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novel mobile radio

Comparison of V2X based on 802.11p, LTE and 5G

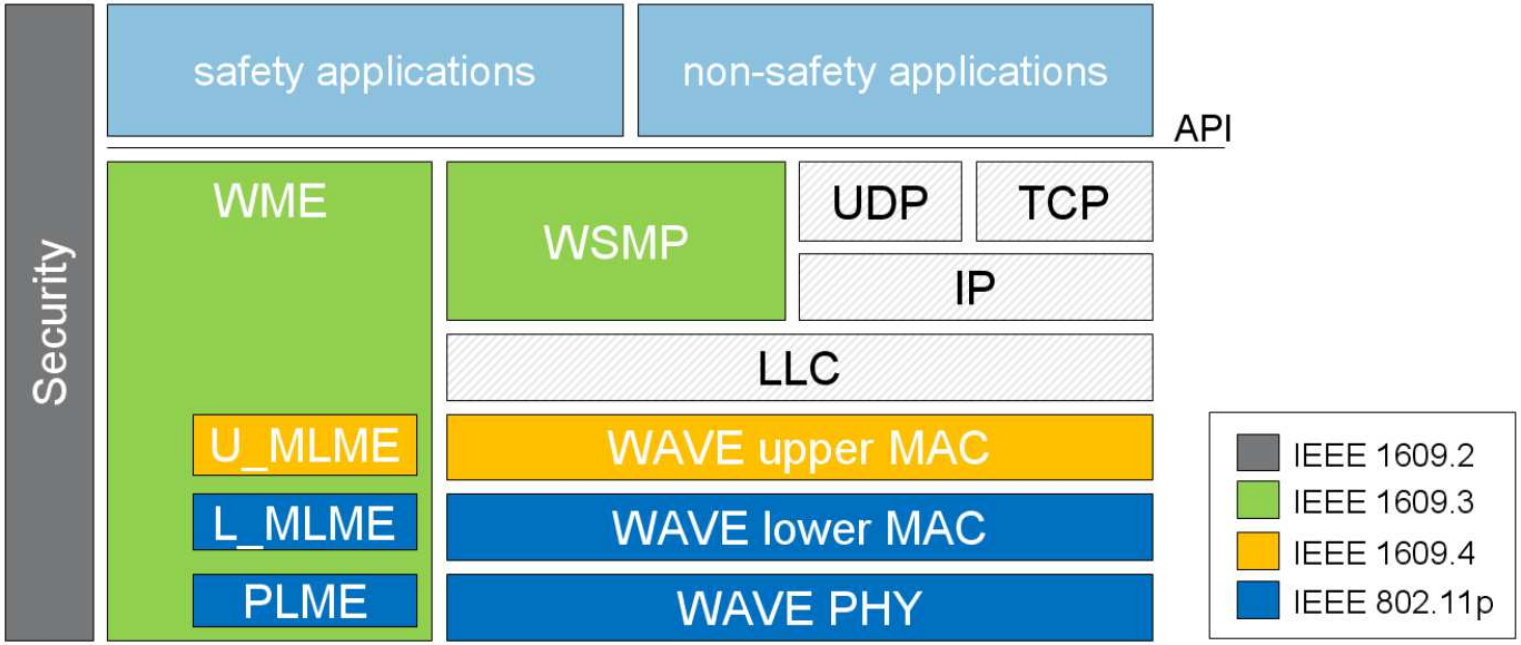
Workshop “Automotive Security”
Darmstadt, Germany
11.04.2019

Outline

- Overview 802.11p
- Overview LTE-V2X
- Comparison 802.11p vs. LTE-V2X
- Outlook NR-V2X

802.11p – Overview

- DSRC = IEEE 802.11p WAVE

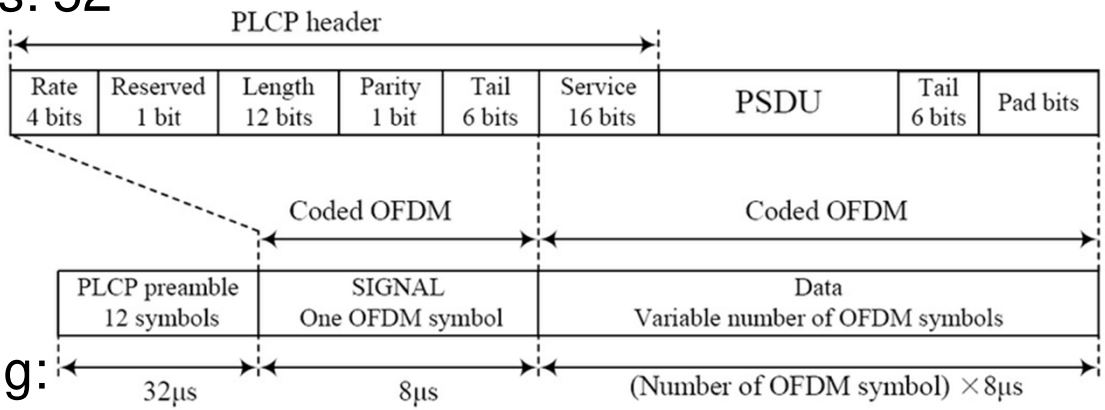


From D. Jiang, L. Delgrossi. "IEEE 802.11p: Towards an International Standard for Wireless Access in Vehicular Environments". In IEEE VTC Spring, 2008.

