



3GPP TSG RAN Meeting #75
Dubrovnik, Croatia, 6 – 9 March 2017

RP-170421

Motivation for SI: Study on NR Vehicular Services

3GPP TSG RAN Meeting #75
Dubrovnik, Croatia, 6 – 9 March 2017
Agenda Item: 9.1

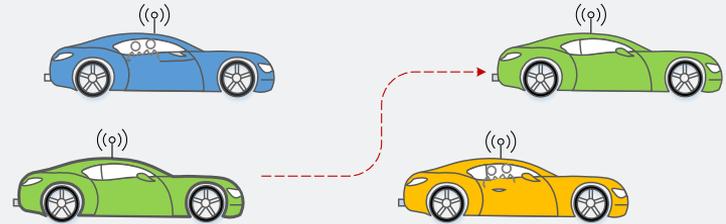
5G V2X Evolution

Major 5G V2X Use Cases(Groups)

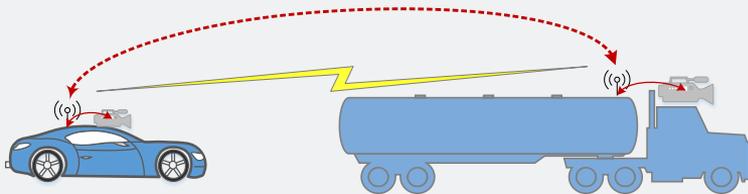
Platooning



Advanced Driving



Extended Sensor



Remote Driving

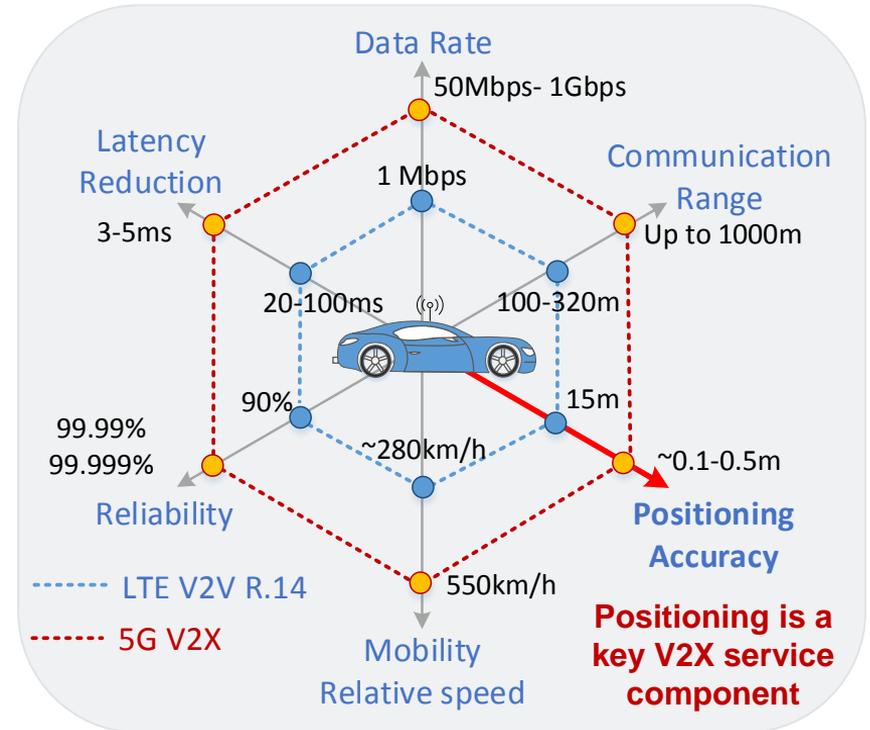


5G V2X

Overview of System Requirements

5G-V2X vs LTE-V2V R14

- Data rate (throughput)
 - ~100x times higher (1-10Mbps to 1Gbps)
- End-to-end latency
 - ~5-20x times lower (20-100ms to 3-5ms)
- Communication range
 - ~2-3x times larger (100-320m to 1000m)
- Positioning accuracy
 - ~10x more accurate (5-15m to 0.1-0.5m)
- Relative vehicle speed
 - ~2x times higher (280km/h to 550km/h)
- Reliability of reception
 - ~1000x times reliable (90% to 99.99%)



