Collective Perception Service in ETSI and CAR 2 CAR Communication Consortium

6th FG-AI4AD workshop
AI for Good Global Summit;
2th June 2021

Outline

- What is Collective Perception
- Collective Perception in ETSI
- C2C-CC Study on Object quality for CPM
- Questions

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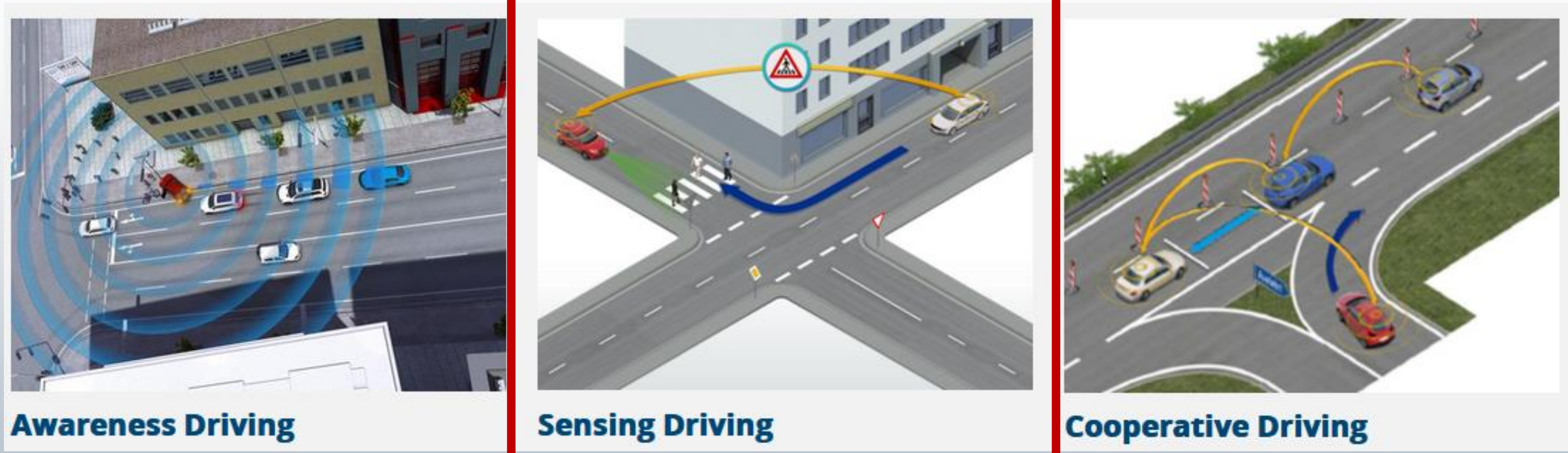
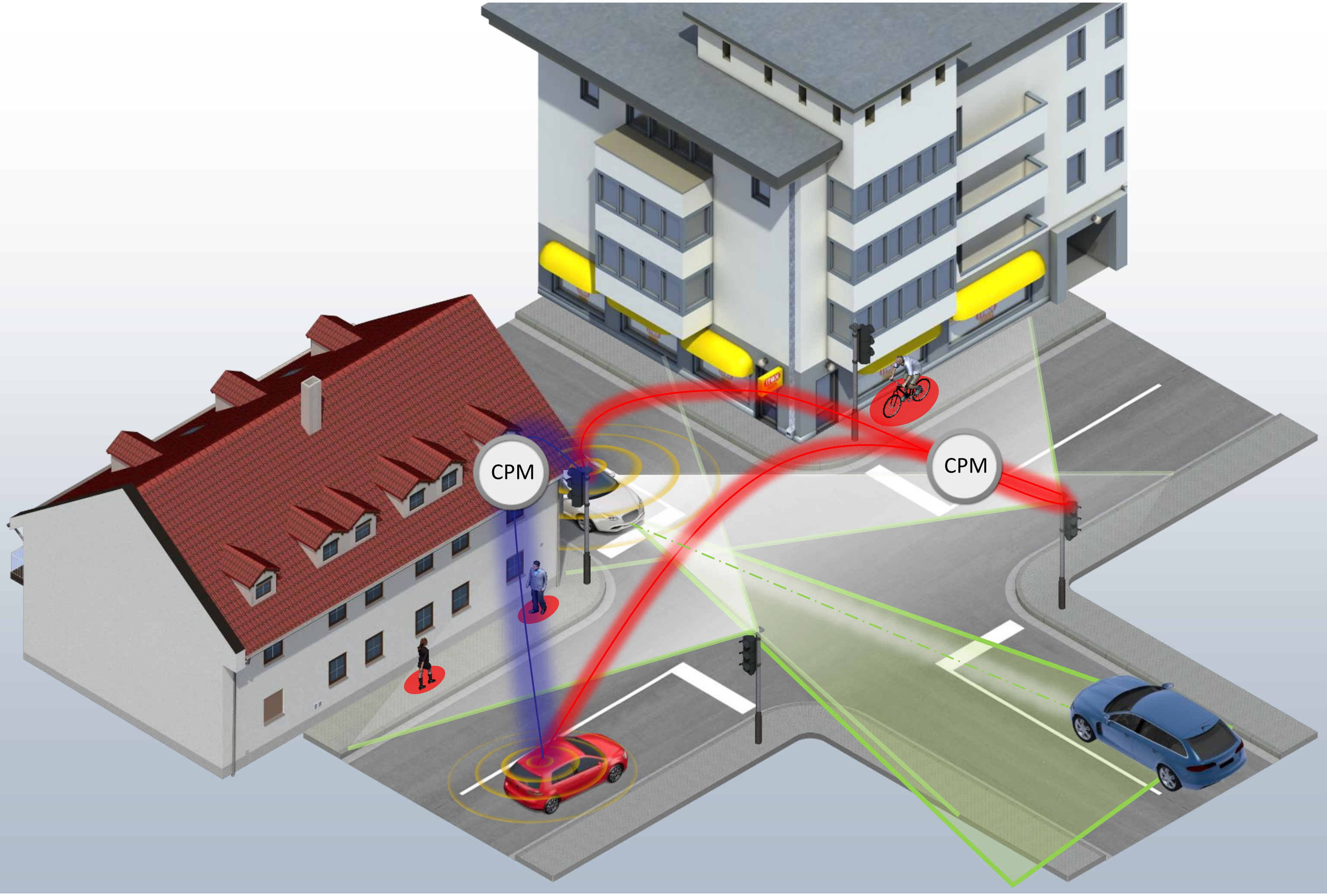
Phases of Cooperative driving



