



3GPP TSG RAN Meeting #80
La Jolla, USA, June 11 - 14, 2018
Agenda Item: 10.1.4

RP-180928

Motivation for SI proposal:

Study on Advanced Receivers for LTE V2X

Intel Corporation

LTE Vehicular Communication

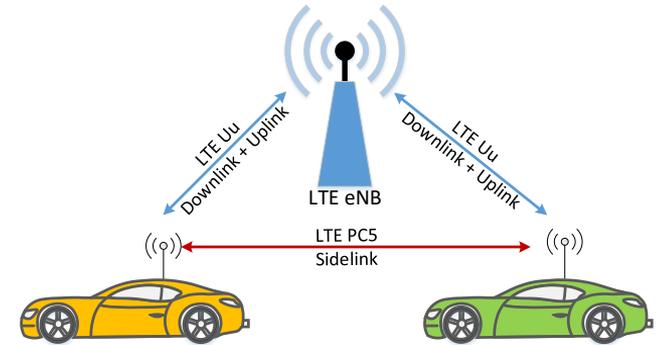
In the Rel-14/15 LTE V2V, V2X and eV2X WIs multiple enhancements of LTE PC5 and Uu air-interfaces, optimizing LTE technology for multiple V2X use cases, were introduced

- LTE PC5 (Sidelink-SL) V2X enhancements

- eNB controlled mode: SL SPS scheduling + Reporting of location information
- UE autonomous mode: 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 Uu (downlink-DL/uplink-UL) V2X enhancements

- MBMS and SC-PTM Downlink transmissions
- Uplink SPS enhancements to efficiently handle quasi-periodic V2X traffic



Existing LTE advanced receivers framework is applicable to LTE Uu operation (e.g. Interference mitigation, multiple 4RX, etc.), however, the LTE PC5 link performance requirements are based on basic receivers.

PC5 V2X Scenarios

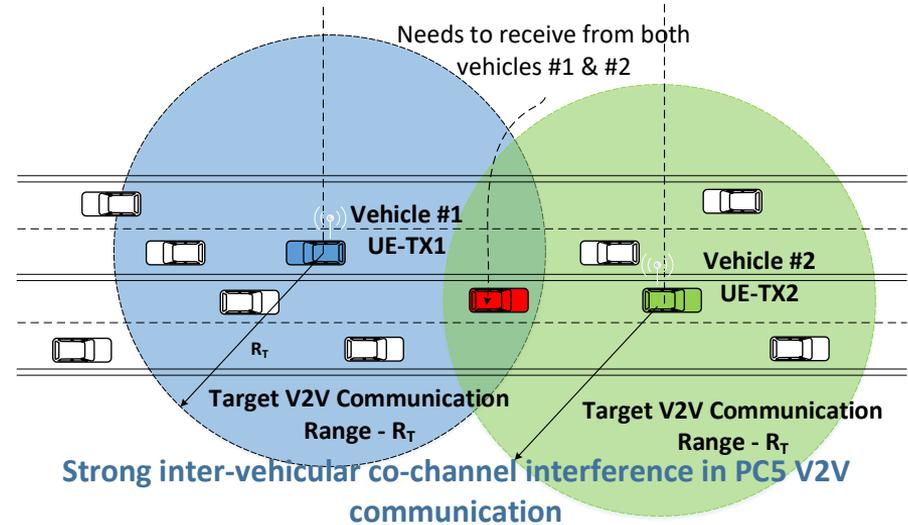
PC5 V2X performance depends on the deployment and traffic scenarios and may vary depending on the density of V2X transmissions

Sparse V2X deployments

- V2X performance depends on the V2X propagation distance and IBE level and is typically noise-limited
- V2X performance is limited by UEs capability to perform receive signal combining

Dense V2X deployments

- Multiple V2X transmissions (PSSCH/PSCCH) may collide in the same time/frequency resources leading to the interference-limited RX conditions
- V2X performance is limited by UEs capability to simultaneously receive multiple packets and to efficiently handle co-channel interference



