



C-ITS SERVICE AND USE CASE DEFINITIONS

**COLLECTIVE PERCEPTION (CP)
[C-ROADS SUD08]**

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Table of Contents

Introduction.....	4
8. Collective Perception (CP)	5
8.1 CP: Service introduction	5
8.2 CP: Use Cases.....	7
8.2.1 CP – Collective Perception on Motorways (CP-MW).....	7
8.2.2 CP – Collective Perception on Urban/Interurban Intersections (CP-UI).....	11

Introduction

The document ‘Service and Use Case Descriptions 01 Intro Document’ [C-Roads SUD01] explains the structure of the service and use case descriptions harmonized in C-Roads. Also, it gives an overview of all harmonized service and use cases and in which document they are described. Each service and its use cases are described in a separate chapter in a separate document. Together, these documents form the integral deliverable of the service and use case descriptions.

All References (in square brackets) refer to the global reference document [WG2 REF], which is part of the whole set of documents of a specific C-Roads release.

8. Collective Perception (CP)

8.1 CP: Service introduction

Service introduction	
Summary	Collective Perception (CP) is an information service to share information about objects that may influence road traffic with vehicles.
Background	<p>Collective Perception is a concept where perception data is shared among vehicles as well as between infrastructure and vehicles. Infrastructure sensors (e.g. radar, lidar and smart cameras) are often mounted at elevated positions, providing an extension of the electronic horizon of a vehicle. This is beneficial on motorways, especially at tunnel entries and in merging situations. In urban environment, it is beneficial in complex and crowded traffic situations, where perception data covers vehicles, cyclists and pedestrians, especially at intersections.</p> <p>Information about the objects such as obstacles/pedestrians are shared via the CP service when they have a potential influence on the traffic. For example, pedestrians are included only when they are on the road or about to enter the road, and static cargo is included only when it disturbs the traffic flow.</p> <p>The CP service is meant to extend the electronic horizon of a vehicle by sharing the data about objects in the form of object lists rather than interpreting the data and deriving as hazardous location notifications. In this sense, the CP service delivers abstract object data, where the interpretation whether it is a normal or a hazardous situation is left to the receiving end in the vehicle. The CP service is generally designed for perception data sharing among all ITS stations, where vehicle ITS stations and roadside ITS stations can be both sender and receiver. C-ROADS focuses on the infrastructure-based variant, where infrastructure sensors provide sensor perceptions in form of object lists to surrounding vehicles.</p>
Objective	<ul style="list-style-type: none"> ○ Safe driving by extending the “electronic horizon” of the vehicle through sensor perceptions beyond the range of a vehicle’s own capabilities. ○ Collision avoidance by providing obstacle and vulnerable road user (VRU) information in poor visibility and obstructed line of sight conditions. ○ Increased awareness on static and dynamic obstacles and vulnerable road users by providing object data directly to the vehicle where it can be presented to the driver, processed automatically in driver assistance systems, or trigger crash avoidance mechanisms. It has the potential to greatly reduce problems in locations which are attributed to higher risks of accidents because of limited line of sight, obstruction or complex traffic situations.
Expected benefits	<ul style="list-style-type: none"> ○ Improved road safety through extended awareness for the vehicles or drivers at heavy traffic or accident-prone locations: Infrastructure-based Collective Perception provides sensor perception beyond the capability of a vehicle’s onboard sensors, and the sight of a driver, especially from the infrastructure

	<p>sensors mounted at elevated positions can help to overcome the limitations of on-board sensors which might be obstructed by the landscape or other vehicles.</p> <ul style="list-style-type: none"> ○ Improved in-vehicle information and application services: The extended awareness/visibility provided by the CPS object data could be used to show hidden dangerous situations to the driver via traditional HMI or head-up display or it could also be automatically processed in advanced assistance systems or become part of automated driving functions.
Use cases	<ul style="list-style-type: none"> ○ Collective Perception on Motorways (CP-MW) ○ Collective Perception at Urban/interurban Intersections (CP-UI)