Source: CAR 2 CAR Communication Consortium

What is Collective Perception?

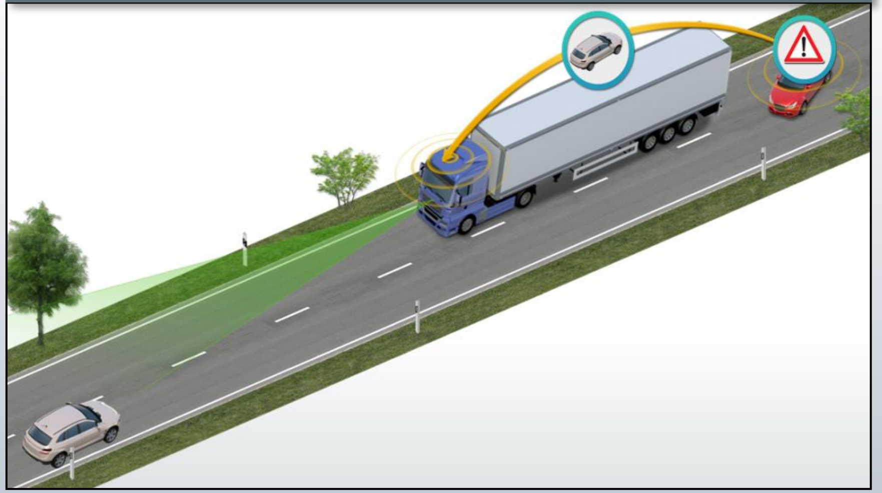


- Increase awareness by sharing information about locally detected objects
- Enables hidden line of sight applications by raising awareness also about non-connected road users (especially VRUs)
- Vehicle sensors and sensors mounted to infrastructure components can share information
- Collective Perception Service on ITS-S generates Collective Perception Message
- ETSI TR 103 562 approved by ETSI WG1, to be published by end of November 2019
- Standardization activities now focus on ETSI TS 103 324

Day 2: Collective Perception

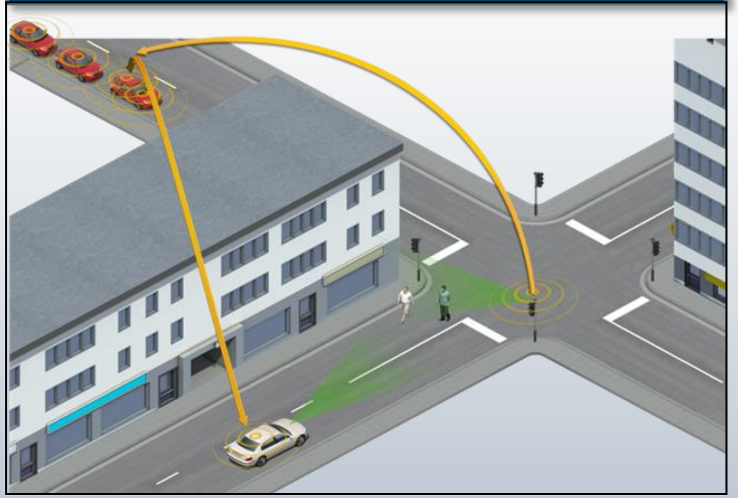
- Sharing abstract descriptions of objects detected by vehicle or infrastructure sensors
- Creates improved awareness even with low C-ITS penetration

Overtaking Warning



Overtaking car analyses the rx info and warn the driver if necessary

VRU Warning



Turning car analyses the rx info and warns the driver if necessary

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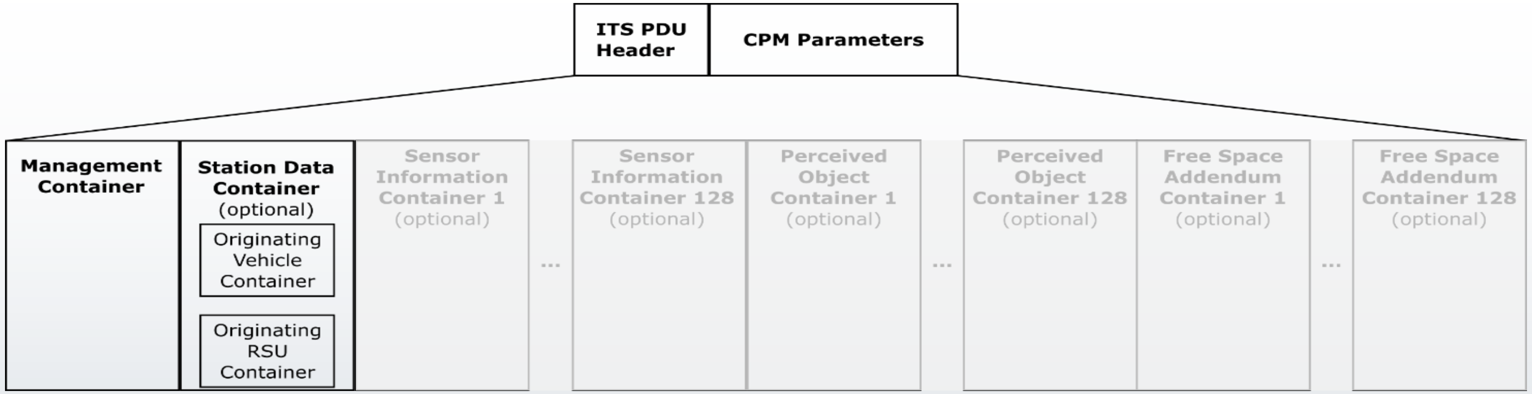
Key Concepts for CPM as described by ETSI TC ITS

