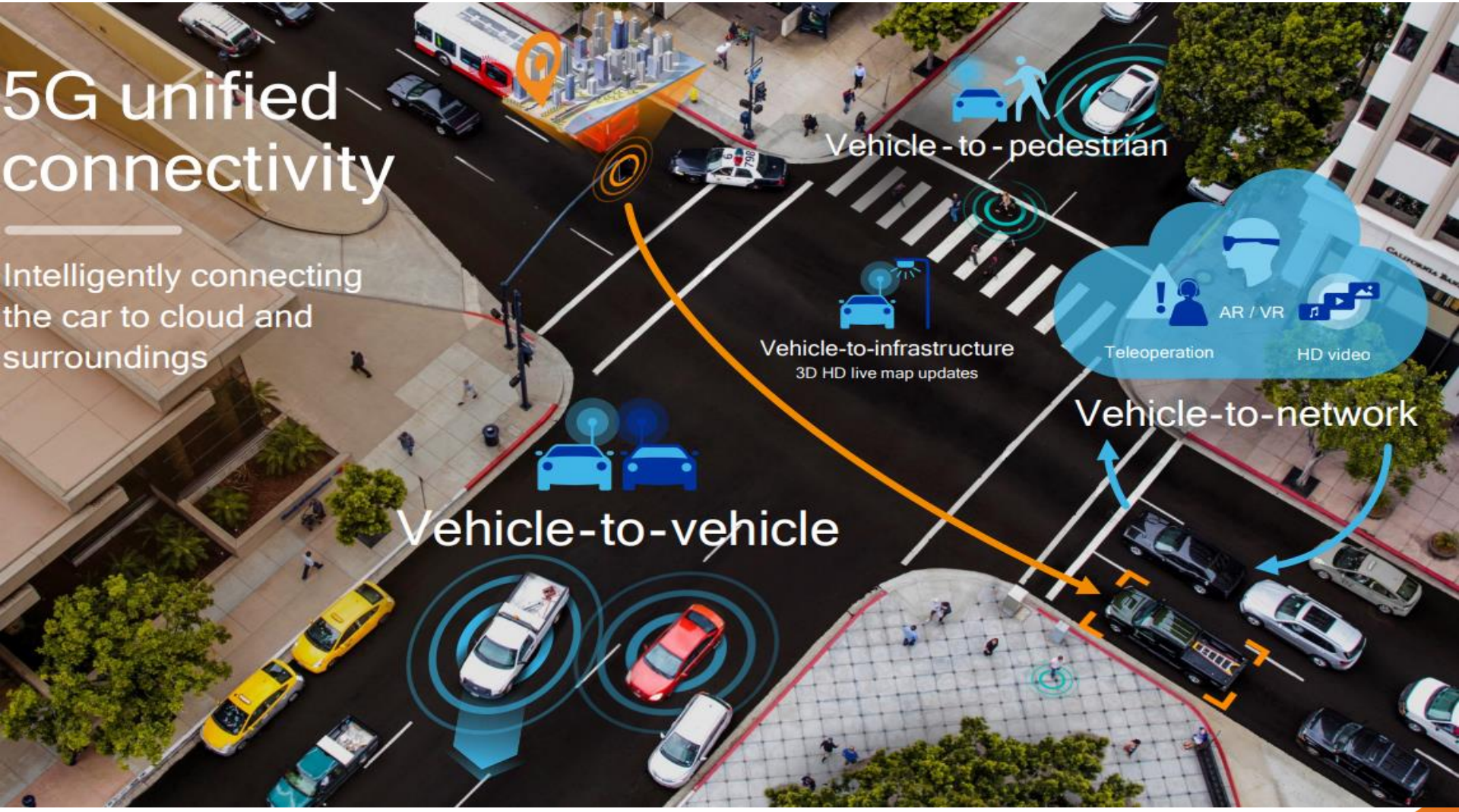
V2X

Vehicle to Everything

Ever heard a Traffic light & Car talking?



