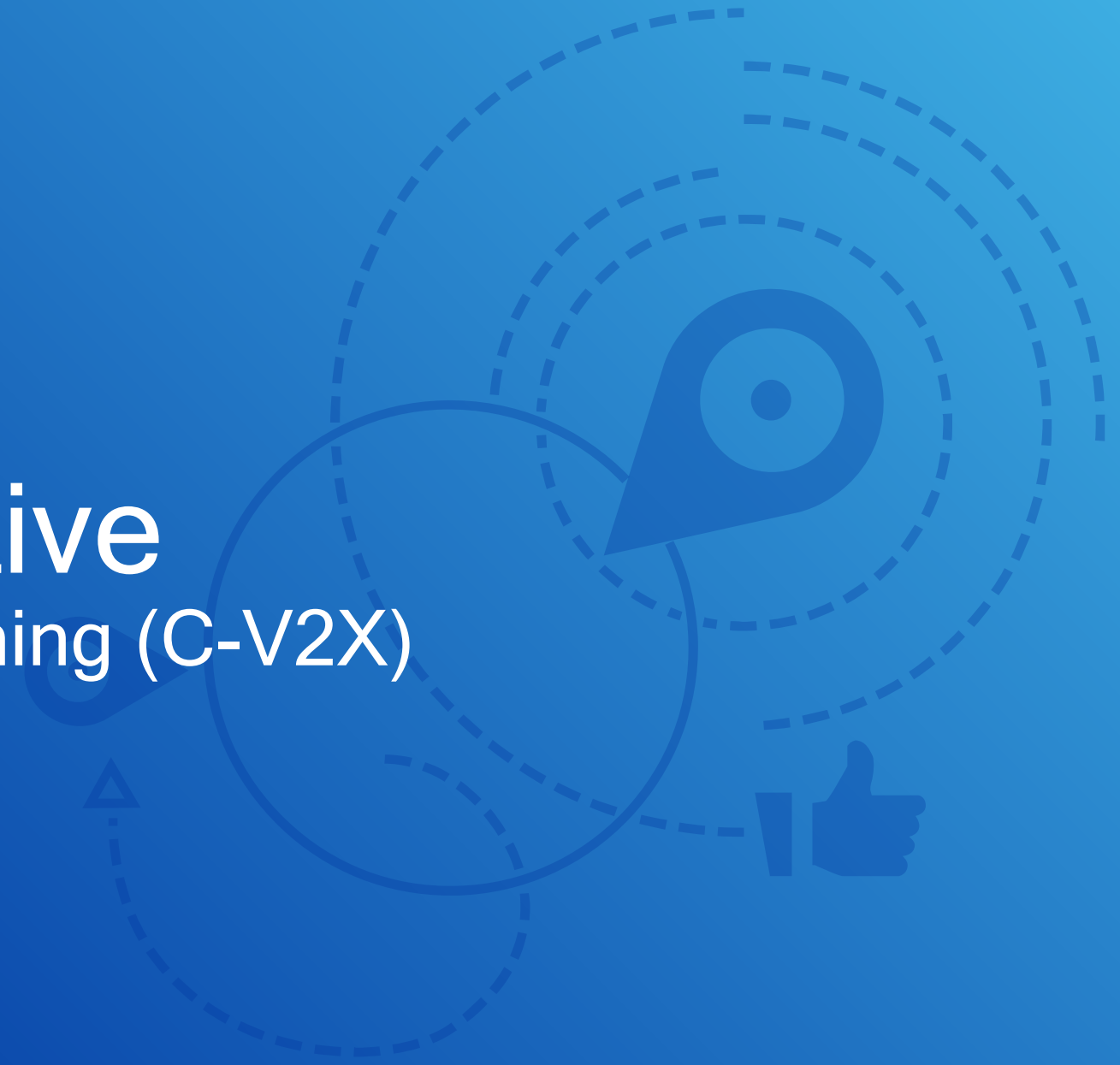
QUALCOMM®

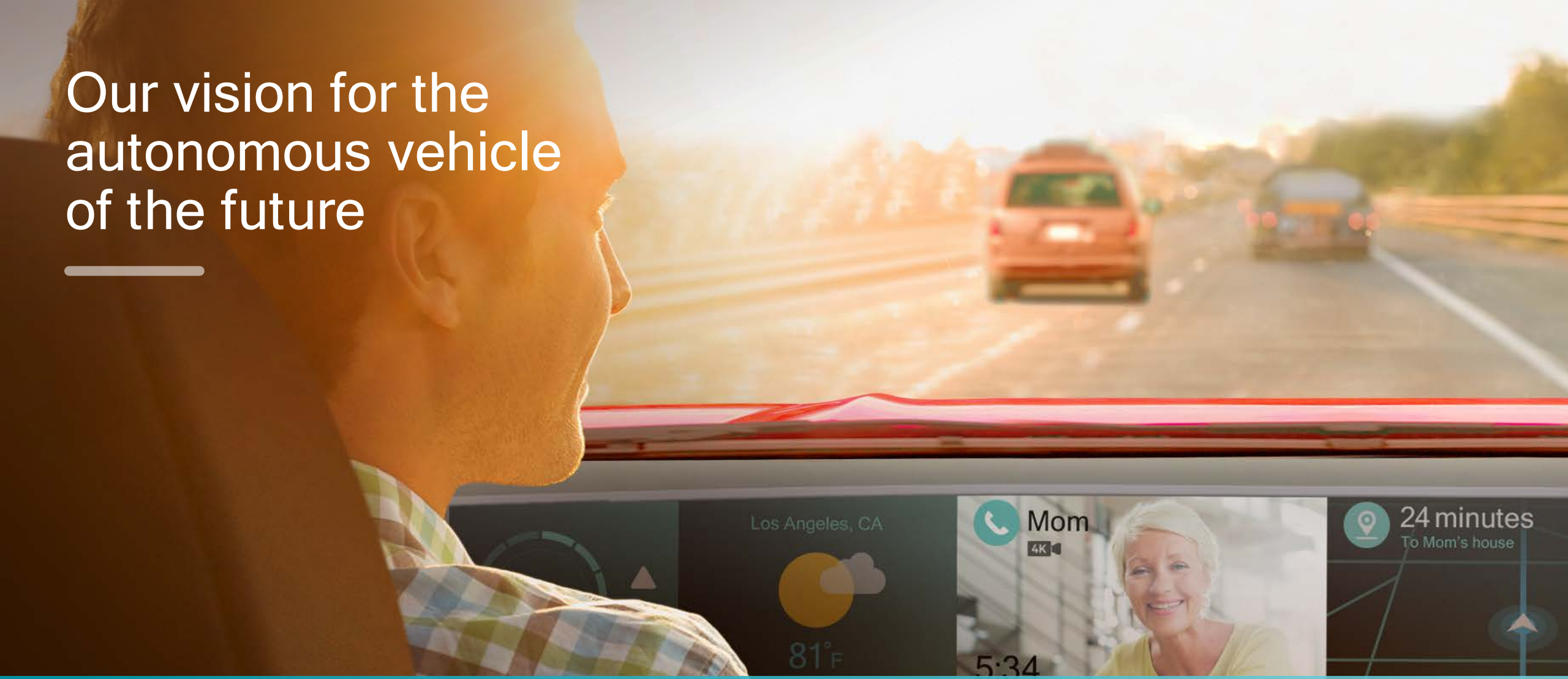
# 5G and Automotive

## Cellular Vehicle-to-Everything (C-V2X)



March 2017

# Our vision for the autonomous vehicle of the future




Intelligently connected

Efficiently shared

Increasingly electric

Increasingly autonomous

# 5G will be a key enabler for our automotive vision

5G

Enhanced mobile broadband


Mission-critical services

Massive Internet of Things

## Unifying connectivity platform for future innovation

Starting today with Gigabit LTE, C-V2X Rel-14, and massive IoT deeper coverage

# V2X offers high level of predictability and autonomy

Complementing other sensor technologies

### Radar
Bad weather conditions, long range, low light situations

