MAVEN

(Managing Automated Vehicles Enhances Network)

Concepts and developments for infrastructure-assisted automated driving

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C2C Forum 2018
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MAVEN is funded by the EC Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727

General Information

- **Duration**
  - ✓ 36 months (Sept ’16 – Aug ‘19)
- **Funding**
  - ✓ ~3M€ under EC H2020 programme
- **Partners:**
  - ✓ From five countries: DE, NL, CZ, BE, UK

DLR · dynniq · HYUNDAI MOTOR GROUP · MAP TRAFFIC MANAGEMENT · TOMTOM

CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE · POLIS · Gemeente Helmond · ROYAL borough of GREENWICH

- **Website**
  - ✓ www.maven-its.eu

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Project summary

Assumption

- Road infrastructure applications will still play a key role in future cooperative automated driving era

Main objective

- Increasing traffic efficiency and safety in urban areas by exploiting automated driving

Approach

- C-ITS infrastructure-based traffic management solutions for cooperative automated vehicles (CAVs) at signalized intersections (traffic lights) and intersection corridors
- V2X-based automated driving extensions for perception and planning
- Use of simulation verification as well as road experiments with CAV and infra prototypes (ETSI ITS G5-based)

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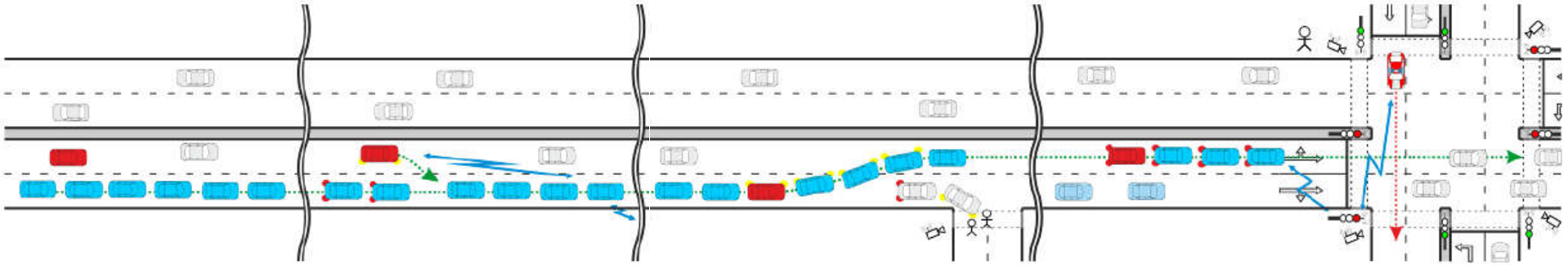
Use cases overview



- **I2V interactions**
  - ✓ V2I “explicit” probing + I2V speed/lane advisory + V2I feedbacks on compliance to advisories
- **Traffic controllers optimization**
  - ✓ Signal optimization, priority management, queue estimation, green wave
- **Platoon management**
  - ✓ Forming, joining, travelling in, leaving, breaking a platoon
- **Inclusion of conventional traffic and VRUs**
  - ✓ Detection/reaction in presence of non-coop cars & VRUs

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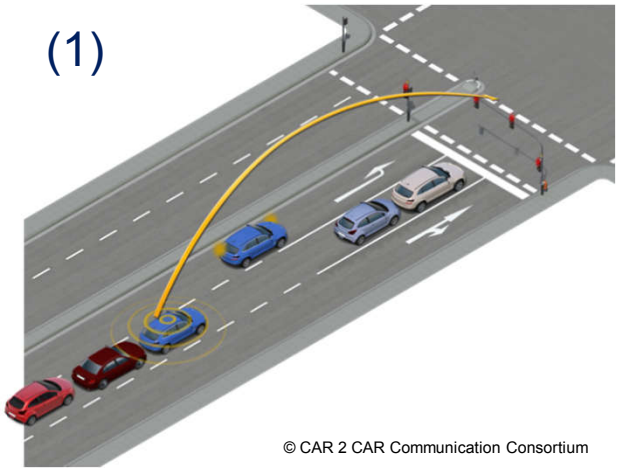
MAVEN I2V interactions

(1)