5G-V2X and NR Technology Transformation

NR-V2X Use Cases

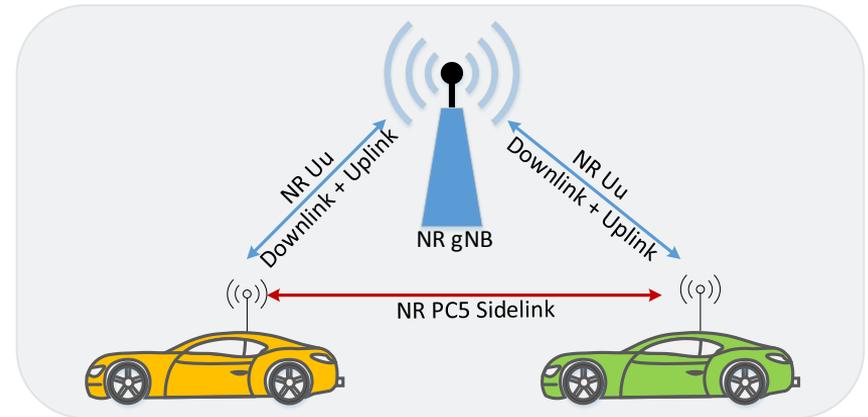
- Aggressive and technically challenging 5G-V2X requirements

Cellular Technology Transformation

- Accurate geo-location and reliable communication is of high importance
- Joint perception of environment & information sharing for automated driving
- Fundamental changes of multiple radio-interfaces are needed
- DL/UL/SL reliable and high data rate communication across multiple bands

ITS Spectrum

- Communication in low band (< 6GHz) and high band (>6 GHz) operation
- Joint ecosystem efforts on ITS spectrum allocation for 5G V2X services



NR V2X Positioning

Precise positioning as a key element of automated driving

Location for NR-V2X Services

Demand for Accurate and Reliable Vehicle Location

Automotive Industry Transformation

- Automotive industry transforms towards support of high automation levels
- Majority of V2X applications require accurate, reliable location operation
 - Road safety / transport / navigation / platooning / automated driving services
- Clear demand for vehicular geo-location and communication technologies

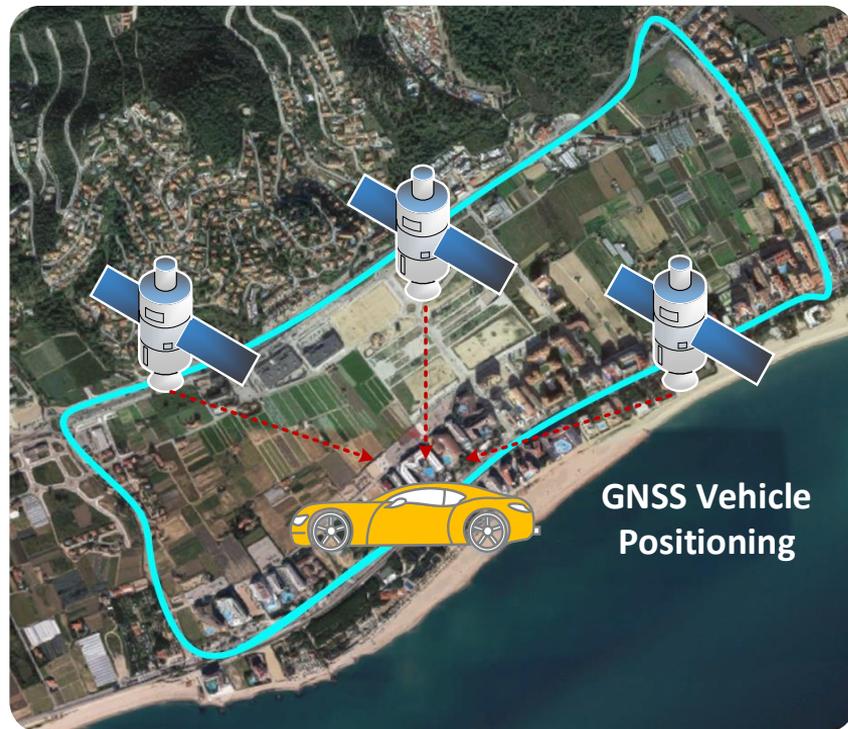
3GPP SA1 “Study on enhancement of 3GPP support for 5G V2X services - R15”

