



# Leading the world to 5G: Cellular Vehicle-to-Everything (C-V2X) technologies

---

George Tsirtsis, Sr Director of Technology  
Qualcomm Technologies, Inc.  
September 2016



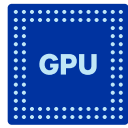
# Our technology is enabling the connected car experience today



Multimedia



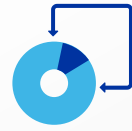
Power Management



GPU



RF



Software/  
HLOS



Position/  
Location



Powerline



Ethernet



Security



Multi-OS support



DSP



Wi-Fi /  
DSRC



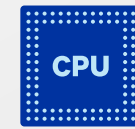
Bluetooth



Wireless EV  
Charging



3G/4G LTE



CPU



Computer  
Vision



# V2X is a critical component to the future of connected cars

## 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

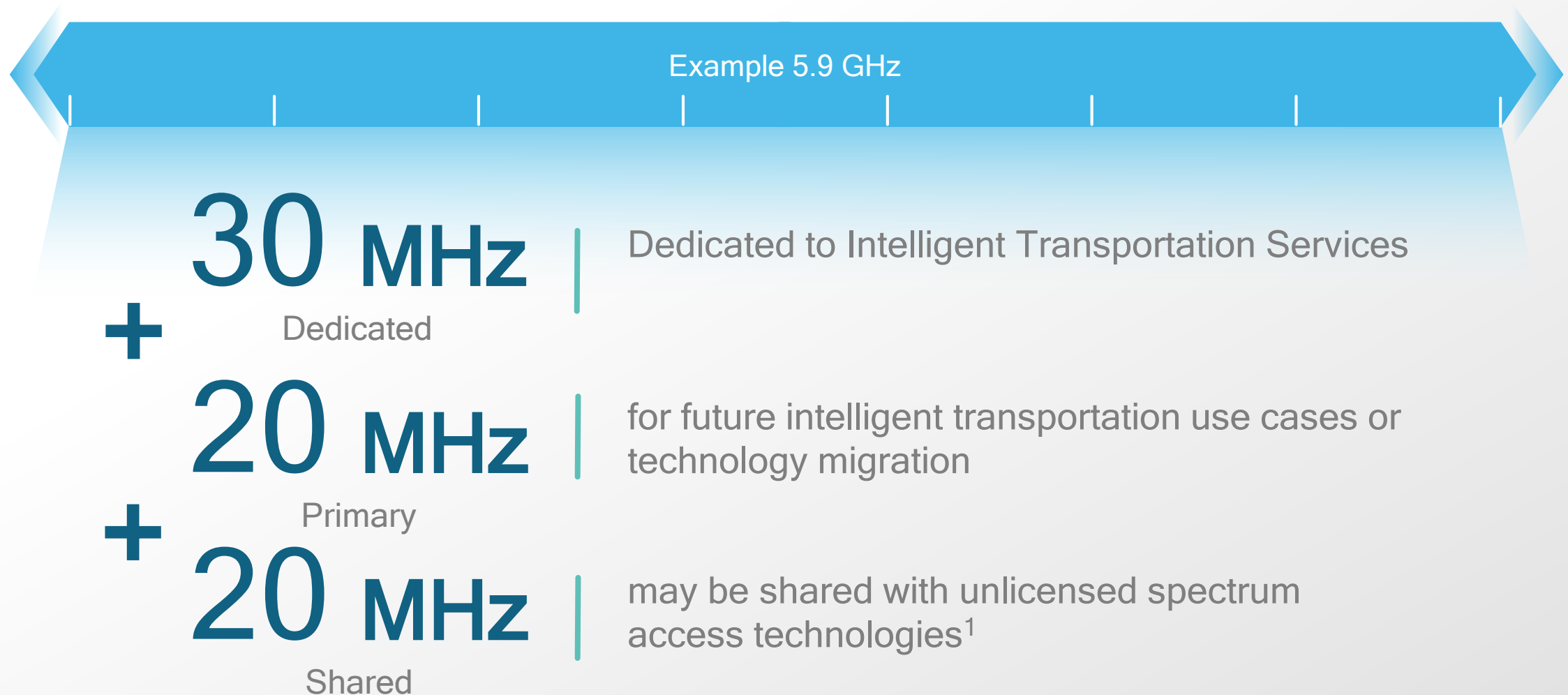