Agenda

- Introduction to V2X?
- Overview of DSRC and C-V2X
- 3GPP Evolution of C-V2X
- Test challenges
- LitePoint Solution portfolio

What is V2X ?

Vehicle to Everything Communication

Enables road safety & autonomous driving allowing vehicles to directly communicate with each other and with the infrastructure around.

Wireless Technologies in V2X

- Two Competing Wireless Standards:
  - **DSRC** (Dedicated Short Range Communications)
  - **C-V2X** (Cellular V2X)

- **DSRC**:
  - Defined by IEEE
  - Dedicated radio in the 5.9 GHz band
  - PHY layer uses 802.11p

- **C-V2X**:
  - Defined by 3GPP
  - Dedicated radio in the 5.9 GHz band
  - Additional radio in the licensed cellular band (LTE/5GNR)

Overview of DSRC

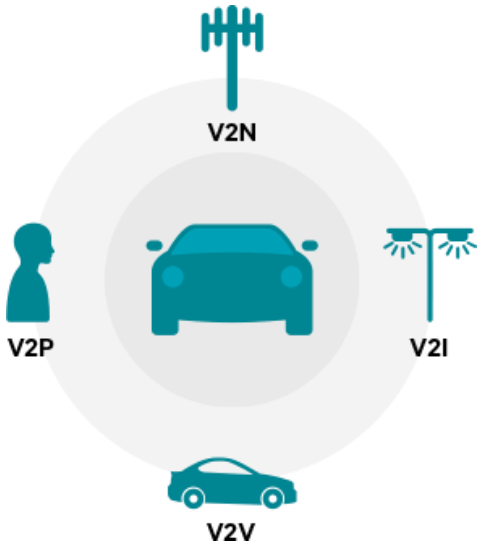
- DSRC was introduced over 10 years ago to add intelligence to transportation systems

- Uses 802.11p wireless technology in the 5.9 GHz band
- Key features enabled by DSRC:
  - Speed detection, collision avoidance, real-time road condition, toll payments, autonomous driving vehicle collaboration
- Mature technology with proven road-tested experience
- Limited market adoption:
  - Not governmentally mandated to be installed in new cars
  - Other technologies have solved some of the use-cases: RADAR, LiDAR, ultrasonic sensors, electronic toll systems
  - Latency of DSRC limits maximum speed for effectiveness

Overview of C-V2X

- C-V2X has recently been defined as part of the 3GPP initiative
  C refers to cellular technologies (4G LTE/5G NR)

- Builds on the capabilities of DSRC, and also adds a wide-area connection to the cellular network (key for autonomous driving)



- Requires (at least) two radios to operate:
  - Cellular radio (sub 6Ghz or mmwave): LTE/NR
  - Dedicated radio (5.9 GHz): improves on 802.11p

