

# V2X for transition of control in cooperative automated driving

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#### **Outline**

TransAID scope

☐ TransAID V2X message set

☐ CAM, DENM and MCM extensions



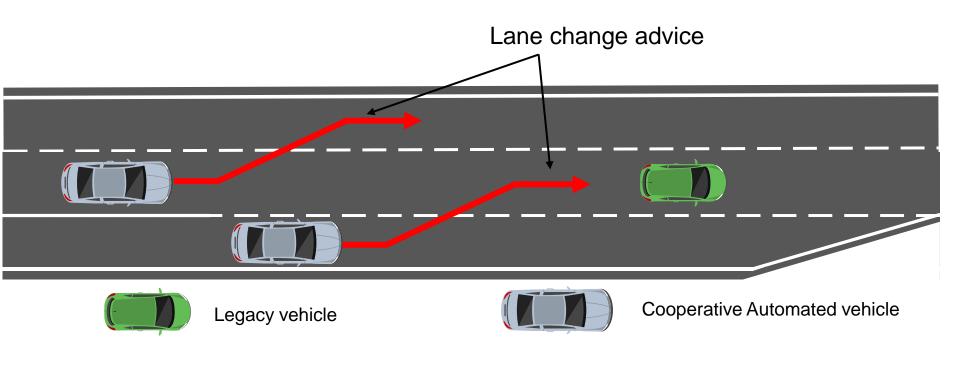
#### TransAID scope

- Transition area: area where multiple vehicles perform automation level transitions
  - If unmanaged transitions of control: potential traffic flow/safety issues
- V2X-based infrastructure-assisted traffic management procedures at transition areas:
  - Manage transition of vehicles
  - Distribute transitions of vehicles in time and space
  - Prevent transitions by providing additional information



#### TransAID scope

- □ Prevent ToC/MRM by providing speed, headway and/or lane advice:
  - Objective: Facilitate merging of on-ramp vehicles

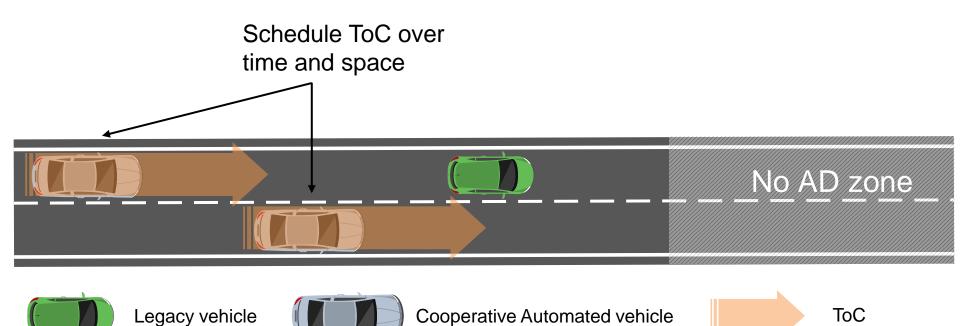


TransAID deliverable 2.1: Link

21/11/2018

#### TransAID scope

- Distribute ToC by scheduling ToC in time and space:
  - Objective: Avoid multiple ToC in the same area



TransAID deliverable 2.1: Link

21/11/2018



#### TransAID V2X message set

- The execution of the TransAID services requires the communication between vehicles or between vehicles and the infrastructure:
  - Messages employed: CAM, CPM, DENM, MAPEM, IVIM, MCM

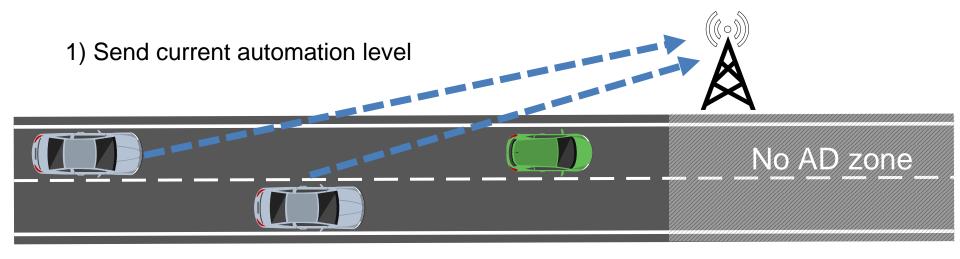
- We should extend current version of V2X message standards in order to manage transitions of control:
  - Messages extended: CAM, DENM, MCM