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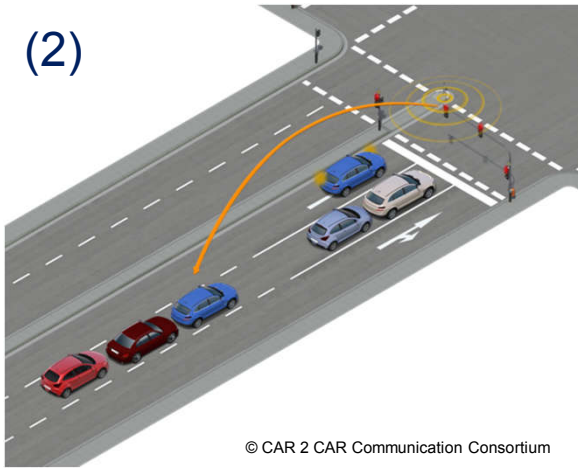

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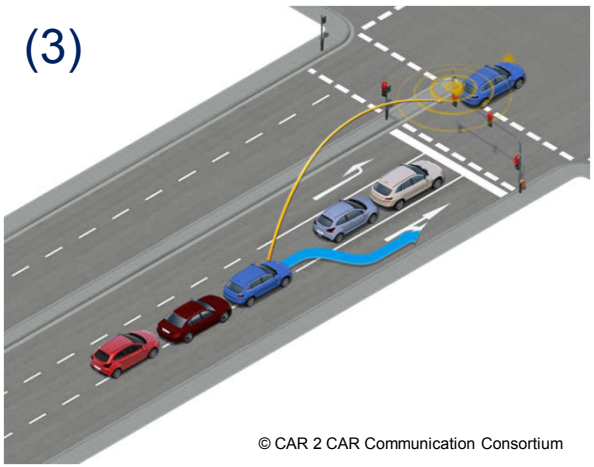

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- **V2I explicit traffic probing (1)**
  - ✓ CAVs and/or platoons transmits planned route, desired speed, platoon characteristics, etc.
- **Traffic light controller signal timing re-optimization and I2V advisories (2)**
  - ✓ Based on rx info/calculations, infra transmits speed /lane change advisories
- **V2I feedbacks on compliance to advisories (3)**
  - ✓ CAVs and/or platoons communicate if advisories can be executed
  - ✓ If yes, traffic light controller “freezes” signal timing optimization

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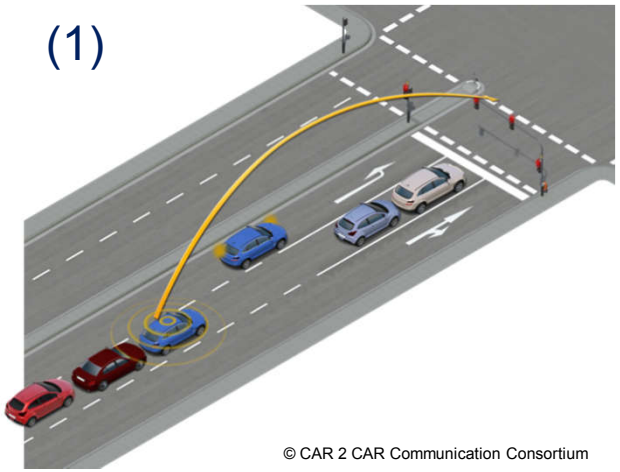
V2X for I2V interactions (1)

(1)



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Ext CAM on SCH0			ItsPduHeader (as in [ETSI EN 302 637-2])
	CoopAwareness		GenerationDeltaTime (as in [ETSI EN 302 637-2])
		CAMParameters	BasicContainer (as in [ETSI EN 302 637-2], includes car position)
			HighFrequency Container = BasicVehicleContainerHighFrequency (as in [ETSI EN 302 637-2], includes dynamic info)
			LowFrequencyContainer = BasicVehicleContainerLowFrequency (as in [ETSI EN 302 637-2])
			SpecialVehicleContainer = MavenAutomatedVehicleContainer

- **Message for V2I traffic probing**
  - ✓ Backward-compatible extension of CAM (on Day1 SCH0)
  - ✓ MavenAutomatedVehicleContainer includes info needed by TLC
    - ✓ CAV route at intersection (e.g. Ingress/egress lane)
    - ✓ Distance to preceding/following vehicle
    - ✓ Platoon id (tx by platoon leader if platoon is present)
    - ✓ Platoon participants (tx by platoon leader if platoon is present)
    - ✓ Desired platoon speed (tx by platoon leader if platoon is present)
    - ✓ ...

