



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

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V2X is a critical component to our vision

Giving vehicles the ability to communicate with each other and beyond

Vehicle-to-infrastructure (V2I)

e.g. traffic signal timing / priority



Vehicle-to-network (V2N)

e.g. real-time traffic / routing, cloud services



Vehicle-to-vehicle (V2V)

e.g. collision avoidance safety systems



Vehicle-to-pedestrian (V2P)

e.g. safety alerts to pedestrians, bicyclists



Delivering significant economic and societal impact

Total potential economic impact of over \$1 Trillion USD per year¹

Fewer driving
fatalities/injuries

>1.2M

people die each year
on the roads worldwide²

More predictable,
productive travel

3.1B

gallons of fuels wasted due
traffic congestion in the US³

Less greenhouse
gas emissions

14%

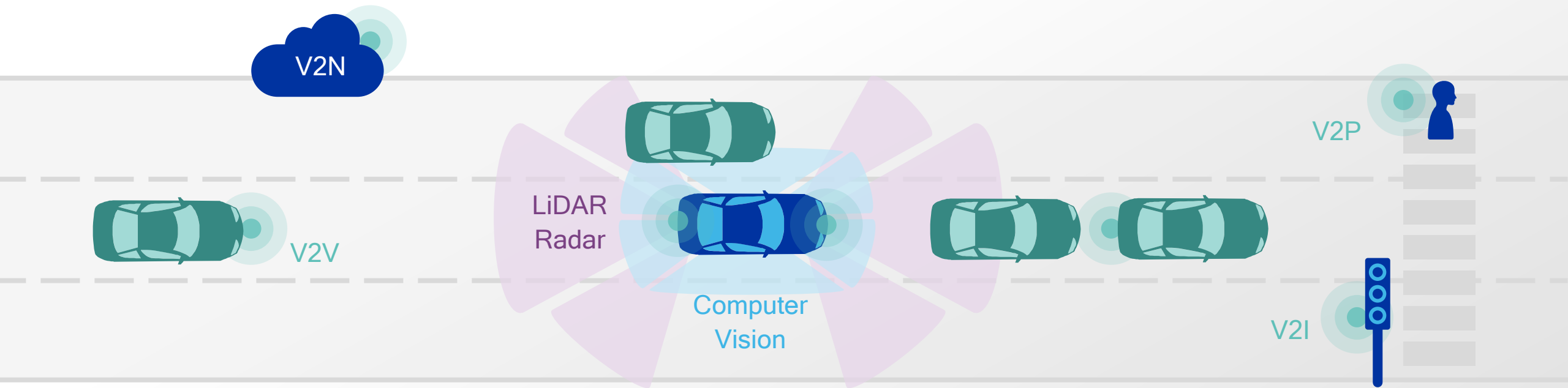
of all global warming
emissions from transportation⁴

¹ Rocky Mountain Institute 2016; ² Global Status Report on Road Safety, World Health Organization 2015; ³ Texas Transportation Institute Urban Mobility Report, 2015;

⁴ U.S., Environmental Protection Agency (EPA) 2014

V2X is a key technology enabler to enhanced ADAS

Bringing significant value to Advanced Driver Assistance Systems (ADAS)



Improved active safety

Provides 360° non-line-of-sight awareness, e.g. intersections/on-ramps, environmental conditions

Better traffic efficiency

Allows vehicles to safely drive closer to each other and enables optimization of overall traffic flow

Increased situational awareness

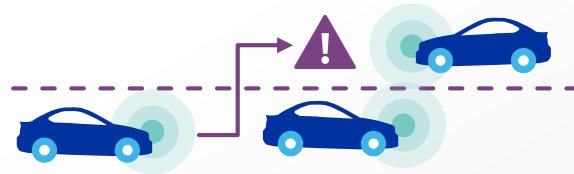
Provides ability to gather data from further ahead to deliver a more predictable driving experience

