The C-V2X Proposition

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My job @ Ford

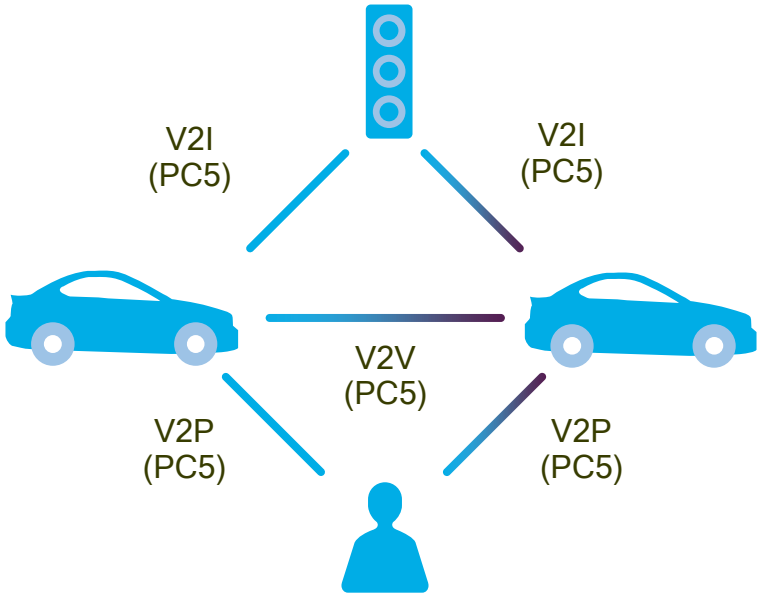
Important cellular radio technology enhancements were codified in Release 14 of 3GPP (2017)

Before	Now
Devices using cellular technology required infrastructure support.	Cellular V2X devices can communicate directly without any network support.
Low latency communication was not possible with cellular solutions.	Cellular V2X technology supports low-latency needs for V2V.
Cellular solutions required use of (costly) licensed spectrum.	Cellular V2X technology can operate in the ITS 5.9Ghz band.
Cellular solutions lacked mechanisms to address privacy issues.	Cellular V2X operates w/out SIM cards and enables anonymity on par to DSRC
DSRC was the only technology available to support V2V.	Cellular technology is a viable alternative to meet and exceed V2V requirements.

C-V2X has two complementary communication modes

Direct

V2V, **V2I**, and **V2P** operating in ITS bands (e.g. ITS 5.9 GHz) independent of cellular network

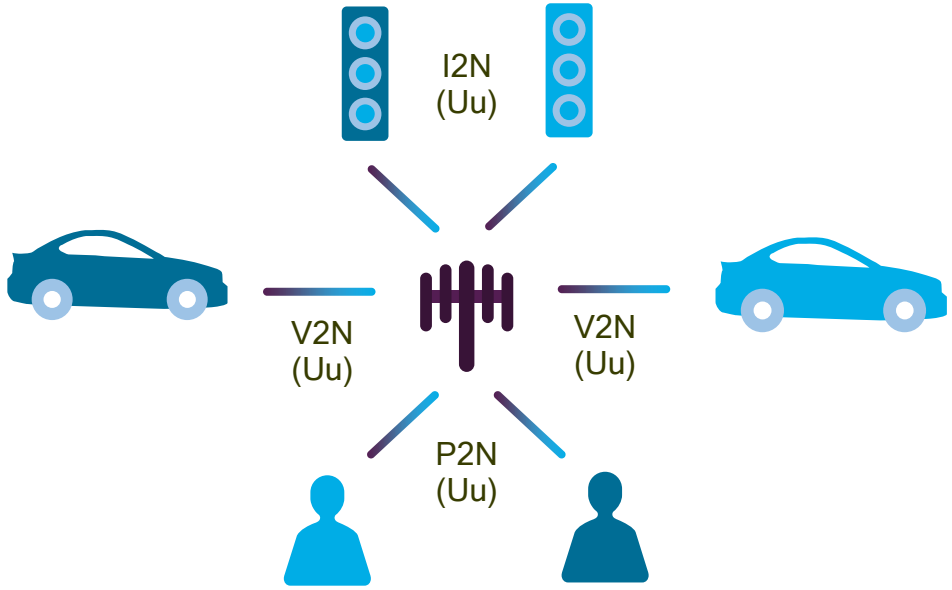


Short range (<1 kilometer), location, speed …

Implemented over “PC5 interface”

Network

V2N operates in traditional mobile broadband licensed spectrum



Long range (>1 kilometers). e.g. accident ahead

Implemented over “Uu interface”

Why is this important?