- High precision positioning techniques should be supported
 - “3GPP system shall support relative lateral position accuracy of 0.1 m”
 - “3GPP system shall support relative longitudinal position accuracy of less than 0.5 m for UEs supporting V2X application in proximity”

GNSS Positioning Field Trials

Field GNSS Measurements

- GNSS receivers (consumer grade) mounted inside a car
- Field trials on predefined routes
 - Route 1: Suburban Freeway (Freeway)
 - Route 2: Urban Dense Canyon (Urban)
- Synchronized measurements from multiple sources
 - Vehicle absolute coordinate error
 - Distance error between two vehicles
- Vehicle speeds varies in the range from 20-100km/h



NR V2X Positioning

GNSS Requirements and Measurements

3GPP GNSS
requirements (TS 36.171)

3GPP GNSS requirements

System	Success rate	2-D position error	Max response time
GNSS	95 %	15 m	20 s

3GPP GPS requirements

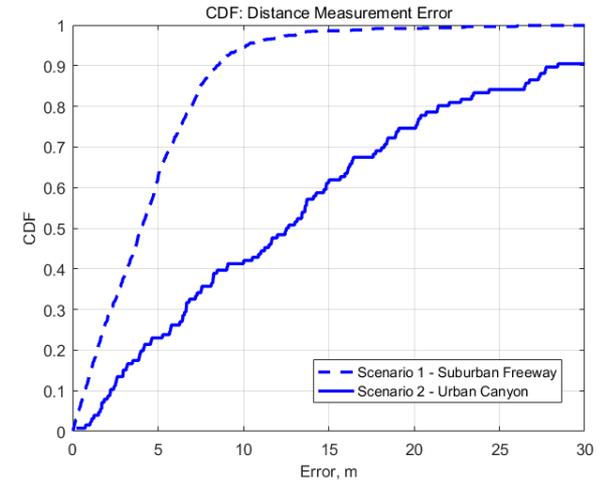
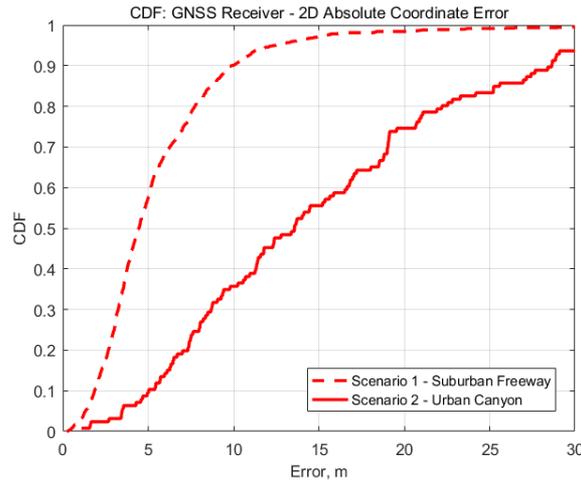
System	Success rate	2-D position error	Max response time
GPS	95 %	30 m	20 s

Observation

- State of the art GNSS receivers may not provide sufficient accuracy for V2X positioning in all scenarios

