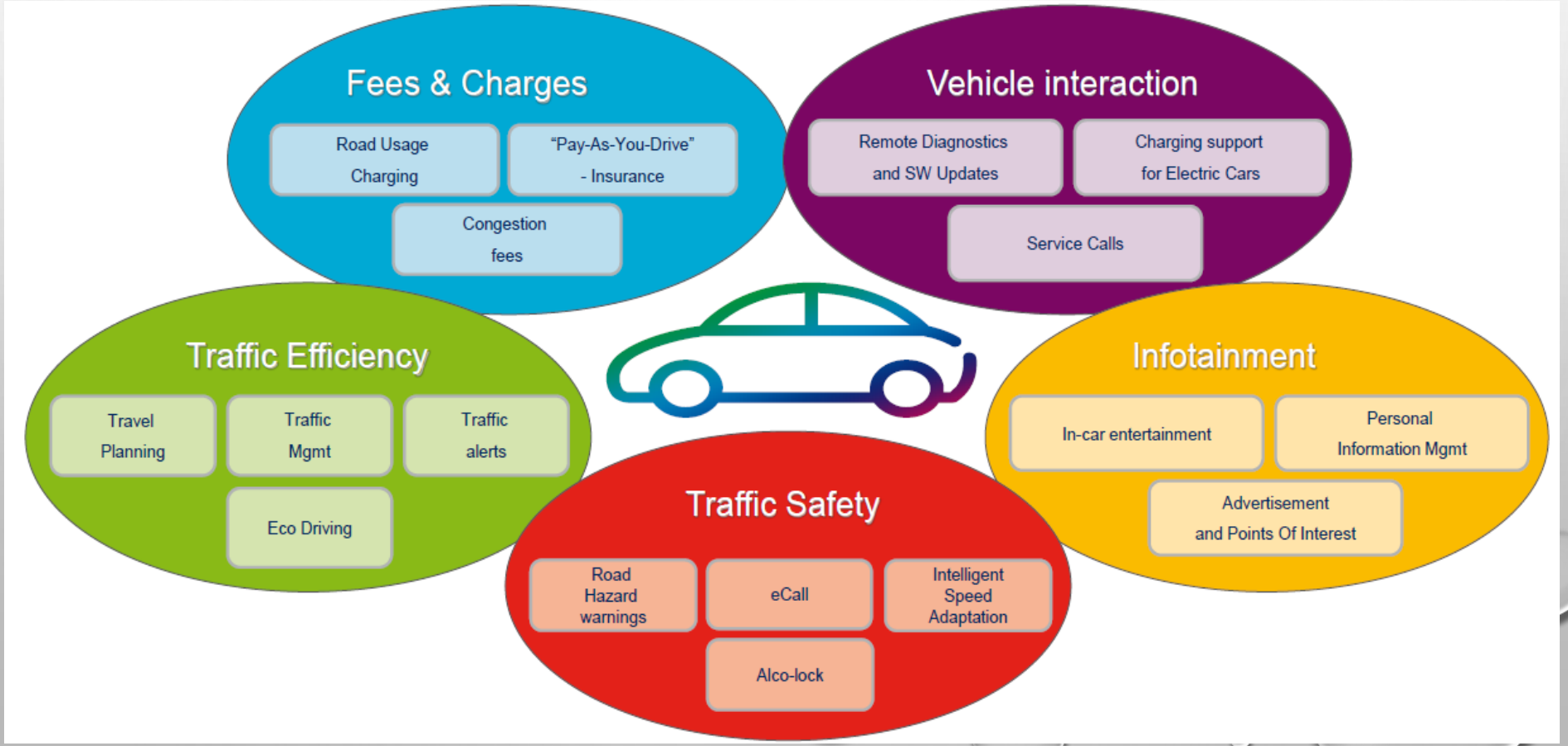
(TELE)COMMUNICATION FOR AUTONOMOUS DRIVING

TOMAS ZELINKA
CTU FTS PRAHA

SCSP2017

CONNECTED CAR - SQ



CONNECTED DRIVING - AVAILABLE SOLUTIONS

- *CONNECTED DRIVING ALREADY STARTED WITH 2.5G MOBILE SERVICES GROWING WITH THE DEPLOYMENT* OF *3G AND LTE MOBILE COMMUNICATION NETWORKS. COVERAGE IS IMPROVING, BUT STILL NOT SUFFICIENT*
- *DRIVERS AND ROAD INFRASTRUCTURE* OPERATORS ALREADY SHARE *INFORMATION* ABOUT ROAD CONDITIONS, TRAFFIC DENSITY, ACCIDENTS, POINTS OF INTEREST, ETC*. VIA INTERNET* APPLIED FOR SERVICES *LIKE INTELLIGENT NAVIGATION (E.G. GOOGLE MAPS) OR TRANSPORT AND LOGISTICS MANAGEMENT.*
- *SERVICES BASED ON IEEE802.11P STANDARD (WAVE AND ITS-G5) ARE ON THE WAY. VEHICLES CAN (IF EQUIPPED WITH SUCH TECHNOLOGY)*