A. **Performance**: C-V2X delivers superior performance and reliability by leveraging the latest advances in radio technology

B. **Implementation Efficiency**: C-V2X can be implemented by utilizing the cellular technology platforms that automakers are already deploying
   - Analysts expect that 90% of new US vehicles will have cellular modems by 2025
   - In the US, by 2019 100% of new Ford vehicles will have cellular modems
   - Integration with existing in-vehicle cellular platforms and services will results in fewer things-gone-wrong at a lower expected cost

C. **Readiness**: Commercial C-V2X products are available for deployment as early as 2019
   - supported by a broad ecosystem reflected in the diversity of 5GAA membership

Why is this important?

D. **Reuse**: C-V2X leverages a very significant portion of the V2X work already done
   - Benefits from existing V2X transport layers and application protocols: safety Apps developed for DSRC will work unchanged with CV2X radios
   - Learnings from past V2X research are reusable

E. **Global Footprint**: C-V2X will be deployed consistently and predictably across the world in the same way that other cellular technologies such as LTE have been

F. **Evolution**: C-V2X is the first step towards 5G that will leverage future improvements in cellular radio technology while remaining backward compatible

C-V2X is the first step towards 5G that can leverage future improvements in cellular radio technology.

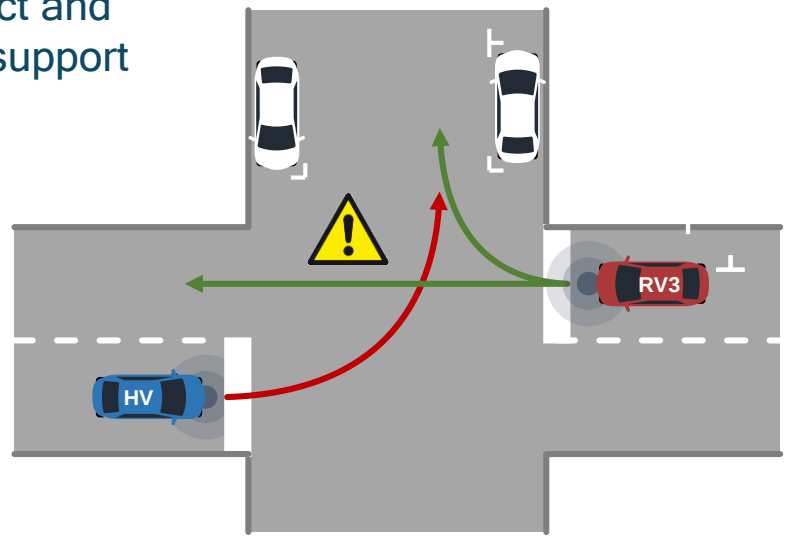
1H17 | 2H17 | 1H18 | 2H18 | 2H20

Rel14 — Rel15 — Rel16

Basic and enhanced safety

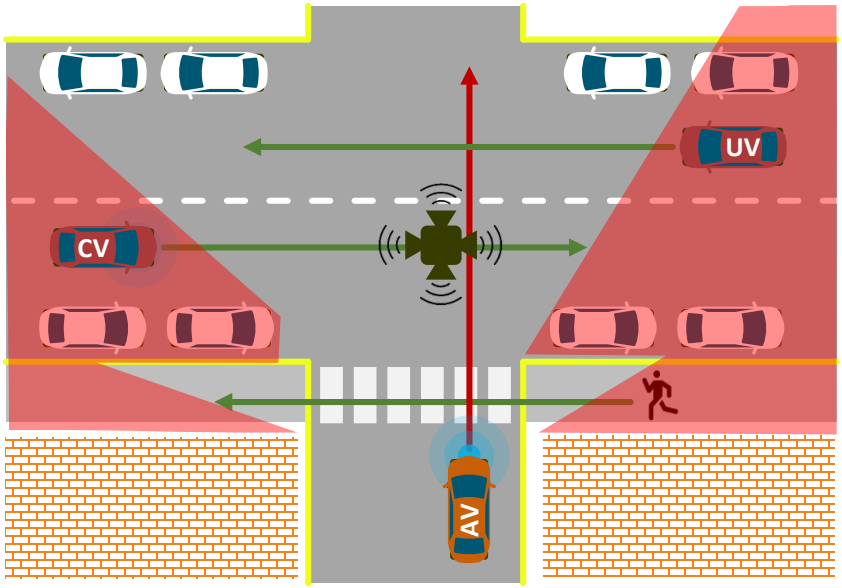
C-V2X R14/R15 with enhanced range and reliability