### Camera
Interprets objects / signs, practical cost and FOV

### Lidar
Depth perception, medium range

### Ultrasonic
Low cost, short range

### V2X wireless sensor
See through, 360° non-line of sight sensing, extended range sensing

### 3D HD maps
HD live map update, sub-meter level accuracy of landmarks

### Precise positioning
GNSS positioning, dead reckoning, VIO

## ADAS

Advanced Driver Assistance Systems

Brain of the car to help automate the driving process

# The path to 5G will enable safer, autonomous driving

## Starting with C-V2X release 14 - specification completion and global trials in 2017


### Synergistic with existing automotive cellular connectivity platform[1]

Cellular already delivering key services today, e.g. telematics, eCall, connected infotainment

### Delivers enhanced range and reliability for V2X direct communications

Improvements over 802.11p, ~2x range[2], or more reliable performance at the same range

### Leverages existing cellular infrastructure for network communications

Offering new business models and economic benefits (e.g. combined RSUs and eNBs)

### Rich roadmap towards 5G with strong ecosystem (infra, MNO, smartphone)

Technology evolution to address expanding capabilities/use cases

1. 60% Cellular penetration in new light vehicles sales by 2021; 2. Based on Qualcomm Research simulations

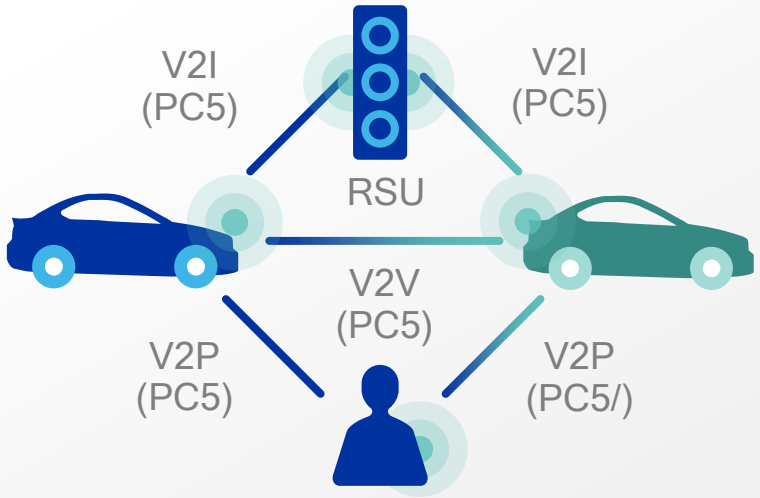
# C-V2X defines two complementary transmission modes

## Direct communications

V2V, V2I, and V2P on “PC5” Interface, operating in ITS bands (e.g. ITS 5.9 GHz) independent of cellular network