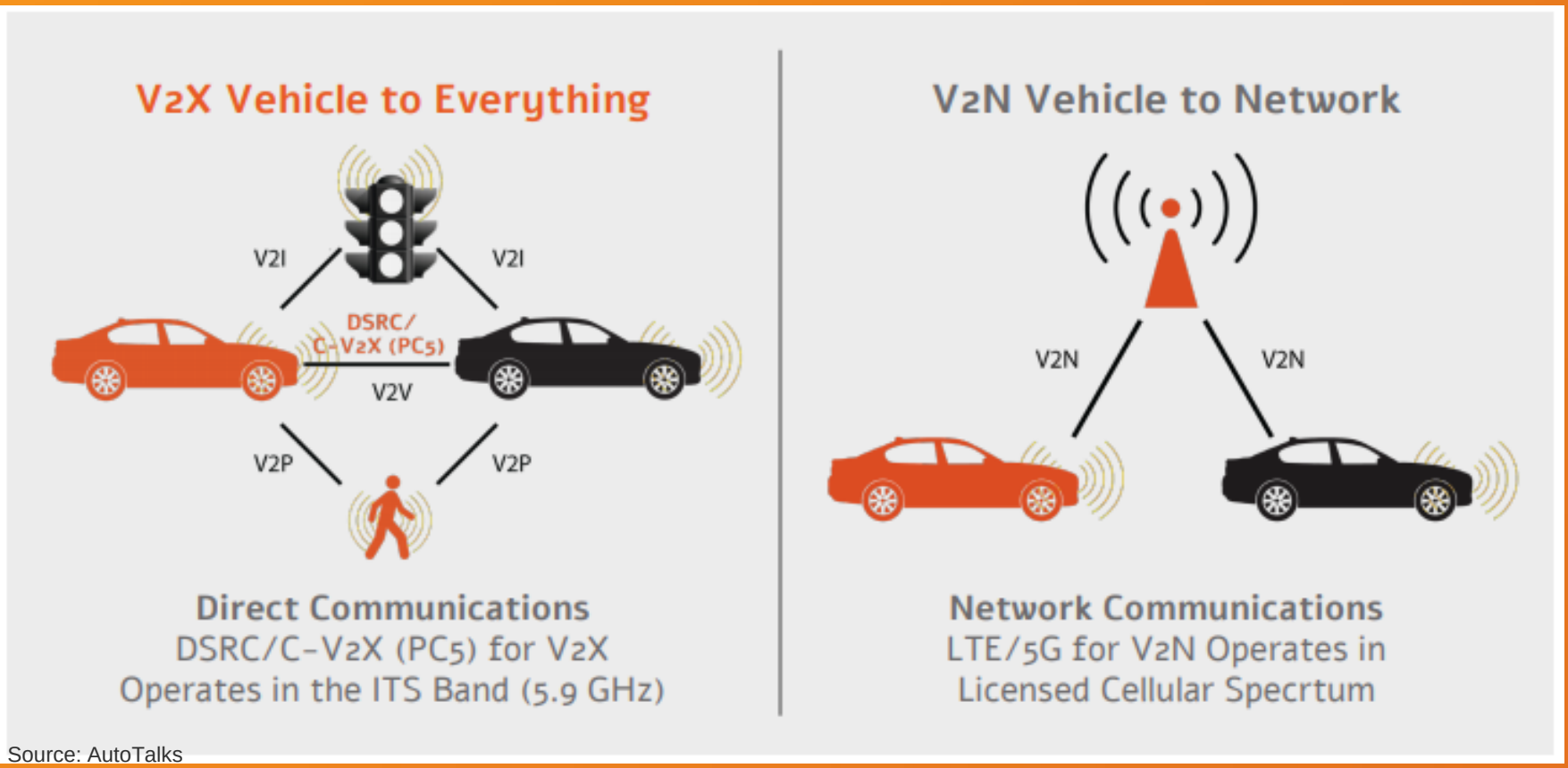
- Lower latency = operates at higher vehicular speeds

- Adoption timing unclear:
  - New technology: automotive market adoption is **SLOW**!!
  - Not governmentally mandated to be installed in new cars

C-V2X Communication Modes

Direct Communication/
(PC5/Sidelink**)**

Network Communication
(Uu Interface**)**



Source: AutoTalks

C-V2X (Release 14) Operation Band

Table 4.3.3.1-1 V2X operating band over PC5

V2X Operating Band	E-UTRA Operating Band	V2X UE transmit			V2X UE receive		
		F_{UL_low}	–	F_{UL_high}	F_{DL_low}	–	F_{DL_high}
47	47	5855 MHz	-	5925 MHz	5855 MHz	-	5925 MHz

Table 4.3.3.1-2 V2X operating band over Uu

V2X Operating Band	Uplink (UL) operating band BS receive UE transmit			Downlink (DL) operating band BS transmit UE receive			Duplex Mode
	F_{UL_low}	–	F_{UL_high}	F_{DL_low}	–	F_{DL_high}	
3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
39	1880 MHz	–	1920 MHz	1880 MHz	–	1920 MHz	TDD
41	2496 MHz		2690 MHz	2496 MHz		2690 MHz	TDD