DSRC: Dedicated Short Range Communication
WAVE: Wireless Access in Vehicular Environments

802.11p – Numerology

- Derived from 802.11a
  - Basically doubling all timings
  - → Better resilience against increased delay spread
- 802.11p parameters:
  - System bandwidth: 10MHz
  - Subcarrier spacing: 156.25kHz
  - Number of subcarriers: 52
    - Data: 48
    - Pilots: 4
    - (DFT length: 64)
  - Symbol duration: 8µs
  - Guard time: 1.6µs
  - Modulation and coding:
    - BPSK, QPSK, 16QAM, 64QAM
    - rate ½, 2/3, 3/4 convolutional code
    - → 3Mbps -27Mbps

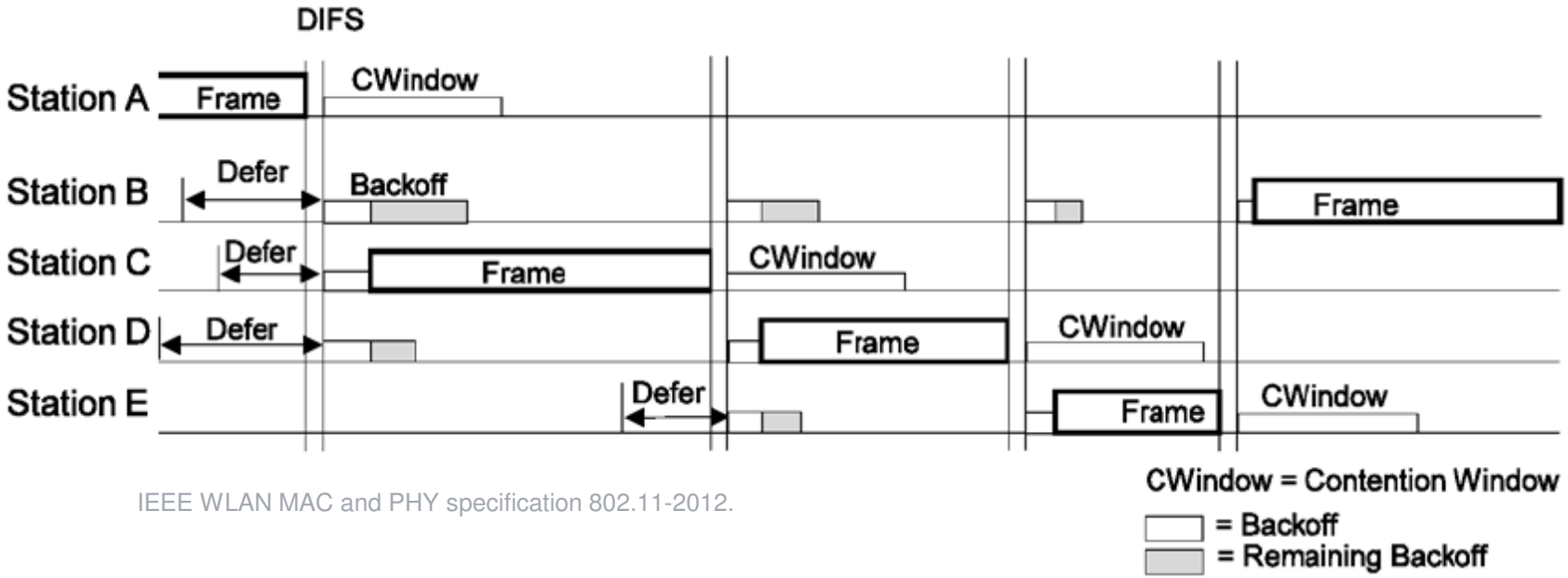


From H. Wen et al. „A novel Framework for Message Authentication in vehicular Communication Networks", Globecom 2009.