## Vehicle-to-pedestrian (V2P)

e.g. safety alerts to pedestrians, bicyclists



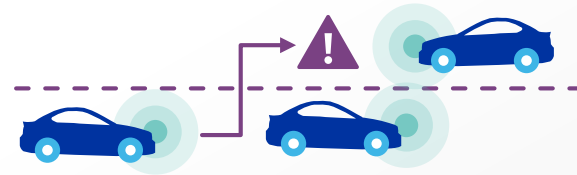
# V2V requires regionally harmonized ITS spectrum



# C-V2X enables a broad and growing set of use cases



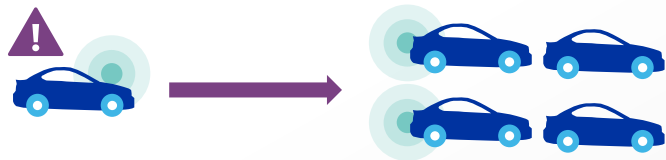
Forward collision warning



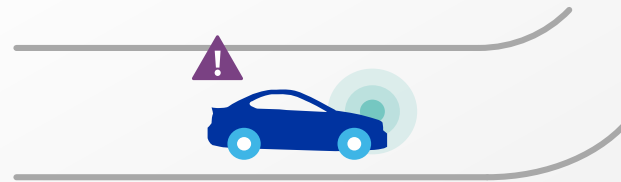
Do Not Pass Warning (DNPW)



Blind intersection



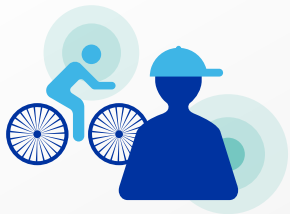
Queue warning



Curve speed warning



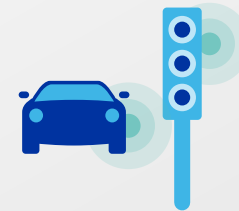
Cooperative adaptive cruise control & platooning



Vulnerable Road User (VRU) alerts



Discover parking and charging



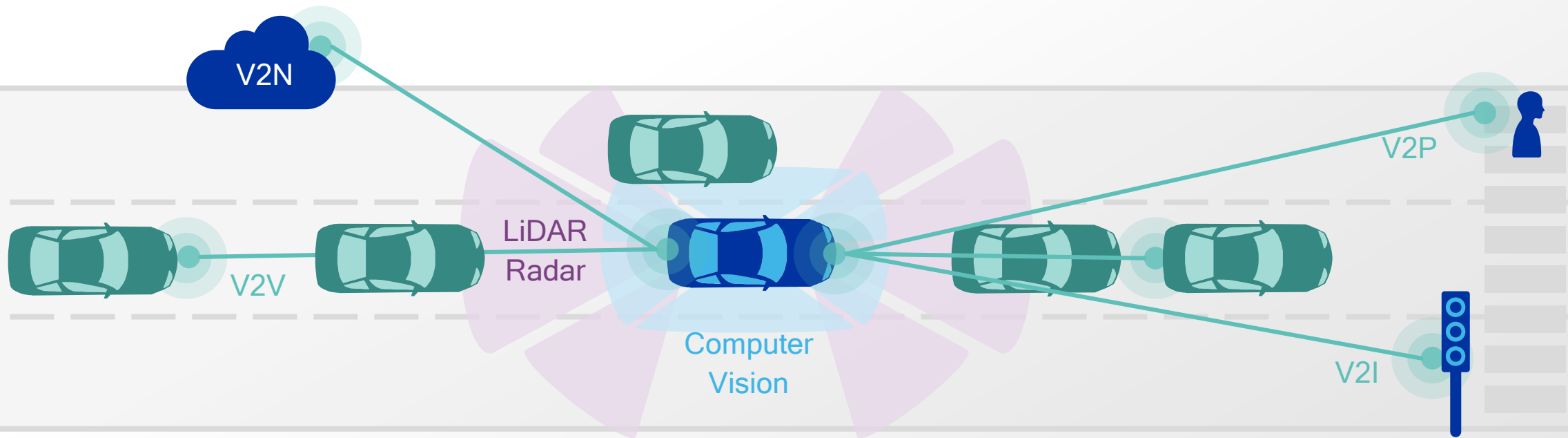
Traffic signal priority and optimal speed advisory