V2X Technology Similarities and Comparisons

Radio Design	DSRC/ ITS-G5	Cellular + Sidelink / C-V2X
Standard	IEEE	3GPP
Radio Technology	802.11p	Optimized Cellular technology (Rel-14/15/16)
Frequency Band	Dedicated radio in 5.9GHz	Dedicated radio 5.9GHz. With optional support for cellular radio
Channel Size	10/20Mhz	Rel 14/15 - 10/20Mhz Rel 16 - 10/20/40/60/80/100/…Mhz
Transmission Mode	TDM (TDD)	Both TDD & FDD (Longer transmission time provides better quality of service)
Resource Selection	Carrier Sense Multiple Access – Collision Avoidance	Semi-persistent scheduling based on relative energy; eNB based scheduling
Latency	<10 msec	<10 msec
Modulation Support	Up to 64QAM	Up to 64QAM direct comm Up to 256QAM with cellular support
Transmission Range	Up to ~250m	~250m using direct communication Large via cellular network infrastructure

Technology Similarities and Comparisons

General	DSRC/ ITS-G5	C-V2X/ Sidelink
Communication	Supports only direct communication (V2V, V2P, V2I)	Includes both direct and network communication (V2V, V2P, V2I and V2N)
Target Use Case	Mainly for safety	Safety, positioning, autonomous driving
Performance	Packet loss at high density	Promise for almost no packet loss at higher densities
High Mobility Support	Up to relative speeds of 500km/hr	For relative speeds much > 500km/hr
Advantages	Mature technology Reliable, road-tested	Leverages LTE infrastructure 3GPP viewed as high reliability
Limitations	Short range comm. Limited scalability Vehicular speed limitations No cloud/local area update	Long range communication Scalable (better spectral efficiency) For speeds >500Km/hr Capable of Real time updates
Market Adoption	N America, Europe, Japan	China

C-V2X Advantages

- Autonomous / Coordinated Driving
- Cellular Infrastructure Independence
- Path Planning & Perception
- 3D mapping and precise positioning
- Situational Awareness
- Enhanced reliability
- Higher throughput/Traffic efficiency
- Lower latency

DSRC evolution to C-V2X?

Adoption dependent on regulation or mandate?

Source: Qualcomm

Automaker Adoption

Despite the regulatory uncertainty and debate between 802.11p/DSRC versus C-V2X, certain automakers have chosen to adopt one and planned roll outs

- DSRC roll out expected in 2019:

  Cadillac, Toyota / Lexus, Volkswagen, General Motors

- CV2X roll out expected by 2021,2022:

  Ford, BMW, Daimler, Groupe PSA, SAIC, Geely, Audi, and Jaguar Land Rover.