### PC5 interface

e.g. location, speed

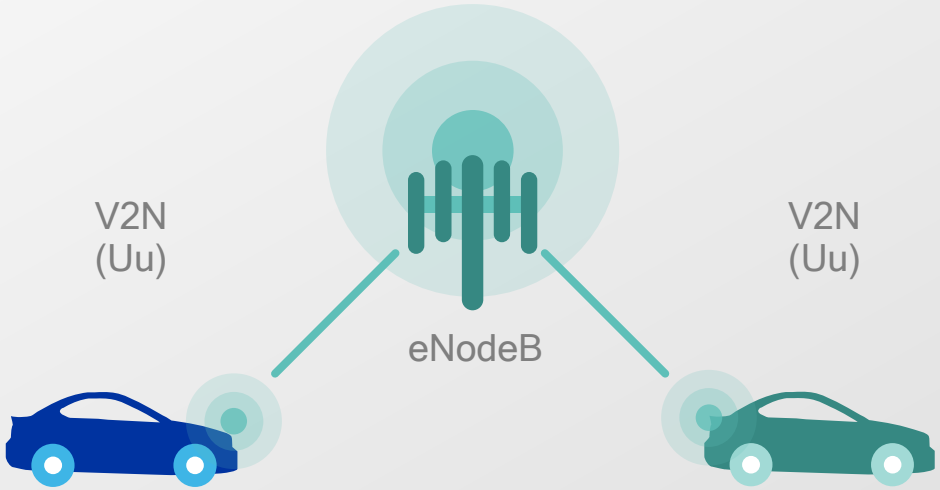



## Network communications

V2N on “Uu” interface operates in traditional mobile broadband licensed spectrum

### Uu interface

e.g. cloud services




PC5 operates on 5.9GHz; whereas, Uu operates on commercial cellular licensed spectrum

# C-V2X is designed to work without network assistance[1]

## V2V/V2I/V2P direct communications enables low latency applications

**USIM-less operation**

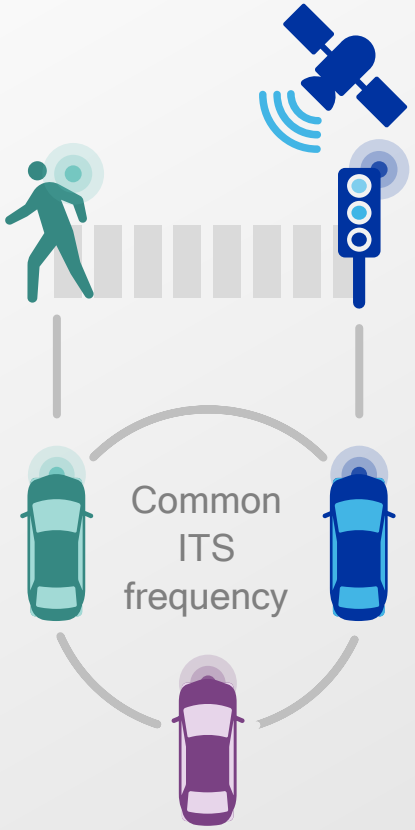
C-V2X direct communications doesn't require USIM

**Autonomous resource selection**

Distributed scheduling, where the car selects resources from resource pools without network assistance

**GNSS time synchronization**

Besides positioning[2], C-V2X also uses GNSS for time synchronization without relying on cellular networks




Direct communications
(via PC5 interface on 5.9GHz)

1; 3GPP also defines a mode, where eNodeB helps coordinate C-V2X Direct Communication; 2 GNSS is required for V2X technologies, including 802.11p, for positioning. Timing is calculated as part of the position calculations and it requires smaller number of satellites than those needed for positioning

# Continuous V2X technology evolution required

## Accommodating ever-evolving use cases and safety requirements

Evolution to 5G, while maintaining backward compatibility

### Basic safety
802.11p or C-V2X R14

Established foundation for basic V2X services

Forward collision warning

### Enhanced safety
C-V2X R14

Better link budget leading to longer range and more reliability


Disable vehicle after blind curve

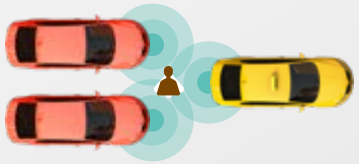
### Advanced safety
C-V2X R15+ (building upon R14)

