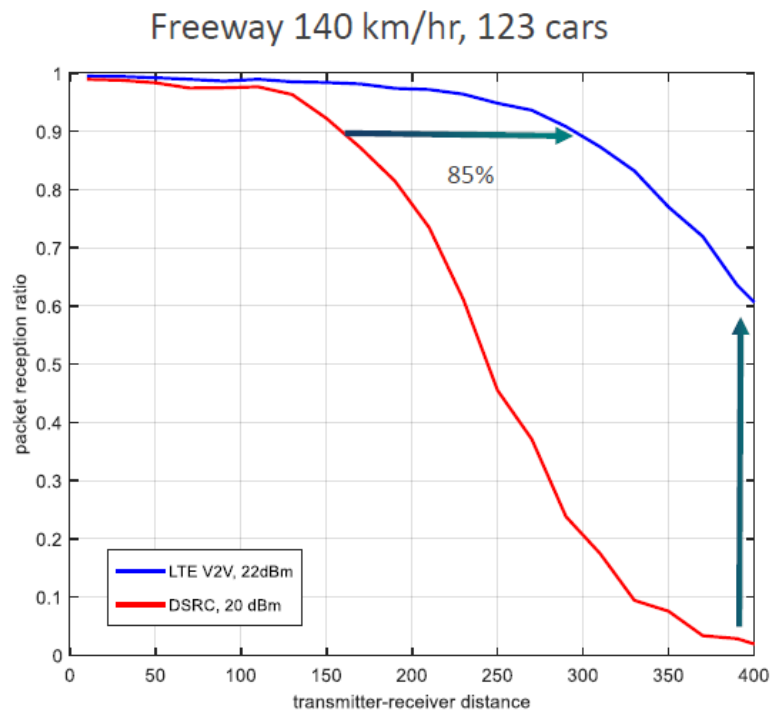


~2X
Longer range

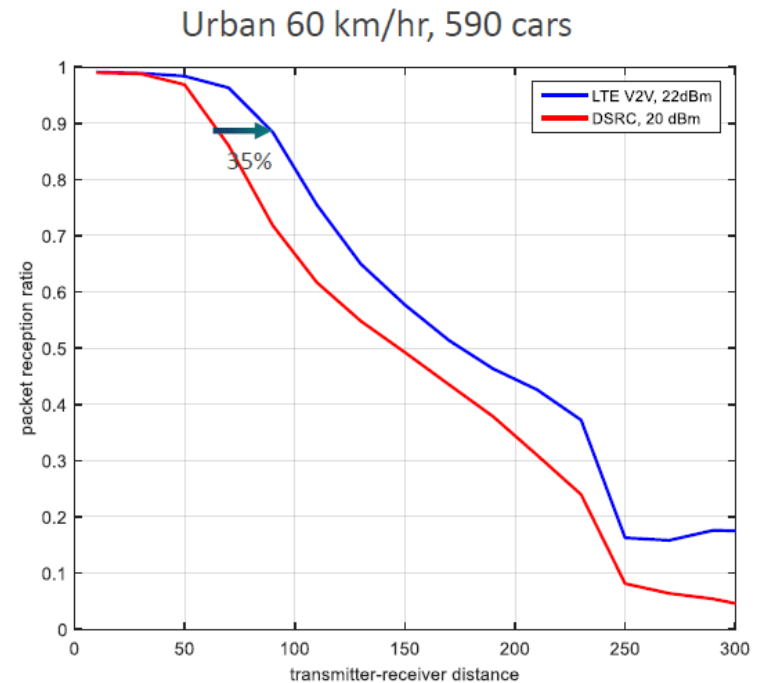
Better efficiency



Performance results

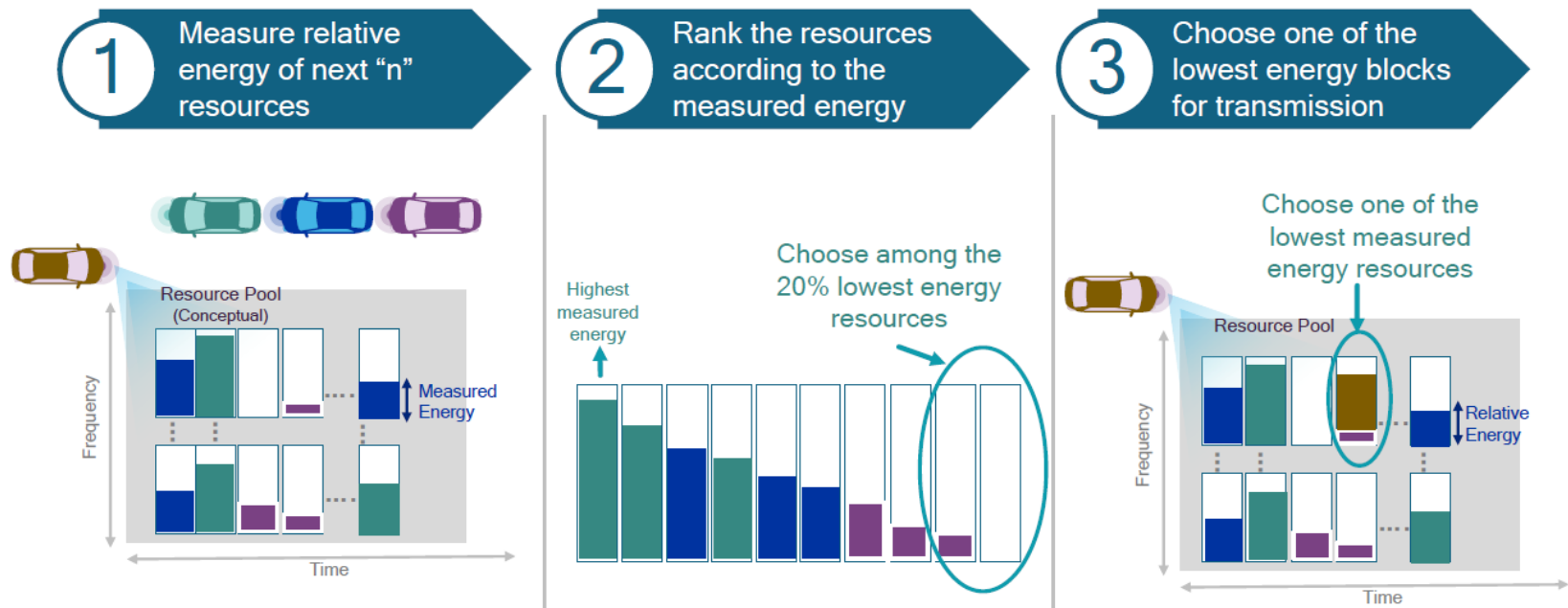


Motorway

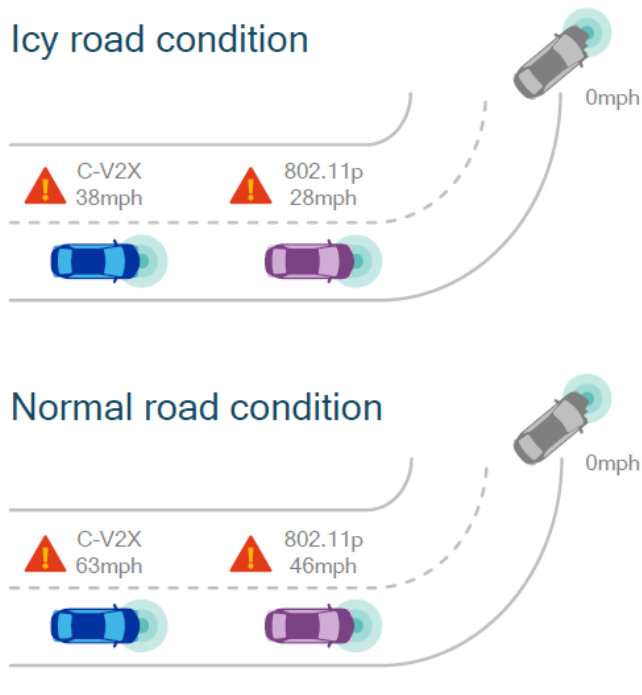


Urban

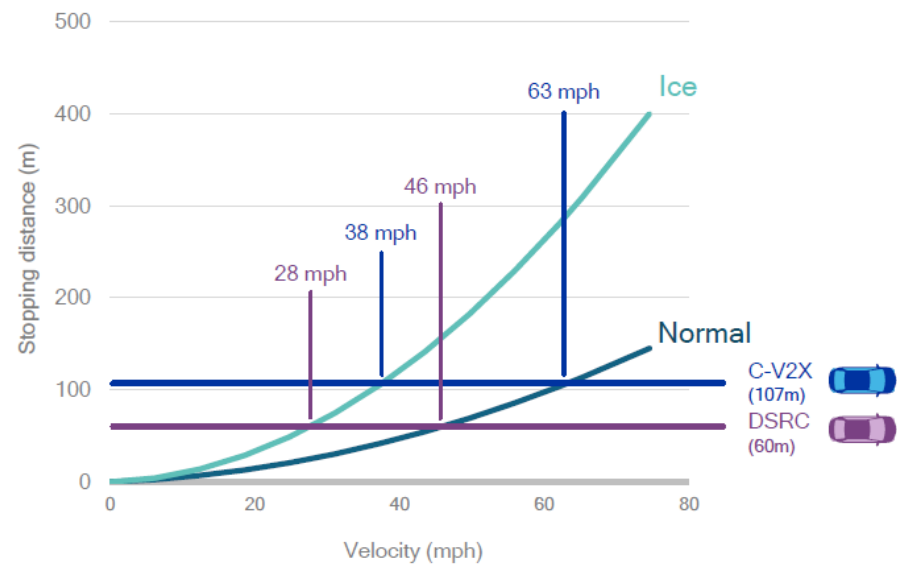
C-V2X Release 14 designed for high contention scenarios



Impact on autonomous driving



Stopping distance estimation¹
(Driver reaction time + braking distance)









Comparison: Operation

Technology operation	802.11p	C-V2X Rel-14/15	C-V2X Rel-16 (expected design)
Specification completed	Completed	Rel-14 completed in 2016. Rel-15 to be completed in 2018	2019
Support for low latency direct communications	✓	✓ (Rel-14 – 4ms)	✓ (≤ 1ms)
Support for network communications	Limited (via APs only)	✓	✓
Can operate without network assistance	✓	✓	✓
Can operate in ITS 5.9 GHz spectrum	✓	✓	✓
SIM-less operation	✓	✓	✓
Security and privacy on V2V/V2I/V2P	✓ (as per IEEE WAVE and ETSI-ITS security services)	✓ (as per IEEE WAVE and ETSI-ITS security services)	✓ (as per IEEE WAVE and ETSI-ITS security services)
Security/Privacy on V2N	N/A	✓	✓
Coexistence in 5.9GHz	✓ (Adjacent channel with 3GPP tech)	✓ (Adjacent channel with 11p; co-channel coexistence from R14 onwards)	✓ (Adjacent channel with 11p; co-channel coexistence from R14 onwards & WiFi)
Evolution path	✗	✓	✓ Compatible with Rel-14/15

