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

RP-170428

Motivation for SI: Study on LTE Vehicular Positioning Technologies

Agenda Item: 10.1.1
Source: Intel Corporation
Document for: Discussion

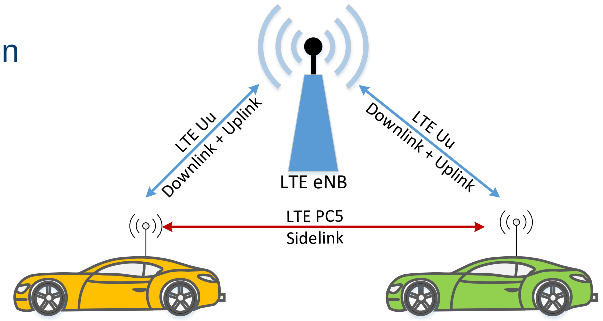
LTE Vehicular Communication

Background on LTE-V2X Enhancements

Work on R.14 LTE-V2X communication is progressing towards completion - Feb'17

LTE-V2X defines enhancements for two complementary air-interfaces: PC5 and Uu

- LTE sidelink V2X enhancements (LTE PC5)
  - eNB controlled mode: SL SPS scheduling + reporting of location information
  - UE autonomous mode: SL sensing & resource selection + geo-zoning
  - Enhancements of L1 structure for robust performance at high speeds
  - GNSS synchronization (GNSS as sync reference for time/frequency)
- LTE downlink and uplink V2X enhancements (LTE Uu)
  - Uplink SPS enhancements to efficiently handle quasi-periodic V2X traffic



Vehicle location information is used for LTE-V2X radio-resource management

- Autonomous radio resource selection or scheduling based on geo-location information of vehicle provides improved communication performance

LTE-V2X and Geo-location

Demand for Accurate and Reliable Vehicle Location

Automotive industry transformation

- Automotive industry transforms towards support of higher automation levels (autonomous driving)
- V2X applications require accurate and reliable geo-location for robust operation
- Demand for tighter integration of vehicular location and communication technologies
  - Road safety / intelligent transportation and traffic management / navigation / platooning / assisted & autonomous driving services

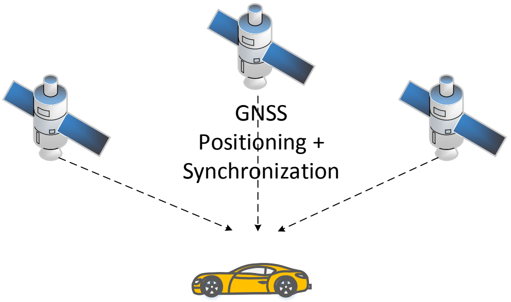
3GPP SA1 “Study on enhancement of 3GPP support for 5G V2X services (Rel.15)”

- High precision positioning techniques should be supported
- V2X positioning requirements - technically challenging targets
  - “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”

V2X Positioning
GNSS Trial Measurements

Experimental GNSS measurements

- Vehicle with GNSS receivers mounted inside a car (consumer grade)
- GNSS accuracy experiment is conducted on predefined route
  - Scenario 1: Suburban Freeway (mostly Freeway)
  - Scenario 2: Urban Dense (+ skyscraper urban canyon)
- Synchronized measurements from different GNSS sources
  - Absolute GNSS measurement: vehicle absolute coordinate error
  - Relative GNSS measurement: distance error between two vehicles
- True coordinates are estimated using MEMS IMU
  - MEMS IMU has accurate GNSS and utilizes data from multiple sensors
- Vehicle speeds varies in the range from 20-100km/h



V2X Positioning

GNSS Requirements and Measurements

3GPP GNSS requirements (TS 36.171)

3GPP GNSS requirements

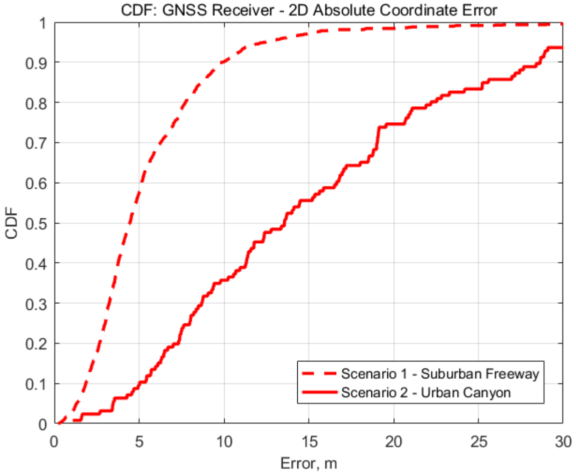
System	Success rate	2-D position error	Max response time
GNSS	95 %	15 m	20 s