802.11p – Access Method

- CSMA/CA (Carrier Sense Multiple Access / Collision Avoidance)
- via DCF (Distributed Coordination Function)
- Principle
  - STAs monitor the channel for activity:
    - ED: Energy detection
    - CCA: Clear channel assessment
  - When channel becomes clear:
    - STAs enter a contention phase
  - When STA's backoff timer (*n* slots) expires:
    - STA transmits (typ. single frame)

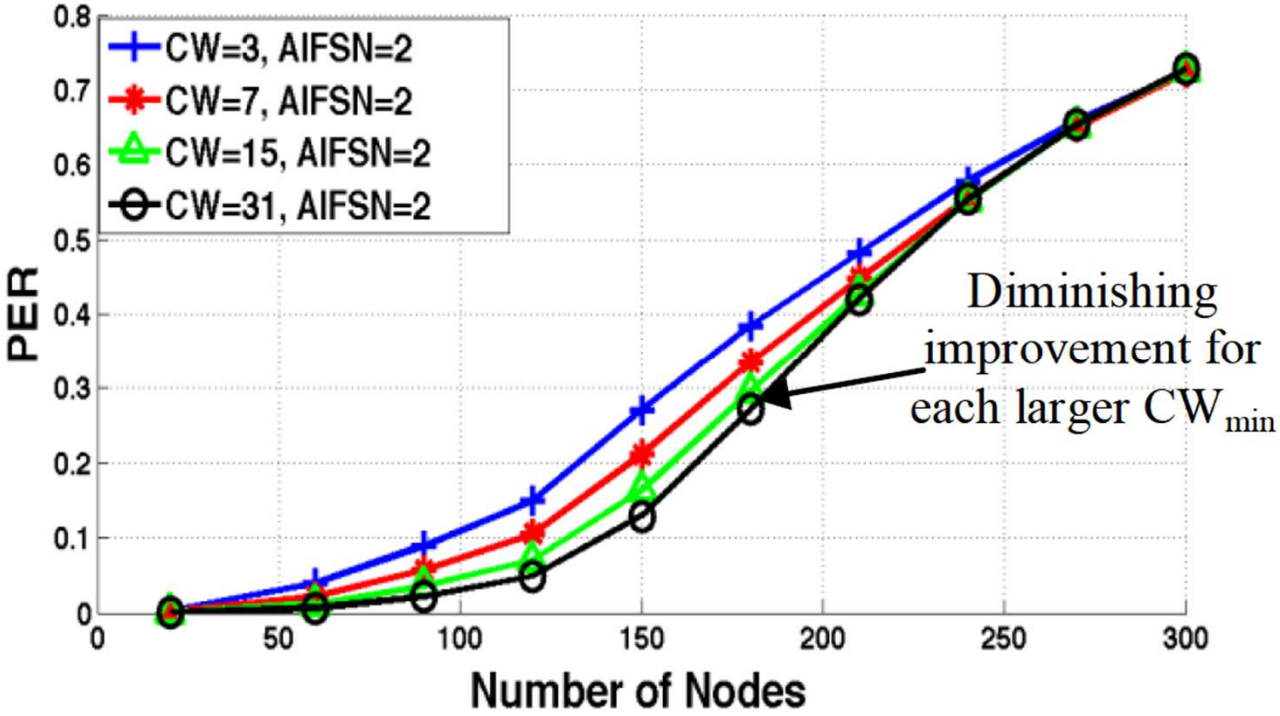
802.11p – Access Method



IEEE WLAN MAC and PHY specification 802.11-2012.

- Parameters
  - DIFS 64µs
    - (SIFS / AIFS[*i*]: 32µs for use with QoS and for timing of signaling)
  - Slot time: 13µs

802.11p – Access Method



S. Sharafkandi et al. „Using EDCA to improve Vehicle Safety Messaging", VNC 2012.

- Characterization
  - TDMA with some residual risk of collision if backoff timers of different STAs expire simultaneously
  - Quite effective avoidance of collisions
    - depends on size of contention window
    - except for hidden source problem

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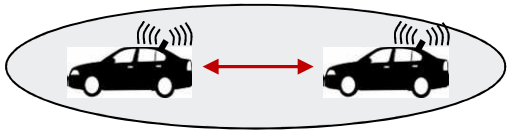
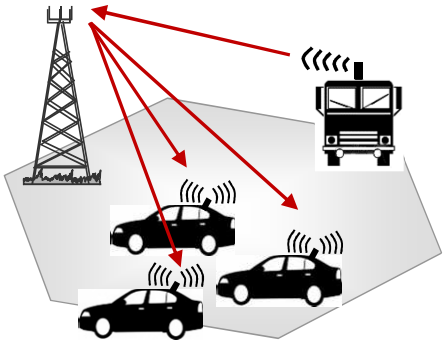
LTE-V2X – Overview

