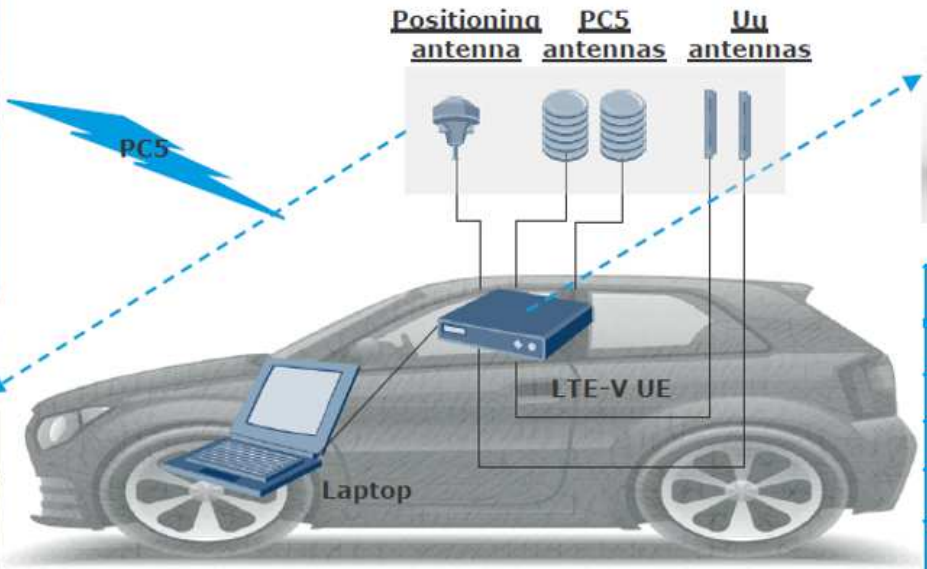
A 5GAA Perspective on C-V2X Performance and Future Capabilities

Field Tests Conducted in Shanghai, China

In the Field Tests carried out at Huawei/SIAC facility in Shanghai, Mode 4 (Out of Coverage V2V/V2I) was used to test out actual performance of the 5.9GHz PC5 RF link.

The Uu interface (V2N) was used only for sending results to the central control system for analysis.

Field Test Equipment Configuration

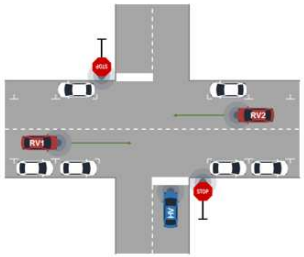


Indicator Name	Indicator Value
Dimensions	305mmx*220 mm*35 mm (length*width*height)
Weight	< 3kg
Power consumption	typical 1T2R : < 100 W
Ambient temperature	-5° C to +40° C(excluding solar radiation)
Relative humidity	5% RH to 95% RH
Atmospheric pressure	70 kPa to 106 kPa
Input power	+12 V DC Range: +10.7 V DC to +13.2 V DC

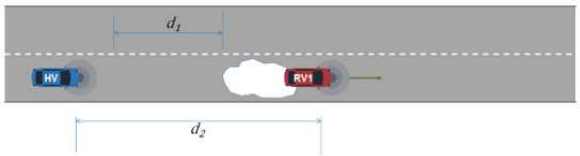
- Laptop is connected to UE for operating and counting.
- Two antennas for V2V direct communication and two antennas for data reporting by Uu.
- Positioning receiver's accuracy is ±10m,coverage range is estimated by receiver's location.

Sample of 5GAA C-V2X Use Cases

Intersection Movement Assist (IMA)

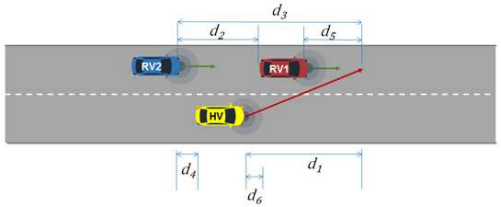


Advanced Driving Assistance (ADA)



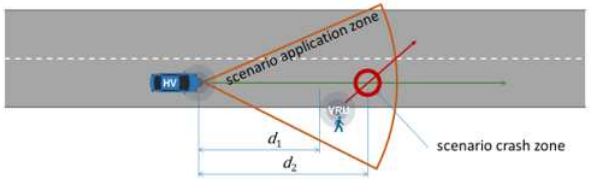
- d_1 = minimum distance for HV to react and prepare for the hazardous situat
- d_2 = distance between HV and RV1

Cooperative Lane Change (CLC)



- d_1 = distance for HV the to complete the lane change
- d_2 = distance between RVs in the target lane

Vulnerable Road User Discovery (VRUD)



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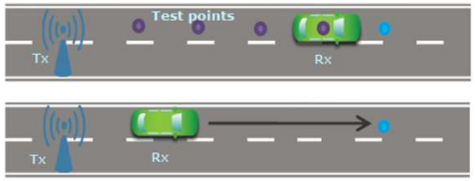
Field Test Scenarios – Different Traffic Densities