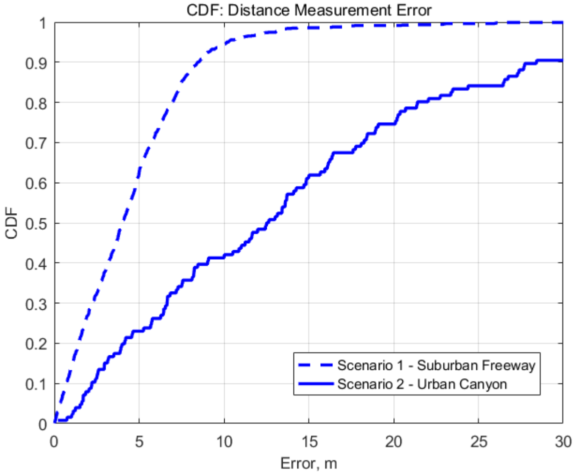
3GPP GPS requirements

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

Field Test Trial

GNSS measurement from different recording sets





Observation

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

V2X Positioning

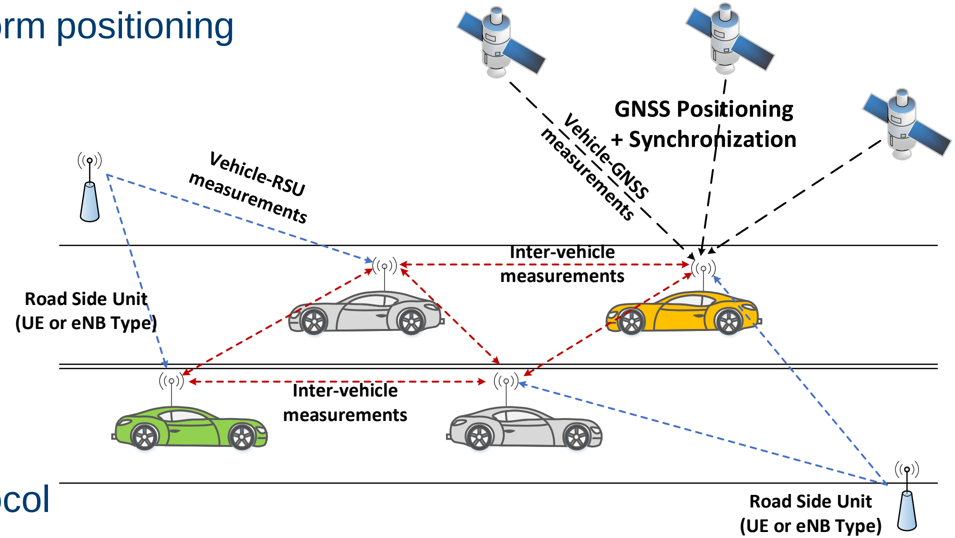
LTE-V2V Radio-Interface in V2X Positioning

Role of LTE V2V Communication in V2X Positioning

- Distance measurements with proximate vehicle(s)/RSU(s)
- Broadcasting of coordinates or location measurements to facilitate relative or absolute positioning
- Enabling cooperative location protocols to perform positioning

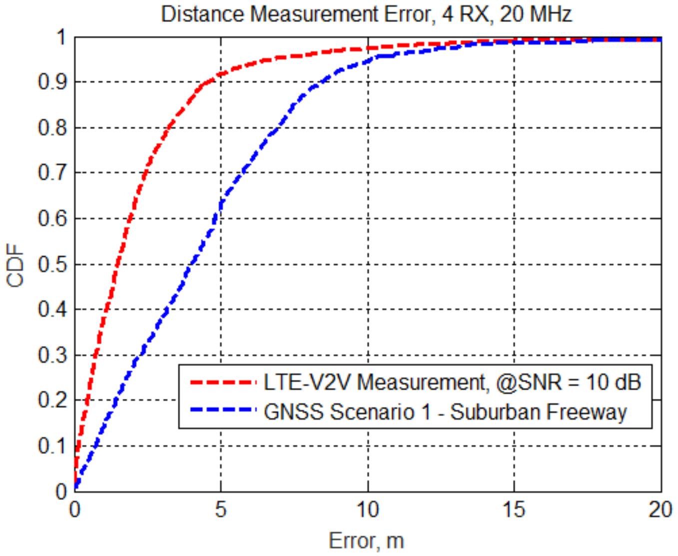
Technical Advantages

- Increased estimation accuracy
  - GNSS is complemented by radio-layer techniques
- Increased system reliability
  - Additional sources of location information
- Increased robustness
  - Multiple links with favorable radio-conditions
- Integrated communication and positioning protocol