- Basic safety messaging
- Dual (direct and network) support



Autonomous driving / Automation

5G NR based C-V2X R16



- Backward compatible
- HD sensor and intent sharing

Key Cellular-V2X Technical Characteristics

A. **Low-latency**: C-V2X is designed for reliable, predictable, low-latency direct communications
B. **Network independence:** "Direct" C-V2X is designed to operate without network assistance (does not require SIM cards to function) *but can use the deployed mobile networks to enhance functionality*
C. **High-speed use cases**: C-V2X is designed for high-speed vehicular use cases. By design and following extensive analyses R14 C-V2X works up to 500 km/h relative Doppler in 5.9 GHz band
D. **ITS spectrum** : C-V2X is designed to operate in the ITS spectrum
E. **Security**: Benefits from established security protocols defined by the automotive standards communities, including SAE, IEEE and ETSI.

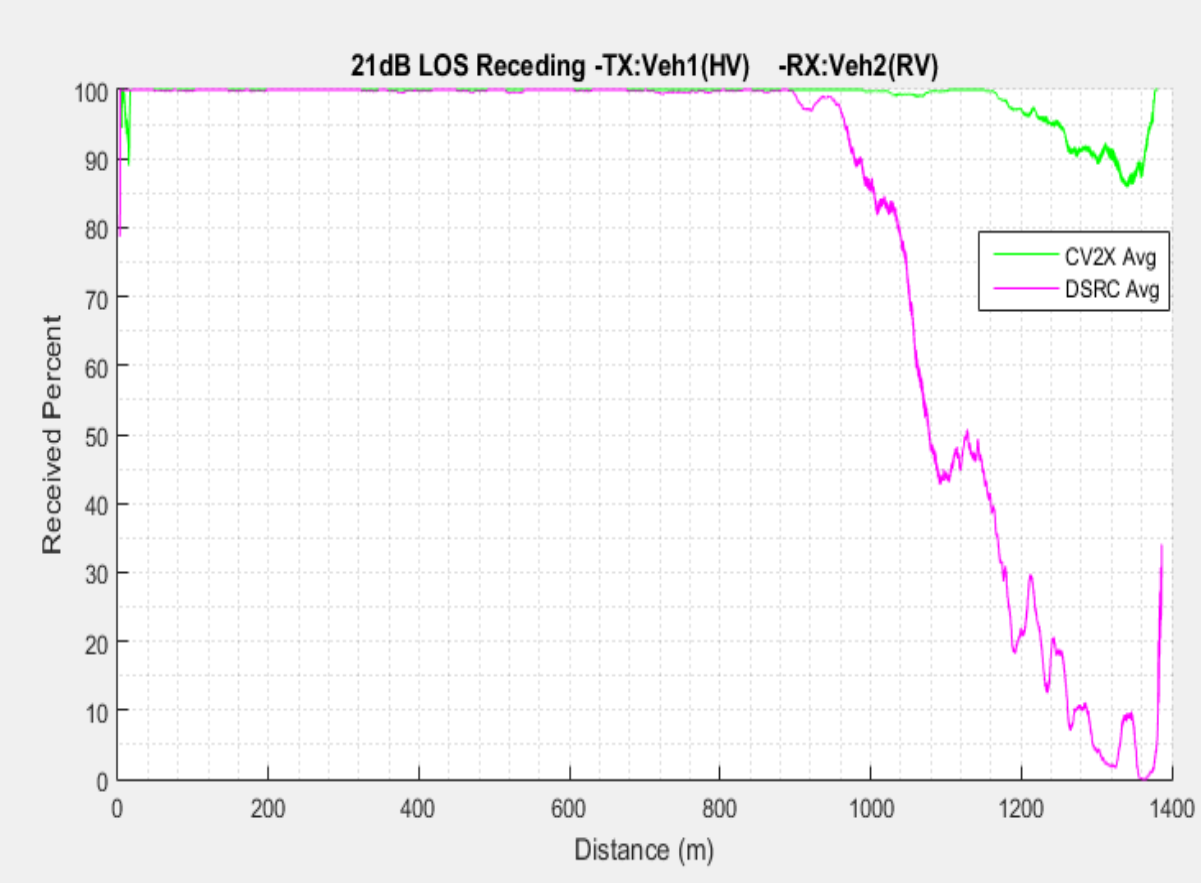
Extensive testing to validate CV2X radio performance initiated in 2017 will be completed by this summer in Ann Arbor, San Diego, Aberdeen and Shanghai.