TRENDS IN AUTONOMOUS DRIVING

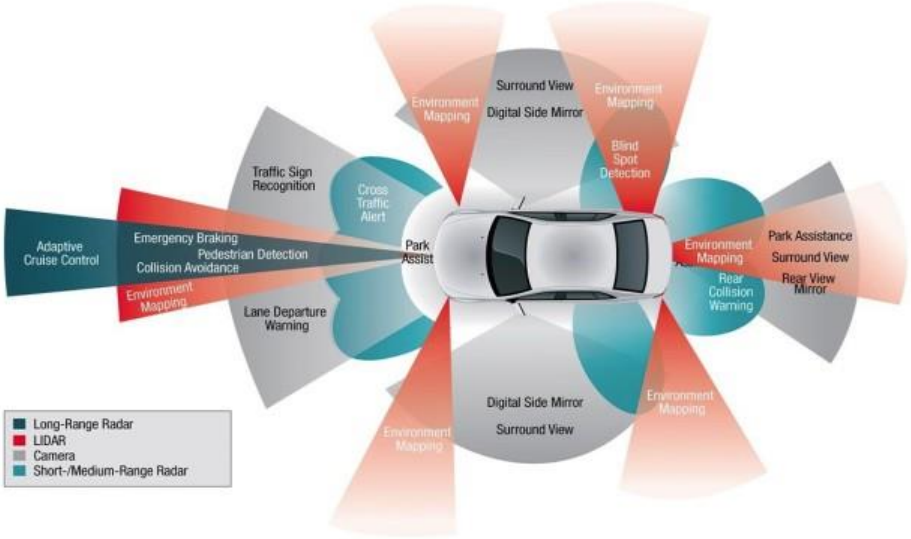
Autonomous Vehicles

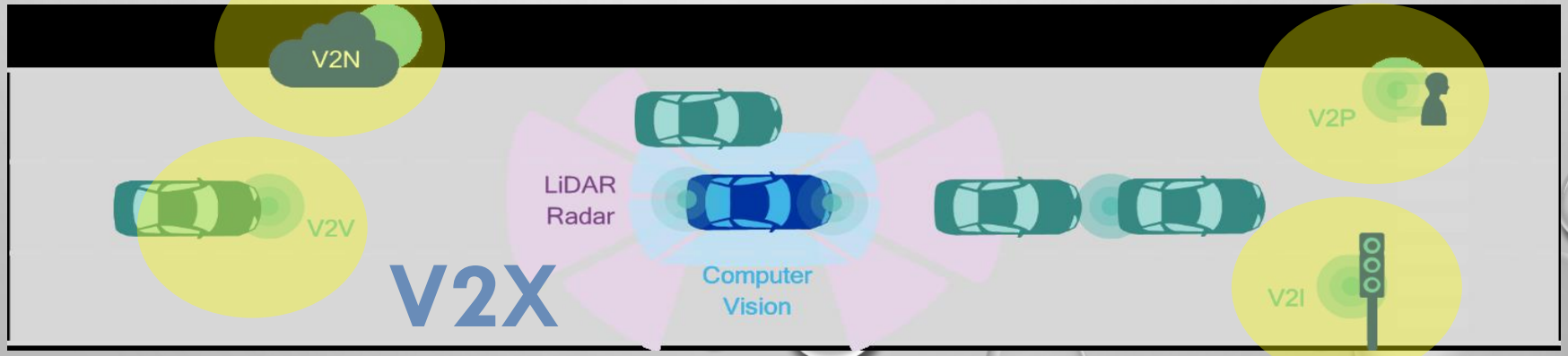
Technology
- Sensors: Lidar, Radar, Cameras, GPS
- Advanced computing and algorithms

Various levels of automation
(defined by NHTSA and SAE)

Connected Vehicle technology is *not required*

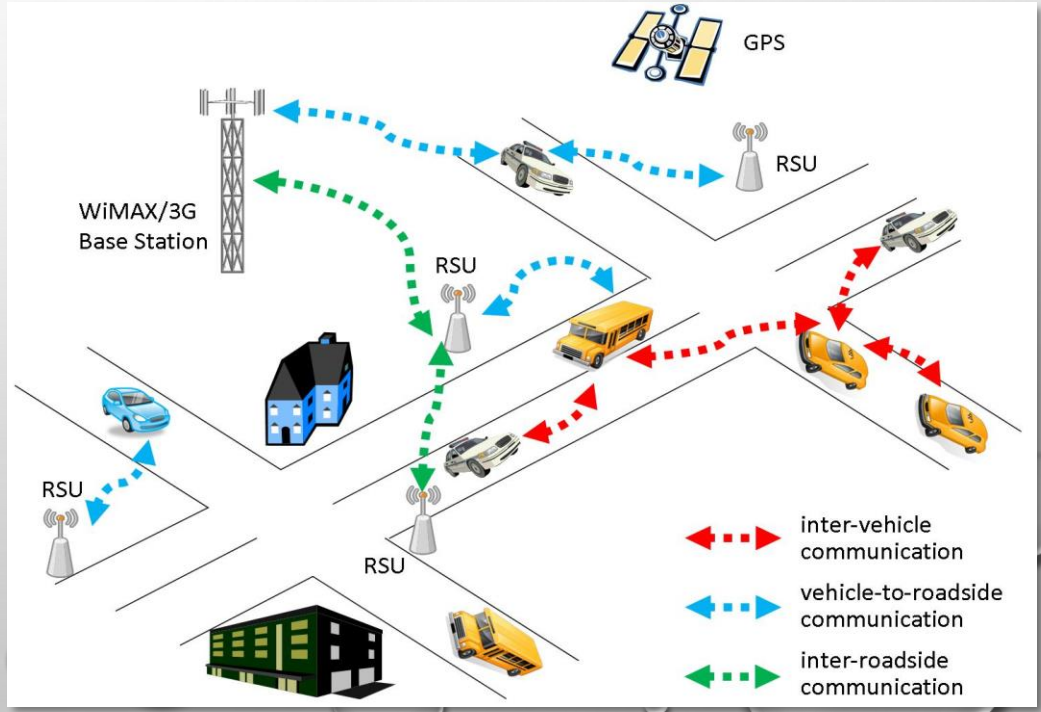
Safety critical functions of the vehicle (steering/throttle) ***are affected*** without direct driver input





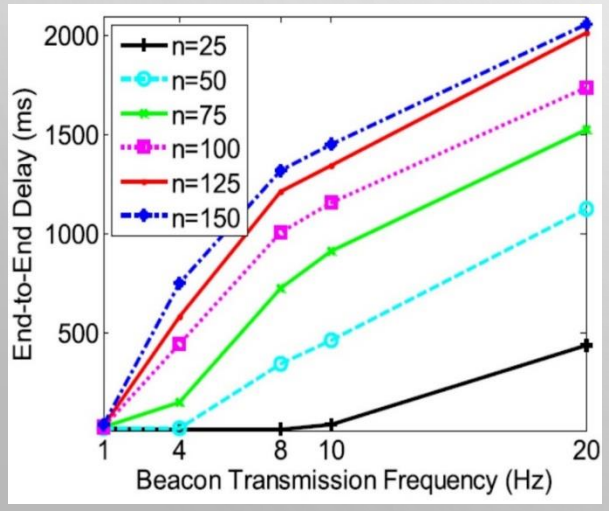
COMMONLY ADOPTED COMMUNICATION SOLUTION FOR C-ITS