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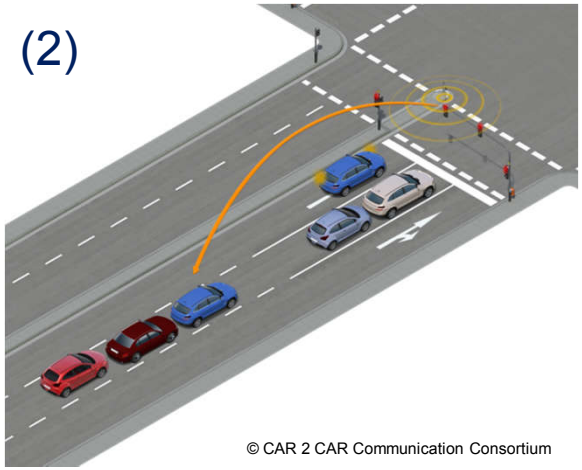
V2X for I2V interactions (2)

(2)



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MAVEN MAPEM	ItsPduHeader (as in [ETSI EN 302 637-2])	
	MapData (as in ISO 19091 DSRC, profiled with lane-specific SignalGroups)	
MAVEN MAPEM	ItsPduHeader (as in [ETSI EN 302 637-2])	
	SPAT (as in ISO 19091 DSRC, profiled with lane-specific SignalGroups)	
MAVEN LAMEM	ItsPduHeader (as in [ETSI EN 302 637-2])	
LAM	TimeInfo	
	LaneAdviceList	

❑ Messages for I2V advisories

- ✓ Lane-specific GLOSA
  - ✓ Suggests speed to be adopted on a given lane, calculated based on queue estimation
  - ✓ Use current standard SPATEM/MAPEM profiled to allocate lane-specific signal groups when needed
- ✓ Lane change advice message
  - ✓ Suggests the lane a CAVor platoon should change to at an intersection
  - ✓ Indicates target lane, distance to stop line, and time for starting the maneuver
  - ✓ Uses a newly defined Lane Advisory Message (LAM) including individual advices

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V2X for I2V interactions (3)

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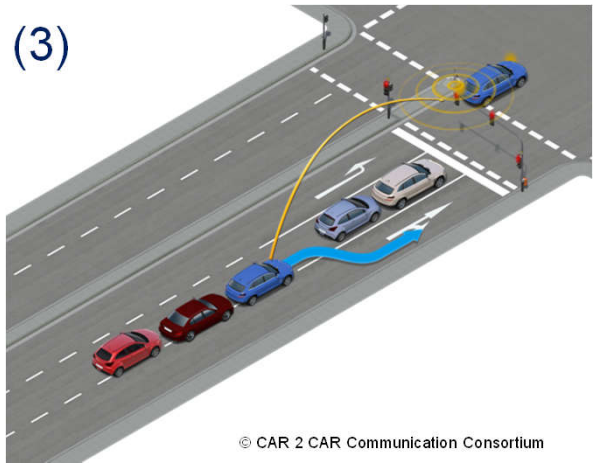

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			SpecialVehicleContainer = MavenAutomatedVehicleContainer

- **Message for V2I feedbacks on compliance to advisories (3)**
  - ✓ Backward compatible extension of CAM message (on Day1 SCH0)
  - ✓ MavenAutomatedVehicleContainer includes feedback needed by TLC
    - ✓ Real-time Acknowledgment on whether the GLOSA is being applied by the CAV
    - ✓ Real-time Acknowledgment on whether the lane change is being executed by the CAV

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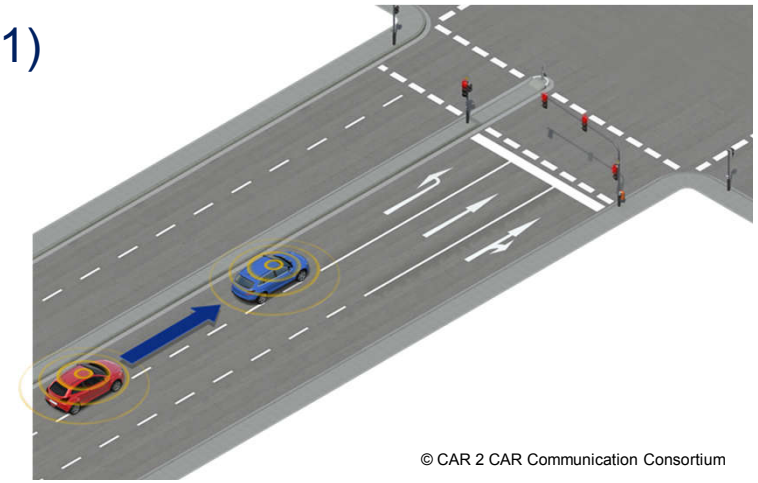
MAVEN platooning