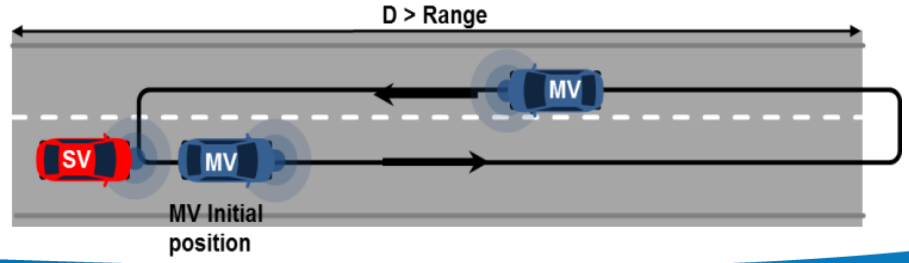
Range	**Lab** Cabled Tx and Rx Tests
	Field LOS Range Tests
	Field NLOS Range Tests
Interference	**Lab** Cabled Tx and Rx Test with Simulated External Interference
	Lab Cabled Near-Far Test
	Field Co-existence with Wi-Fi 80 MHz Bandwidth in UNII-3
	Field Co-existing of C-V2X with Adjacent DSRC Carrier (CH172 and CH174)
Congestion	**Lab** Cabled Congestion Control
	Field Congestion Control Field Test: Multi-Lane Line-of-Sight Highway