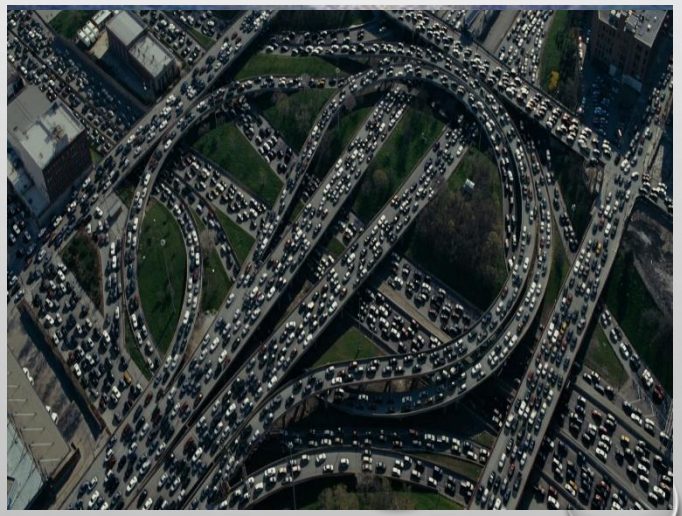
- *IEEE 802.11P BASED COMMUNICATION SYSTEMS - ITS-G5 IN EUROPE AND WAVE (IEEE 1609) IN THE UNITED STATES* – SUPPORT IN DISTRIBUTED COORDINATION REGIME (DCF) ***WITHOUT NEED OF ANY INFRASTRUCTURAL SUPPORT*** BOTH V2V (VEHICLE TO VEHICLE) AND V2I (VEHICLE TO INFRASTRUCTURE) COMMUNICATION.
- *IN DCF REGIME DSRC 5.9 SERVICE PERFORMANCE CANNOT BE GUARANTEED*
- IN CASE IF MORE EFFECTIVE *PCF* (POINTED COORDINATION FUNCTION) ORIGINALY DESCRIBED BY WAVE/802.11E STANDARD THERE IS *REQUIRED RSU (ROAD SIDE UNIT) INSTALLATION* IN EACH OF SERVED AREA

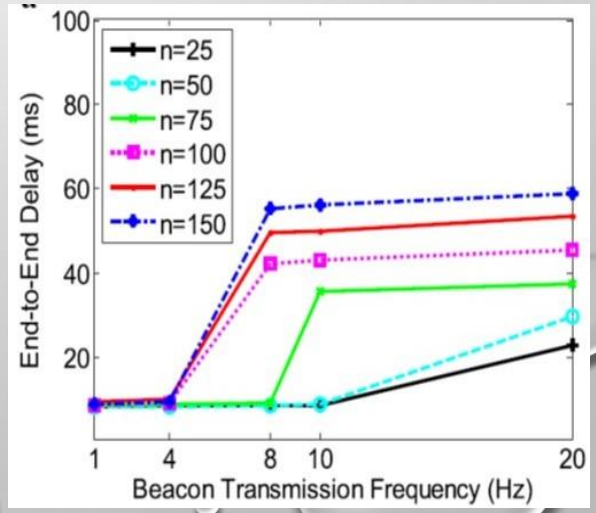


DISTRIBUTED COORDINATION MODE

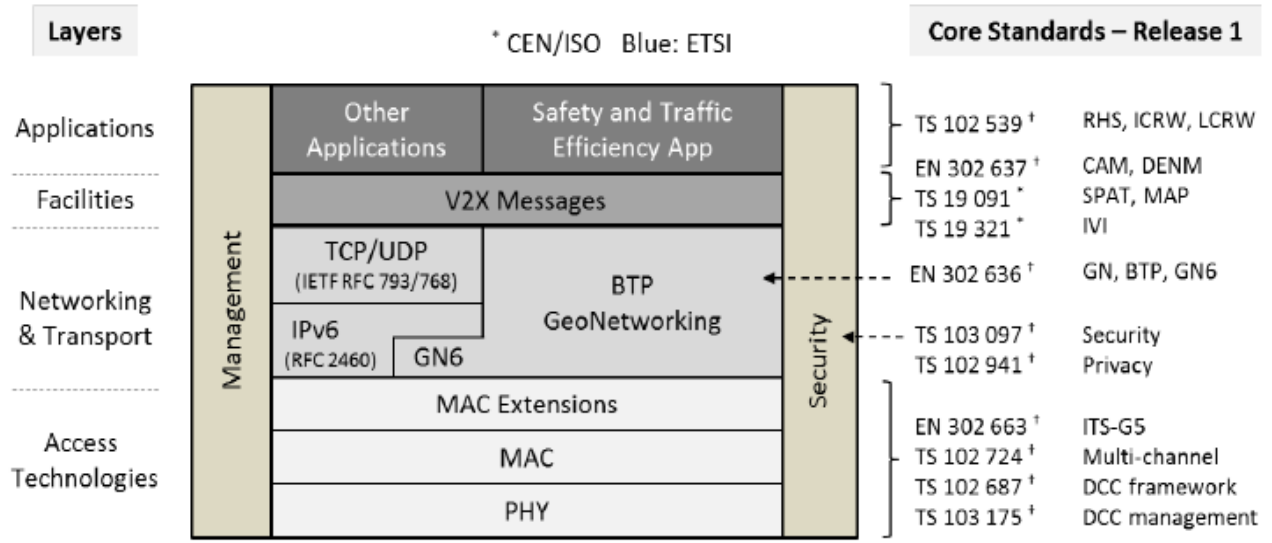
- OVERHEAD OF DCP MODE BASED ON CSMA/CA MAC SCHEME IS SEVERAL TIMES HIGHER THAN IN THE PCF MODE AND *IF LATENCY BELOW 100MS IS EXPECTED, THAN THE ONLY FRACTION OF FRAMES NUMBER DELIVERABLE IN PCF MODE CAN BE REACHED*
- GRAPHS BASED ON MATHEMATICAL SIMULATION PRESENT RESULTS FOR REACHED NUMBER OF WAVE MESSAGES IN THE BASIC CONFIGURATION. SIMULATION RESULTS CAN BE COMPARED WITH RESULTS MODELLED FOR "TRADITIONAL" LTE ALTERNATIVE (NO LTE/V MODE).