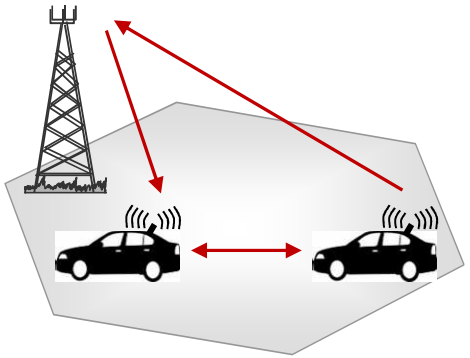
- Part of cellular communication system LTE
- Different options
  - Via network (Uu interface)
    - UL unicast + DL multicast
    - UL unicast + DL eMBMS
    - UL unicast + DL SC-PTM
  - Via D2D direct mode (PC5 interface)
    - Essential for delay critical communication
- Can be operated in
  - dedicated V2X spectrum (5.9GHz)
  - any LTE carrier

Dedicated V2V Spectrum



Licensed Spectrum





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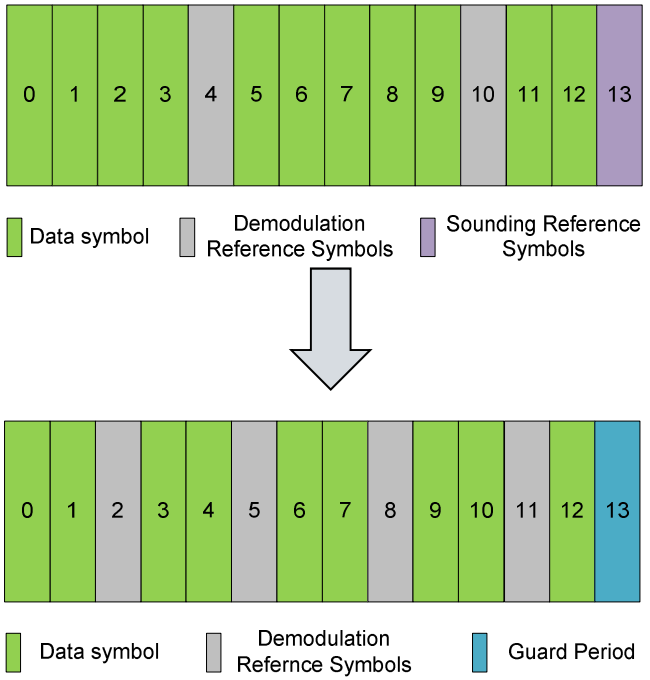
LTE-V2X – PC5 Numerology

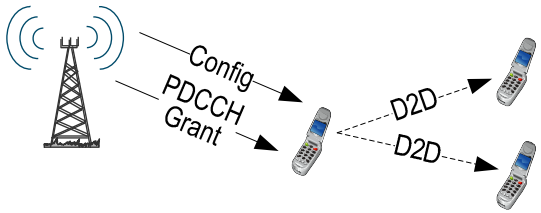
- Derived from UL numerology
  - 2 additional pilot (DMRS) symbols
  - 1 OFDM symbol guard period
- LTE-V2X parameters:
  - System bandwidth: 10MHz
  - Subcarrier spacing: 15kHz
  - Number of subcarriers: 600
  - Symbol duration: 1/14ms ≈ 71µs
  - Guard time: ≈ 5µs
  - Modulation and coding:
    - QPSK, 16QAM, (release 15: 64QAM)
    - Turbo code (various rates)
  - MIMO
    - Release 14: single Tx antenna
    - Release 15: option for small delay cyclic delay diversity (SD-CDD)



LTE-V2X – Access Method

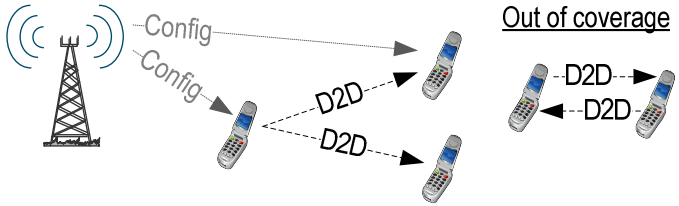
Resource Allocation

Mode 3: Scheduled by eNB



- limited to in-coverage
- eNB schedules every transmission
- centralized control of resources
- UE must be in RRC Connected
  - UE sends eNB a scheduling request
- more suitable for licensed spectrum
  - e.g. coordination of Uu and PC5