Testing

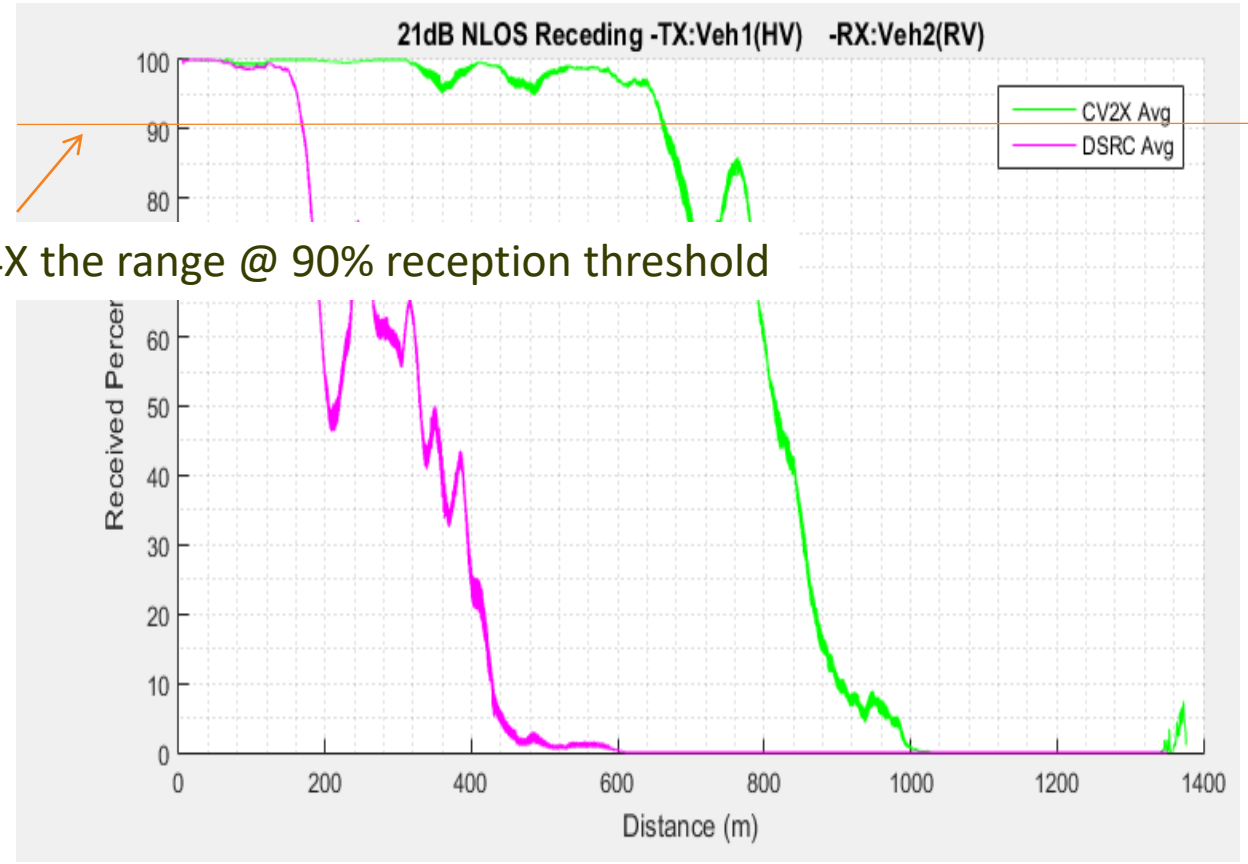
- Ford in partnership with Qualcomm (in US) and Datang (in China) has been testing C-V2X devices since 2H17. Work will be completed in 2H18.
- Test procedures have been documented and are now being harmonized in 5GAA to ensure global uniformity.
- Initial results are consistent and very encouraging. They support our beliefs in the benefits of the technology.