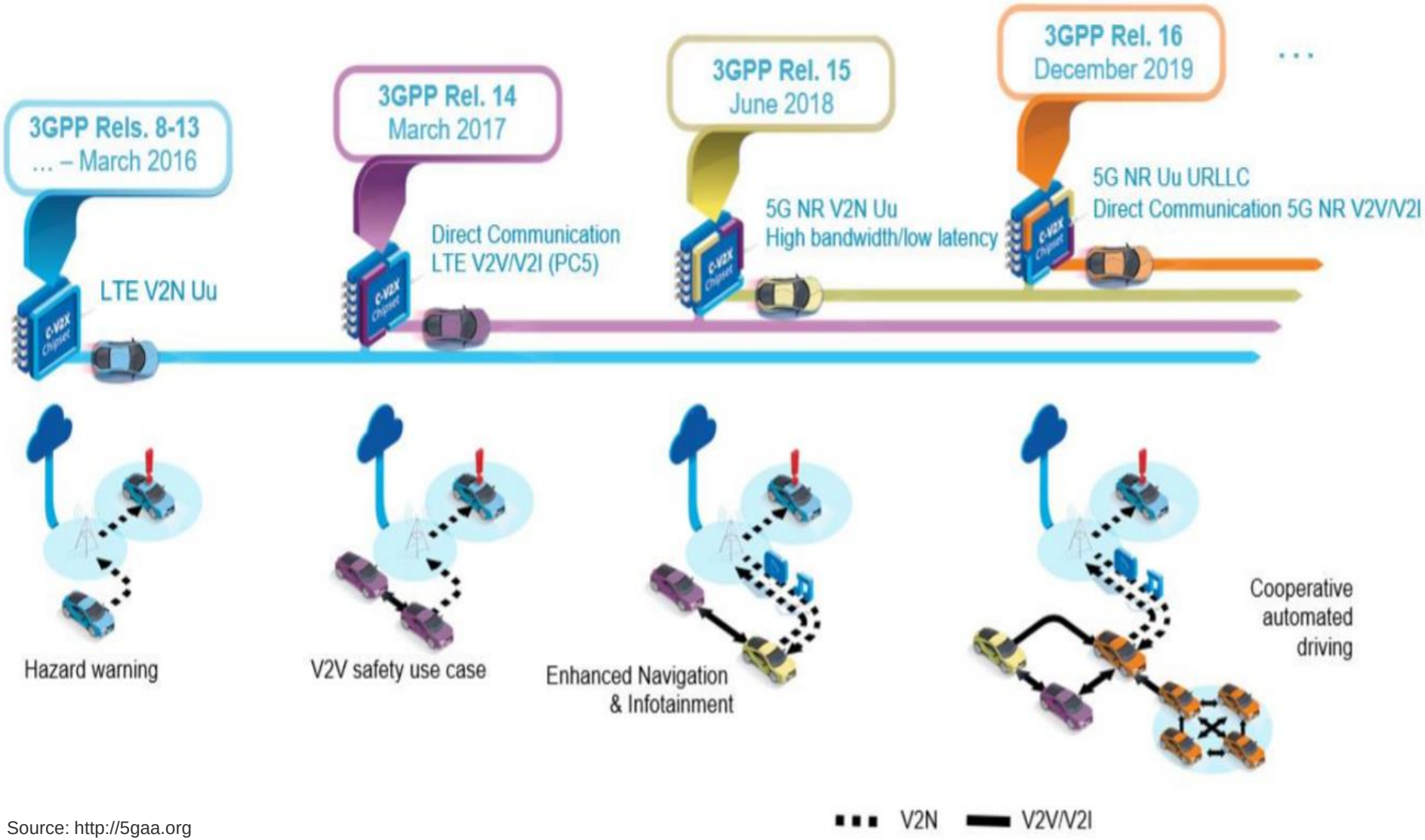
Global spending on V2X is expected to grow at a CAGR of more than 170% between 2019 and 2022.

Research predicts that by the end of 2022, V2X market will account for a market worth $1.2 Billion, with nearly 6 Million V2X-equipped vehicles worldwide.