Field Test Trial

GNSS measurement from different recording sets



NR V2X Positioning

Main Principles and Benefits

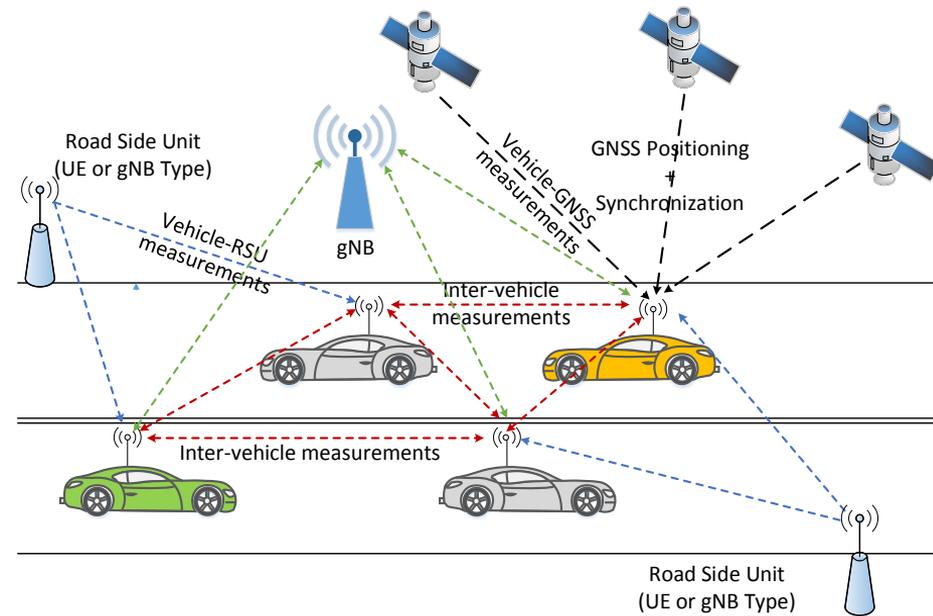
Role of NR V2X Positioning

- Relative and absolute location with vehicle(s)/RSU(s)/gNB(s)
- Broadcasting of location information
- Enabling cooperative location

Technical Advantages

- Wider bandwidths, angular information
- Improved accuracy (especially in Urban)
- Increased reliability / robustness (multiple location sources)
- Communication and positioning protocol