V2X enables a broad and growing set of use cases

Much more than collision avoidance



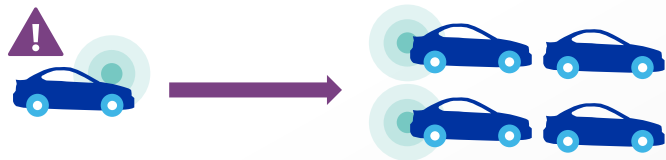
Forward collision warning



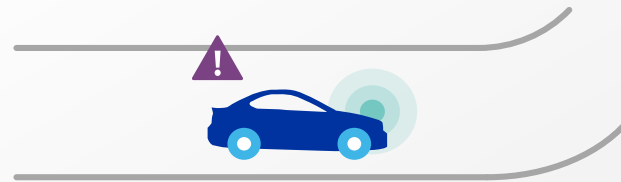
Do Not Pass Warning (DNPW)



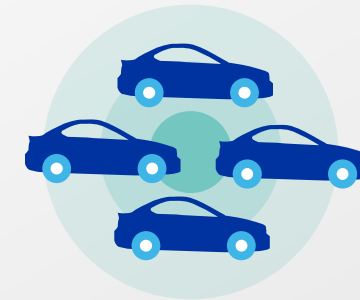
Blind intersection



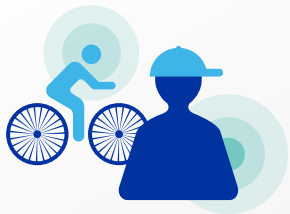
Queue warning



Curve speed warning



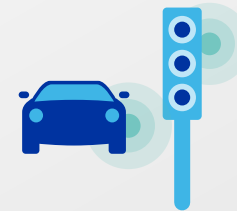
Cooperative adaptive cruise control & platooning



Vulnerable Road User (VRU) alerts



Discover parking and charging



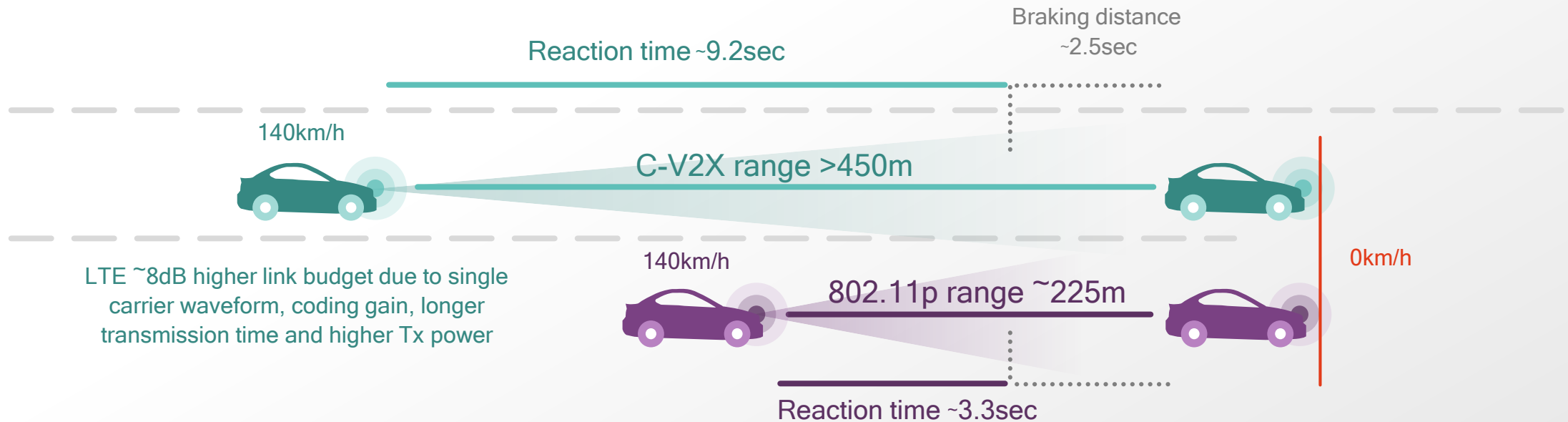
Traffic signal priority and optimal speed advisory



