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Towards the improvement of V2X standards for automated driving
Some characteristics of Automated Driving...
// Need for Cooperation

- Automated vehicles in Stand-Alone mode operate in isolation using only on-board sensors to sense their environment.
- Decreased road capacity due to increased inter-vehicle distance and lack of coordination.

- Communication between vehicles (and infrastructure) can make automated vehicles smarter.
  - Coordinated trajectories and higher awareness can improve safety, comfort and traffic efficiency.
AutoNet2030 Motivation

- **Convergence** between *stand-alone* vehicle automation and cooperative *V2X communications*

  - **Key to develop the right concepts for mutually useful convergence of these trends, demonstrate improved** cost-efficiency and performance as opposed to pure sensor-based solutions
  - **Keep overall system complexity as low as feasible**
    - stand-alone automated driving is already complex enough
// AutoNet2030 Project Facts

- **Project duration:** November 1, 2013 - October 31, 2016
- **Project budget:** 4.6M Euro
- **EC contribution:** 3.35M Euro
- **Partners:** ICCS (coordinator)
  - BroadBit
  - ARMINES
  - BaseLabs
  - Fiat Research Center
  - EPFL
  - Hitachi Europe
  - Technical University of Dresden
  - Scania Trucks
AutoNet2030 Objectives

1. Specifications of V2X messages for automated driving, also feeding ETSI ITS standardization

2. Development of maneuvering control algorithms for cooperative automation

3. Development of cost-effective on-board architecture for integrated sensing and communications

4. Development of a new HMI system facilitating the interaction between manual driven and automated vehicles
AutoNet2030 Highway Use-cases

- 4 cooperative AD *freeway* use-cases
  1. Convoy Driving: Multi-Lane Platoon under Distributed Control i.e. no *leading* vehicle
  2. Merging: Joining a convoy
  3. Splitting: Leaving a convoy
  4. Cooperative Lane Change: Lane change agreement between neighbor vehicles
AutoNet2030 Urban Use-cases

1. Cooperative AD urban use-cases:
   1. Cooperative Intersection Control: Infrastructure-based coordination of vehicle entry on intersections using relative priorities
// Communication Requirements

- **Functional Requirements**
  - *Cyclic* broadcast of data for **cooperative sensing**
    - Sensors: position, speed, acceleration, etc. (10Hz)
    - Perception: occupancy grid (2Hz)
    - Control: target trajectory, speed & acceleration, group composition (2Hz)
  - *Event-based* uni-/broadcast of data for **cooperative maneuvering**
    - Ad-hoc lane change negotiation
    - Intersection priority request / assignment

- **Data Quality Requirements**
  - Absolute localization accuracy (< 0.5m)

- **Delay Requirements**
  - End-to-end delay < 100ms. for high dynamic data
  - End-to-end delay < 500ms. for maneuver negotiation
European V2X Standards

- ITS Architecture defined by ETSI TC ITS follows OSI layered architecture and contains several V2X protocols & messages.
- Well fit for **convergence** with Autonomous Driving:
  - Perception, HMI in **Facilities**-layer
  - (Cooperative) Automated Vehicle Control in **Applications**-layer
- Current V2X standards in EU like the Cooperative Awareness Message (CAM) partly satisfy AutoNet2030 use-case requirements. **Need for extensions.**

ISO OSI layers
- 7 Application
- 6 Presentation
- 5 Session
- 4 Transport
- 3 Network
- 2 Data Link
- 1 Physical

**Applications**
- RHS
- ICRW
- LCRW

**Facilities**
- CAM
- DENM
- MAP/SPAT

**Network & Transport**
- BTP
- IPv6
- GN
- GN6
- TCP
- UDP

**Management**
- DCC

**Access Technologies**
- ITS-G5
- Cellular

**Security**
- Digital Signatures & Certificates
- Anonymity Support

**Definitions**
- CAM = Cooperative Awareness Message
- DENM = Decentralized Environmental Notification Message
- SPAT = Signal Phase & Timing
- BTP = Basic Transport Protocol
- GN = GeoNetworking

(Image of diagram showing the ITS Architecture layered model, with various protocols and standards indicated.)
AutoNet2030 V2X Extensions

Joint effort between AutoNet2030 and AdaptIVe resulted in:

1. New and extended Facilities-layer messages
   - CLCS (Lane Change), CCCS (Convoy), CICS (Intersection) to satisfy Cooperative Maneuvering requirements
   - CPS (Occupancy Grid) and Extended CAM for Cooperative Sensing requirements

2. Reliable BTP to support Cooperative Maneuvering

3. Innovative GN routing algorithms to improve uni-/broadcast communication

Full specification available at: http://www.autonet2030.eu/

AutoNet2030 Architecture

- CLCS = Cooperative Lane Change Service
- CCCS = Cooperative Convoy Communication Service
- CICS = Cooperative Intersection Control Service
- CPS = Cooperative Perception Service
- RBTP = Reliable BTP