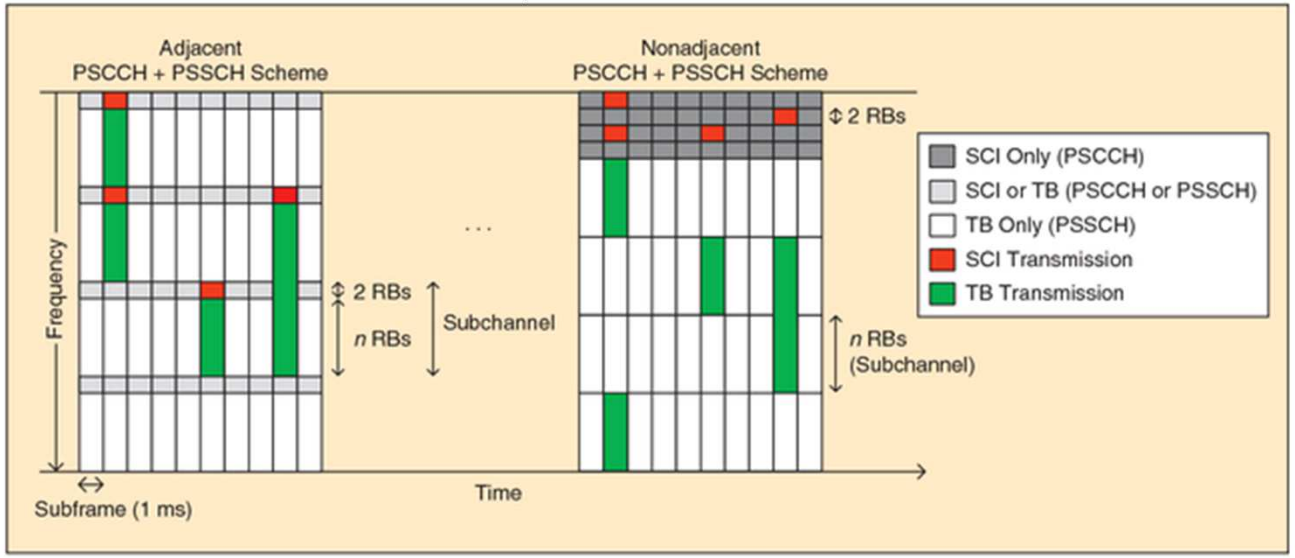
Mode 4: Autonomous Mode



- also supports out of coverage
- eNB configures resource pools
- collisions are possible
  - → sensing!
- UE might be in RRC IDLE
  - own resource selection from a pool
- more suitable for V2X spectrum
  - limited range and high traffic load

LTE-V2X – Sidelink Channels

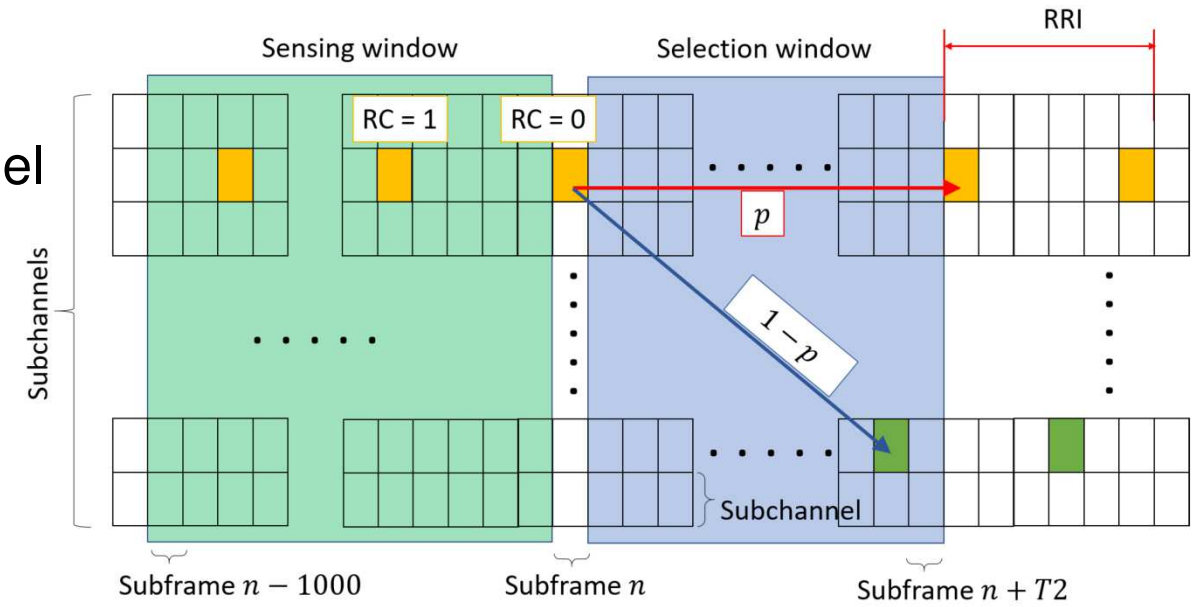
- PSCCH: Control channel to carry SCI that indicates
  - use of corresponding PSSCH
  - transmission parameters of PSSCH (e.g. MCS)
  - whether next PSSCH (acc. to SPS scheduling) will also be used.
  - …
- PSSCH: Carries transport block



R. Molina-Masegosa et al.: "LTE-V for Sidelink 5G V2X Vehicular Communications: A new 5G Technology for short-Range V2X Communications", IEEE Vehicular Technology Magazine 2017

LTE-V2X – Autonomous Resource Selection

- Based on
  - Sensing of channel
  - Semi-persistent subchannel selection



From: Y. Jeon et al.: "Reducing Message Collisions in SPS by using Reselection Lookaheads in Cellular V2X", Sensors 2018.