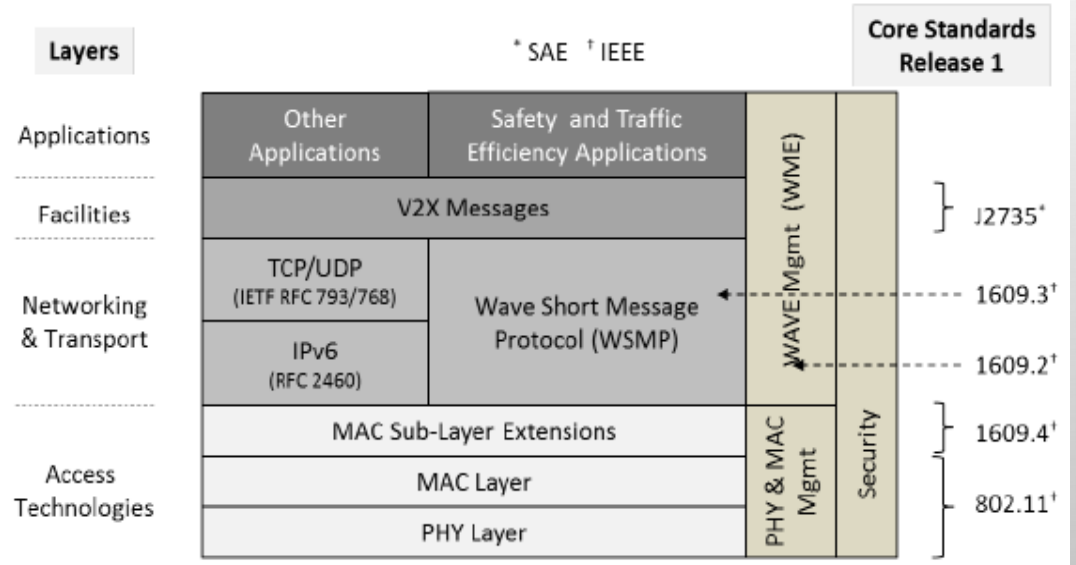






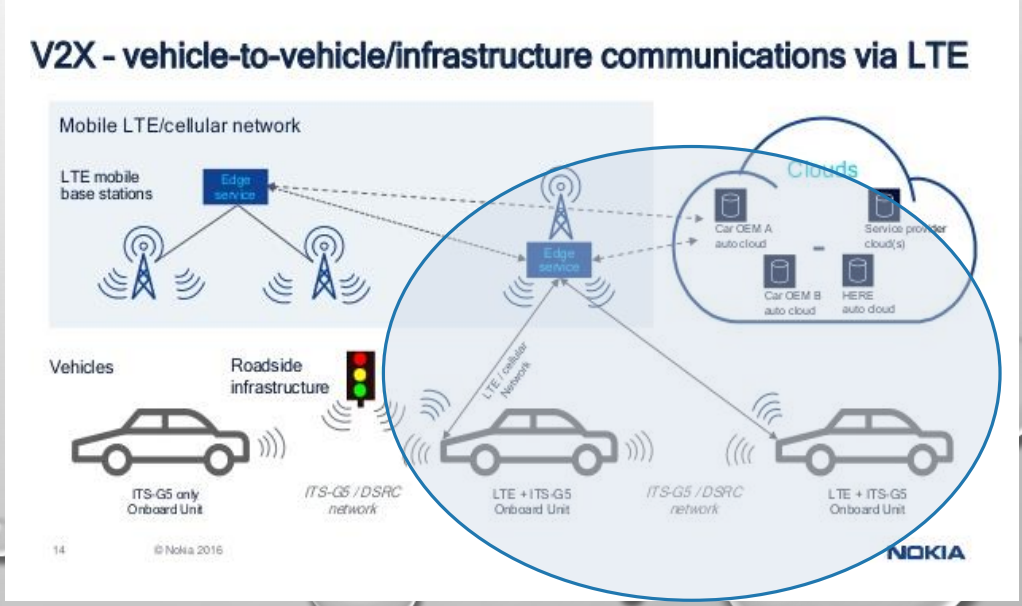
USA / EUROPE


Layers
* CEN/ISO Blue: ETSI
Core Standards – Release 1
Applications
Facilities
Networking & Transport
Access Technologies
Management
Other Applications
Safety and Traffic Efficiency App
V2X Messages
TCP/UDP (IETF RFC 793/768)
IPv6 (RFC 2460)
GN6
BTP GeoNetworking
MAC Extensions
MAC
PHY
Security
TS 102 539 † RHS, ICRW, LCRW
EN 302 637 † CAM, DENM
TS 19 091 * SPAT, MAP
TS 19 321 * IVI
EN 302 636 † GN, BTP, GN6
TS 103 097 † Security
TS 102 941 † Privacy
EN 302 663 † ITS-G5
TS 102 724 † Multi-channel
TS 102 687 † DCC framework
TS 103 175 † DCC management


Layers
* SAE † IEEE
Core Standards Release 1
Applications
Facilities
Networking & Transport
Access Technologies
Other Applications
Safety and Traffic Efficiency Applications
V2X Messages
TCP/UDP (IETF RFC 793/768)
IPv6 (RFC 2460)
Wave Short Message Protocol (WSMP)
MAC Sub-Layer Extensions
MAC Layer
PHY Layer
WAVE Mgmt (WME)
PHY & MAC Mgmt
Security
J2735*
1609.3†
1609.2†
1609.4†
802.11†