NR V2X Positioning System



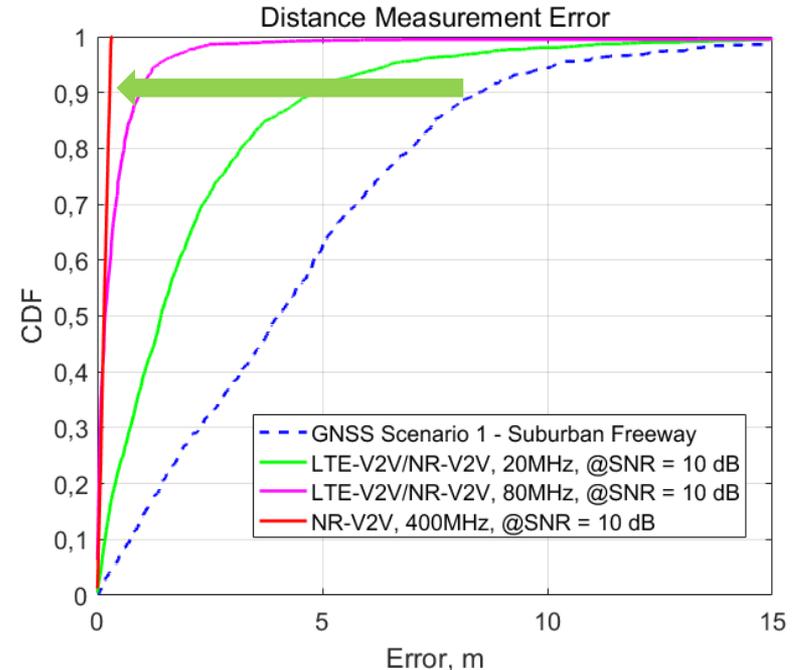
NR V2X Positioning Performance

Link Level Analysis

Evaluation Assumptions

Parameter	Value
Bandwidth	20 MHz (LTE-V2V LB), 80 MHz (NR-V2V LB), 400 MHz (NR-V2V HB)
SCS	15 kHz (LTE-V2V LB), 60 kHz (NR-V2V LB), 240 kHz (NR-V2V HB)
Number of RX antennas	4 omni (LTE V2V), 4 omni (NR-V2V), 1 (directional NR-V2V high band)
Timing estimation	Single shot, first path detection, advanced timing estimation
Channel model	TR 36.875 <ul style="list-style-type: none">• LTE V2V LB• NR V2V LB NR V2V HB – please refer to [2]

Distance Estimation Accuracy



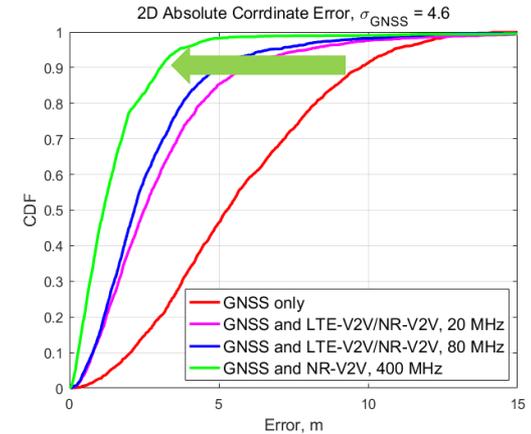
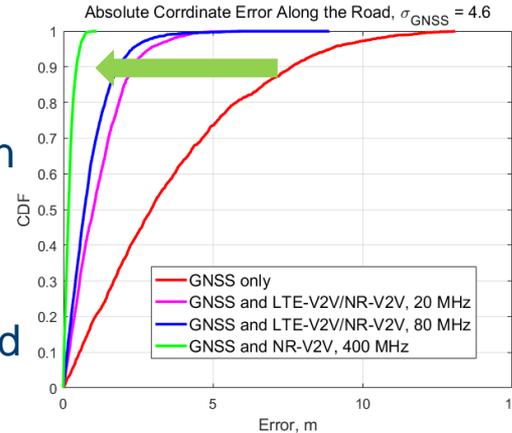
NR V2X Positioning Performance

System Level Analysis (Freeway, GNSS, w/o RSU)

Evaluation Assumptions

- Typical GNSS Freeway error (based on field trials)
- GNSS error is modelled as Gaussian distribution ($\sigma_{\text{GNSS}} = 4.6\text{m}$)
- No RSUs deployed along the road
- V2V links with SINR > 10dB are used for timing estimation
- NR-V2V in high band applies directional antenna and no co-channel interference is assumed

System Level Evaluation Results



Conclusion

- NR-V2V positioning can substantially improve vehicle positioning performance

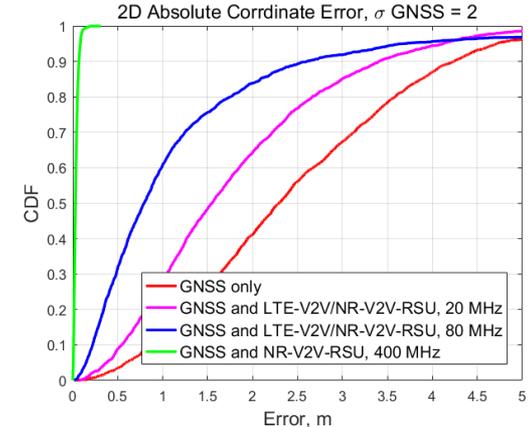
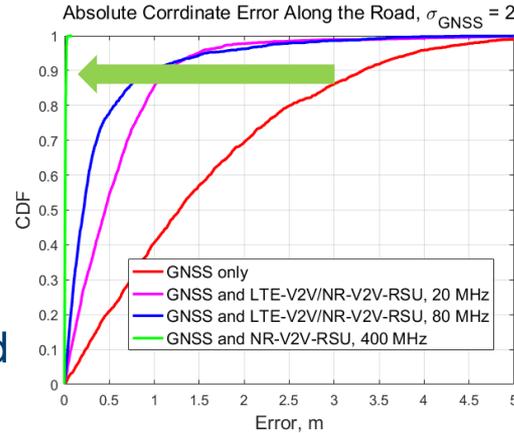
NR V2X Positioning Performance