Source: prnewswire.com

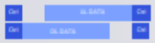
3GPP Evolution of C-V2X

C-V2X Evolution with 3GPP Release



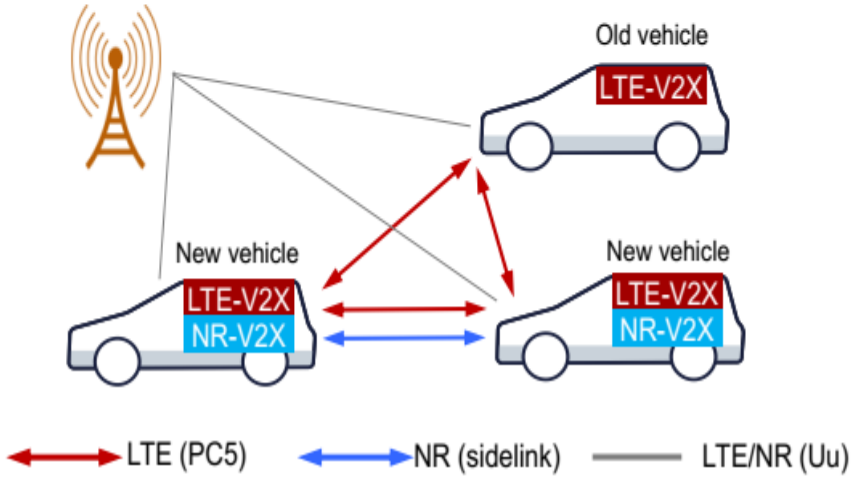
Source: http://5gaa.org

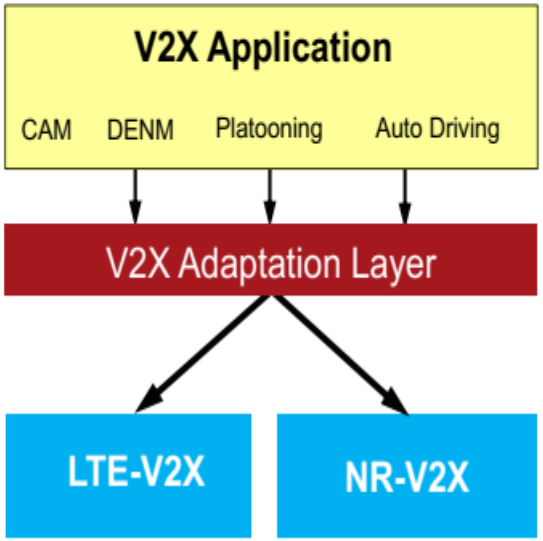
Newer Capabilities for Sidelink

NR Design		5G NR C-V2X capabilities for autonomous driving
Scalable OFDM-based air interface		5G C-V2X is expected to efficiently addresses diverse spectrum bands for different use cases Leveraging wideband carrier support and OFDMA to deliver higher data rates
Self-contained slot structure		Smaller slot structure with immediate feedback to enable ultra reliable low latency communications
Advanced channel coding		State of the art LDPC/polar coding to deliver higher reliability with low complexity
Wideband carrier support		Wideband carrier based higher data rates and system capacity
Larger number of antenna		Efficiently utilize larger number of antennas than Rel-14 to deliver higher data rate and long range

LTE C-V2X and NR C-V2X

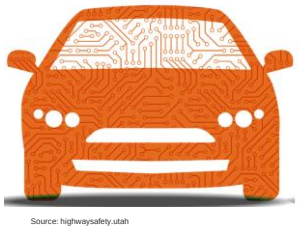
Basic safety application by LTE-V2X (PC5) @ 5.9 GHz	Flexible selection between LTE-V2X and NR-V2X
New vehicles deploy both LTE-V2X and NR-V2X to enable the inter-operability with old vehicles: 1) LTE-V2X (PC5): Basic safety 2) NR-V2X (sidelink): Autonomous Driving	Provide policies/criteria to UE to assist radio technology selection, according to V2X application type, QoS requirements, etc.