Collective Perception (CP): The concept of sharing the perceived environment of a station based on perception sensors. In contrast to Cooperative Awareness (CA), an ITS-S broadcasts information about its current (driving) environment rather than about its current state. Hence, CP is the concept of actively exchanging locally perceived objects between different ITS-Ss by means of V2X communication technology. CP decreases the ambient uncertainty of ITS-Ss by contributing information to their mutual Field-of-Views.

Object: An object in the context of the CP Service refers to the state space representation of a physically detected object within a sensor's perception range.

Object List: A collection of objects temporally aligned to the same timestamp.

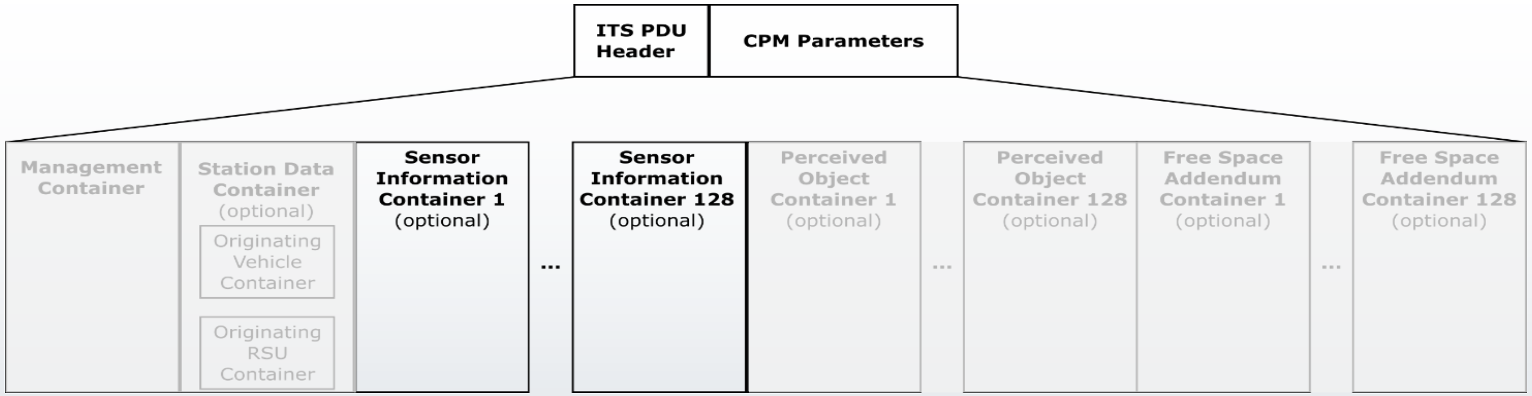
CP Message Format and Data Elements

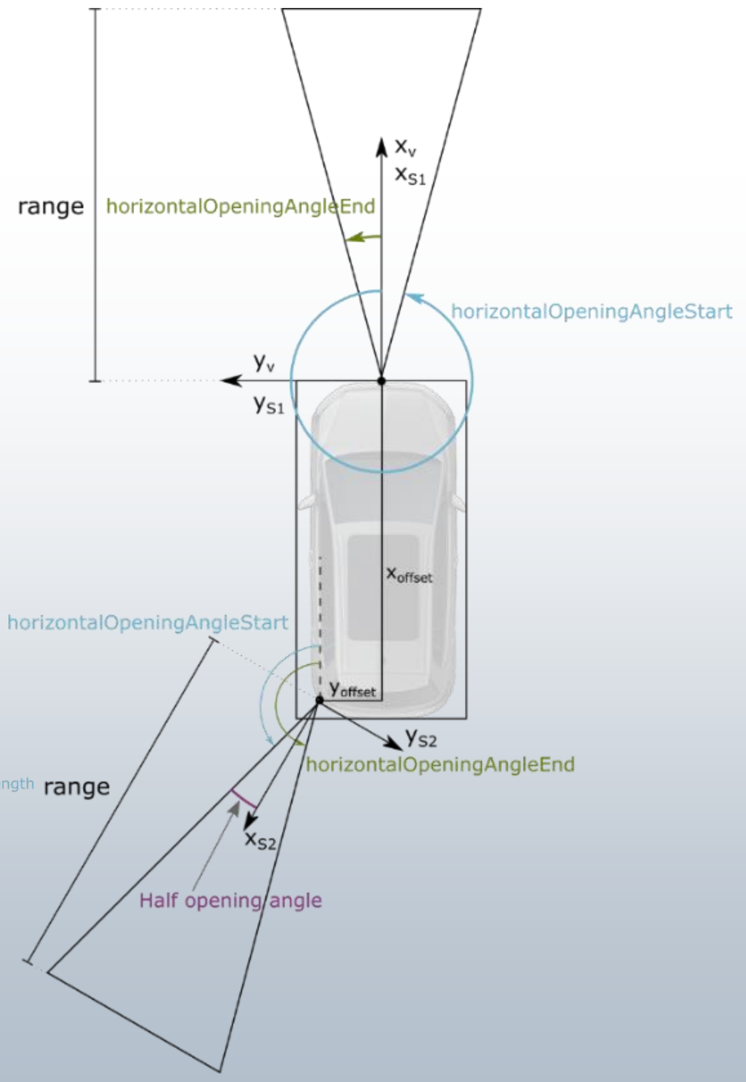


Management & Station Data Container

- Information about the originating ITS-S
- Position of Reference Point
- ITS-S type
- Optional Message Segmentation Information
- Differentiate between vehicle and RSU as transmitter
  - Vehicle: Position and attitude information along with confidence
  - RSU: References to optional MAP messages transmitted alongside the CPM