V2X Positioning Performance
Link Level Analysis

Parameter	Value
Bandwidth	20 MHz
SCS	15 KHz
Number of RX antennas	4
Timing estimation	Single shot
Channel model	V2V Channel Model (TR 36.875)
First path detection	Advanced timing estimation



Conclusion

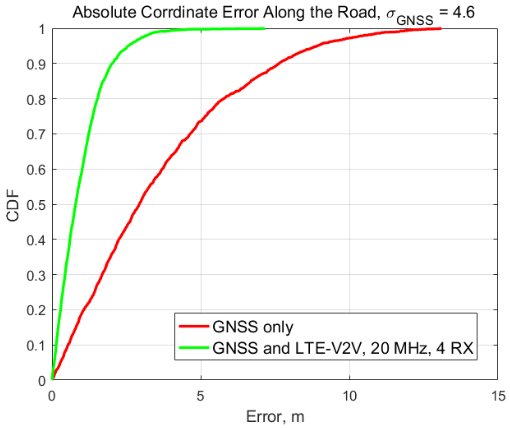
- Advanced timing estimation techniques can provide accurate timing measurements that can outperform GNSS based distance measurement

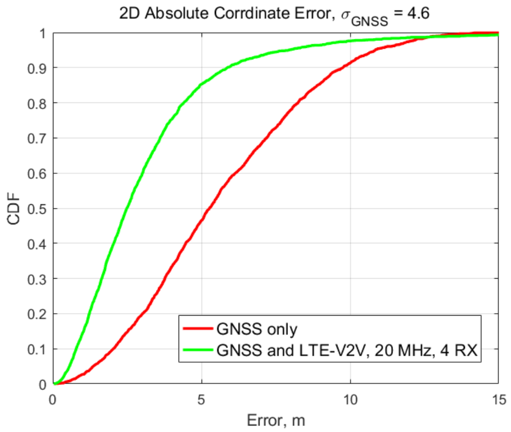
V2X Positioning Performance

System Level Analysis – Freeway Scenario

CDF of Absolute Positioning Error

Parameter	Value
Bandwidth	20 MHz
SCS	15 KHz
Number of RX antennas	4
Timing estimation	Advanced Timing Estimation
Channel model	V2V Channel Model (LTE-V2V TR 36.875)
Inter-vehicle distance distribution	LTE-V2V Evaluation Methodology (Freeway Scenario 70km/h)
Positioning	1) GNSS only 2) GNSS + Distance





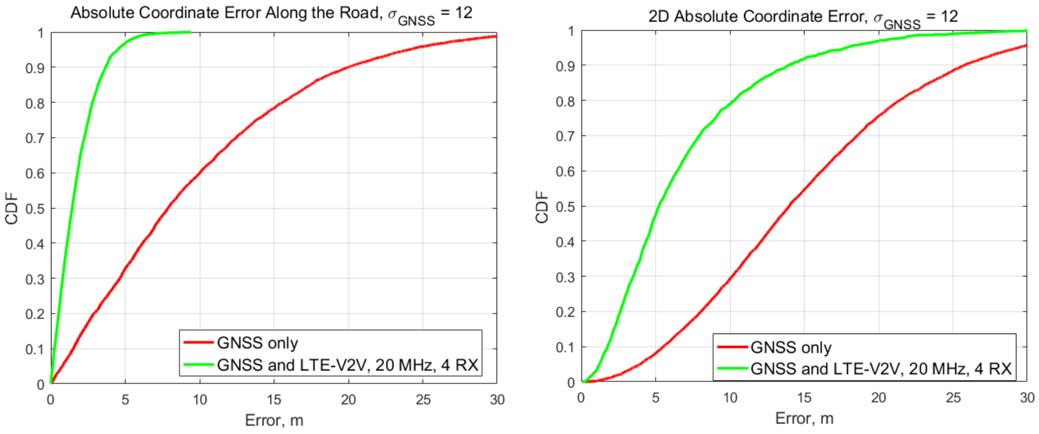
- Combination of accurate radio-layer timing measurements and GNSS location provides improved positioning accuracy in Freeway scenarios