Emergency vehicle alert

# C-V2X as enabler to enhanced ADAS

Vehicular communications as a non-line-of-site sensor for moving objects



## 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

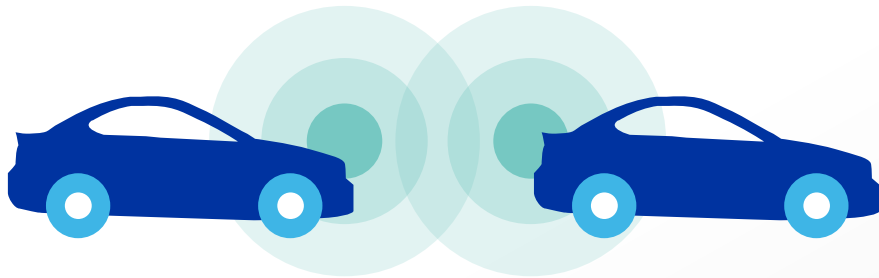
## Increased situational awareness

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

# C-V2X defines two complementary transmission modes

## PC5 interface

e.g. location, speed



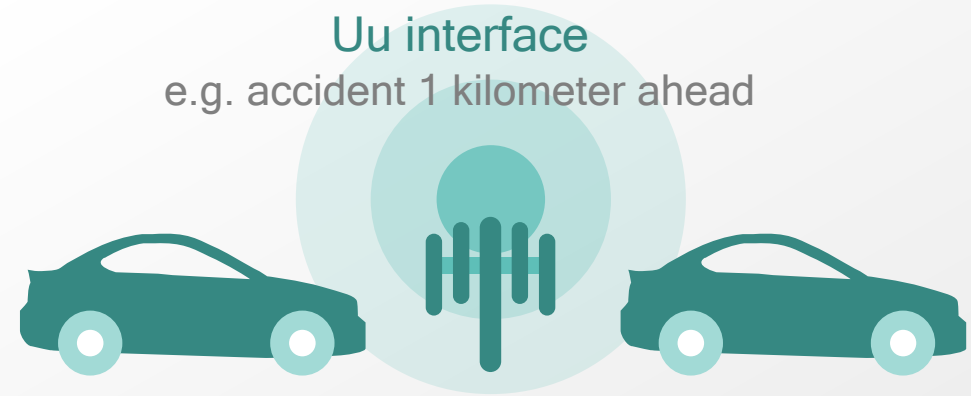
## Direct communications

Building upon LTE Direct device-to-device design with enhancements for high speeds / high Doppler, high density, improved synchronization and low latency

- Proximal direct communications (100s of meters)
- Operates both in- and out-of-coverage
- Periodic broadcast messaging
- Latency-sensitive use cases, e.g. V2V safety

## Uu interface

e.g. accident 1 kilometer ahead



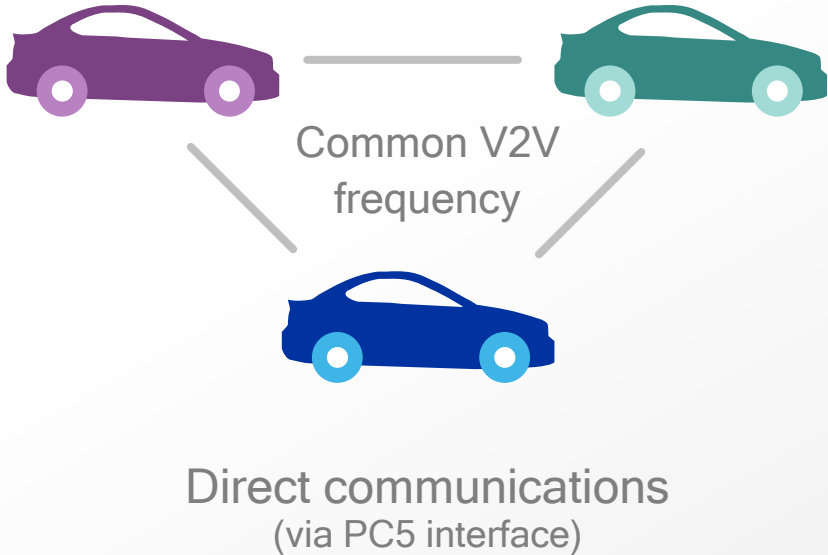
## Network communications

Using LTE Broadcast to broadcast messages from a V2X server to vehicles and beyond. Vehicles can send messages to server via unicast.