Cellular - V2X

Manned Vehicle
without C-V2X

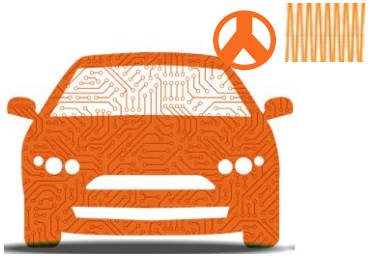


No blind Spot detection
Chances of collision

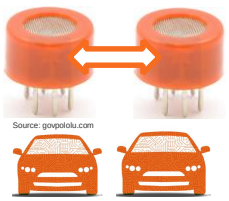
Smart vehicle
without C-V2X

Still less reliable
higher latency & response time

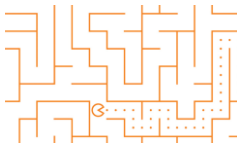
Smart vehicle
with 5GNR + C-V2X



Highly reliable, safe & fast

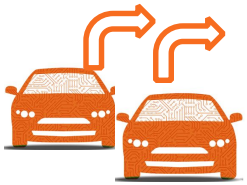


Sensor data sharing



Path Planning

Real time Updates



Coordinated Driving

Wideband Carrier Support

High Throughput

Low Latency

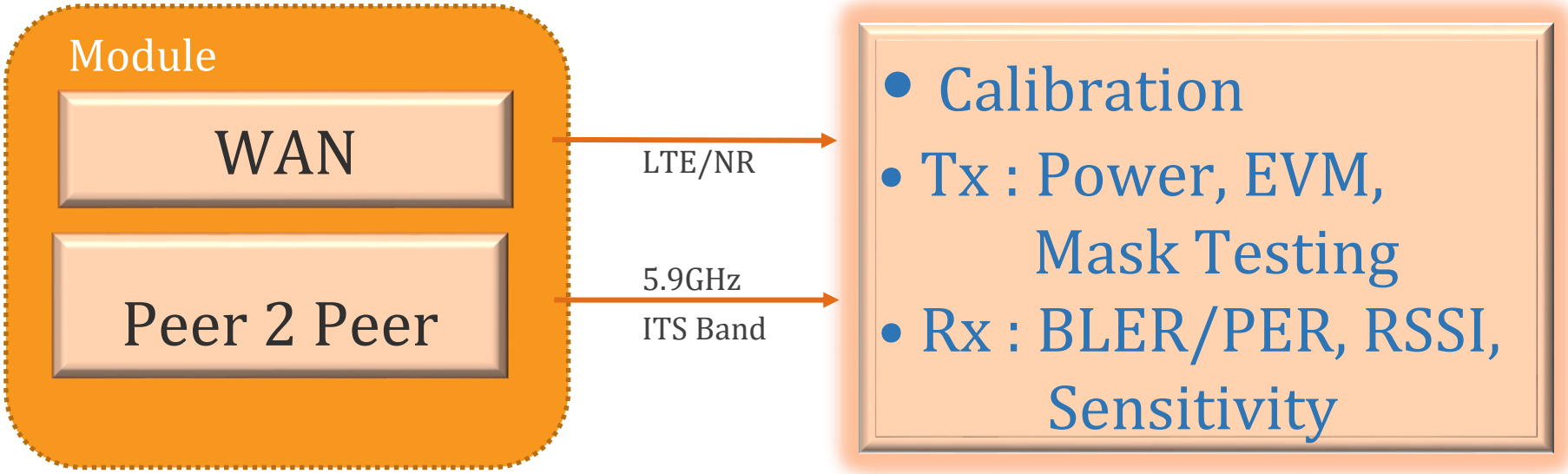
Ultra High Reliability

Innovation does not come easy

Test challenges for PC5 / Sidelink

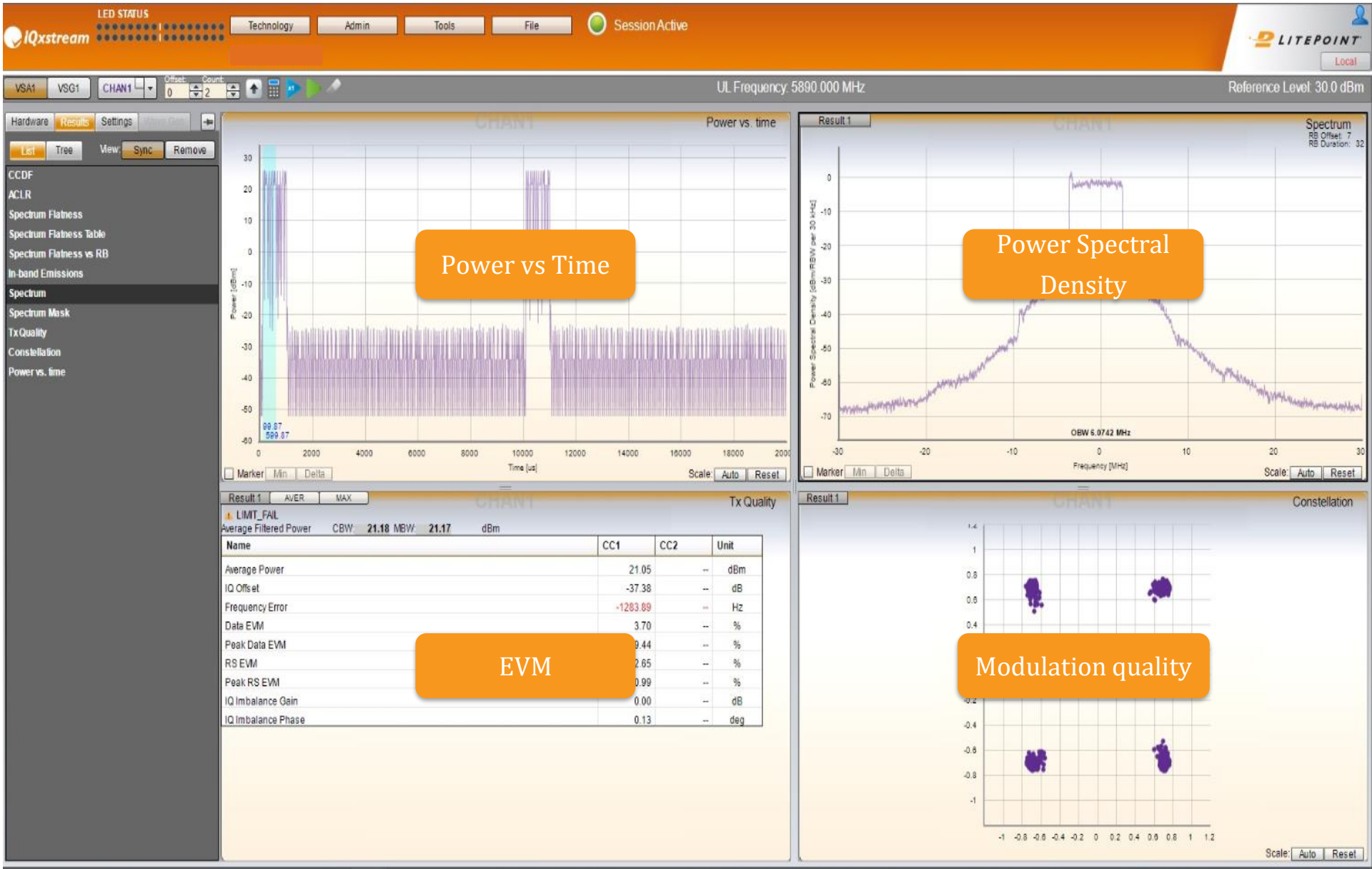
- Scalability
- Rx Sensitivity/Low PER
- Calibration
- Wide Area Network (WAN)
- Small Error Tolerance

Physical Layer Testing




LitePoint at your rescue
With a comprehensive solution