PC5 V2X Receiver Enhancements

INTERFERENCE MITIGATION

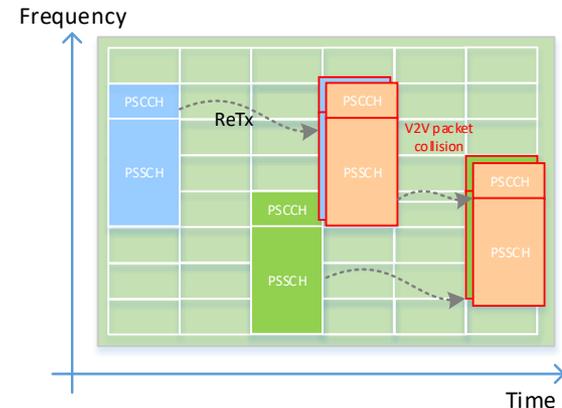
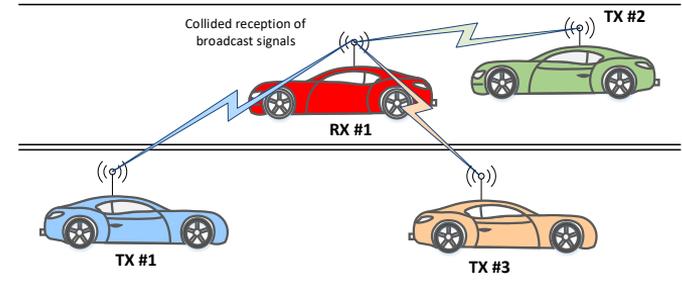
- Rel-14 V2X requirements are based on interference unaware receivers and interference mitigation (IM) receivers can be used to improve performance
- Different IS/IC receiver types can be used to ensure improved UE demodulation performance including **LMMSE-IRC**

MULTI PACKET DECODING

- Rel-14 requirements imply that UE would make single packet decoding in case of collision of multiple PSSCH/PSCCH in the same resources
- Advanced receivers may be capable to perform **multi PSSCH/PSSCH packet decoding**. At least 2 decoding iterations may be considered.

4 RX ANTENNAS

- Rel-14 V2X requirements are defined under assumptions of UEs equipped with 2RX chains.
- Vehicles typically don't have constraints for antenna placements and **4RX antennas** can be considered to improve performance in both noise- and interference- limited scenarios

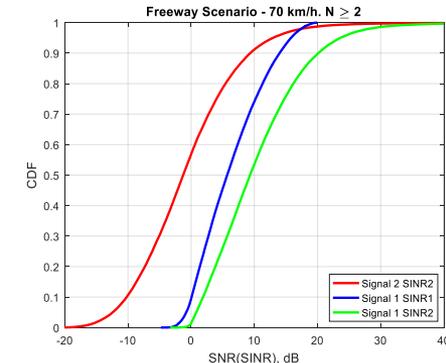
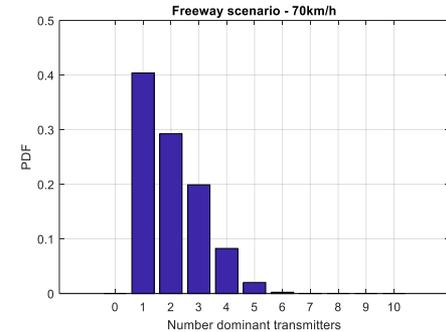
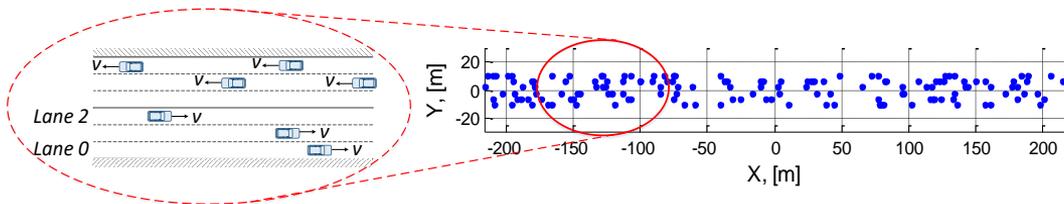


V2X Interference Statistics

V2X interference statistics depends on multiple factors: deployment model, traffic model, resource allocation, and resource selection algorithm.