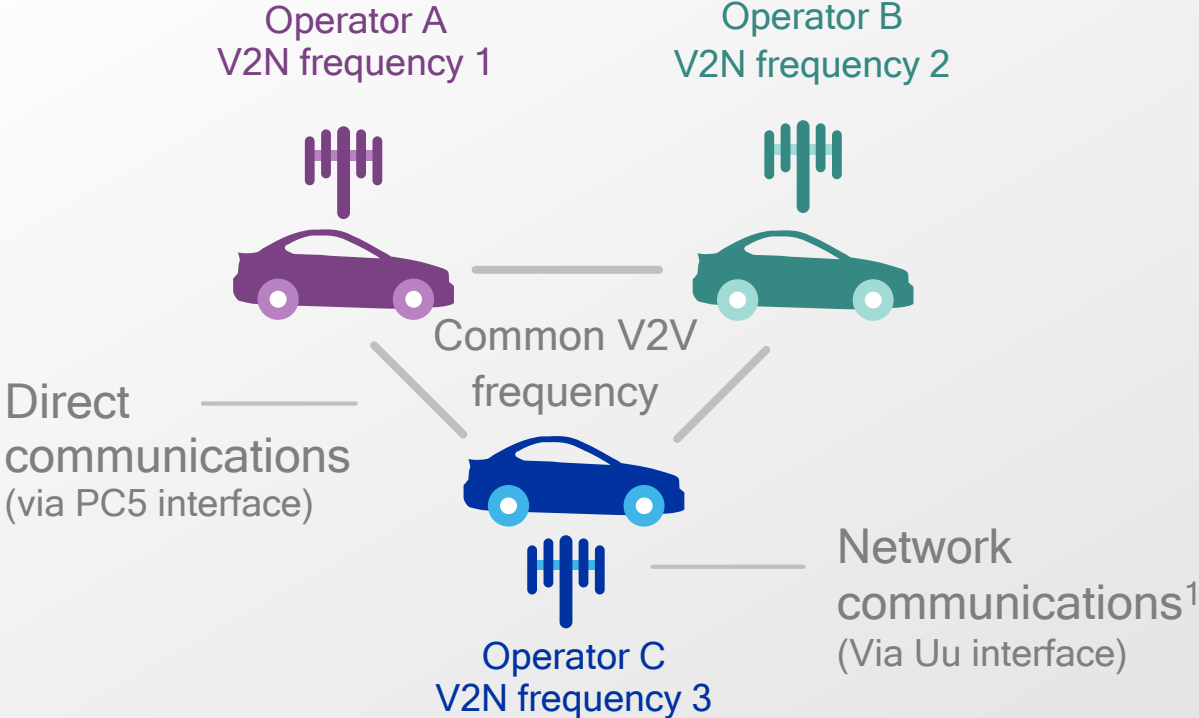
- Wide area networks communications
- Leverages existing LTE networks
- Event based messaging
- More latency tolerant use cases, e.g. V2N situational awareness