Source: thepoetryplace.wordpress.com

C-V2X waveform analysis

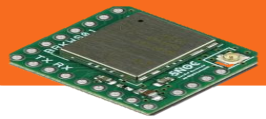


Transforming Complexity to Simplicity

Comprehensive V2X solution

Chipset

Module



Product

OEM / CM

Calibration Algorithms
Measurement Algorithms

Characterization
Data Visualization

Automation
Solutions

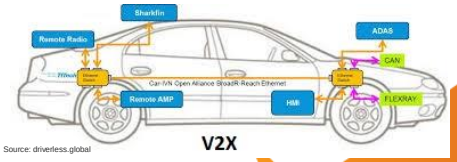
R&D
IC / Module development Test

DVT
Design Verification Testing

Final Product Manufacturing Test

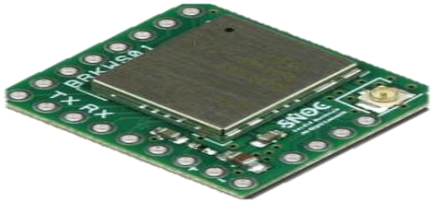
Source: Iginnotek

Source: commsignia



Source: driverless.global

Testing made much simpler and faster



Chipset or Module

we test it all

Higher Throughput

with multi DUT testing

Source: cloudlibrariandownunder.wordpress.com

Shorter time to market

LITEPOINT

A Teradyne Company

Source: entrepreneur.com

Reduced Testing cost

Source: barcodedatalink

Customer Support

Thank You!

- Thank You!