(1)



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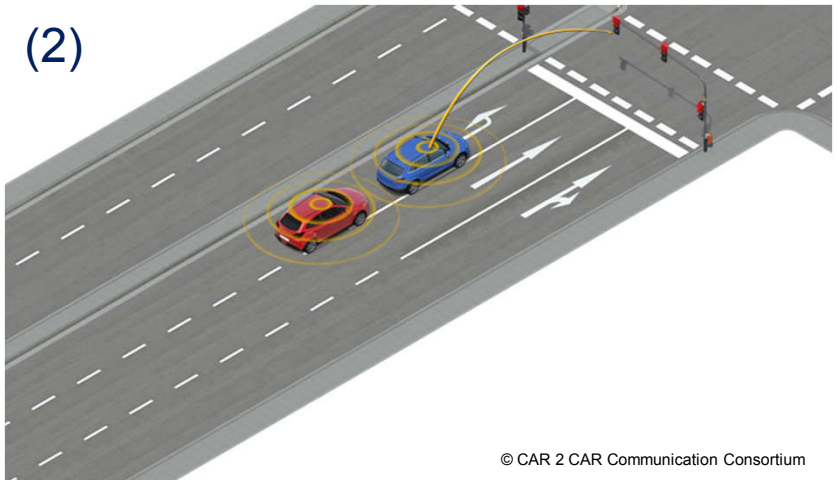

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- **Mix between distributed and centralized approach**
  - ✓ Based on common distributed algorithm and V2V exchanged info, individual vehicles form platoons and manage their operation (joining, leaving, etc.) (1)
  - ✓ Yet, platoon leader has the central role of communicating platoon features to the infra for explicit traffic probing (2)
- **Use of 2 parallel ITS G5 channels**
  - ✓ One for advertising vehicle and/or platoon characteristics to other vehicles or infra
  - ✓ The other, to convey more frequent platoon control and management info

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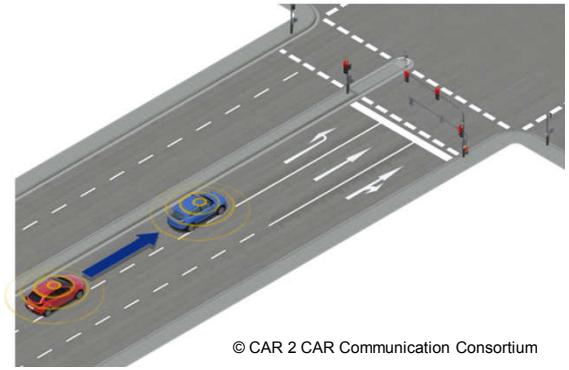
V2X for MAVEN platooning



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Ext CAM on SCH0		
ItsPduHeader (as in [ETSI EN 302 637-2])		
CoopAwareness	GenerationDeltaTime (as in [ETSI EN 302 637-2])	
	CAMParameters	BasicContainer (as in [ETSI EN 302 637-2], includes car position)
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Ext CAM on SCHx		
ItsPduHeader (as in [ETSI EN 302 637-2])		
CoopAwareness	GenerationDeltaTime (as in [ETSI EN 302 637-2])	
	CAMParameters	BasicContainer (as in [ETSI EN 302 637-2], includes car position)
		HighFrequency Container = AutomatedVehicleContainerHighFrequency
		LowFrequencyContainer = AutomatedVehicleContainerLowFrequency

- **Message for platooning initialization**
  - ✓ Backward compatible extension of CAM message (on Day1 SCH0)
  - ✓ MavenAutomatedVehicleContainer carries info for CAVs to detect opportunities for building/joining a platoon (e.g. Based on same expected route, desired speed, etc)
- **Message for platooning management and control**
  - ✓ CAM tx on a parallel SCH with higher frequency [fixed 10Hz]
  - ✓ Carries limited set of info
    - ✓ for platoon control (e.g. Planned path, position, speed, acceleration, heading)
    - ✓ for platoon management: joining, brake-up, termination (e.g. flags representing the vehicle status in the platoon and used by the platoon logic)