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

## Out-of-coverage



## In-coverage

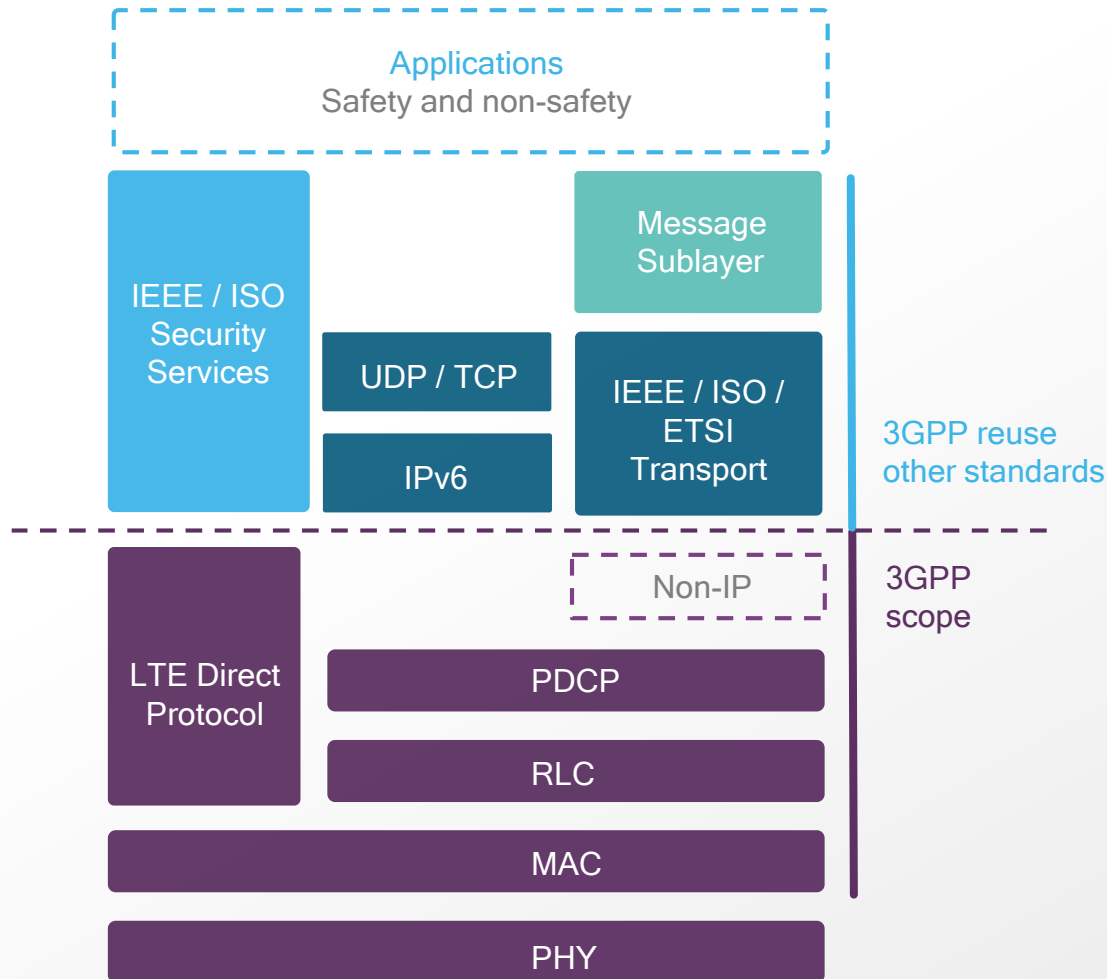


<sup>1</sup> C-V2X also supports a single MNO managed network for in-coverage



# C-V2X is a transport layer alternative to 802.11p

While reusing ITS application, security, and upper layers



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

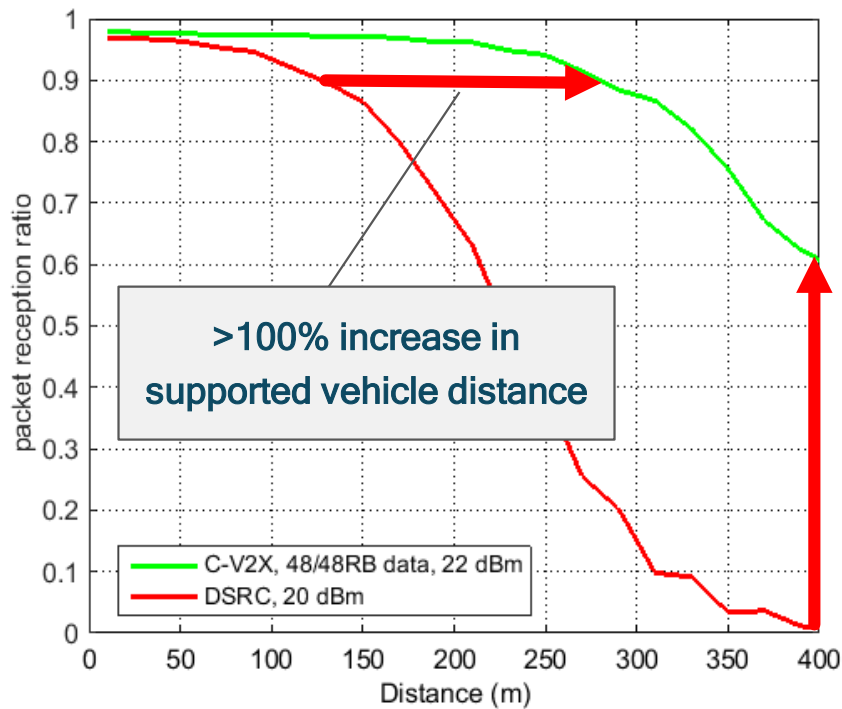