Emergency vehicle alert

C-V2X increases reaction time over 802.11p/DSRC

For improved safety use cases - especially at high-speeds, e.g. highway



Safer driving experience

Increased driver reaction time

Support for high speeds

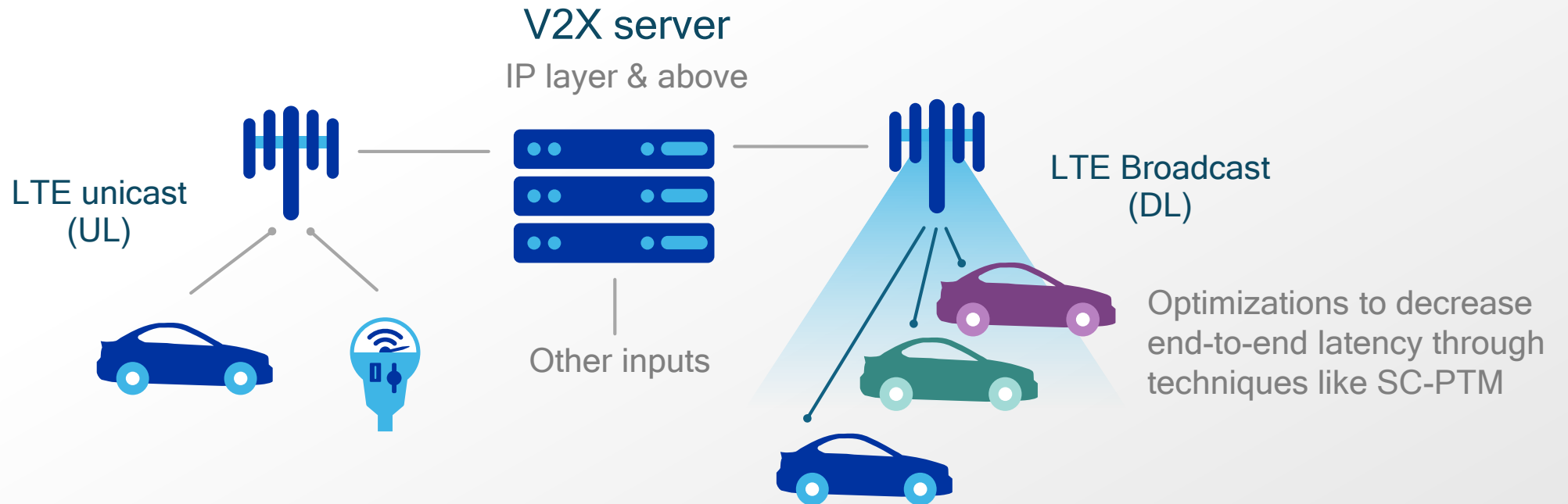
Relative speeds up to 500km/h

Increased situational awareness

Gather data from further ahead

C-V2X leverages existing, ubiquitous LTE networks

With V2X communications via the network



Increase range / utility

Increase situational awareness using messaging via the network

Further enhance V2V safety

By rebroadcasting V2V info via network in high-density use cases

Unified service platform

New opportunities for MNOs² combined with today's services

¹ SC-PTM: Single-Cell - Point-To-Multipoint; ² MNOs: Mobile Network Operators

5G will build upon and enhance C-V2X

New 5G platform will augment / complement C-V2X—no 'rip and replace'



Multi-mode vehicle with simultaneous connectivity across 4G LTE, C-V2X and 5G

4G LTE

Continue to evolve and provide ubiquitous coverage as 5G is rolled out

C-V2X

C-V2X direct and network communications

5G

Bring new capabilities for C-V2X network communications and augment C-V2X direct communications over time

In summary



V2X is a critical component of our vision for the always-connected, more autonomous vehicle of the future

Cellular V2X brings improvements over 802.11p/DSRC for active safety use cases and beyond - part of 3GPP Release 14

Roadmap to 5G will bring even more potential for the connected vehicle—built upon C-V2X, so no ‘rip or replace’

Qualcomm is leading the way to the connected vehicle of the future - pushing wireless boundaries and bringing new levels of on-device intelligence

Learn more at: www.qualcomm.com/C-V2X

Back Up



Introducing Cellular V2X (C-V2X)

A unified connectivity platform for the connected vehicle of the future



Part of Release 14 of the global 3GPP standard

Target C-V2X specification completion end of 2016¹

Builds upon existing LTE connectivity platform for automotive

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

Enhances LTE Direct for V2X direct communications

Improvements over 802.11p - up to a few additional seconds of alert latency and 2x range²