- Principle
  - Subchannel selection
    - UEs measure received signal power on different available PSSCH subchannels (with averaging over time)
    - Randomly select one out of the 20% best subchannels
  - Update
    - Selected subchannel is used periodically for *n* u.i.i.d. in [5,15] time instances
    - Then new subchannel is selected with probability 1-*p* (e.g. *p=0.8*).
    - Otherwise same subchannel is used for another *n* u.i.i.d. in [5,15] time instances
    - Or when latency requirement for a packet would be exceeded

LTE-V2X – Access Method

- Characterization
  - TTI grid imposes restrictions on collision avoidance
    - Also: UEs must be synchronized (eNB, GPS or by some UE acting as “sync source”)
  - Sensing in combination with async. subchannel re-selection and SPS to have good subchannel selection based on reasonable subchannel quality measurements
  - Problem: If two UEs close to each other happen to select the same subchannel, the collision will persist for a while.

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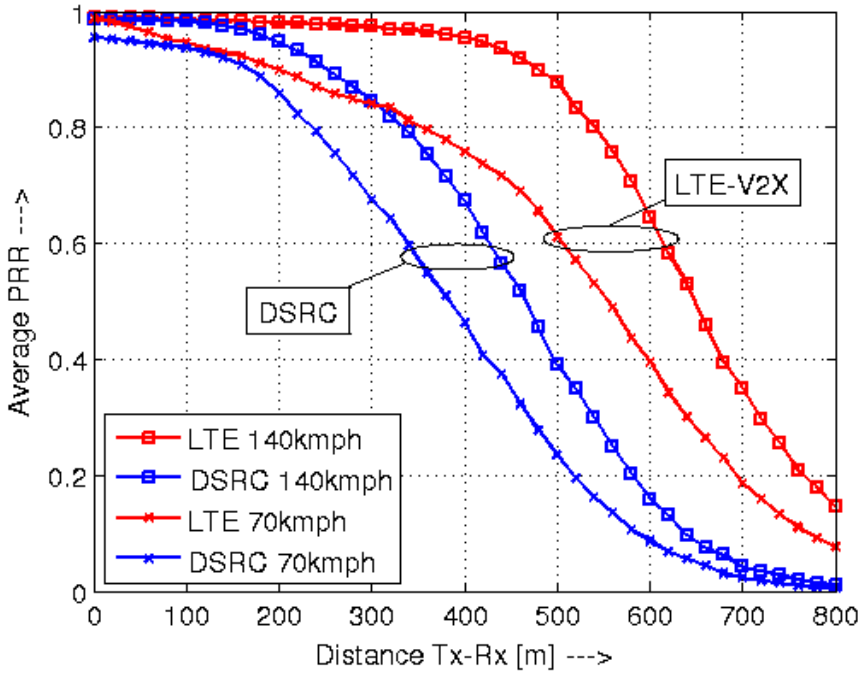
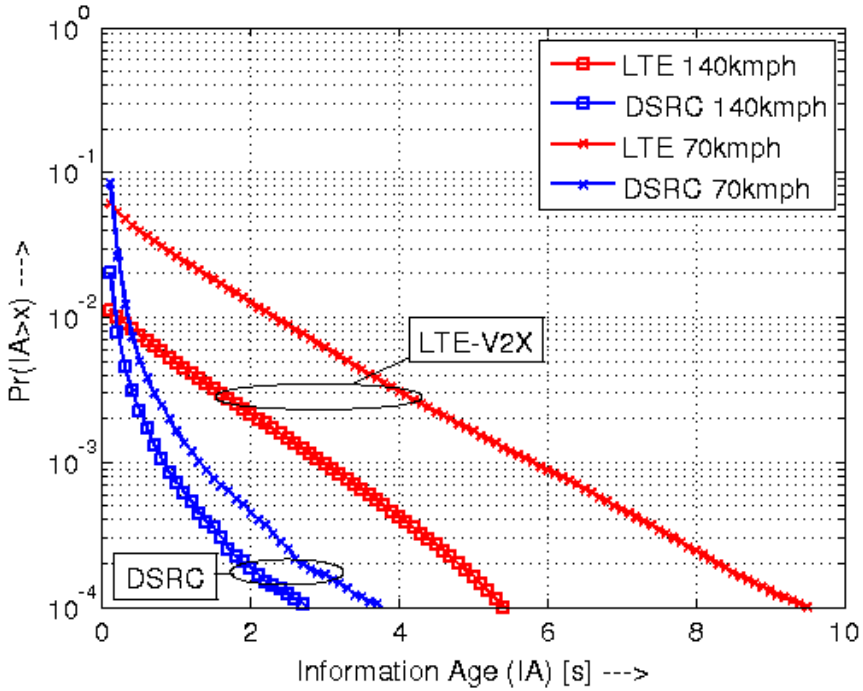
Simulation Assumptions