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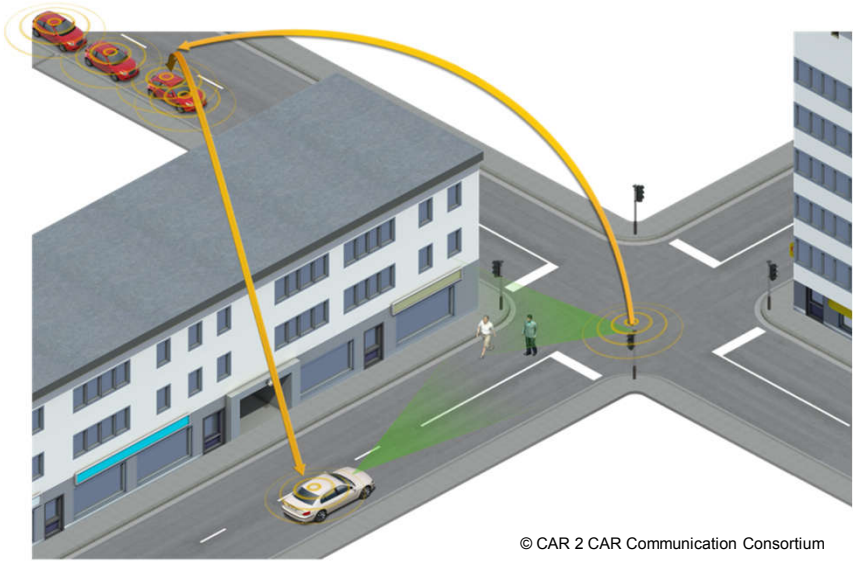
Inclusion of conventional traffic and VRUs



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- **Use of collective perception for improved detection and reaction**
  - ✓ Both CAVs and infra can detect and share info about non-cooperative road users
  - ✓ Improved awareness used to adapt CAV maneuver/path planning for increased safety
  - ✓ Isolated CAVs or CAVs in platoon keep monitoring the environment and control the system all the time to possibly undertake emergency (automated) reactions

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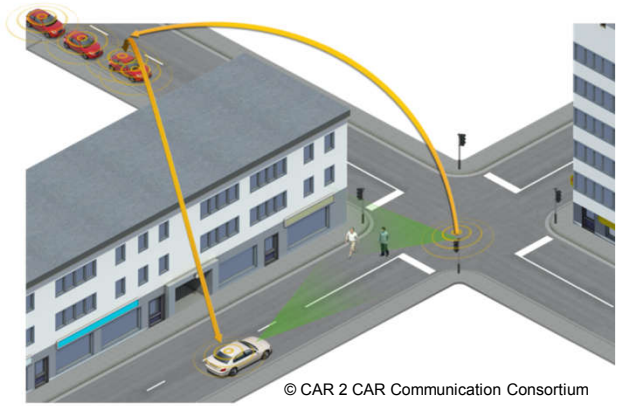
V2X for inclusion of conventional traffic & VRUs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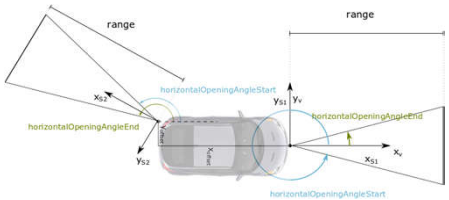
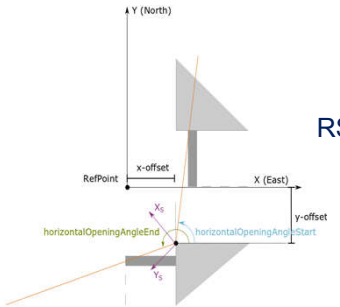
CPM		
ItsPduHeader (as in [ETSI EN 102 894-2])		
CollectivePerception	GenerationDeltaTime (as in [ETSI EN 302 637-2])	
	CPMParameters	OriginatingStationContainer
		SensorInformationContainer
		PerceivedObjectContainer