Enhancements to LTE Direct PHY/MAC

To address latency-critical, reliable V2X communications

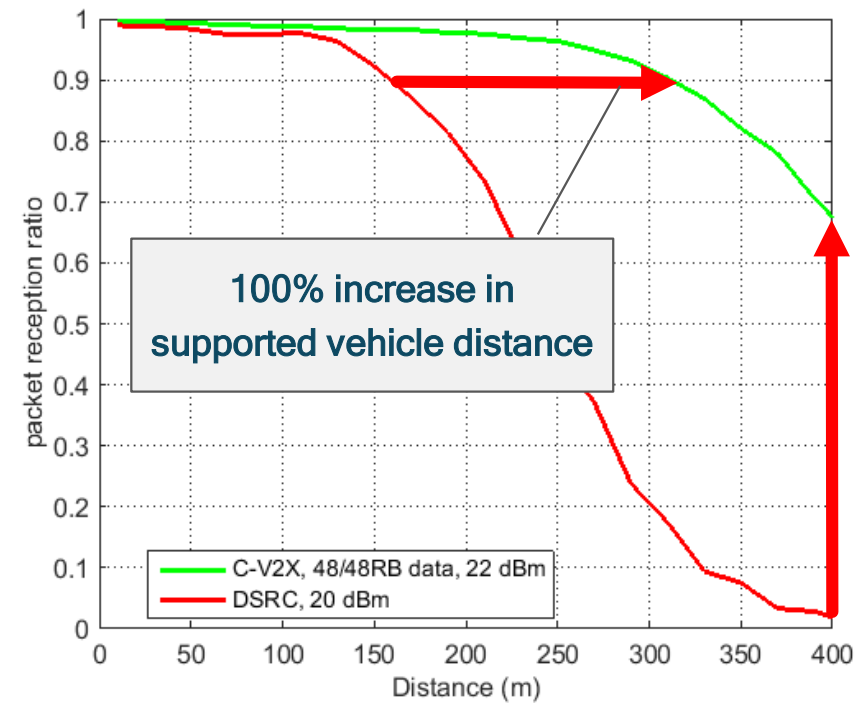
# 3GPP freeway drop

## C-V2V significantly outperforms DSRC at medium/long distances

Very high speed, long-distance scenario\*  
250 kph, 69 cars, 170m inter-vehicle distance



High-speed, medium-distance scenario\*\*  
140 kph, 123 cars, 100m inter-vehicle distance