Higher throughput

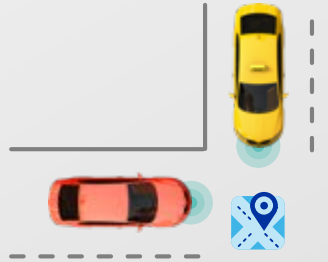
Higher reliability

Wideband ranging and positioning

Lower latency



See-through / camera sensor sharing

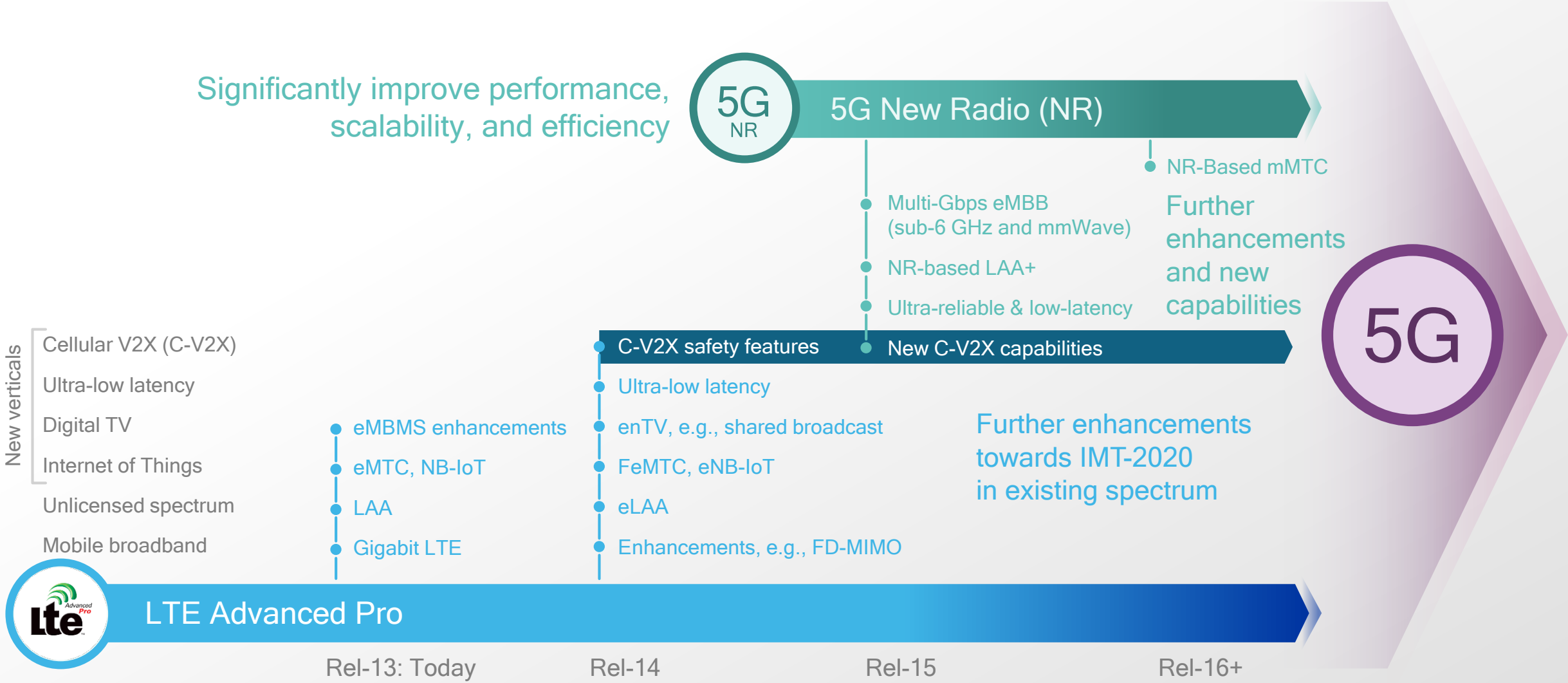


Bird's eye view / HD map updates

Cooperative driving

# LTE Advanced Pro establishes the foundation for 5G

## Pioneering 5G NR technologies and verticals



# C-V2X gaining support from automotive and telecom leaders

## 5GAA is a cross-industry consortia helps define 5G V2X communications

**Automotive industry**

Vehicle platform, hardware, and software solutions

5GAA Automotive Association

**Telecommunications**

Connectivity and networking systems, devices, and technologies

**End-to-end solutions for intelligent transportation mobility systems and smart cities**

Audi BMW MINI Rolls-Royce China Mobile Continental Daimler Danlaw

Denso Ericsson Ficosa Ford Gemalto Huawei Intel LG

NTT DoCoMo Qualcomm Rohde & Schwarz Saic Motor Samsung SK Telecom

T Mobile Valeo Verizon VLAVI Vodafone ZTE Nokia

Source: http://5gaa.org/; accurate as of February 1st , 2017

# Thank you

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