System Level Analysis (Freeway, GNSS+RSU)

Evaluation Assumptions

- Accurate GNSS is emulated
- GNSS error is modelled as Gaussian distribution ($\sigma_{\text{GNSS}} = 2\text{m}$)
- RSUs are deployed from different sides of the road every 100m
- V2V links with SNR > 10dB are used for timing estimation
- NR-V2V in high band applies directional antenna and no co-channel interference is assumed

System Level Evaluation Results



Conclusion

- Deployment of RSUs along road allow to achieve very accurate positioning
 - 80MHz: <1m for 90% of cases; 400 MHz <0.5m for 100%

Summary

Conclusions

- Accurate location is a key enabler of future vehicular services
- Enabling range measurements between vehicles improves location accuracy
- NR-V2X communication can play crucial role to improve vehicular positioning by providing complementary solution to GNSS or other technologies
- 3GPP NR-V2X technology can enable positioning bounds beyond GNSS limits

Proposal

- Study NR-V2X positioning to analyze enhancements that can be provided by 3GPP NR radio-interface(s) for vehicular services

NR V2X Communication

NR V2X Downlink / Uplink / Sidelink Radio-interfaces

NR-V2X Communication

Potential 5G-V2X Requirements

Target Scenarios

- Sparse and dense vehicular scenarios within, partial or out of network coverage

Data Rates

- Up to 1Gbps (typically 2-50Mbps)

End-to-end Latency

- Down to 3-5ms (typically < 20ms)

Reliability Target

- Ultra reliable (99.99% - 99.999%)

Traffic

- Periodic, event-driven, video streaming

Communication Types

- Unicast / multicast / broadcast
- URLLC + High data rate

Radio Links / Interfaces

- Radio-links DL, UL, SL / (Uu & PC5)

Communication Bands

- Below 6 GHz and above 6 GHz

Relaying

- Coverage extension and reliability

RSU Support

- Radio resource management, non-transparent to radio layers

Potential ITS Frequency Bands

ITS Spectrum Allocation in Europe

ITS Frequency Bands (Europe)

- 3.4 GHz – need further discussion
 - Redundancy and de-correlation from 5.9GHz for a purpose of safety related applications
- 5.9 GHz (70 MHz - 5855-5875, 5875-5905 and 5905-5925 MHz)
 - Occupied by DSRC and/or LTE-V2V and/or NR-V2V (below 6 GHz)
- 63-64 GHz
 - One GHz of spectrum in the frequency range of oxygen absorption region - 15dB/km
 - Overlaps with IEEE 802.11ad (Wi-Gig) frequency operation range => potential coexistence issues
- 76-81 GHz
 - Better channel propagation characteristics
 - Larger chunk of spectrum allocation is available that can be used for ITS applications

Conclusion

- NR-V2X is at least supported at 5.9 GHz and mmWave bands (e.g. 76-81 GHz)

NR V2X – Impact on Radio Interfaces

Platooning



- Accurate vehicle positioning
- URLLC sidelink(groupcast/broadcast)
- Sidelink radio resource management
- Support of DL and UL communication

Extended Sensors



- High throughput sidelink
- Support of broadcast, multicast, unicast
- URLLC sidelink

Advanced Driving



- Accurate vehicle positioning
- URLLC sidelink
- Support of DL and UL communication, including URLLC

Remote Driving



- Ultra reliable and low latency DL / UL (i.e. Uu radio-interface)
- High throughput UL is needed
- No impact on sidelink air-interface