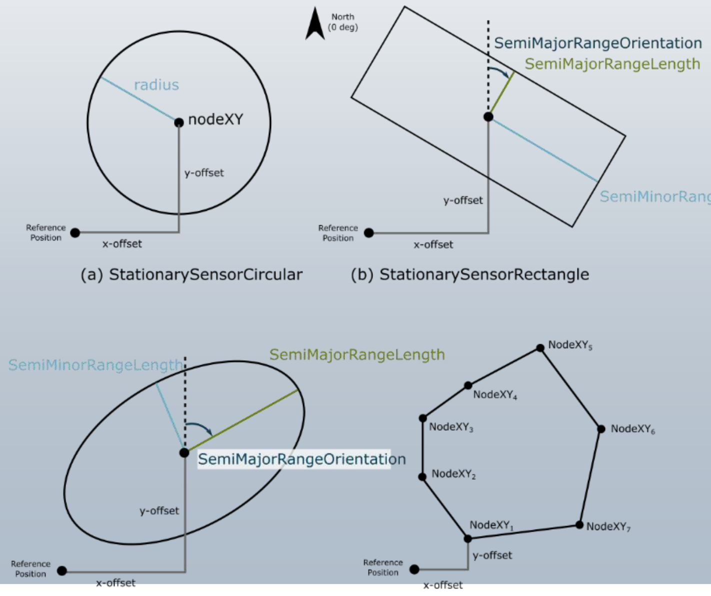
CP Message Format and Data Elements





Sensor Information Container

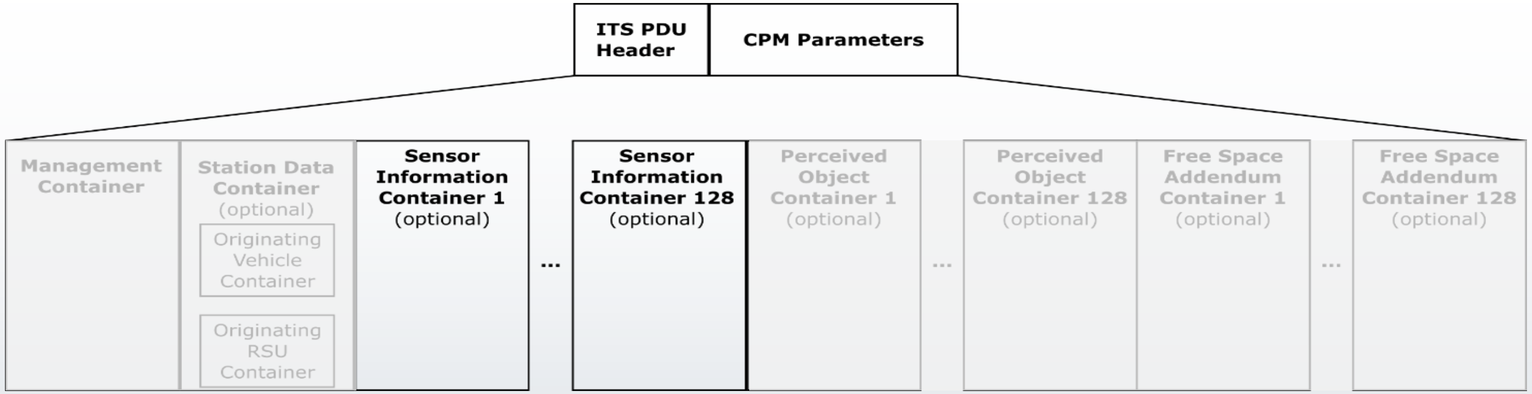
- Description of perception capabilities of transmitting station
- Differentiation between RSU and vehicle