Line-of-Sight (LOS) Range / Reliability Road Test in Fowlerville, Michigan

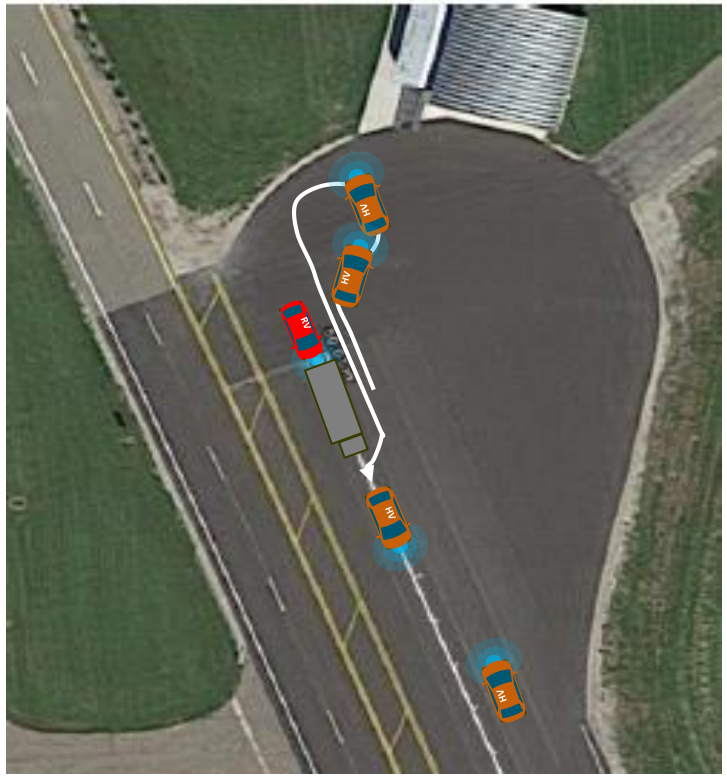


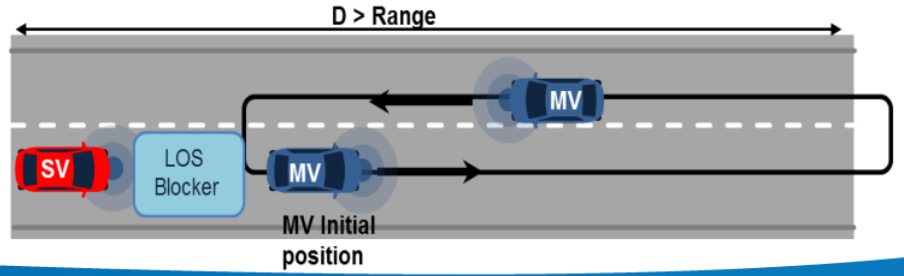


Obstructed Non-Line-of-Sight (NLOS) Range/Reliability Road Test in Fowlerville, Michigan