3GPP NR-V2X Study Directions

Study Directions for 3GPP NR V2X Technology Development

- Worldwide ITS spectrum allocation and regulation
- Sidelink channel model for carrier frequency > 6 GHz (i.e. mmWave)
- Accurate vehicle positioning principles and mechanisms
- Utilization of geo-location information for radio-layer enhancements
- Ultra reliable and low latency sidelink for unicast, groupcast, broadcast
- High throughput sidelink for unicast, groupcast, broadcast
- Relaying for reliability and range extension
- Study NR URLLC/eMBB DL/UL designs in application to 5G-V2X requirements
- Considerations on forward compatibility with the next releases (R16/R17)

NR-V2X Conclusions

5G-V2X Service Requirements

- 5G-V2X require accurate vehicle positioning (beyond GNSS limits)
- 5G-V2X services need wideband spectrum allocation below and above 6GHz
- 5G-V2X services rely on both NR-Uu and NR-PC5 air-interfaces

NR-V2X Technology Attributes

- NR should assist in accurate geo-location for vehicles
- NR should support eMBB & URLLC communication on DL/UL/SL
- NR should support unicast / groupcast / broadcast on DL/UL/SL
- NR should operate below 6 GHz and mmWave band (e.g. 76-81 GHz)

NR V2X Study Item

Objectives and timelines

NR V2X Study Item

Proposed Objectives

Work Direction-1

- Worldwide ITS spectrum allocation and regulation & Evaluation methodology
 - Clear understanding on 5G-V2X spectrum demands for low and high bands, ITS spectrum allocation regulation, mapping of ITS services => 3GPP assessment
 - Sidelink channel modeling for above 6 GHz (i.e. mmWave 60-80 GHz), accurate channel modeling for mmWave ITS is needed for proper system design
 - Refinement of NR V2X evaluation methodology whether needed

Work Direction-2

- Accurate vehicle positioning principles and mechanisms
 - Distributed and centralized mechanisms, utilization of low and high bands
- Utilization of location information for radio-layer enhancements

NR V2X Study Item

Proposed Objectives

Work Direction-3

- Ultra reliable and low latency sidelink for unicast, groupcast, broadcast
 - Resource management/selection, ACK/NACK feedback, numerology considerations
- High throughput sidelink for unicast, groupcast, broadcast communication
 - MIMO, high order modulation, advanced ISIC receivers, multi-carrier/band operation
- Relaying for reliability and range extension
 - Distributed relaying and radio-layer dissemination

NR V2X Study Item

Proposed Objectives

Work Direction-4

- Study NR URLLC/eMBB DL/UL designs in application to 5G-V2X requirements
 - Check if NR URLLC and eMBB designs are sufficient to cover 5G-V2X requirements
 - Study enhancements to NR URLLC and eMBB designs if needed
- Study NR / LTE V2X coexistence/interoperability aspects

NR V2X Study Item Proposal

Timelines

2016	2017				2018				2019			
Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4

5G V2X NR study item

5G V2X NR work item

Backup

Evaluation Assumptions / Vehicle Positioning System / References

Link and System Level Evaluation Assumptions

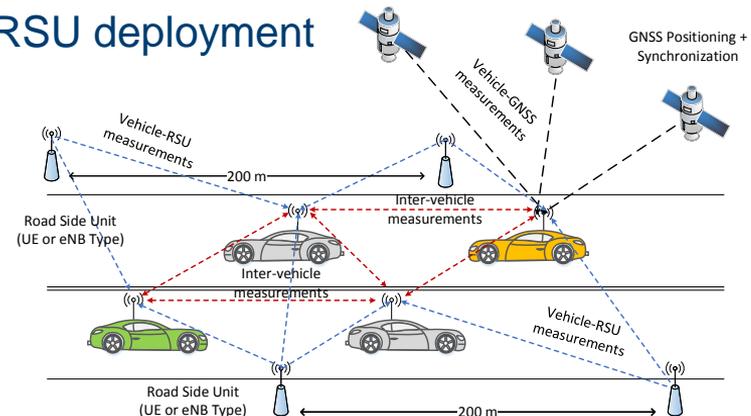
V2X Positioning

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Number of RX antennas	4 omni (LTE V2V), 4 omni(NR-V2V), 1(directional NR-V2V HB)
Timing estimation	Single shot, first path detection, advanced timing estimation
Channel model	TR 36.875 <ul style="list-style-type: none"> • LTE V2V LB (20 MHz) • NR V2V LB (80 MHz) NR V2V HB [2] (400 MHz). • Ideal beamforming pointing towards LOS direction. Interference impact is not considered.