- Additional information needed:
  - Current automation level

Distribute ToC by scheduling ToC in time and space

CAVs need to execute a ToC before entering the no AD Zone





Legacy vehicle



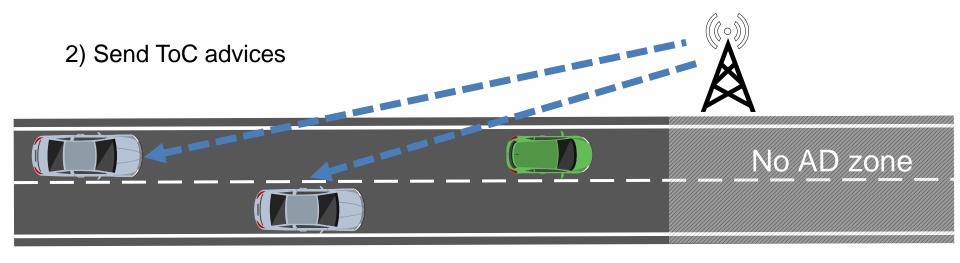
Cooperative Automated vehicle



- Additional information needed:
  - Current automation level

Distribute ToC by scheduling ToC in time and space

CAVs need to execute a ToC before entering the no AD Zone





Legacy vehicle



Cooperative Automated vehicle





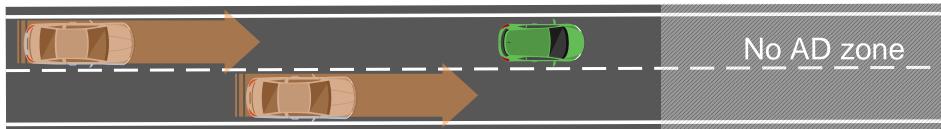
- Additional information needed:
  - Current automation level

Distribute ToC by scheduling ToC in time and space

CAVs need to execute a ToC before entering the no AD Zone

3) Execute ToC







Legacy vehicle



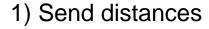
Cooperative Automated vehicle

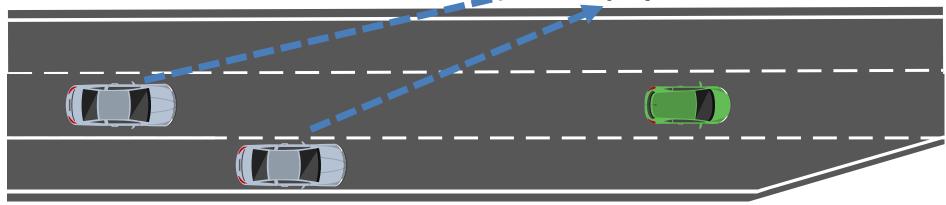


- Additional information needed:
  - Current automation level
  - Distance to following vehicle
  - Distance to preceding vehicle

Prevent ToC/MRM by providing speed, headway and/or lane advice

CAVs on the on-ramp needs to merge to the main road







Legacy vehicle



Cooperative Automated vehicle

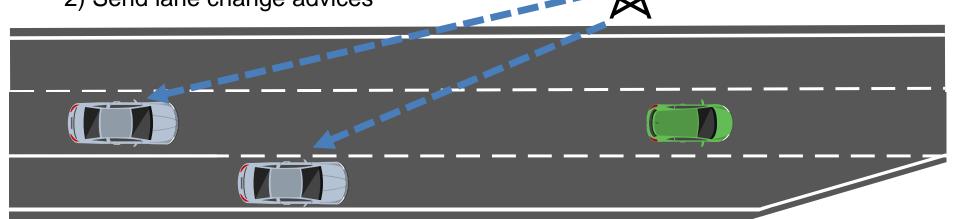


- Additional information needed:
  - Current automation level
  - Distance to following vehicle
  - Distance to preceding vehicle