Leverages existing LTE networks for V2X network communications

Using LTE Broadcast optimized for V2X to offer additional applications/services

Rich roadmap towards 5G with strong ecosystem support

Technology evolution to address expanding capabilities/use cases

¹ For Direct communications component (enhancements to LTE Direct) - overall spec completion expected mid-2017; ² Based on Qualcomm Research simulations (see future slides for further information)

Part of rich roadmap of technologies

Paving the path to 5G

5G

Advanced MIMO
256QAM
FeICIC
Carrier aggregation
SON+
CoMP

Unlicensed spectrum
Internet of Things
FDD-TDD CA
Device-to-device
Dual connectivity

eLAA
Enhanced CA
Massive/FD-MIMO
Enhanced Broadcast
C-V2X
Low Latency

Rel-15 and beyond



Rel-10/11/12
LTE Advanced



Rel-13 and beyond
LTE Advanced Pro

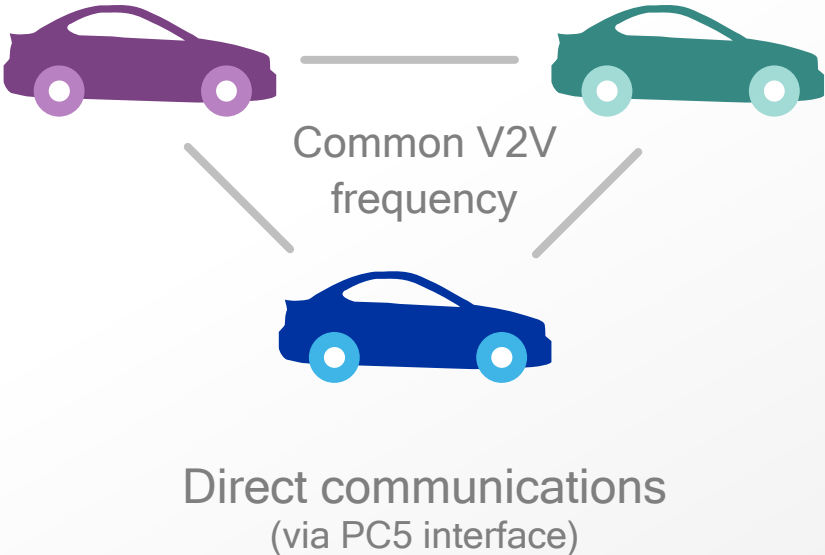
2015

2020+

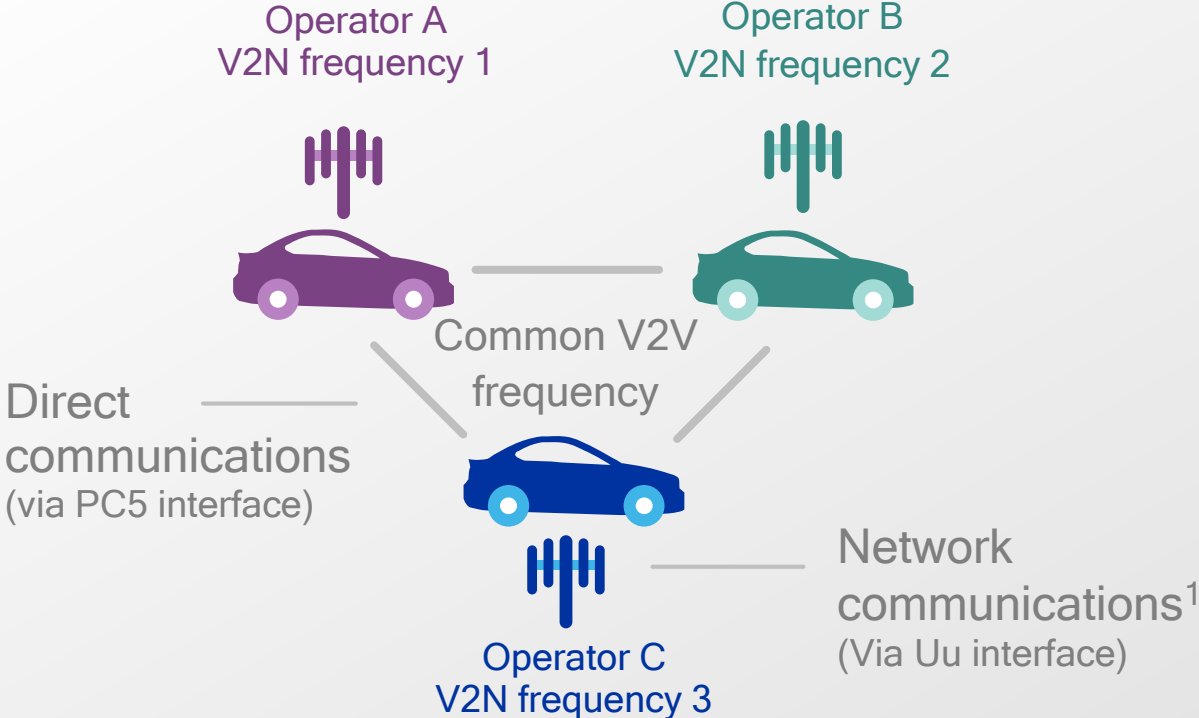
Note: Estimated commercial dates. Not all features commercialized at the same time