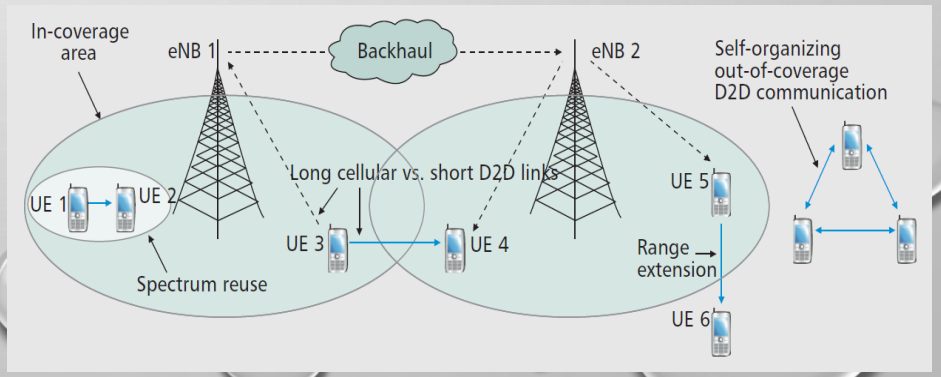
MOBILE SERVICES

- MOBILE SERVICES HAVE BEEN *ADOPTED IN HYBRID (HETEROGENEOUS) COMMUNICATION SYSTEMS.*
- *2G/3G/LTE (REL. 8) AND LTE-A (REL. 10) ARE CENTRALLY MANAGED SERVICES PROMISING POTENTIAL OF GUARANTEED SERVICES QUALITY PROVISIONING. SET OF SECURITY TOOL IS INCLUDED. HOWEVER, ONLY LIMITED COVERAGE OF NAMELY LOWER CLASSES ROADS.*
- *CENTRALIZED NETWORK TOPOLOGY (BTS/(e)NodeB) TOPOLOGY MEANS DOUBLE HOP COMMUNICATION VIA CENTRAL BASE STATION EVEN WITH CLOSEST NEIGHBOR. ADDITIONAL MANAGEMENT SYSTEM OVERHEAD MUST BE TAKEN IN ACCOUNT, AS WELL!*
- *EXCLUSIVELY IP ADDRESSING MODE (UNICAST OR MULTICAST SUPPORTED E.G. BY eMBMS (ORIGINALLY DESIGNED FOR MULTIMEDIA CAUSING ADDITIONAL LATENCY) ESSENTIALLY DIFFERS OF ITS-G5/WAVE ADDRESSING MODE. GEOLOCATION BASED MANAGEMENT OF BOTH UPLINK AND DOWNLINK MIGHT IMPROVE SITUATION.*

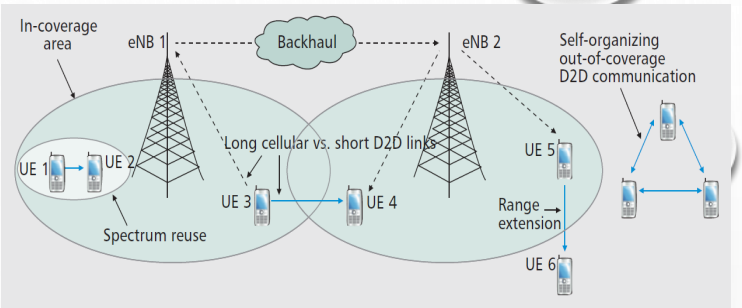


MOBILE SERVICES ENABLING V2X

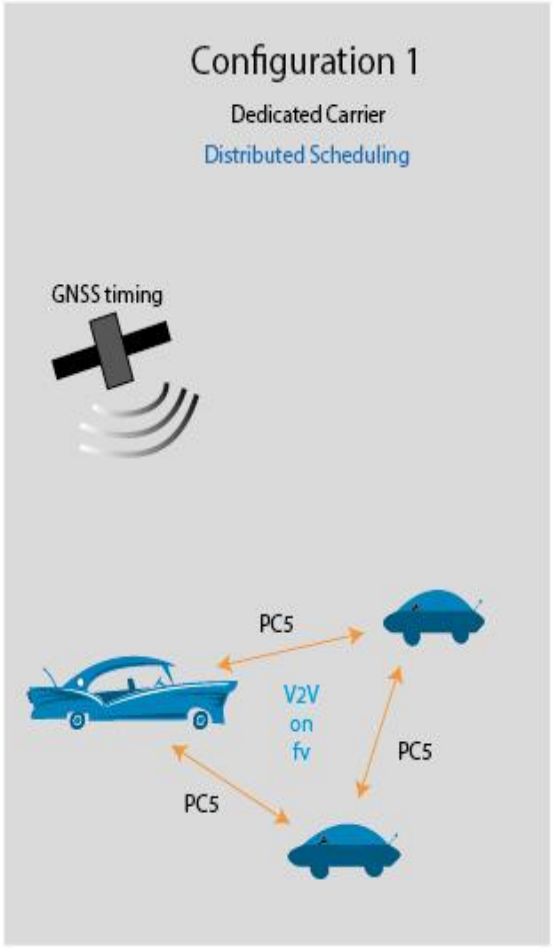
- 3GPP COMMENCED STRONG CONCERN IN V2X COMMUNICATION COMMITTING EXPECTED POTENTIAL OF OUTSTANDING BUSINESS OPPORTUNITIES FOR MOBILE OPERATORS IN THIS AREA. RECENTLY INTRODUCED D2D (DEVICE TO DEVICE) DIRECT COMMUNICATION - *3GPP REL. 12* DEFINES PRINCIPLES OF DIRECT COMMUNICATION BETWEEN NETWORK MEMBERS (ONE HOPE), HOWEVER, IN STATIC REGIME, ONLY.
- *RELEASE 14+ INTEND TO RESOLVE CRITICAL REQUIREMENTS FOR V2X SOLUTIONS – SUCH AS EXTENDED NUMBER OF SERVED VEHICLES, HIGH SPEED TOLERANCE, EFFECTIVE SUPPORT IN CASE OF eNodeB SUPPORT ABSENCE ETC.*
- *EVEN THOUGH 3GPP REL. 14 WAS RELEASED IN MARCH 2017* (PC5 DEDICATED FOR 5.9 GHZ, BUT NOT ONLY) SOME TIME WILL BE NEEDED FOR IMPLEMENTATION. NEVERTHELESS, *PILOT IMPLEMENTATION* BASED ON REL. 14 PRINCIPLES *ARE ALREADY AVAILABLE AND TESTED* BY AD HOCK CONSORTIA AS LTE-V TEST BEDS /- E.G. IN EUROPE:
  - Audi, Deutsche Telekom, Huawei, Toyota Motor Europe, or
  - AUDI, Ericsson, Qualcomm, SWARCO and the University of Kaiserslautern or
  - Continental, Deutsche Telekom, Fraunhofer ESK and NOKIA networks etc.).