2) Send lane change advices

Prevent ToC/MRM by providing speed, headway and/or lane advice

CAVs on the on-ramp needs to merge to the main road





Legacy vehicle



Cooperative Automated vehicle

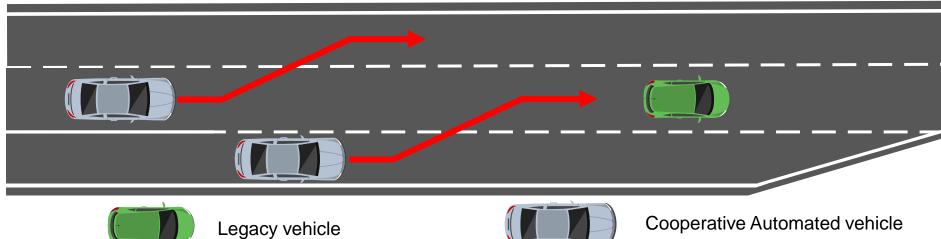


- Additional information needed:
  - Current automation level
  - Distance to following vehicle
  - Distance to preceding vehicle
  - 3) Execute lane changes

Prevent ToC/MRM by providing speed, headway and/or lane advice

CAVs on the on-ramp needs to merge to the main road







- Additional information needed:
  - Current automation level
  - Distance to following vehicle
  - Distance to preceding vehicle

Create a new type of Special Vehicle Container to assure backwards compatibility

CAM		ItsPduHeader				
	CoopAwareness	GenerationDeltaTime				
		S	BasicContainer			
Extended		SAMParameters	HighFrequency Container = BasicVehicleContainerHighFrequency			
EX			LowFrequencyContainer = BasicVehicleContainerLowFrequency			
		0	SpecialVehicleContainer = AutomatedVehicleContainer			

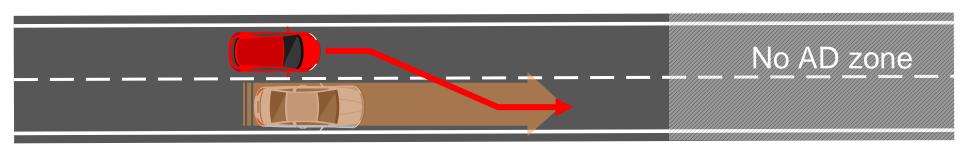


#### **DENM: Extensions**

- Additional Information:
  - ToC alert
  - MRM alert

Distribute ToC by scheduling ToC in time and space

Problematic situation due to CAV executing ToC while a CV is executing a lane change





Connected vehicle



Cooperative Automated vehicle



## **DENM: Extensions**

- Additional Information:
  - ToC alert
  - MRM alert

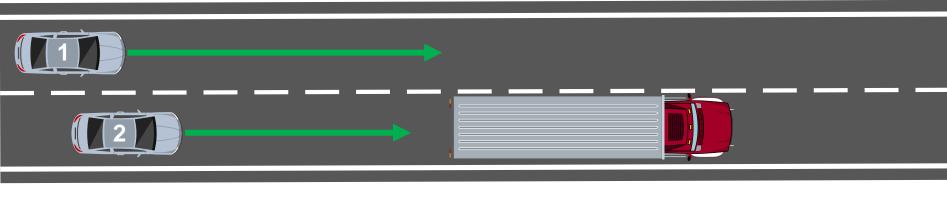
Extend Event Type field in the Situation Container

	ItsPduHeader				
DENM	DENM	ManagementContainer			
ded [		Situation Container			
Extended		LocationContainer			
ш		AlaCarteContainer			