C-V2X designed for both in-coverage and out-of-coverage

Out-of-coverage



In-coverage

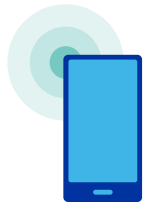


¹ C-V2X also supports a single MNO managed network for in-coverage

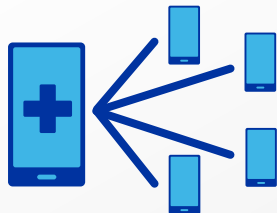
Evolving the LTE Direct device-to-device platform

Release 12

D2D platform for consumer and public safety use cases



Discovery of 1000s of devices/services in ~500m



Reliable one-to-many communications (in- and out-of-coverage)²

Release 13

Expanded D2D discovery and D2D communications



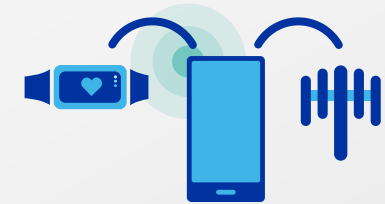
More flexible discovery such as restricted/private¹ and inter-frequency



Device-to-network relays²

Release 14 and beyond

Multi-hop communication and more use cases



Additional D2D communication capabilities, e.g. multi-hop for IoT

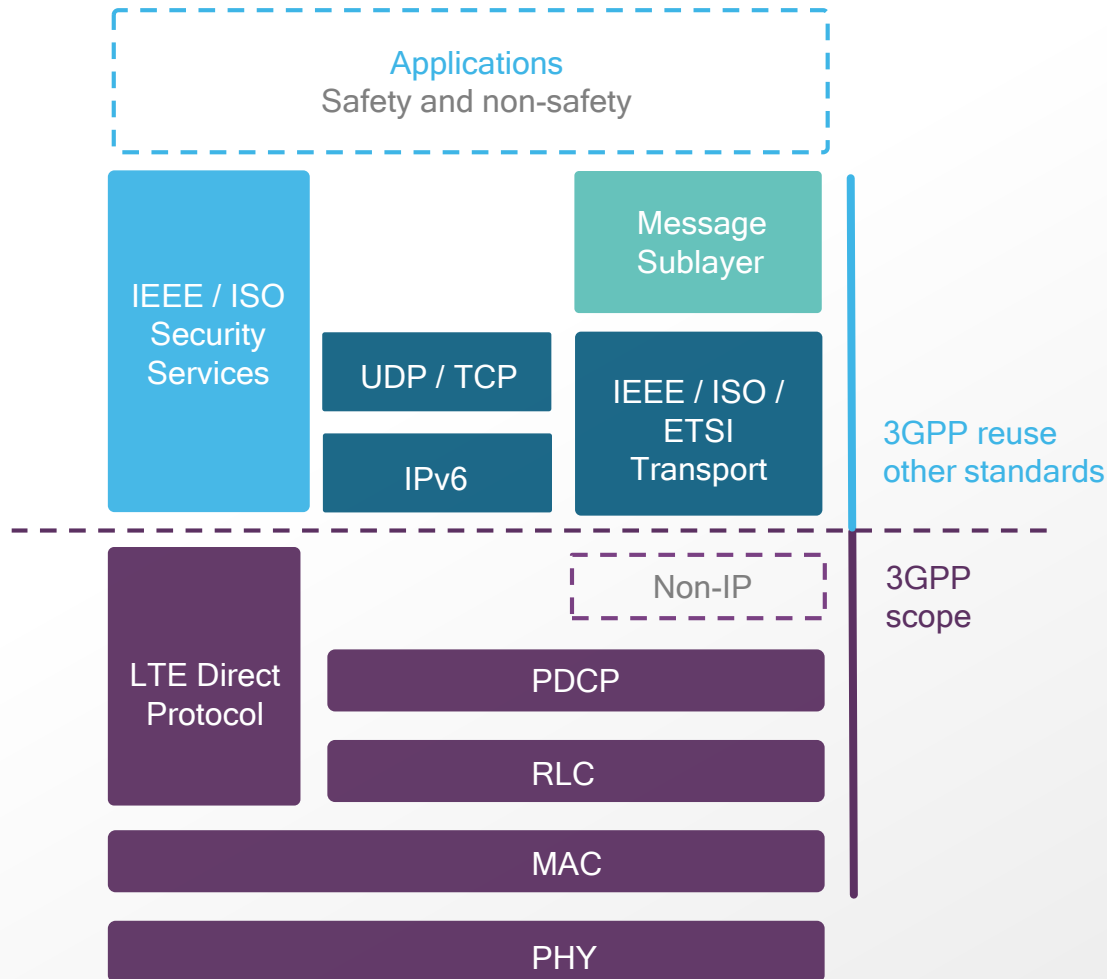


Enhancements for vehicle-to-everything (V2X)

¹ Important for e.g. Social Networking discovery use cases; ² Designed for Public Safety use cases

C-V2X builds upon LTE Direct D2D communications

With enhancements to address V2X requirements



Reuse established service & app layers

Already defined by automotive community, e.g. SAE