- Abstract descriptions possible (circular, polygon, rectangle, ellipse)



(a) StationarySensorCircular (b) StationarySensorRectangle

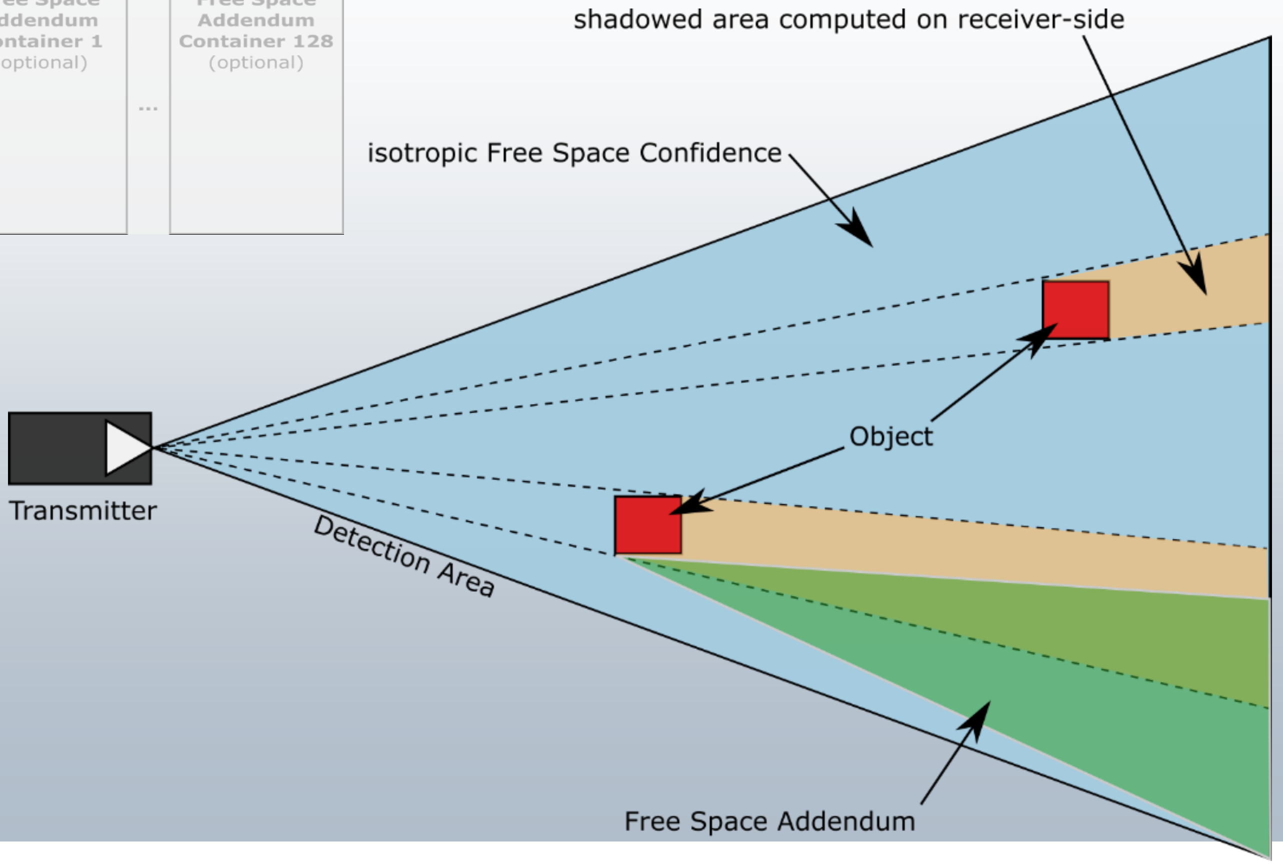
(c) StationarySensorEllipse (d) StationarySensorPolygon