Access Technologies

- ITS-G5
- Cellular

Network & Transport

- RBTP
- TCP / UDP
- GN
- IPv6

Facilities

- CLCS
- CCCS
- CICS
- CPS
- Extended CAM
- DENM
- MAP/SPAT

Applications

- Autonomous Driving

Management

Security

AutoNet2030 V2X extensions --- standard V2X components
ETSI TC ITS activities on Automated Driving

- 2 Work Items in WG1 (Application Requirements and Services)
  - Definition, use cases, requirements, recommendation on technical specifications targeting at extending the release 1 standards (CAM, DENM, GN, ITS-G5 etc.) to support Platooning & C-ACC applications

1. TR 103 298 - Platooning pre-standardization study
   - Rapporteur: Ms. Sjöberg (Volvo Technology Corporation)
   - Status: WI Adopted by Technical Committee.

2. TR 103 299 - C-ACC pre-standardization study
   - Rapporteur: Ms. Lan (Hitachi Europe)
   - Status: Early draft of Technical Report

AutoNet2030, AdaptIVe and i-GAME are contributing to the above work items.
Conclusions

1. *Cooperative* Automated Driving can further improve safety, comfort and traffic efficiency

2. AutoNet2030 has defined use-cases and communication requirements for Cooperative Automated Driving
   - Convergence between V2X and stand-alone AD
   - Communication complements on-board sensors, no replacement

3. Current V2X Standards in EU are insufficient to meet *Cooperative Maneuvering* and *Cooperative Sensing* requirements of AutoNet203

4. AutoNet2030 has defined extension to EU standards for V2X communication and contributes to ongoing standardization activities in EU
Thank you.

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Technical Workshop
Athens, Greece
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## Extended CAM content

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
<th>Transmission Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving Mode</td>
<td>The driving mode engaged by the vehicle that sent the CAM.</td>
<td>2 Hz</td>
</tr>
<tr>
<td>Automated Control</td>
<td>Lists the automated vehicle control systems engaged by the vehicle that sent the CAM.</td>
<td>2 Hz</td>
</tr>
<tr>
<td>Braking Capacity</td>
<td>The maximum braking capacity and its confidence of the vehicle that sent the CAM.</td>
<td>2 Hz</td>
</tr>
<tr>
<td>Target Speed</td>
<td>The target speed of the vehicle that sent the CAM.</td>
<td>2 Hz</td>
</tr>
<tr>
<td>Target Longitudinal Acceleration</td>
<td>The target longitudinal acceleration of the vehicle that sent the CAM.</td>
<td>2 Hz</td>
</tr>
<tr>
<td>Target Distance to Preceding Vehicle</td>
<td>The target distance between the front bumper of the vehicle that sent the CAM and the rear bumper of its preceding vehicle in the same lane.</td>
<td>10 Hz</td>
</tr>
<tr>
<td>Target Distance to Following Vehicle</td>
<td>The target distance between the rear bumper of the vehicle that sent the CAM and the front bumper of its following vehicle in the same lane.</td>
<td>2 Hz</td>
</tr>
<tr>
<td>Predicted Path</td>
<td>The predicted future trajectory of the vehicle that sent the CAM.</td>
<td>2 Hz</td>
</tr>
<tr>
<td>Group Identifier</td>
<td>The platoon of convoy identifier in which the vehicle that sent the CAM is driving.</td>
<td>2 Hz</td>
</tr>
<tr>
<td>Group Speed</td>
<td>Target speed of the convoy or platoon the vehicle is driving in</td>
<td>2 Hz</td>
</tr>
</tbody>
</table>

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![Diagram showing CAM content structure](https://example.com/structure_diagram.png)

**Common data**
- ITS common header
- Basic container

**Profile specific data**
- High Frequency container (dynamic)
- Low frequency container (static)
- Special Vehicle container

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Communication facility to support a cooperative lane change of a single or group of vehicles. A Cooperative lane change is executed in three phases:

- **Search Phase (optional):** finding the right target vehicle in case awareness of potential target vehicles is insufficient.

- **Preparation Phase:** longitudinal adjustment of subject and target vehicles.

- **Execution Phase:** lateral lane change of subject vehicles.
Cooperative Lane Change Service cont’d

Search phase (optional)

- Lane Change Search Request (BTP+BC)
- Lane Change Search Response (RBTP+UC)
- Lane Change Announce (BTP+BC)
- Lane Change Announce Response (RBTP+UC) [Acknowledged]

Preparation phase

- Lane Change Announce (BTP+BC)
- Lane Change Prepared Notification (RBTP+UC)

Execution phase

- Lane Change Search Response (RBTP+UC)
- Lane Change Announce (BTP+BC)

Other Vehicle

- No objection