Comparison: Radio design

Radio design	802.11p	C-V2X Rel-14/15	C-V2X Rel-16(expected design)
Synchronization	Asynchronous	Synchronous	Synchronous
Channel size	10/20Mhz	Rel-14 – 10/20Mhz Rel-15 – 10/20/Nx20 MHz ¹	10/20 MHz and wideband (e.g. 40/60/80/100/...MHz)
Resource multiplexing across vehicles	TDM only	TDM and FDM	TDM and FDM possible
Data channel coding	Convolutional	Turbo	LDPC
HARQ Retransmission	No	Rel-14/15 – yes Rel-15 – ultra-reliable communication possible ²	Yes, along with ultra-reliable communication
Waveform	OFDM	SC-FDM	Likely OFDMA but many options available
Resource Selection	CSMA-CA	Semi-persistent transmission with frequency domain listen-before-talk	Many options available
MIMO support	No support standardized	Rx diversity for 2 antennas mandatory Tx diversity for 2 antennas supported	Support up to 8 tx/rx antennas Mandatory support for 2tx/rx antennas Both diversity and spatial multiplexing supported
Modulation support	Up to 64QAM	Up to 64 QAM	Up to 256QAM

Comparison: Performance

Use Cases			
	802.11p	C-V2X Rel-14/15	C-V2X Rel-16(expected design)
Target Use Cases	Day 1 safety only	Day 1 safety & enhanced safety use cases	Advanced use cases to assist in autonomous driving including, ranging assisted positioning, high throughput sensor sharing & local 3D HD map updates
Performance			
High density support	 Packet loss at high densities	 Can guarantee no packet loss at high densities	 Can guarantee no packet loss at high densities
High mobility support	 Up to relative speeds of 500 km/hr with advanced receiver implementation	 Up to relative speed of 500 km/hr as a minimum requirement.	 Up to relative speed of 500 km/hr as a minimum requirement
Transmission range @ 90% error, 280 km/hr relative speed	Up to ~225m	-Over 450m using direct mode -Very large via cellular infrastructure	-Over 450m using direct mode -Very large via cellular infrastructure
Typical transmission frequency for periodic traffic	Once every 100msec (50ms is also possible)	Once every 100ms (20ms is also possible)	Supports packet periodicities of a few ms.

25-28 February 2019

Where
technology
goes?



**INTELLIGENT
CONNECTIVITY**

5G Mobile Devices



ZTE Axon 10 Pro 5G



LG V50 ThinQ



Samsung S10 5G



Xiaomi Mi Mix 3 5G



Huawei Mate X

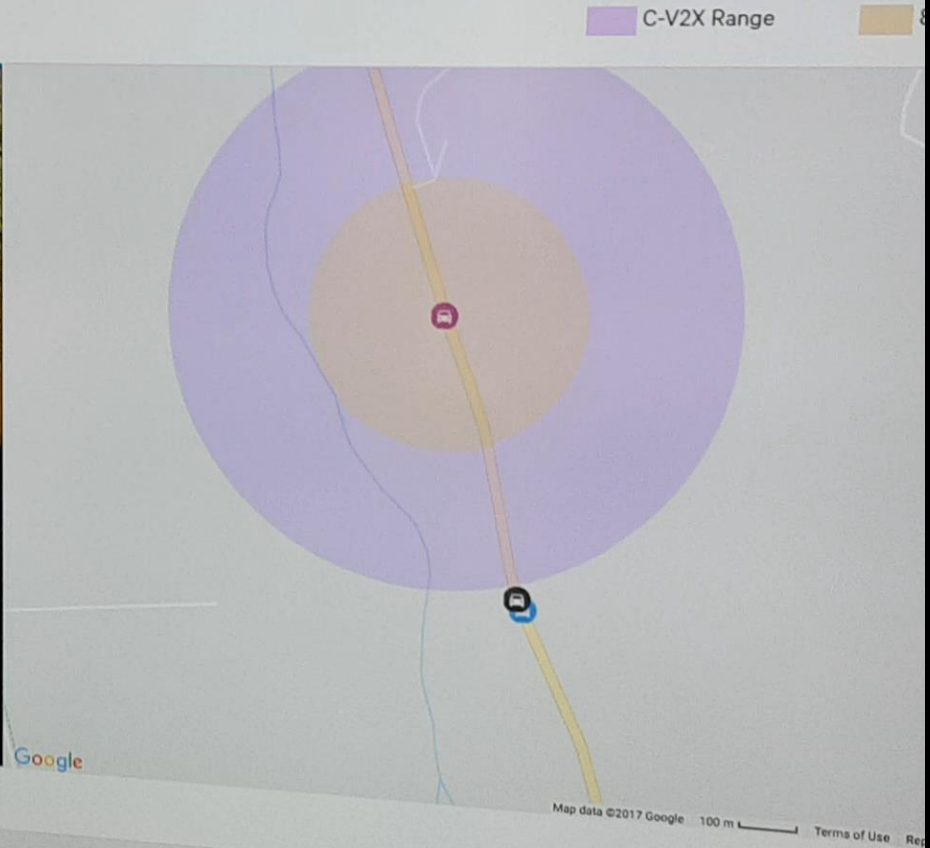
3.23 Gbps of User Experience!!