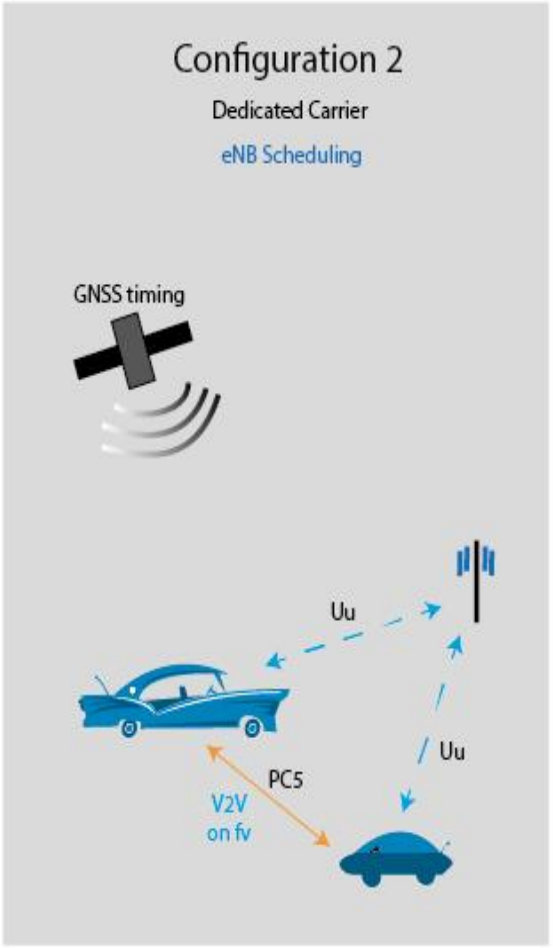


LTE – V (V2X)



- V2V AS PART OF PROXIMITY SERVICES (PROSE) *D2D INTERFACE PC5* IS INTRODUCED ENABLING
  - *HIGH MUTUAL VEHICLES SPEED* UP TO 250KMPH
  - *UP TO THOUSANDS OF SERVED NODES,*
  - *OPERATION BOTH WITH/WITHOUT eNodeB SUPPORT ARE POSSIBLE.*





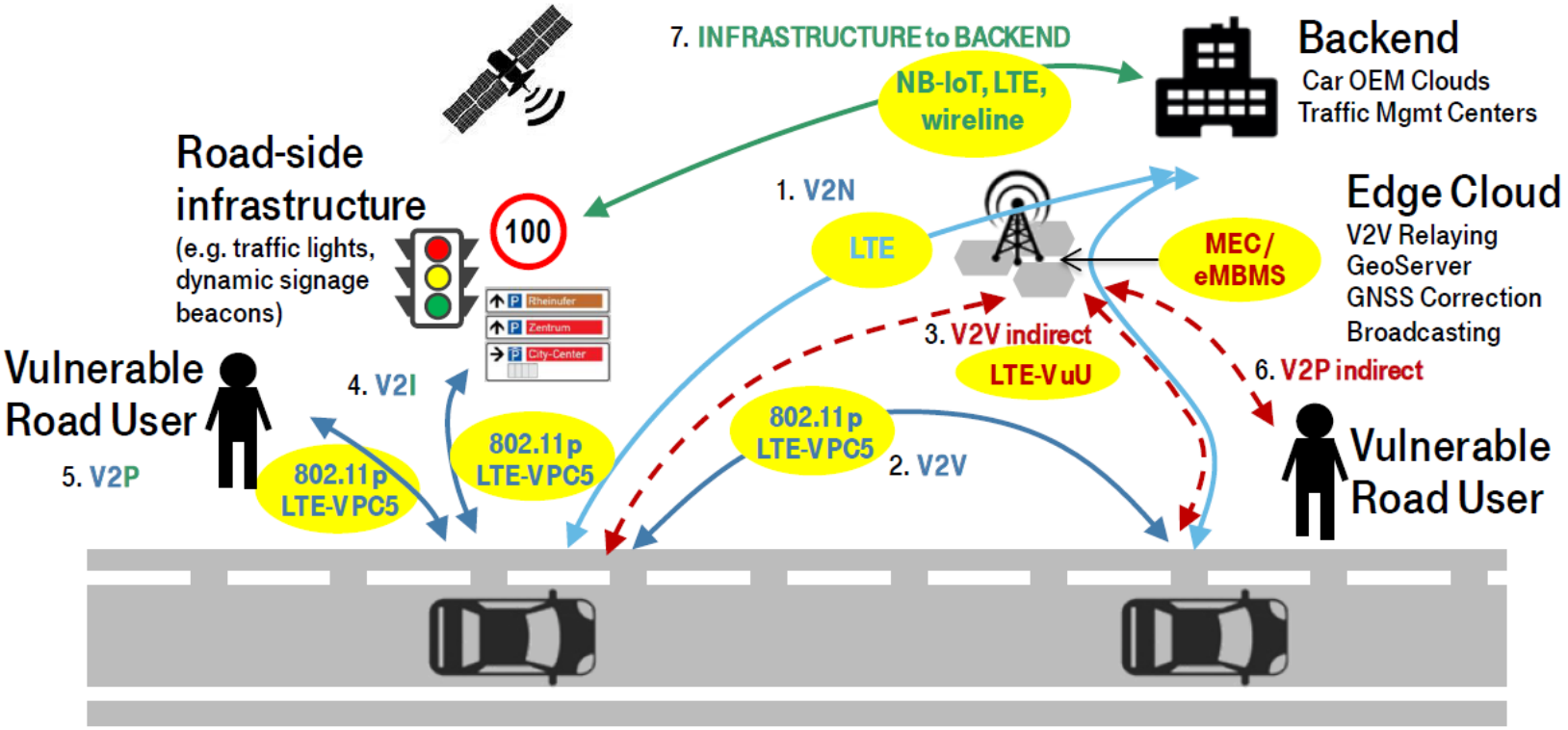
3GPP resources

CONNECTED AUTOMATIZED DRIVING FUTURE TRENDS??