8.2 CP: Use Cases

8.2.1 CP – Collective Perception on Motorways (CP-MW)

Type of road network	Motorway
Type of vehicle (receiver)	All
Use case introduction	
Summary	Collective Perception on Motorways delivers perception data from infrastructure sensors to vehicles on the motorway. Infrastructure sensors can be mounted at elevated position, such as overhead gantries or posts, providing an extension of the electronic horizon of a vehicle. This is beneficial especially at tunnel entries and in merging situations, where the additional awareness can contribute to safe driving and collision avoidance. In linear, open range motorway sections, CP is generally not required.
Background	There are locations on motorways, where the vehicles' sensor capabilities are limited, either by obstruction or by a change of the environment – e.g. when entering or exiting a tunnel. The tunnel entry is a challenging environment for camera systems as well as for radar sensors, because the environment changes significantly. In this case, the CP service provides object detections where the vehicles' own sensors are limited.
Objective	The aim is to increase the perception of drivers by providing additional information on static and dynamic obstacles present in its immediate environment. Which will contribute to improving road safety.
Desired behaviour	<p>Drivers can:</p> <ul style="list-style-type: none"> ○ be made aware of any kind of static or dynamic obstacle on the road ahead ○ drive more attentive based on objects beyond their line of sight. <p>The vehicle's perception can be extended and/or augmented by the object detections provided by the infrastructure and extend their electronic horizon. The information may be used by Advanced Driver Assistance Systems for assisted or automated driving.</p>
Expected benefits	<ul style="list-style-type: none"> ○ Enhanced traffic safety ○ Reduction of accidents or near accidents and critical driving situations
Use case description	
Situation	In general, all situations where an obstructed line of sight and a change of environment could lead to a decreased awareness of the situation. We focus on two situations in particular:

1. Motorway tunnel entry

- In this situation the vehicle is about to enter a tunnel, and besides obstructions of other vehicles, the view of its own sensors into the tunnel is limited.



Figure 8:1 Motorway tunnel entry situation

2. Motorway merge situation

- In this situation, the vehicle is merging into motorway traffic and the location is characterised by obstructed line of sight, due to topology or artificial structures such as noise barriers.



Figure 8:2 Motorway merge situation

Triggering conditions: The CP service is continuously monitoring the environment and generating continuously perception data.

Logic of transmission

I2V

Actors and relations

- **Road operator / service provider:** The source of the data is a sensor system maintained by the road operator/service provider. The road operator / service provider is expected to ensure the data quality of the content of the messages is consistent when sending CPMs.
- **Drivers:** The CP information is continuously received by C-ITS equipped vehicles and can be presented to the drivers or processed by assistance systems. The exact details of the presentation (how and when) is based on the individual application designer's decision.

Use case scenario	<ul style="list-style-type: none"> ○ The infrastructure sensors detect dynamic and static objects within the sensor perception region. The perceptions are used to generate an object list, potentially with classifications of the objects. The object list is included into a CP message and broadcasted at the location which is relevant for the detected objects. ○ The message is received in the vehicle and presented to the driver, if relevant. It may also be automatically processed by driver assistance systems, which trigger braking or a speed decrease. ○ The drivers can act accordingly. <div data-bbox="469 613 1426 967"> </div> <p style="text-align: center;"><i>Figure 8:3 Sensor setup and principle of the tunnel entry scenario</i></p>
Intended Presentation/Alert principle	<ul style="list-style-type: none"> ○ The vehicle (driver or driving system) receives the obstacle information early enough to act accordingly and ensure a safe traffic operation. ○ The HMI presentation is at the vehicle manufacturer's own responsibility.
Functional constraints / dependencies	The use case depends on inputs of sensor systems.
Link to other use cases	<p>HLN-OR and HLN-APR are closely related use cases, where the object has been identified as being an obstacle, or an animal or a person on the road. Also stationary vehicles (HLN-SV) are static objects.</p> <p>The main difference between CPM and DENM (HLN) is the fact that with the HLN service the infrastructure evaluates the object as a hazard to all of the vehicles and decides to send out a specific warning instead of general perception data (CPM).</p>
Interoperability Requirements	
Message profile requirements	<ul style="list-style-type: none"> ○ The CP message for CP-MW is profiled in the chapter 4.2.6 of [C-Roads MP]. ○ ObjectInclusionConfig shall be set to "0". ○ The sets of CPMs shall include all objects which are located on the driveable carriageway and whose object perception quality exceeds ObjectPerceptionQualityThreshold = 3.