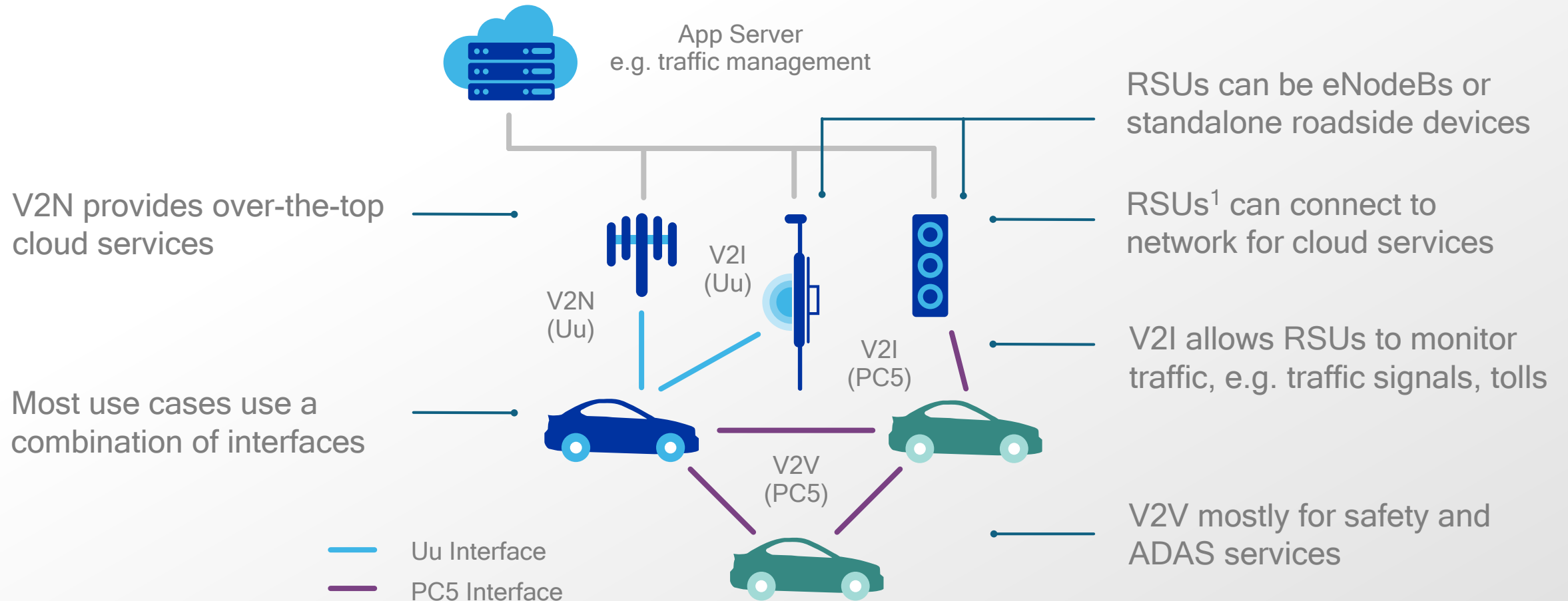


\* Improves PRR from 0.01 to 0.61 at 400m vehicle distance; Improves supported vehicle distance from 126m to 280m at 0.9 PRR; note that 500kph=140m/s

\*\* Improves PRR from 0.02 to 0.68 at 400m vehicle distance; Improves supported vehicle distance from 158m to 312m at 0.9 PRR; note that 280kph=80m/s

# Delivering advanced services to vehicles

Opening up new opportunities and diverse business models for MNOs



<sup>1</sup> Road Side Units

# Cellular V2X - take aways

- Can and will work out of network coverage
- Outperforms 11p in all cases and provides 2x range at high speeds
- Reuses all upper layers, security, and apps developed for DSRC
  
- Cellular and road side infrastructure will likely merge
- Combination of V2V/I/N in cellular context is very powerful
- Cellular V2V 3GPP WI is now frozen; global spec a reality
- Fast evolving cellular ecosystem will deliver superior technology

# Thank you

---

Follow us on:    

For more information, visit us at:

[www.qualcomm.com](http://www.qualcomm.com) & [www.qualcomm.com/blog](http://www.qualcomm.com/blog)

Nothing in these materials is an offer to sell any of the components or devices referenced herein.

©2016 Qualcomm Technologies, Inc. and/or its affiliated companies. All Rights Reserved.

Qualcomm and Snapdragon are trademarks of Qualcomm Incorporated, registered in the United States and other countries. Why Wait is a trademark of Qualcomm Incorporated. Other products and brand names may be trademarks or registered trademarks of their respective owners.

References in this presentation to “Qualcomm” may mean Qualcomm Incorporated, Qualcomm Technologies, Inc., and/or other subsidiaries or business units within the Qualcomm corporate structure, as applicable. Qualcomm Incorporated includes Qualcomm’s licensing business, QTL, and the vast majority of its patent portfolio. Qualcomm Technologies, Inc., a wholly-owned subsidiary of Qualcomm Incorporated, operates, along with its subsidiaries, substantially all of Qualcomm’s engineering, research and development functions, and substantially all of its product and services businesses, including its semiconductor business, QCT.