- G5/WAVE CAN BE OPERATED *WITHOUT INFRASTRUCTURE SUPPORT,* HOWEVER, WITH *LIMITED NUMBER OF SIMULTANEOUSLY SERVED VEHICLES, ONLY AND NO GUARANTEED PERFORMANCE*
- *FULL V2I COVERAGE OR EVEN PCF MODE INFRASTRUCTURE* WOULD NEED MASSIVE INVESTMENT (*4000 €/KM²*) *WITH SIGNIFICANT OPEX AND NO SYNERGY* WITH OTHER PUBLIC SERVICES
- *EXTENSION OF THE CURRENT LTE CELLULAR INFRASTRUCTURE ALSO REQUIRES INVESTMENT TO* PRINCIPAL HW AND SW UPGRADES AND GROWTH OF PENETRATION. HOWEVER, *SYNERGY WITH OTHER PUBLIC ACTIVITIES IS EXPECTABLE*
- MOST PROBABLY *FULLY MANAGED HYBRID/HETEROGENEOUS SOLUTION BASE DON 5G/IEEE 802.11P* CAN BE EXPECTED AS THE FINAL ALTERNATIVE WITH 5G HETEROGENEOUS APPROACH

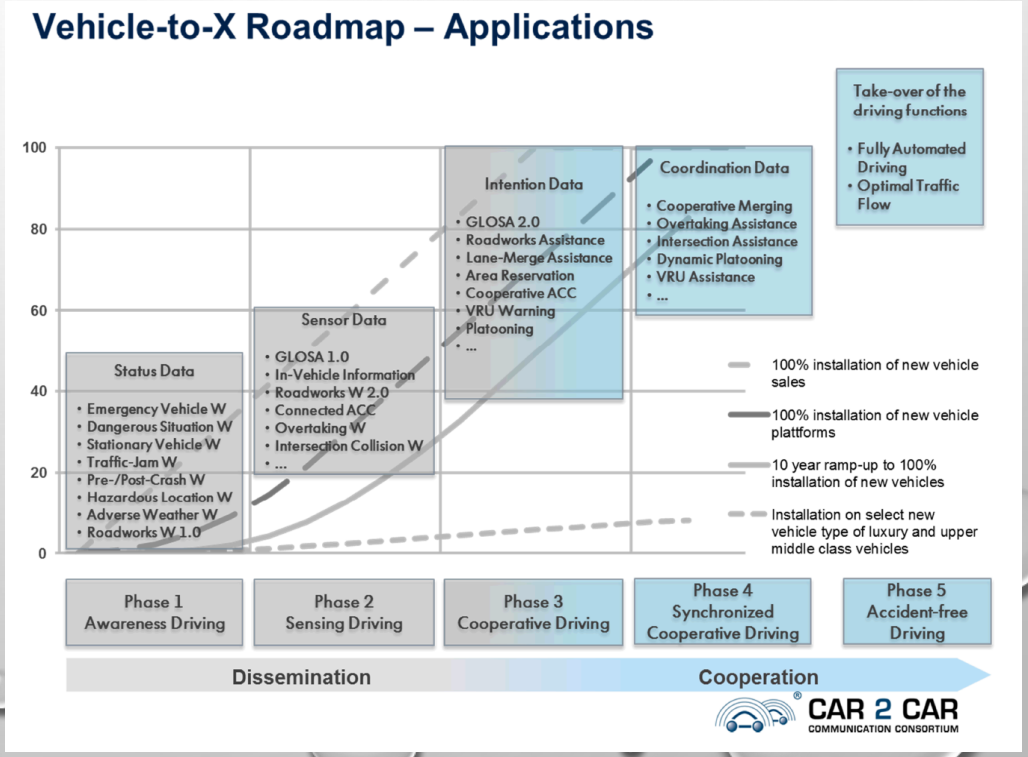
V2X HYBRID COMMUNICATION DT VIEW (CODECS MEETING)