Security and data protection requirements	<p>Security requirements and specifications of certificates are described in [C-ITS Security Requirements and Specifications].</p> <p>An overall introduction to the common European trust model is described in [C-ITS Security and Governance] which is referring to the relevant ETSI standards for certificates and PKI management as the underlying technical basis.</p> <p>The CPM permissions (SSP) shall be encoded as defined in [ETSI TS 103 324] where the bitmap SSP consists of version field.</p> <p><i>NOTE: The definition of relevant SSPs will be added in a later release.</i></p>
Communication technology requirements: ITS-G5	<p>For ITS-G5 based implementations of use cases where roadside stations are used, the requirements of [C-Roads RSP] shall apply, using SCH1 for dissemination (as defined in RS_RSP_113(1)).</p> <p>For ITS-G5 based implementations of use cases where mobile stations are used, the requirements of C-Roads, [C-Roads MSP] shall apply.</p> <p>Channel offload procedures are not recommended.</p> <p>For CP-MW, sets of CPMs (containing at least one CPM) shall be generated at a constant rate. It is recommended to use a rate of 1Hz.</p>
Communication technology requirements: IP based	<p><i>NOTE: Currently, no IP implementation is known of this use case. Specific interoperability requirements will be added after evaluation of an IP implementation.</i></p>
Test and validation requirements	<p>The document “C-ITS Cross-Border Testing and Validation Concept” [C-Roads_TVC] contains the generic applicable framework and process for interoperability testing.</p> <p>The applicable message and service generic and use case specific test cases are listed in the document “C-ITS Test Plan” [C-Roads_TP].</p>

8.2.2 CP – Collective Perception on Urban/Interurban Intersections (CP-UI)

Type of road network	Urban Area and Interurban Area
Type of vehicle (receiver)	All
Use case introduction	
Summary	Collective Perception on urban/interurban intersections delivers object perception data from infrastructure sensors to vehicles on intersections. Infrastructure sensors can detect vulnerable road users, but also obstacles on the road. This is beneficial especially in situations where vehicles are turning at intersections and crossing the paths of pedestrians and cyclists.
Background	Vulnerable Road Users (VRU) are defined in the ITS directive as “non-motorised road users, such as pedestrians and cyclists as well as motor-cyclists and persons with disabilities or reduced mobility and orientation”. A main motivation of this use case is to create awareness on cyclists and pedestrians as VRU. But also other traffic participants such as powered two-wheelers as well as or not clearly visible obstacles can be part of it.
Objective	The aim is to increase the perception of drivers by providing additional information on static and dynamic obstacles present in its immediate environment. Which will contribute to improving road safety. The use case is particularly valuable when the driver is distracted or visibility is poor.
Desired behaviour	Approaching vehicles (drivers or driving systems) are able to adjust their speed and driving trajectory accordingly (including emergency stop) to avoid collisions with VRU.
Expected benefits	<ul style="list-style-type: none"> ○ Enhanced traffic safety by avoiding accidents between vehicles and VRU or other obstacles. ○ Improved attractivity for cycling and walking by the reduction of dangerous situations with vehicles.
Use case description	
Situation	The situation is characterised by vehicles approaching and entering an urban or interurban intersection where VRUs are present. Especially the situation where the paths of pedestrian and cyclists cross the paths of turning vehicles are considered dangerous.