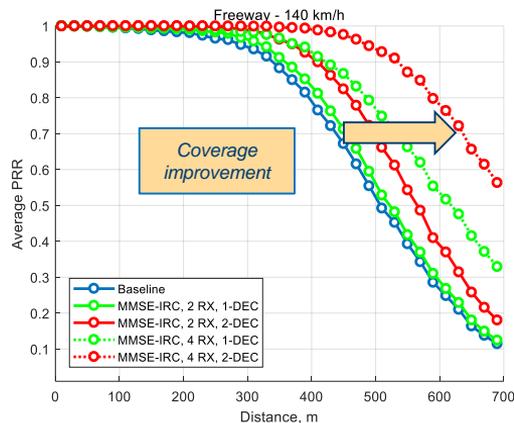
Freeway deployment scenarios (70 km/h)

- Noise-limited scenarios with single dominant PSSCH transmissions have ~40% probability => *May benefit from 4RX enhancements*
- Scenarios with 2 or more dominant PSSCH transmissions have ~60% probability. Nearly 30% of all scenarios have strong 2nd dominant PSSCH transmission => *May benefit from IM, multi-packet decoding and 4RX enhancements*

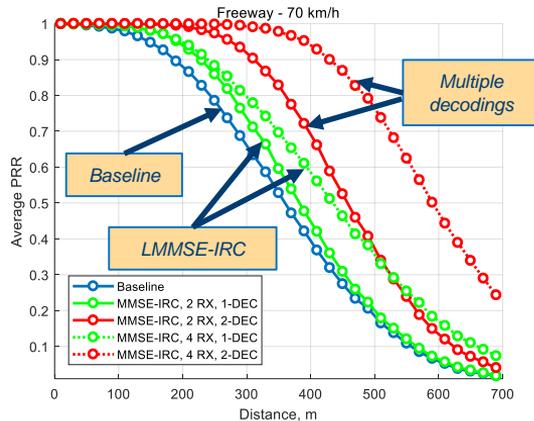


System-level Performance

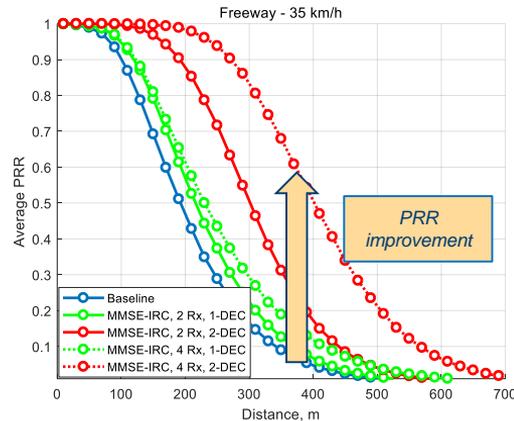
Freeway Sparse (140 km/h)



Freeway Dense (70 km/h)