V2X Positioning Performance

System Level Analysis - Urban Scenario

CDF of Absolute Positioning Error

Parameter	Value
Bandwidth	20 MHz
SCS	15 KHz
Number of RX antennas	4
Timing estimation	Advanced Timing Estimation
Channel model	V2V Channel Model (LTE-V2V TR 36.875)
Inter-vehicle distance distribution	LTE-V2V Evaluation Methodology (Urban Scenario 70km/h)
Positioning	1) GNSS only 2) GNSS + Distance



- Combination of accurate radio-layer timing measurements and GNSS location provides improved positioning accuracy in Urban scenarios

Summary

Conclusions

- Presented analysis shows benefits of enabling range/distance measurements for vehicular services
- Accurate and reliable location and proximity is a key enabler of future vehicular services
- LTE-V2X communication can play crucial role to improve V2X positioning (complementary solution)
- 3GPP LTE-V2X and NR technologies can be used to enable new positioning accuracy bounds beyond current GNSS limits

Proposal

- Organize 3GPP V2X positioning study item to analyze V2X positioning enhancements that can be provided by 3GPP radio-interface(s) LTE or NR
- Start from LTE-V2X positioning given that NR air-interface is in active study/development stage

LTE V2X Positioning Study Item Proposal

Objectives

Definition of LTE-V2X positioning evaluation scenarios

- Identification of deployment scenarios for analysis of vehicle-to-vehicle or vehicle-to-RSU distance measurements and vehicle positioning protocols based on LTE communication technology including both LTE-Uu and LTE-PC5 air-interfaces [RAN1]
- Definition of necessary evaluation assumptions and performance metrics on top of the existing LTE-V2X communication methodology [TR 36.885] for LTE-V2X vehicle positioning [RAN1]

Study of physical layer enhancements to enable inter-vehicle distance measurements

- Study accuracy and feasibility of distance measurements using LTE-Uu and/or LTE-PC5 air-interfaces for vehicular positioning [RAN1, RAN4]
- Study LTE-Uu and/or LTE-PC5 enhancements beneficial for accurate vehicle-to-vehicle, vehicle-to-RSU, or vehicle-to-eNB distance measurements [RAN1]
- Study accuracy of advanced timing estimation algorithms, facilitating distance measurements [RAN1, RAN4]

Study positioning protocols to facilitate enhanced V2X positioning based on LTE technology

- Study LTE-Uu and/or Sidelink protocol enhancements to enable positioning protocols utilizing positioning technologies including but not limited to inter-vehicle distance measurement, GNSS information, etc. [RAN1, RAN2]
- Study of LTE positioning protocols enhancements beneficial for LTE-V2X positioning [RAN1, RAN2]

Identify specification impact to enable V2X positioning [RAN1, RAN2, RAN4]

LTE V2X Positioning Study Item Proposal

Tentative Work Plan and Timelines

WG Meetings	Date	RAN1 TUs	RAN2 TUs	RAN4 TUs	Work planning
RAN1#88bis /RAN2#97bis /RAN4#82bis	Apr'17	3	0	0	RAN1: Define scenarios for LTE-V2X range and positioning based on evaluation assumptions of LTE-V2V methodology. Identify design principles and protocols for range estimation and positioning
RAN1#89 /RAN2#98 /RAN4#83	May'17	4	1	0.5	RAN1: Link and system level evaluation of range estimation and positioning accuracy. Analysis of design options to support LTE V2X positioning RAN2: L2 aspects of range estimation and positioning (based on RAN1 input). Architectural consideration / LPP considerations. RAN4: Feasibility / accuracy analysis based on RAN1 input
RAN1#90 /RAN2#99 /RAN4#84	Aug'17	4	2	0	RAN1: Finalization of evaluation results, summary of design principles for range and positioning estimation. Recommendations on L1 design enhancements. RAN2: Conclusions on L2/upper layer aspects of identified positioning protocols.

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Backup

V2X Positioning System

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