Figure 8:4 VRU paths at an urban intersection

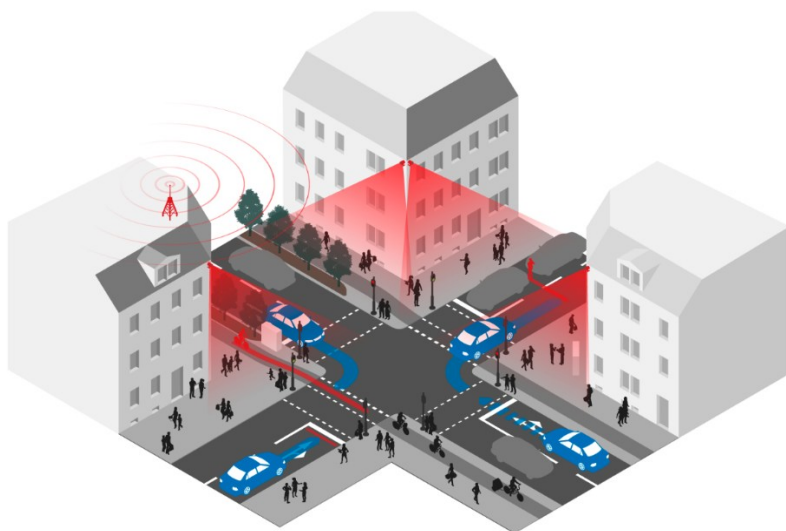


Figure 8:5 Vulnerable road users and vehicles at an urban intersection

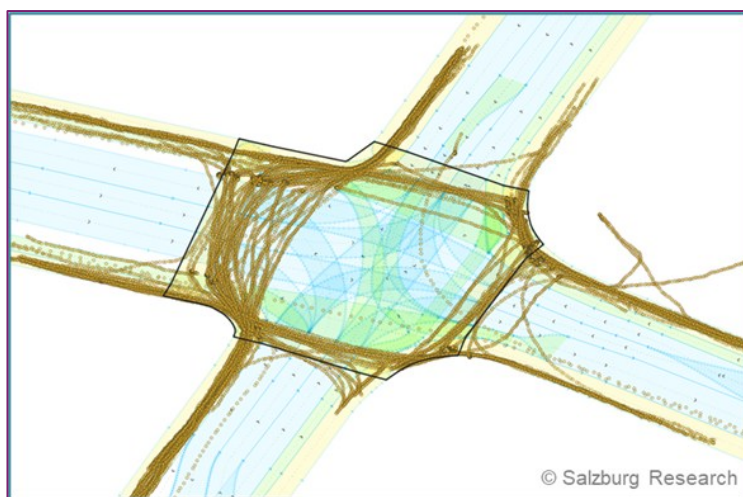


Figure 8:6 Sensor perception of pedestrian paths at an intersection

Triggering Conditions: The CP service is continuously monitoring the environment and generating continuously perception data.

Logic of transmission	I2V
Actors and relations	<ul style="list-style-type: none"> ○ Road operator / service provider: The source of the data is a sensor system maintained by the road operator/service provider. The road operator / service provider is expected to ensure a continuous data quality of the content of the messages when sending CPMs. ○ Drivers: The CP information is continuously received by C-ITS equipped vehicles and can be presented to the drivers or processed by assistance systems. The exact details of the presentation (how and when) is based on the individual application designer's decision. ○ VRUs: The locations and movements of VRUs are perceived by the sensor system.
Use case scenario	<ul style="list-style-type: none"> ○ The infrastructure sensors detect dynamic and static objects within the sensor perception region. The perceptions are used to generate an object list, potentially with classifications of the objects. The object list is included into a CP message and broadcasted at the location which is relevant for the detected objects. ○ The message is received in the vehicle and presented to the driver, if relevant. It may also be automatically processed by driver assistance systems, which trigger braking or a speed decrease.
Presentation/Alert principle	The vehicle (driver or driving system) receives the information of the VRU early enough to act accordingly and ensure a safe traffic operation (e.g. turning operation).

Functional constraints / dependencies	The use case depends on inputs of sensor systems.
Link to other use cases	<ul style="list-style-type: none"> ○ The use case can also be accompanied by a warning system that detects potentially hazardous situations with VRU and generates and sends out HLN messages to approaching vehicles (drivers or driving systems). ○ There are related HLN use cases, which provide an event position for a hazardous situation, whereas CP delivers the abstract object data. As an example, HLN-OR and HLN-APR are related, where the object has to be identified as being an obstacle or person, before sending the respective message. ○ The main difference between CPM and DENM (HLN) is the fact that with the HLN service the infrastructure evaluates the object as a hazard to all of the vehicles and decides to send out a specific warning instead of general perception data (CPM).
Interoperability Requirements	
Message profile requirements	<ul style="list-style-type: none"> ○ The CP message for CP-UI is profiled in the chapter 4.2.6 of [C-Roads MP].
Security and data protection requirements	<p>Security requirements and specifications of certificates are described in C-Roads, [C-ITS Security Requirements and Specifications].</p> <p>An overall introduction to the common European trust model is described in [C-ITS Security and Governance] which is referring to the relevant ETSI standards for certificates and PKI management as the underlying technical basis.</p> <p>The CPM permissions (SSP) shall be encoded as defined in [ETSI TS 103 324] where the bitmap SSP consists of version field.</p> <p><i>NOTE: The definition of relevant SSPs will be added in a later release.</i></p>
Communication technology requirements: ITS-G5	<p>For ITS-G5 based implementations of use cases where roadside stations are used, the requirements of [C-Roads RSP] shall apply using SCH1 for dissemination (as defined in RS_RSP_113(1)).</p> <p>For ITS-G5 based implementations of use cases where mobile stations are used, the requirements of C-Roads, [C-Roads MSP] shall apply.</p> <p>For CP-MW, sets of CPMs (containing at least one CPM) shall be generated at a constant rate. It is recommended to use a rate of 1Hz.</p>
Communication technology requirements: IP based	<p><i>NOTE: Currently, no IP implementation is known of this use case. Specific interoperability requirements will be added after evaluation of an IP implementation.</i></p>

<p>Test and validation requirements</p>	<p>The document “C-ITS Cross-Border Testing and Validation Concept” [C-Roads_TVC] contains the generic applicable framework and process for interoperability testing.</p> <p>The applicable message and service generic and use case specific test cases are listed in the document “C-ITS Test Plan” [C-Roads_TP].</p>
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