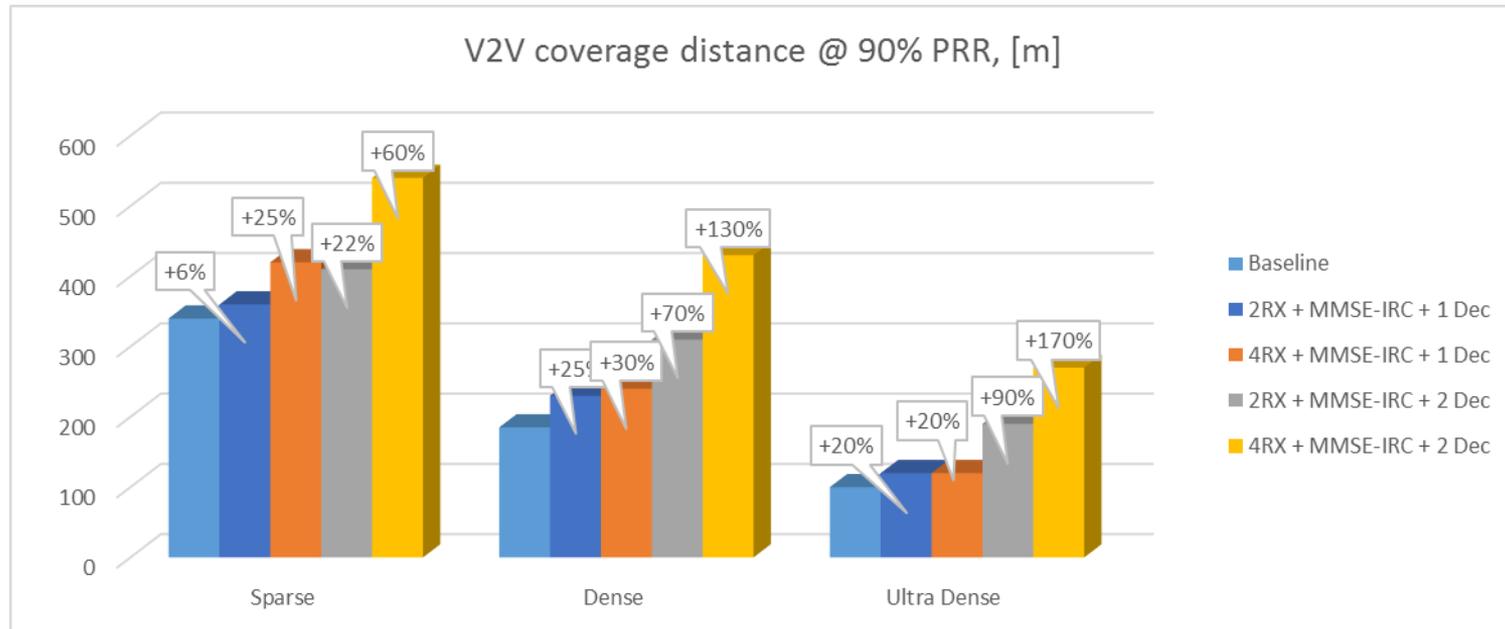
Freeway Ultra Dense (35 km/h)



Deployment	Freeway Sparse (140 km/h) Freeway Dense (70 km/h) Freeway Ultra Dense (35 km/h)
V2V parameters	PSSCH - 20 PRB, 2 TTIs ; PSCCH – 2 PRB; 190 byte packet
Receiver	Baseline RX: 2RX, MMSE-MRC, 1 decoding Advanced RX: 2RX & 4RX, MMSE-IRC, 1 & 2 decodings

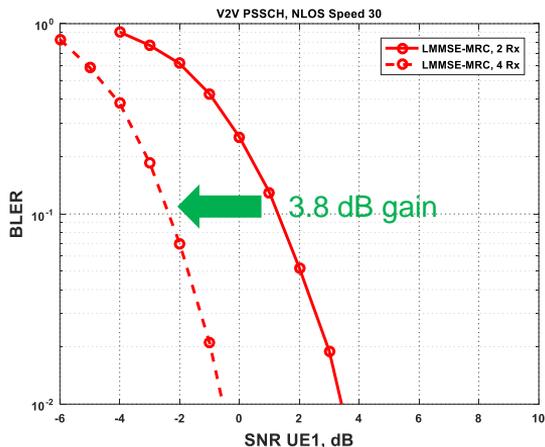
“MMSE-IRC” and “Multi-packet decoding” and “4RX” receivers provide substantial V2V coverage and PRR improvement