- Based on 3GPP TR 36.885 channel model and scenarios
  - Highway scenario
    - 2 x 3 lanes
    - average inter-vehicle arrival time per lane 2.5s
  - Carrier frequency 5.9GHz
  - Dedicated carrier of 10MHz BW
  - Modulation and coding
    - Rc≈0.5
    - QPSK
  - CAM model
    - Message size: 300 bytes
    - Periodicity 100ms
  - LTE-V2X mode: 4 (autonomous)

Simulation Results





- LTE-V2X superior w.r.t. packet reception ratio (PRR)
  - ← Better link-level performance
- DSRC superior w.r.t. information age (IA)
  - Probability of large IA reduced
  - ← Semi-persistent scheduling in LTE-V2X

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NR – Numerology

- Related to LTE, but many extensions
  - OFDM(A) with 15kHz subcarrier spacing and 1ms subframe is one option, but there are others with 30kHz, 60kHz and 120kHz and sub-ms subframe length
  - OFDM(A) is an additional option for the UL
  - Subframes, slots, minislots, …
  - Much more (massive) MIMO incl. hybrid beamforming also for mm-wave frequencies
  - LDPC codes for data
  - Polar codes for layer 1 control

- … Longum est;-)

NR-V2X – gNB Scheduled Mode 1

- Scheduled transmission modes
  1. Dynamic scheduling by gNB scheduler
     - Similar to LTE-V2X Mode 3
  2. gNB configured sidelink grants
     - Similar to LTE Semi-Persistent Scheduling configured by RRC signalling
     - No need for scheduling requests by UE and dynamic scheduling by gNB
  3. Grant-free transmission ????

NR-V2X – UE Autonomous Mode 2

- Different modes of operation under discussion
  - a) Autonomous resource selection
    - Similar to LTE-V2X mode 4
    - Simplest scheme is random selection, but efficiency can be improved by short and long term sensing, resource reservation and listen-before-talk
    - The following schemes for resource selection are evaluated, including
      - Semi-persistent scheme: resource(s) are selected for multiple transmissions of different TBs
      - Dynamic scheme: resource(s) are selected for each TB transmission
  - b) UE assists resource selection of other UEs
    - Studied as a functionality that can be part of other Mode 2 operations, when one UE assists sidelink resources selection for other UE(s)
    - Not supported / studied as a standalone sidelink resource allocation mode

