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
TransAID scope

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

TransAID deliverable 2.1: [Link]
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
CAM: Extensions

- Additional information needed:
  - Current automation level

1) Send current automation level

Distribute ToC by scheduling ToC in time and space

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

- 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

2) Send ToC advices

Legacy vehicle

Cooperative Automated vehicle

ToC

No AD zone
CAM: Extensions

- 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

No AD zone

Legacy vehicle  Cooperative Automated vehicle  ToC
CAM: Extensions

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

1) Send distances

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

CAVs on the on-ramp need to merge to the main road
CAM: Extensions

- 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

21/11/2018
CAM: Extensions

- 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
CAM: Extensions

- 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

<table>
<thead>
<tr>
<th>Ext. CAM</th>
<th>CoopAwareness</th>
<th>CAMP</th>
<th>ItsPduHeader</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GenerationDeltaTime</td>
<td>BasicContainer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HighFrequencyContainer = BasicVehicleContainerHighFrequency</td>
<td>BasicVehicleContainerLowFrequency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LowFrequencyContainer = BasicVehicleContainerLowFrequency</td>
<td>AutomatedVehicleContainer</td>
<td></td>
</tr>
</tbody>
</table>

TransAID deliverable 5.1: [Link](#)
**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  ToC
```

```bash
No AD zone
```
## DENM: Extensions

### Additional Information:
- ToC alert
- MRM alert

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**Extend Event Type field in the Situation Container**

<table>
<thead>
<tr>
<th>Extended DENM</th>
</tr>
</thead>
<tbody>
<tr>
<td>ItsPduHeader</td>
</tr>
<tr>
<td>ManagementContainer</td>
</tr>
<tr>
<td>SituationContainer</td>
</tr>
<tr>
<td>LocationContainer</td>
</tr>
<tr>
<td>AlaCarteContainer</td>
</tr>
</tbody>
</table>
Maneuver Coordination Service

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

1) CAVs exchange planned trajectory
Maneuver Coordination Service

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

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

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

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

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

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

<table>
<thead>
<tr>
<th>ItsPduHeader</th>
<th>GenerationDeltaTime</th>
</tr>
</thead>
</table>
| BasicContainer (RefPos + StationType) | ManeuverContainer = CHOICE [
| VehicleManeuver OR RsuManeuver] | VehicleManeuver (Dynamics + plannedTrajectory + desiredTrajectory + transition of control info) |
| RsuManeuver (list target vehicle-specific advices: speed, lane change, transition of control) | MCMParameters | ManeuverCoordination | MCM |
### 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**

<table>
<thead>
<tr>
<th>Vehicle Maneuver</th>
<th>Planned trajectory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Desired trajectory</td>
</tr>
<tr>
<td></td>
<td>Vehicle dynamics (heading, speed, acceleration, lane postition, curvature, etc.)</td>
</tr>
<tr>
<td></td>
<td>Target automation level</td>
</tr>
<tr>
<td></td>
<td>Time of take over request</td>
</tr>
<tr>
<td></td>
<td>Trigger time of MRM</td>
</tr>
<tr>
<td>Advice response list</td>
<td>Advice ID</td>
</tr>
<tr>
<td>Advice response</td>
<td>Advice followed</td>
</tr>
</tbody>
</table>

TransAID deliverable 5.1: [Link](#)
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

TransAID deliverable 5.1: [Link](#)
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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