CARS BUT LESS



Do Not Pass Warning (DNPW)

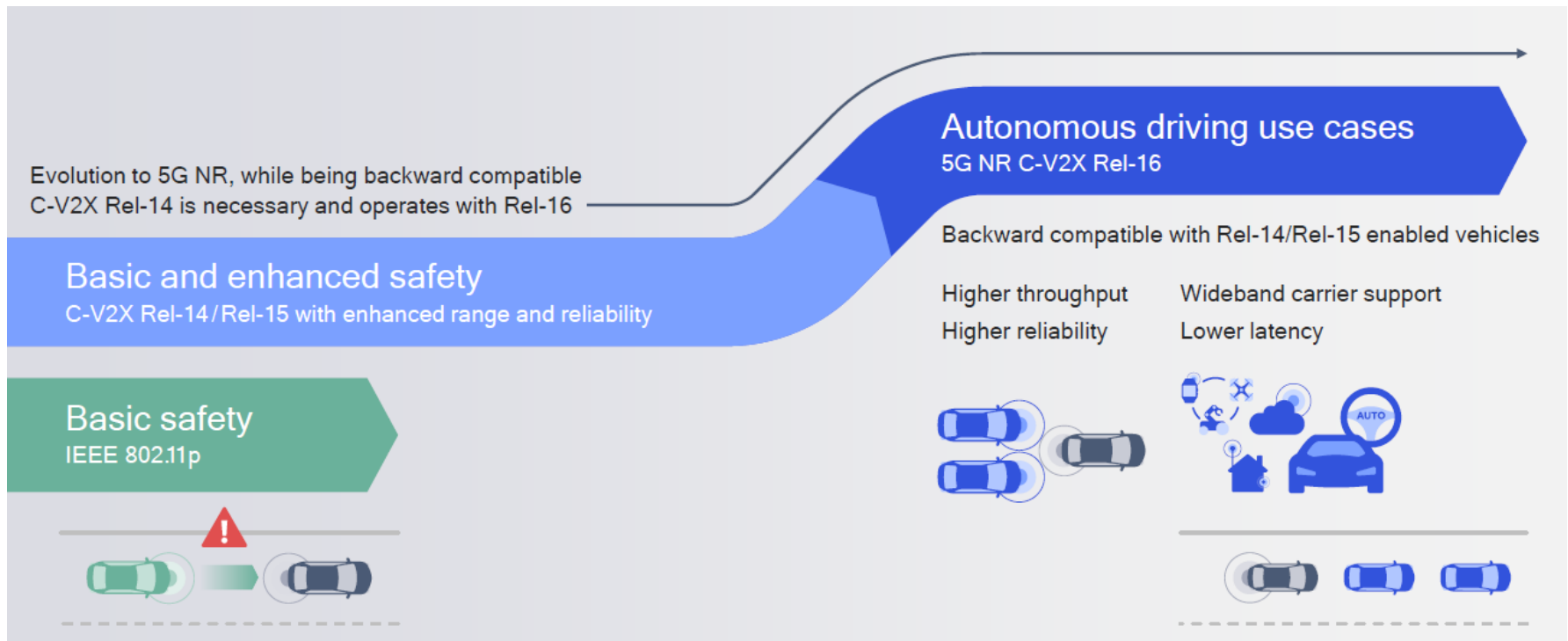




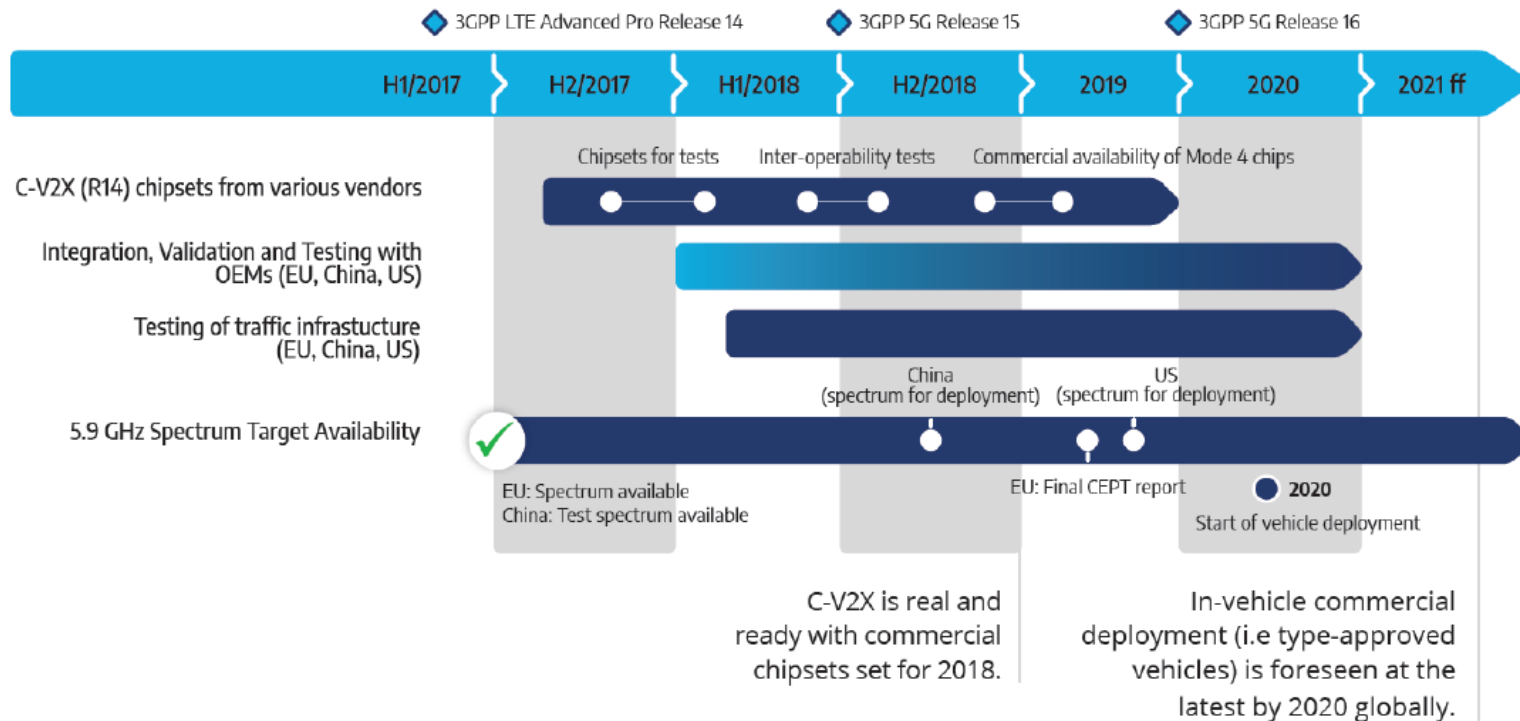
Huge support of C-V2X



Evolution towards 5G



Roadmap for integration



* On march 13th EU talks about ITS-G5

Requirements for autonomous driving

Uses cases for **autonomous driving** applications (SA1 TR22.886)