Message for collective perception

- ✓ Adoption of Collective Perception Message (CPM) in pre-standardization at ETSI ITS (TR 103 562 and TS 103 324) and consideration at the C2C-CC
- ✓ Active contribution to ETSI CPM standardization to accommodate MAVEN requirements
  - ✓ General restructuring of CPM to accommodate detections from RSUs
  - ✓ Definitions based on RSU-specific reference system in all containers
  - ✓ Possibility to match detected objects to topological information transmitted in MAP messages



Vehicle ref. system



RSU ref. system

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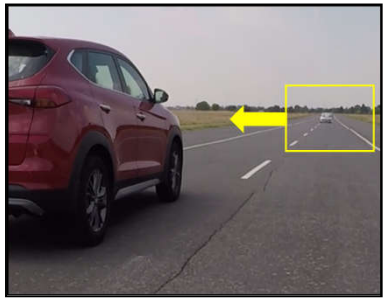
Latest developments & future work

Latest developments

- ✓ V2X verification on test bench and integration in cooperative automated driving SW frameworks
- ✓ Recording of real V2X traffic light data (SPAT/MAP) to reuse in AD tests
- ✓ AD tests of speed adaptation, cooperative lane change and collective perception on test track
- ✓ Initial V2X interoperability tests for platooning (Hyundai + DLR vehicles)



Next steps:

- ✓ Complete platooning tests on test track
- ✓ Test I2V and V2V use cases on real road (Helmond + Braunschweig)

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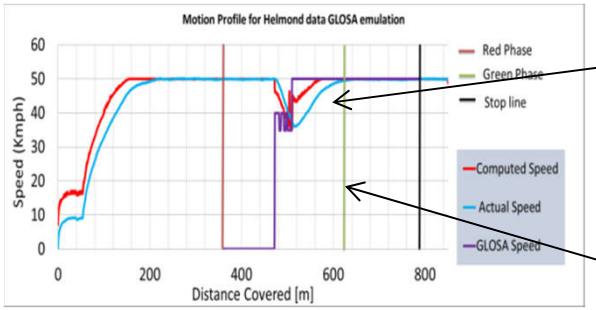
Initial results

Automated speed adaptation to V2X GLOSA

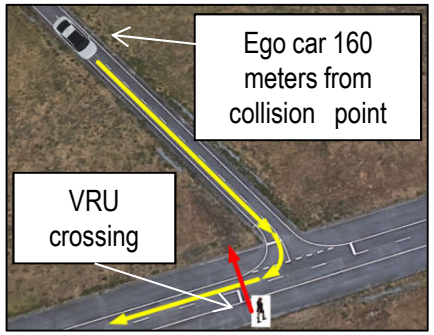
GLOSA speeds provided by infra @ multiple zones dynamically adapted to real signal phase and timing

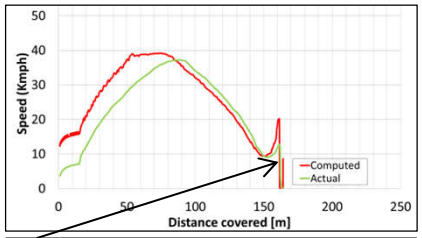


Automated adaptation to V2X traffic light GLOSA speed

Ego AD vehicle passes with green light

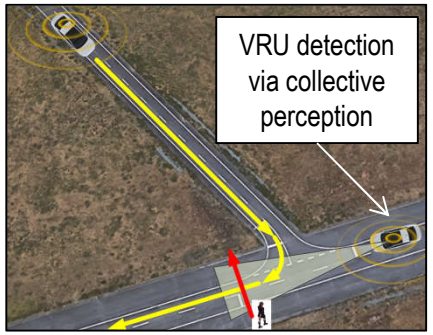
Detection/reaction via collective perception

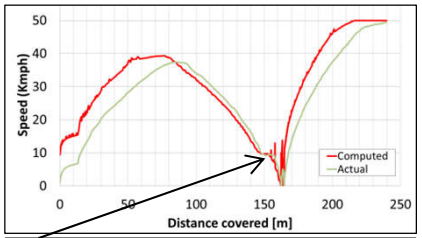




Ego car speeds up while turning and does not detect VRU in time → manual braking to avoid collision

Scenario 1: ego car without V2X CPM, only ego sensors used





Ego car knows about VRU (via V2X), smoothly slows down while turning, detects VRU in time → automated braking, collision is prevented; speeds up again after VRUs crosses

Scenario 2: ego car also considers V2X CPM info

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Additional information can be found atat:

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Do not hesitate to contact us!

Thank you!

Questions?

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