V2V Communication Coverage

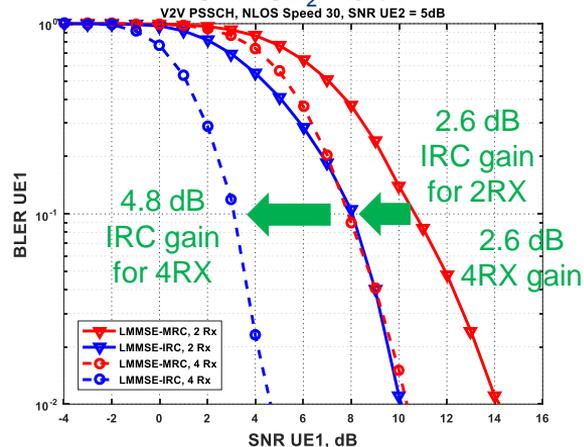


Link-level Performance

UE₁ BLER vs SNR
Noise limited scenario



UE₁ BLER vs SNR
Interference limited scenario
SNR UE₂ = 5 dB



LMMSE-IRC receivers provide substantial link-level performance improvement over legacy Rel-14 receivers for interference limited scenarios

Increasing of number of RX antennas allows to achieve substantial performance improvement for both noise and interference limited conditions

Potential Standard Impact from Advanced RX

Background

- Many LTE DL enhanced interference mitigation receivers were standardized in RAN4 in the recent releases
 - Many of existing LTE advanced receivers are transparent to the Core specification and do not require network assistance (e.g. Rel-11 LMMSE-IRC, Rel-12 SU-MIMO R-ML and CWIC receivers, R14 Enhanced SU-MIMO)
 - RAN4 introduced enhanced minimum performance requirements for enhanced receivers in TS 36.101 to ensure that UEs with corresponding features can guarantee proper performance in the networks under interference limited conditions
- Multiple RX chains
 - Base LTE DL requirements were defined under 2RX chains assumptions
 - 4RX and 8RX DL receivers were allowed from the Core specification perspective for a long time. The respective requirements were introduced only as a part of R13/R15 RAN4 work items with the purpose to ensure that UE performance gains can be extracted from the implementation of additional RX chains.

Potential specification impact (in WI stage)

- Enhanced V2X receiver performance requirements
 - LMMSE-IRC requirements in interference limited environments
 - 4RX V2X performance requirements in noise-limited and interference-limited conditions
- RF Core requirements for 4RX V2X UEs (e.g. REFSSENS)
- Other specification impacts can be studied as a part of SI (e.g. benefits of network assistance, etc.)

Summary

CONCLUSIONS

- Support of efficient vehicular communication is one of the key directions of further LTE evolution
- In LTE Rel-14 initial V2V functionality was introduced. The Rel-14 LTE V2V demodulation requirements are based on the single packet decoding assumptions, non-interference aware processing and 2RX antennas.
- System- and link-level analysis show substantial benefits of supporting advanced V2V receivers based on the three key features:
 - Interference mitigation receivers
 - Multi-packet decoding
 - 4RX antennas

PROPOSAL

- Organize RAN4 LTE Advanced V2V receivers study item to investigate the proposed enhancements
- Focus on transparent solutions applicable to be used for LTE Rel-14/15 V2X devices

Study Item Objectives

Study feasibility of advanced LTE V2X receivers for Sidelink [RAN4]

- Identify and agree on the target scenarios and assumptions including
 - Realistic deployment scenarios (based on Rel-14 RAN1 work)
 - Simulation assumptions for link-level evaluations
 - Interference models for link-level evaluations
- Identify reference advanced LTE V2X receiver structures and evaluate their performance/complexity trade-off and implementation feasibility
 - Investigate feasibility of the following receiver structures
 - LMMSE-IRC with single PSCCH/PSSCH decoding (i.e. no decoding of multiple overlapping PSCCH/PSSCH transmissions)
 - LMMSE-IRC with multiple PSCCH/PSSCH decodings (i.e. decoding of multiple overlapping PSCCH/PSSCH transmissions)
 - Investigate feasibility of receiver structures with 2RX and 4RX antennas
- Evaluate advanced LTE V2X receivers performance benefits over baseline Rel-14/15 V2X receiver
 - Baseline receiver: LMMSE-MRC with single PSCCH/PSSCH decoding and 2RX antennas
- Identify impact on the UE performance requirements or other specification impacts