Vehicle
Platooning



Cooperative Operation,
Sensor sharing



Remote Driving



Advanced Driving

NR-V2X requirements for **autonomous driving** (SA1 TS22.186)

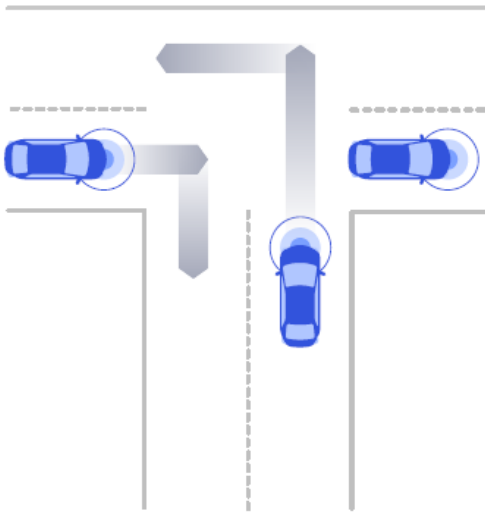
Use Cases	E2E latency (ms)	Reliability (%)	Data rate (Mbps)
Vehicle Platooning	10	99.99	65
Advanced Driving	3	99.999	53
Extended Sensors	3	99.999	1000
Remote Driving	5	99.999	UL:25, DL:1
	Lateral (m)	Longitudinal (m)	
Positioning Accuracy	0.1	0.5	

Note: 5GAA may adjust the above requirements according to inputs from car OEMs.

Intention or trajectory sharing

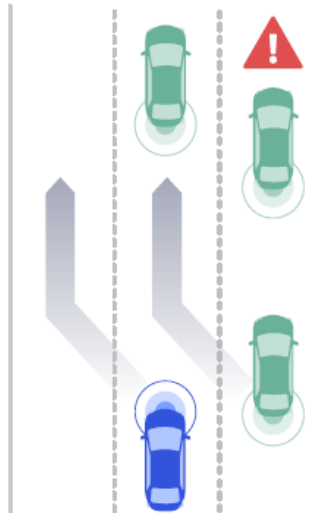
Efficient maneuvers

Autonomous vehicles are able to make quicker, yet safe maneuvers by knowing the planned movements of surrounding vehicles



Advanced path planning

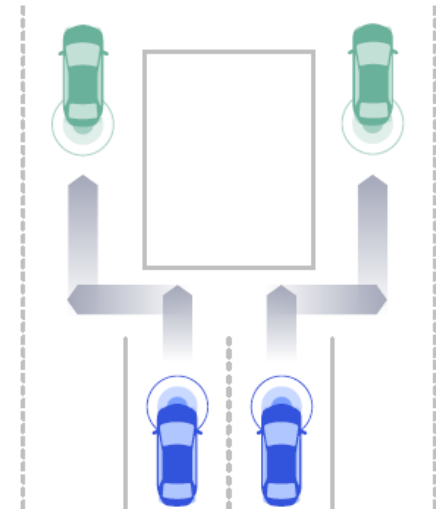
Supporting the level of predictability needed for advanced path planning for autonomous driving