GNSS Error Modeling

- Gaussian distribution
 - $\sigma_{\text{GNSS}} = 2 \text{ m}$ (emulates accurate GNSS, e.g. differential)
 - $\sigma_{\text{GNSS}} = 4.6 \text{ m}$ (emulates GNSS performance in Freeway based on field trial)
- RSU deployment



mmWave Evaluation Assumptions

Antenna Model and Channel Model

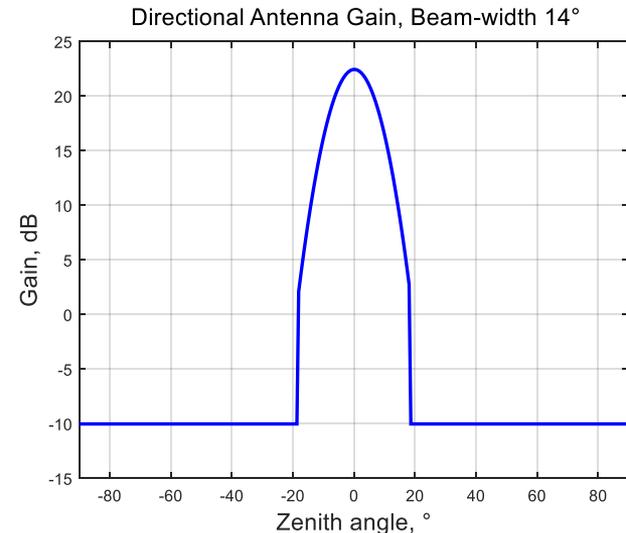
Directional Antenna Model

- 3D directional antenna model [1] was implemented and used in analysis
- Antenna-pattern is normalized, so that overall/integral antenna gain is equal to 1

Beam-Width (degrees)	Side-lobe (dBi)	Direct gain (dBi)
14°	≈ -10	≈ 22.5

mmWave Channel Model

- 3D mmWave channel model for outdoor scenarios was implemented [2] (stochastic model based on New-York measurements – similar to 3GPP SCM)



V2X Positioning

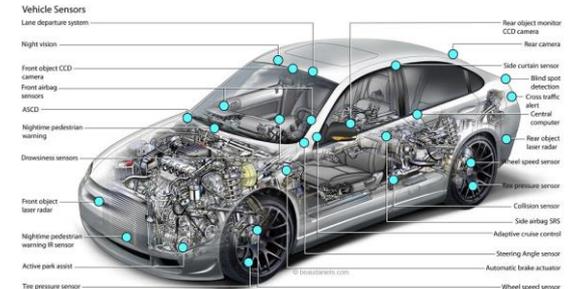
Heterogeneous Solution

V2X Positioning

- Multiple technical challenges to get accurate and reliable vehicle coordinate or inter-vehicle distance
 - High mobility, GNSS signal blockage in Urban scenarios, LOS and NLOS multipath propagation, interference
- Primary technology is GNSS based positioning, which is not sufficient in all scenarios
 - GNSS based positioning accuracy, availability and reliability in Urban scenarios is of concern

Vehicular Positioning Systems (Heterogeneous System)

- Combination of multiple technologies with pros and cons (camera / lidar / radar / sensor / radio)
- Strict requirements on accuracy, reliability and availability



References

[1] IEEE P802.15 Working Group for WPANs

[2] 3D mmWave Channel Proposal, Timothy A. Thomas, Huan Cong Nguyen