- Current ETSI proposal:
  - Based on the exchange of trajectories

1) CAVs exchange planned trajectory





Cooperative
Automated vehicle



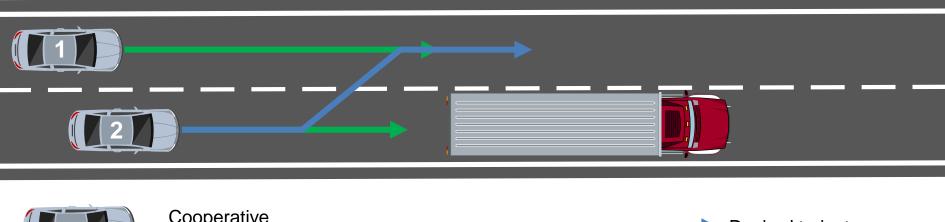
Planned trajectory





- Current ETSI proposal:
  - Based on the exchange of trajectories

2) CAV-2 wants to start cooperative maneuver and sends its desired trajectory

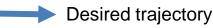




Cooperative
Automated vehicle



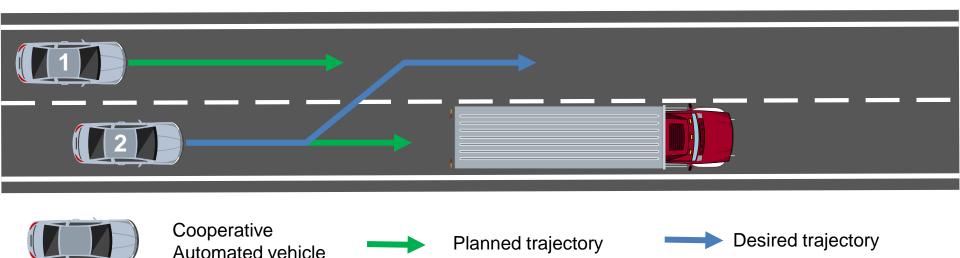
Planned trajectory





- Current ETSI proposal:
  - Based on the exchange of trajectories

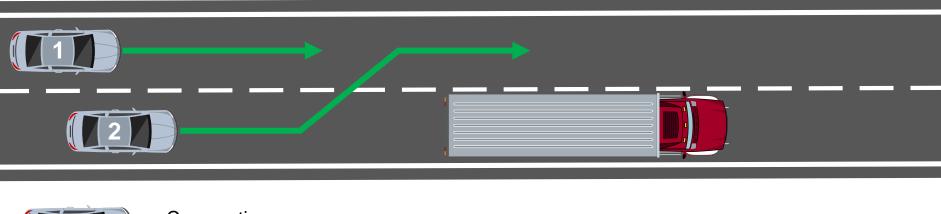
3) CAV-1 accepts cooperative maneuver and updates its planned trajectory