THE FULL PICTURE OF HYBRID COMMUNICATION IN C-ITS



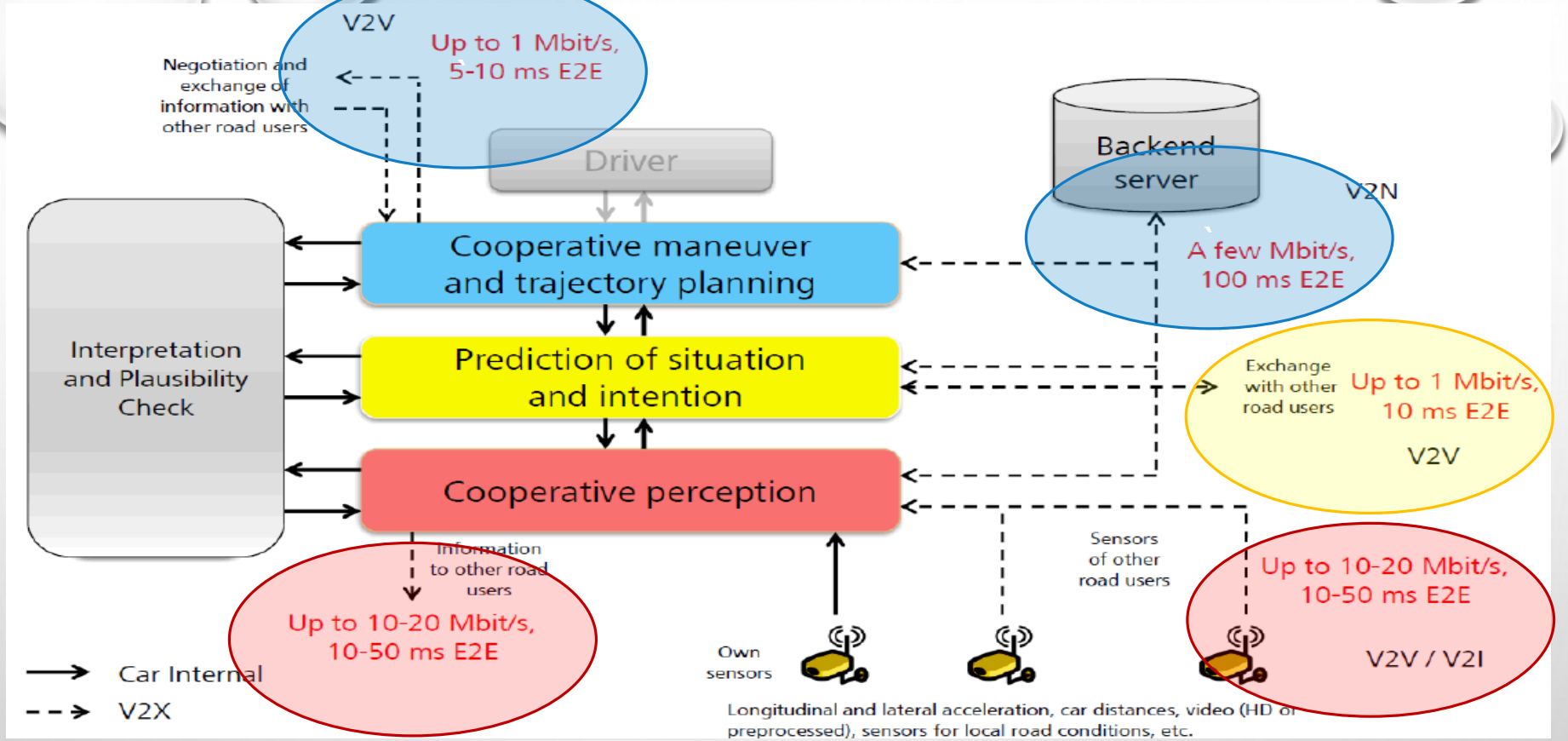
FUTURE OF AUTOMATED DRIVING

- *ANY UNCERTAINTY HAS TO BE TAKEN IN ACCOUNT* SINCE *IT IS NOT 100% CERTAIN WHAT ANOTHER VEHICLES INTEND TO DO* IN THE NEAR FUTURE.
- *IF ALL VEHICLES DISSEMINATE THEIR OWN STATUS AND PLANS*, OTHER VEHICLES CAN USE THEM TO *ESSENTIALLY REDUCE THE UNCERTAINTIES*.
- *PRINCIPALLY REDUCED UNCERTAINTIES* ENABLE AUTOMATED DRIVING VEHICLES TO
  - *DRIVE CLOSER TO EACH OTHER* AND SO *IMPROVE USAGE OF ROADS CAPACITY* AND
  - BETTER REACT ON OTHER VEHICLES MANEUVERS *TO BE ABLE TO BETTER PREVENT COLLISIONS*.

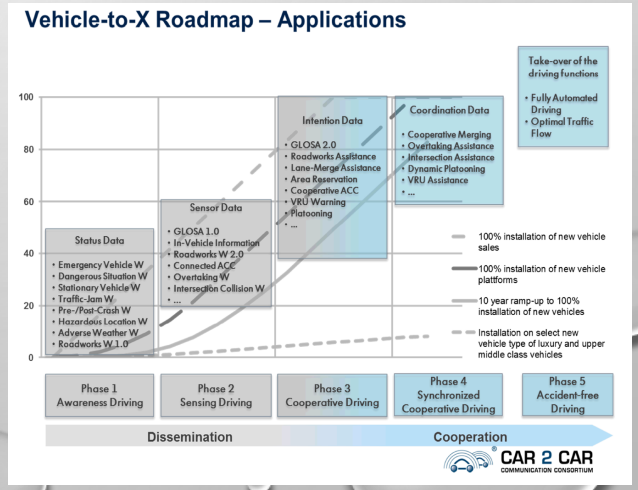


COM-SYSTEM PERFORMANCE REQUIREMENT

Use Case	KPIs	Background	Security Requirements
Cooperative Collision Avoidance	*Trajectory handshake:* 100 ms 10^{-5} (99.999%) *Status updates:* 10 ms 10^{-3} *Positioning:* 30 cm	In a critical driving situation, trajectories have to be exchanged, rated and agreed upon in order to avoid a collision. This handshake must be completed within 100 ms and shall not fail with a probability higher than 10^{-5}. Upon agreement, during the execution phase, lateral and longitudinal controllers need status updates within their 10 ms cycle time. The status information is used by each vehicle to update its trajectory and inform its controllers (in case of minor deviations from the agreed trajectory) or cancel the maneuver (in case of major deviations). A status message shall be received within 10 ms with a probability of 99.9% (packet loss rate of 10^{-3}).	Mutual authentication Authenticity Integrity Confidentiality
High Density Platooning	10 ms 10^{-5} 30 cm	The idea behind high-density platooning is that vehicles will be driving very close to each other. Thus, latency and reliability become the KPIs. The control cycles of typical longitudinal controllers are in the range of 10 ms (as above). The platoon must have their own synced timing. Kinematic data needs to reach all participants of the platoon within a single cycle (10 ms) with ultra-high reliability, and, optionally, all participants need to acknowledge that they can provide the necessary control within this cycle.	Mutual authentication Authenticity Integrity Confidentiality User privacy



SUMMARIZED ARE CONNECTIVITY DEMANDS OF CONNECTED VEHICLES. CONSIDERED AREAS DESCRIBED BY C2C IN PHASE 4 (COOPERATIVE MANEUVER AND TRAJECTORY PLANNING).



CONCLUSIONS

- *SMART MOBILITY CAN LEAD TO HIGHER ROAD TRANSPORTATION COMPETENCE*, HOWEVER, RELIABLE AND POWERFUL V2X COMMUNICATION MUST BE AVAILABLE
- CONTEMPORARY ADOPTED ALTERNATIVE *G5/WAVE CAN HARDLY MEET ALL FUTURE CAD EXPECTATIONS* - SOLUTION BASED ON COEXISTENCE WITH 5G IS EXPECTED TO BE ADOPTED IN ALREADY ADOPTED HYBRID (HETEROGENEOUS) CONFIGURATION,
- *5G IN HYBRID/HETEROGENEOUS COOPERATION WITH G5/WAVE AND POTENTIALLY OTHER COMING TECHNOLOGIES CAN OPEN SPACE FOR* AMBITIOUS AN HIGHLY DEMANDING *CAD (CONNECTED AUTOMATIZED DRIVING)*, HOWEVER, STILL WITH LOWER THAN REQUIRED CAPACITY
- *STRUCTURE AND VOLUME OF EXCHANGED INFORMATION* WITHIN C-ITS/CAD SOLUTIONS *MUST BE REEVALUATED AND OPTIMIZED* TO REDUCE IT TO REALISTIC RESOLVABLE LEVEL

Thank you!