Reuse existing security and transport layers

Defined by ISO, ETSI, and IEEE 1609 family

Enhancements to LTE Direct PHY/MAC

To address latency-critical, reliable V2X communications

5G will bring new capabilities for the connected vehicle

New OFDM-based 5G air interface scalable to an extreme variation of requirements



Extreme throughput

Up to multi-Gpbs with more uniformity—wider bandwidths, advanced antenna techniques

Edgeless connectivity

New ways of connect, e.g. multi-hop to extend coverage, plus natively incorporate D2D

High reliability

Ultra-reliable transmissions that can be time multiplexed with nominal traffic through puncturing

1ms end-to-end latency

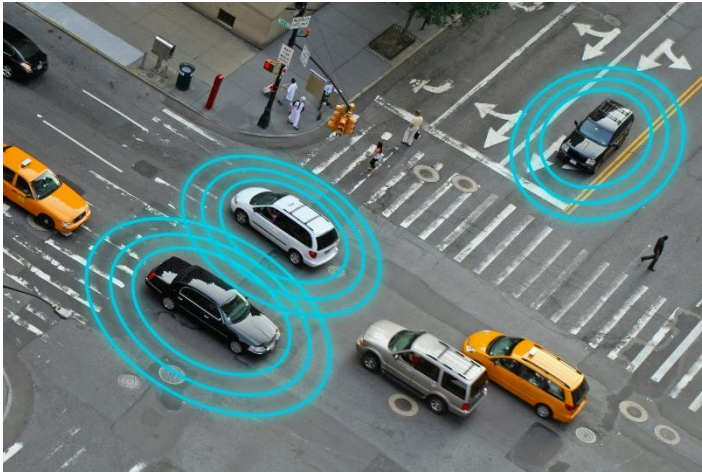
Through a faster, more flexible frame structure; also new uplink RSMA non-orthogonal access

High availability

Multi-connectivity to provide multiple links for failure tolerance and mobility

Enabling the next gen of connected vehicle experiences

Sample use cases



Fully autonomous driving

e.g. cooperative collision avoidance and high-density platooning which requires new levels of latency and reliability, plus larger message sizes