- Current ETSI proposal:
  - Based on the exchange of trajectories

4) CAV-2 can now employ its desired trajectory as a planned trajectory





Cooperative
Automated vehicle



Planned trajectory

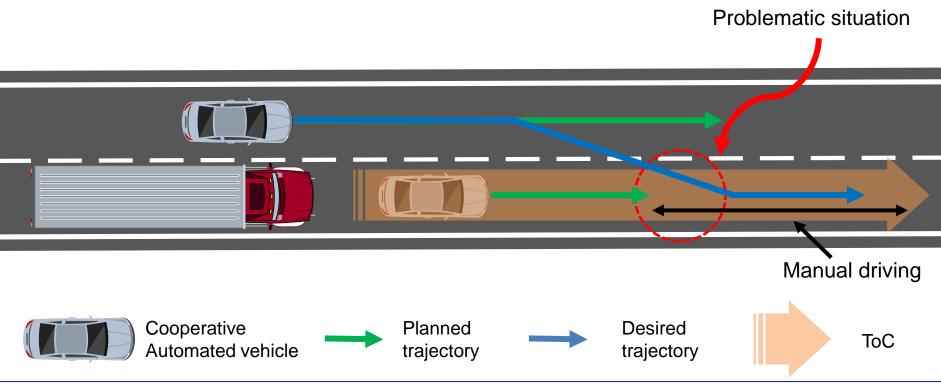


Desired trajectory



#### MCS Challenges

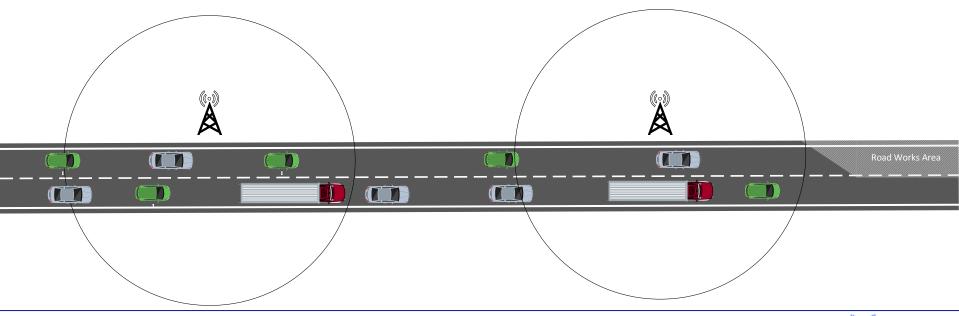
- Uncertainties during Transition of Control:
  - When the human driver will take control of the vehicle?





#### **MCS Challenges**

- Perception capabilities of CAVs:
  - Challenges increase when cooperative maneuvers imply vehicles at more than one hop communications distance
  - How to increase the overall traffic flow/safety?





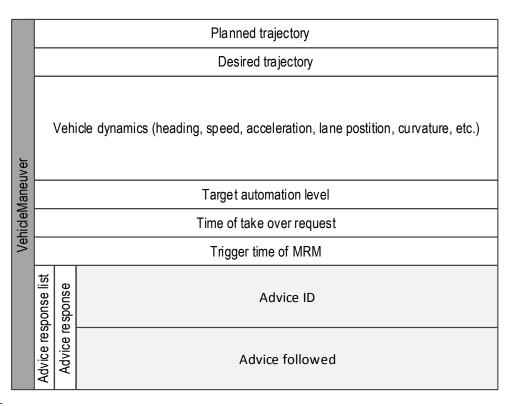
# **MCM: Message Format**

- Proposal format for the MCM:
  - Specific containers for different ITS-S: CAV and RSU
  - Vehicles can locally execute cooperative maneuvers
  - RSU provide advices to increase overall traffic flow/safety

MCM	ItsPduHeader							
		GenerationDeltaTime						
	ManeuverCoordination	MCMParameters	BasicContainer (RefPos + StationType)					
			ManeuverContainer = CHOICE [VehicleManeuver] OR RsuManeuver]	VehicleManeuver (Dynamics + plannedTrajectory + transition of control info)				
				RsuManeuver (list target vehicle-specific advices: speed, lane change, transition of control)				

#### MCM: CAV

- Vehicle Maneuver Container:
  - Sent by CAV
  - Planned trajectory
  - Desired trajectory
  - Vehicle dynamics
  - Information about future ToC
  - Acknowledgement of advice acceptance
- ToC information is included to increase safety during ToC
- Surrounding vehicles can plan its manuevers accordingly





#### MCM: RSU

- RSU Maneuver container:
  - Sent by RSU
  - Vehicle advice list
  - Lane advice
  - Speed and gap advice
  - ToC advice
- Infrastructure can provide multiple advices to multiple vehicles
- Vehicle decides if the advice will be followed

				intersectionReferenceID				
	roadSegmentreferenceID							
	Vehicle advice list	Vice		Target Station ID				
			Lane ad vice	Request ID				
				Lane change position				
				Lane change time				
				Lane change speed				
				Target lane				
uver				Triggering time of ToC				
RsuManeuver			p advice	Request ID				
Rsul		Vehicle advice		Advice lane ID				
		Vehic	and gap	Advice position				
			Speed ar	Target gap				
				Target speed				
			ToC advice	Request ID				
				To C advice reason				
				Position to start of ToC				
				Time to trigger ToC				
				Position to end ToC				

#### **Conclusions**

- Need to manage transitions of control
- ☐ Extensions of CAM, DENM, MCM needed

☐ Infrastructure can support managing multiple transitions of control





#### Thanks for your attention!

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