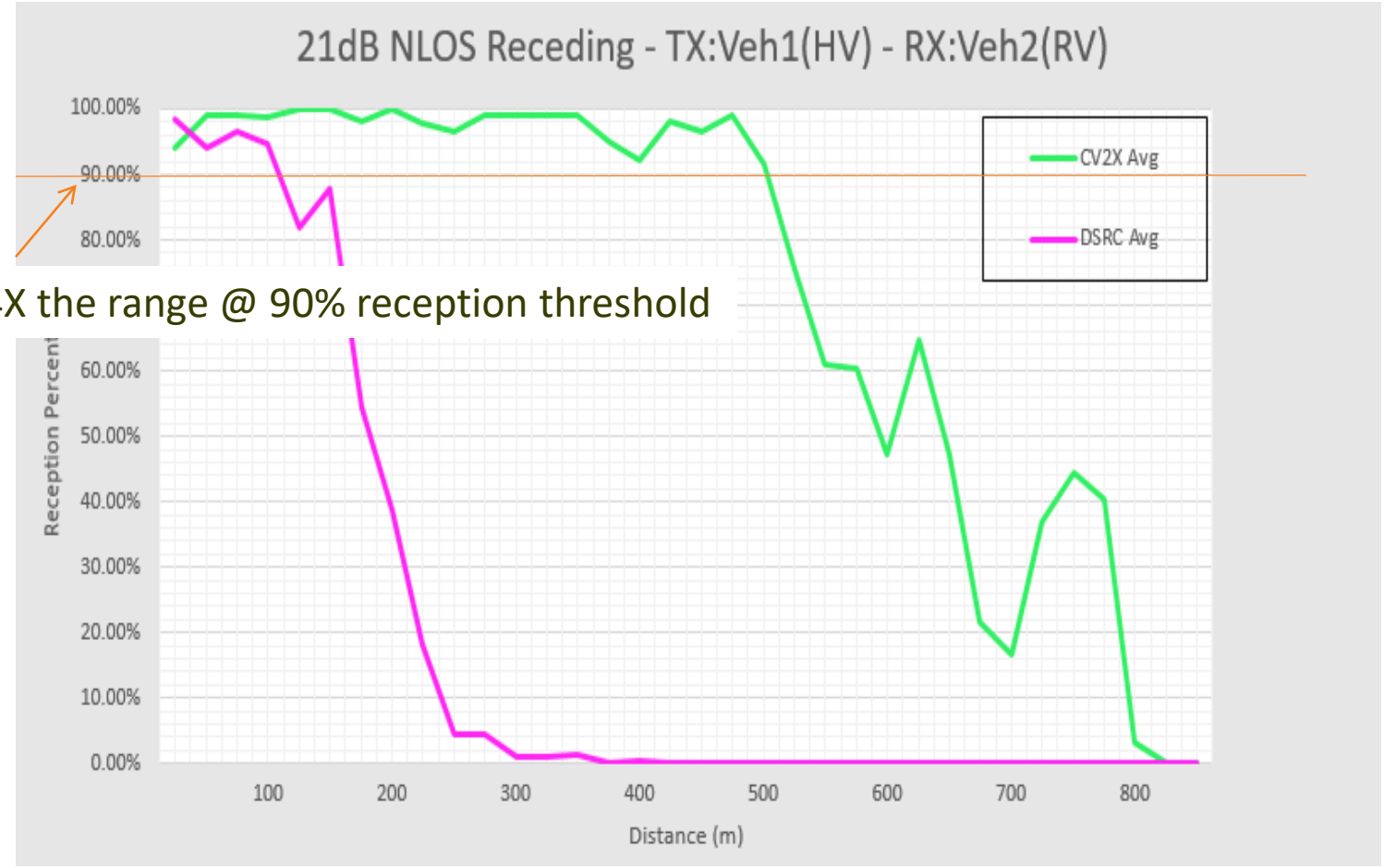


4X the range @ 90% reception threshold





Obstructed Non-Line-of-Sight (NLOS) Range/Reliability Road Test in Miramar, San Diego



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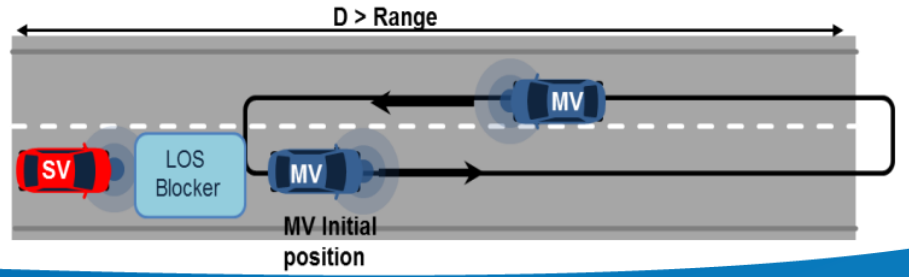
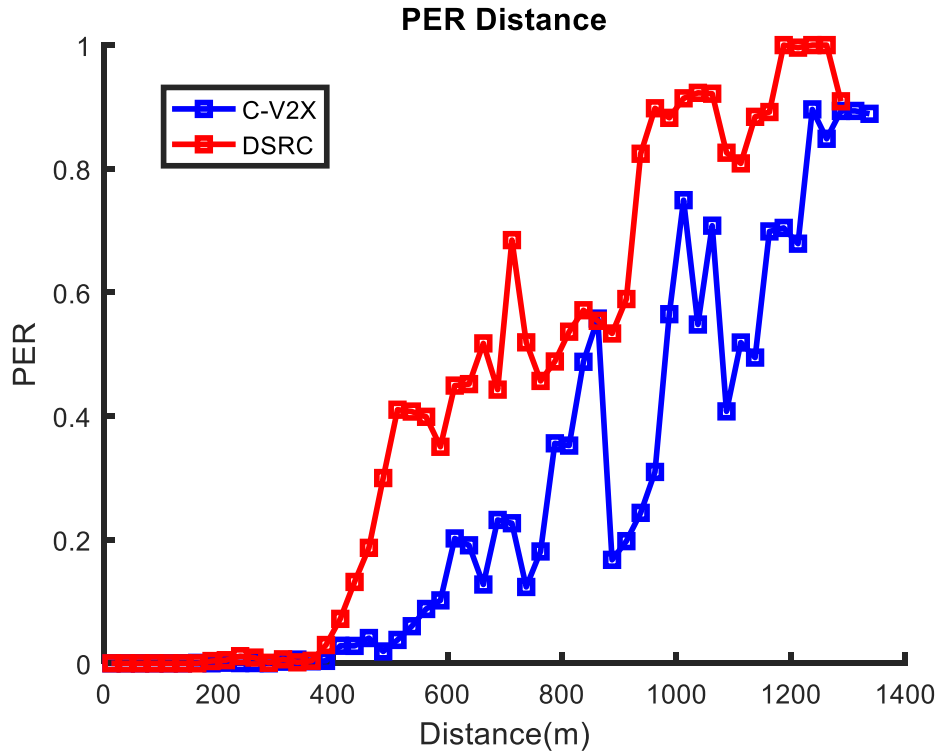


Highway Testing Near Beijing



- Vehicles driven at 80 km/h, 100 km/h and 120 km/h
- Both cars slowly separating until no packet received, then closing gap, three times
- Distance maintained at 200m, 400m, 600m etc. for 5 min

Thank You!