V2X augmented reality

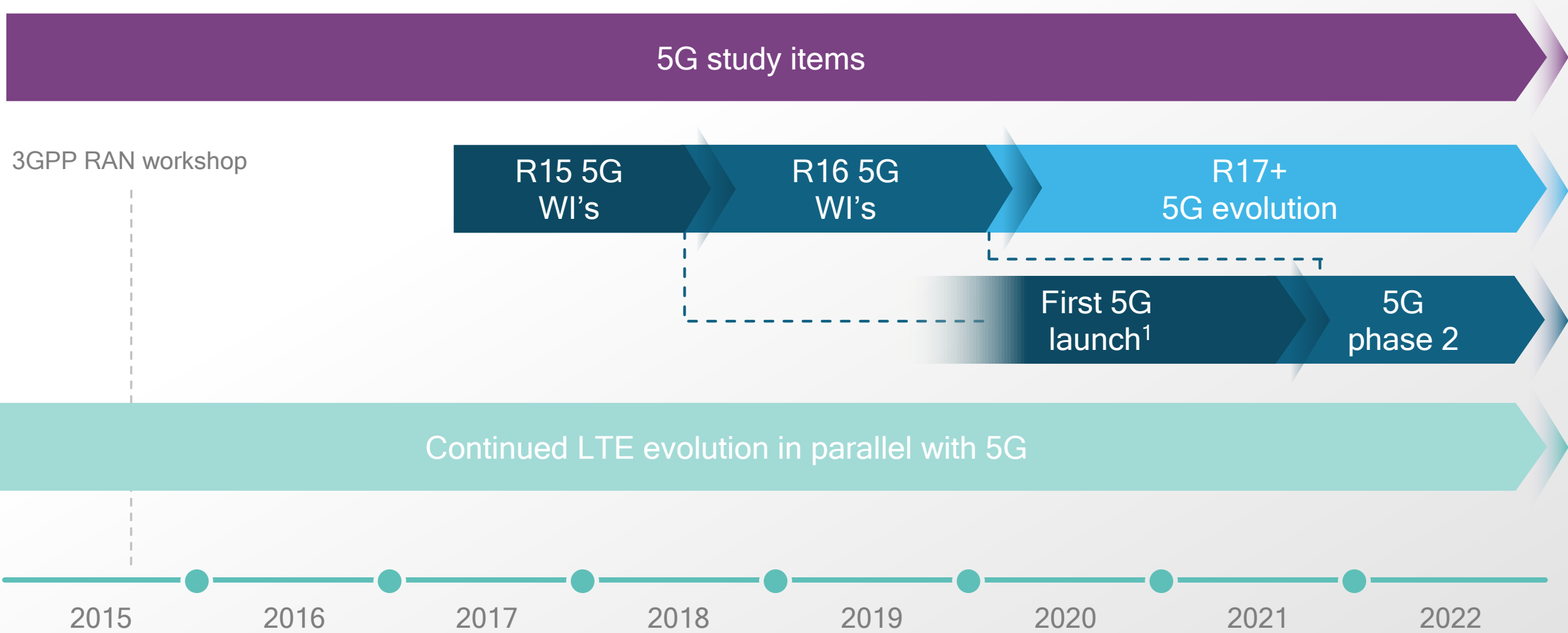
e.g. see-through capability when driving behind truck or leveraging real-time video feeds for navigation systems



Extreme mobile broadband

Passengers can enjoy the next generation of connected immersive experiences, e.g. Virtual Reality, 3D/UHD video telepresence

5G standardization progressing for 2020 launch



Learn more at: www.qualcomm.com/5G

Note: Estimated commercial dates: 1 Forward compatibility with R16 and beyond

Pioneering C-V2X technologies

LTE Direct and LTE Broadcast are the foundation to C-V2X

LTE Direct
Device-to-device
communications
platform

Main contributor to 3GPP
World's 1st LTE Direct discovery demo
World's 1st LTE Direct communications demo

LTE Broadcast
Multicast
communications
platform

Main contributor to 3GPP
World's 1st LTE Broadcast solution
Powered the 1st commercial launch



C-V2X

Actively driving ongoing C-V2X
Release 14 Work Item