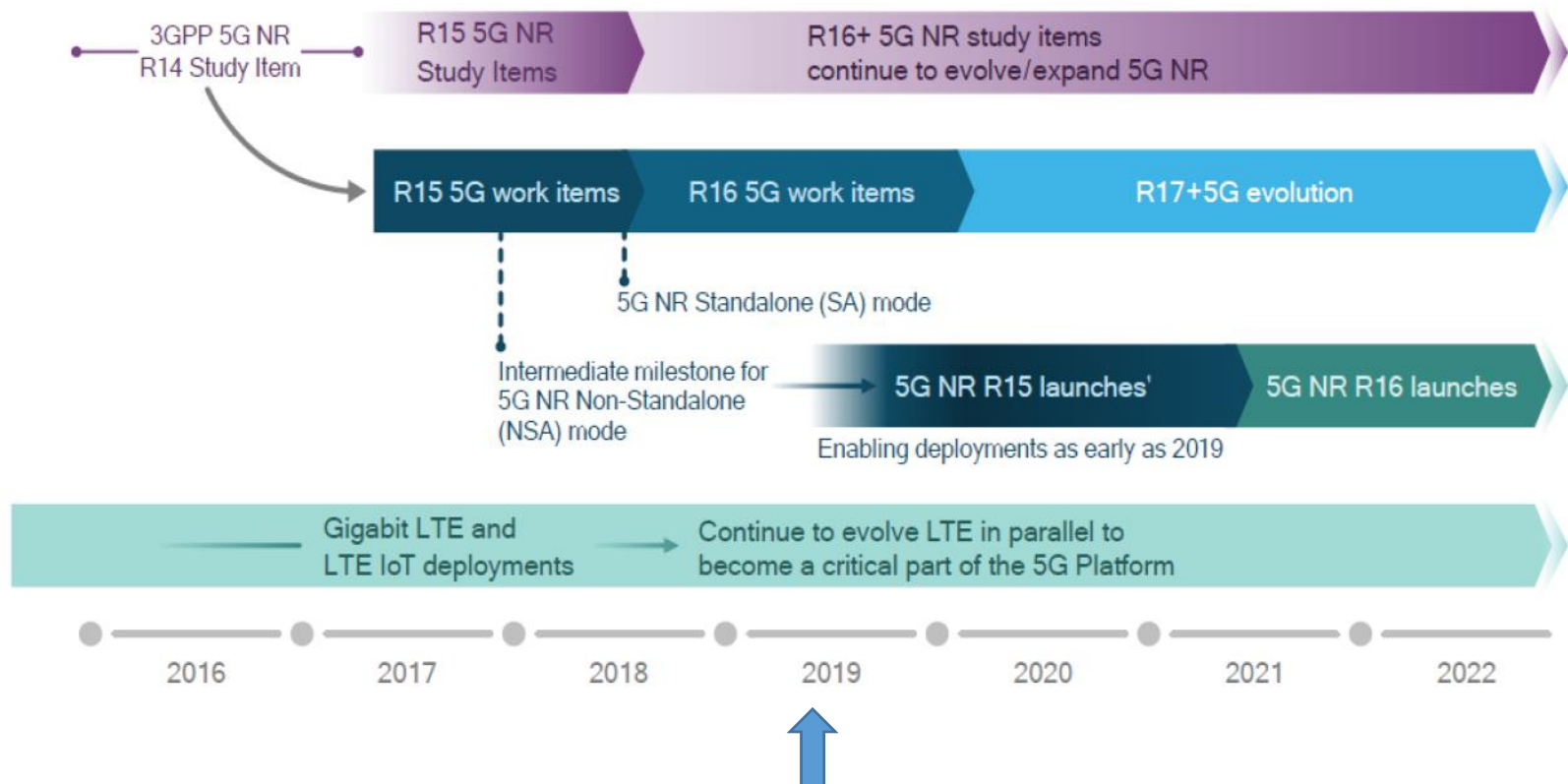
Sudden braking
and lane change
on a freeway

Coordinated driving

Autonomous vehicles are able to choose time-efficient paths toward their given destinations as they know the planned movements of other vehicles



Evolution of the specs



There is a study item on NR C-V2X without significant progress so far... only an index on May 3rd

5G unified connectivity

Intelligently connecting
the car to cloud and
surroundings





Questions?

Prof. Jose F. Monserrat