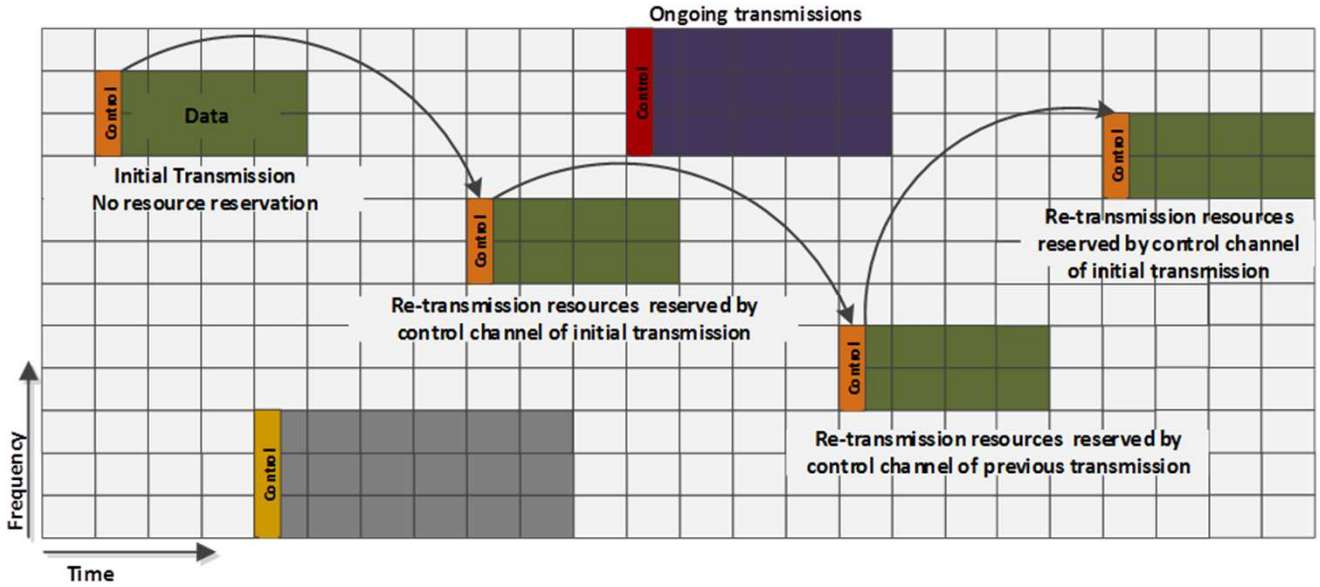
NR-V2X – UE Autonomous Mode 2

c) UE is configured with sidelink grants
- Similar to LTE Semi-Persistent Scheduling for sidelink
- Configuration of one or multiple transmission patterns in each sidelink resource pool
  - Out of coverage: pre-configuration
  - In coverage: configured by gNB
- Sensing only if multiple patterns are configured for a UE.

d) NEW: UE schedules sidelink transmission of other UEs
- Supported of advanced use cases like platooning.
- Might require the election of a cluster head UE for scheduling of a group.
- Functionality might be limited to some UEs.
- In the context of Mode-2(d), NR V2X supports the following functionality:
  - A UE informs gNB about group members.
  - gNB provides individual resource pool configuration and / or individual resource configuration through the same UE to each group member UE within the same group.
  - No direct connection between other member UEs and gNB is required.

NR-V2X Reservation of Resources for Re-transmissions

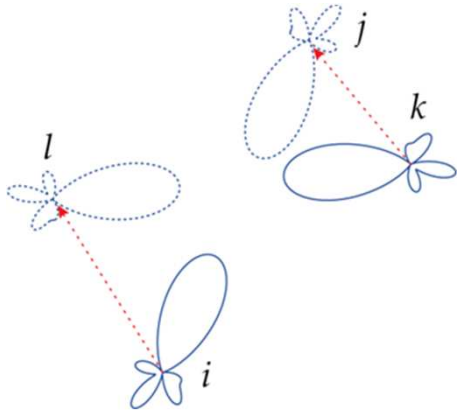
- Resources for the retransmissions can be reserved in advance to reduce the impact of collisions in the system
  - The 1st transmission of a TB can reserve resources for subsequent transmissions.
  - This reservation can be indicated through the control channel.



Source: 3GPP Tdoc R1-1902997 Qualcomm

NR-V2X – Beam Forming

- New functionality
  - Sidelink SSB structure and beam sweeping
  - Fast and efficient beam management
  - Side-information assisted beam management
  - Resource allocation strategy considering beam-based transmission/reception



  - Allows vehicles to use the same sidelink resources without interference despite their proximity.

Source: 3GPP Tdoc R1-1903075 Huawei

NR-V2X – Beam Management

- Beam management is beneficial.
- In FR1 (cm-wave), it is feasible to support V2X use cases without beam management.
- In FR2 (mm-wave), it is feasible to support some V2X use cases without beam management in some scenarios.
  - Panel selection is necessary to improve the communication range in FR2.
- To enable beam sweeping for the sidelink in Mode 1, some signaling from the gNB will be needed.
- For Mode 2, beam sweeping for the sidelink can be based on (pre-) configured procedures / resources.

Summary

- DSRC vs. LTE-V2X: Two quite different systems for V2X
- 3GPP LTE-V2X pro's
  - Better link-level performance
  - Option for collision avoidance based on centralized scheduling by eNodeB.
- 3GPP LTE-V2X con's
  - Out of coverage: only mode 4 based on SPS approach can be used.
  - → Inferior information-age performance compared to DSRC
- Enhancements to LTE-V2X being added
- NR-V2X in the process of being standardized
  - Further enhancements to link-level performance and probably also layer-2 procedures
  - To provide much lower delays and higher data rates for advanced use cases
- Open issue: coexistence between DSRC and LTE-V2X (and NR-V2X)

Company Facts

- Industry: IT Telecommunication
- Headquarter: Munich, Germany
- Founded: September 2004
- Spin off from Munich University of Technology
  - First real-time simulations GPRS/UMTS in 1999
  - Fully privately owned, always profitable from day one
  - Successful sale of LTE eNB Protocol Stack business in 2013
  - Today 18 highly qualified R&D engineers + admin staff
- Vendor independent research / consultancy services
- Service focussed around 4G/5G technology
  - Research/development projects and system simulation services
  - Demonstrators and HW/SW prototype development
  - Consultancy, standardisation and patents support
  - Technology training and knowhow transfer

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