Field Test Scenarios – Low/Med/High Packet Sizes

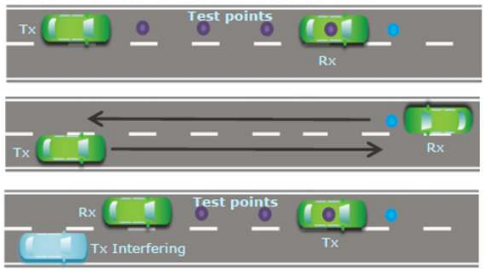
V2I Field Test Scenarios



Static
1 Car

Relative Speed=30km/h
1 Car

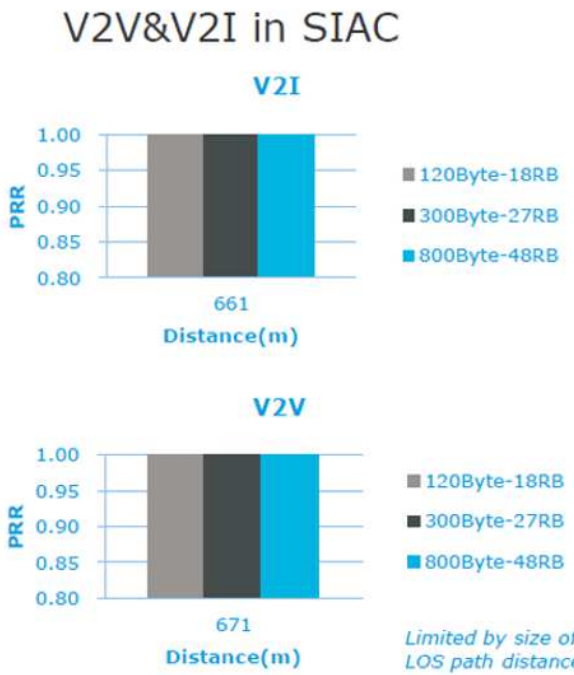
V2V Field Test Scenarios



Static
2 Cars

Relative Speed=60km/
2 Cars

Static
2 Cars



Limited by size of field, only the PRR with maximum LOS path distance is given

100% Reliability was achieved in all Packet Sizes for both V2I and V2V

Field Test Scenarios – Successful Near-Far Test

There are 3 cars in this test.

Two cars at different distances transmit packets to a third car.

Objective of Test.
Test if signals from near transmitters interfere with signals from far transmitter.

Far Distance	Near Distance	Near Transmit	PRR (Far Tx)
836m		OFF	100%
836m	60m	ON	100%
836m	10m	ON	100%
Far Distance	Near Distance	Near Transmit	PRR (Far Tx)
615m		OFF	100%
615m	60m	ON	100%
615m	10m	ON	100%

Results:
Weak packets from vehicles at a distance of 836m and 615m were received reliably in the presence of signals from a near vehicle.

This performance is more than enough performance for most V2V scenarios.

Field Test Near-Far Scenario was successfully demonstrated.

Use Case Field Tests Meet 5GAA Requirements

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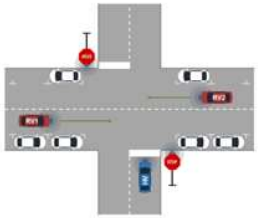

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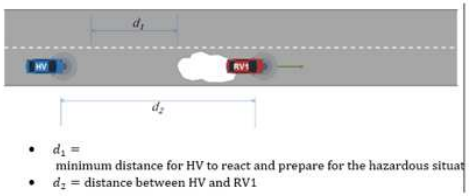

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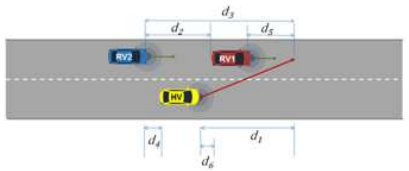

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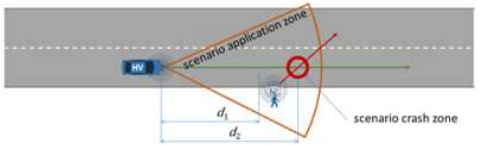

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Use Case	5GAA Range Specification	5GAA Reliability Specification	5GAA Latency Specification	5GAA Density Specification
IMA	100-500m	95%	10-100ms	High >500km^2
Result	300m	>95%	<20ms	>2000/km^2
ADA	Low <100m Medium 100-500m	Low-High	10-100ms	Medium-High
Result	<100m 300m	>99% >95%	<20ms <20ms	Medium Medium
CLC	Low <100m Medium 100-500m	Low-High	10-100ms	Medium-High
Result	<100m 300m	>99% >95%	<20ms <20ms	Medium Medium
VRUD	Low <100m Medium 100-500m	Low-High	1-10ms	Medium-High
Result	<100m 300m	>99% >95%	<20ms <20ms	Medium Medium

Conclusions

- Multiple C-V2X simulations have been made which predicted performance
- 5GAA have developed Day 1 Use Cases and target specifications which serves as a base line
- Field Tests using actual C-V2X Equipment was carried out in Shanghai
- Variations in distance, density, packet size and speed were used for authentic test scenarios
- Overall performance **met** or **exceeded** target specifications on 5GAA Use Cases

Annex

Link Level and System Level Simulations - References

Link Level Simulations

- Preliminary Comparison of Suitability of DSRC and LTE-V2X for V2V Safety Applications
- Cellular V2X as the Essential Enabler of Superior Global Connected Transportation Services
- Leading the world to 5G: Cellular Vehicle-to-Everything (C-V2X) technologies
- 3GPP LTE Enhancements for V2V and Comparison to IEEE 802.11p
- Comparison of LTE and DSRC-Based Connectivity for Intelligent Transport Systems
- Link Level Performance Comparison Between LTE V2X and DSRC
- Link Beaconing from Connected Vehicles:

System Level Simulations

- 5GAA_P-170076 Performance comparison of LTE-V2X and DSRC in System Level simulation perspective
- 3GPP R1-16302_QSensing
- Cellular V2X as the Essential Enabler of Superior Global Connected Transportation Services

Liaison Statements From Other Organisations

- LS on Technology Evaluation of LTE-V2X and DSRC from NGMN (Draft)

Shanghai International Automobile City

National Intelligent Connected Vehicle (Shanghai) Pilot Zone