CP Message Format and Data Elements

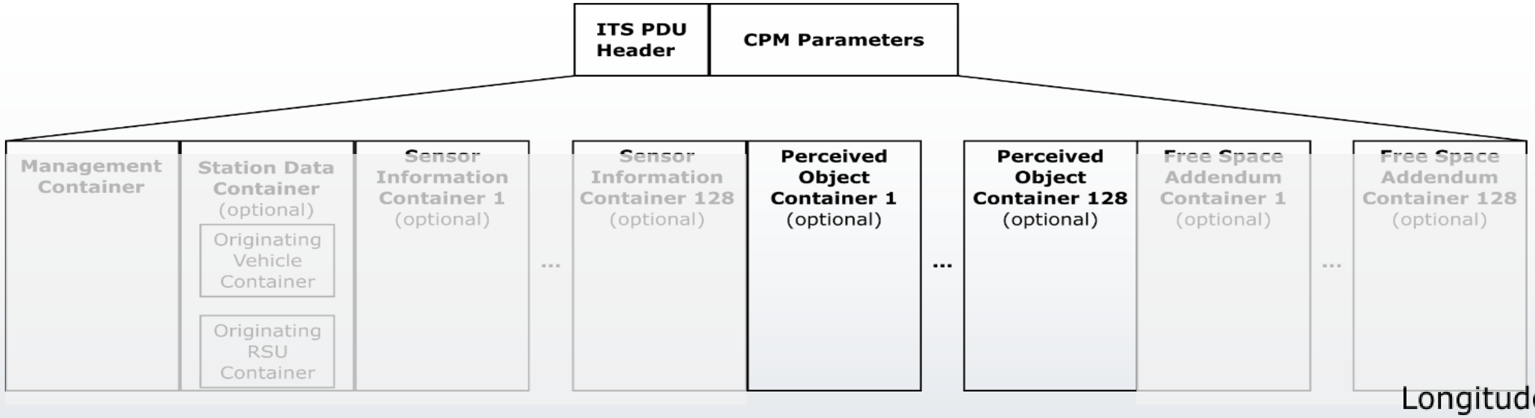


Sensor Information Container

- Description of perception capabilities of transmitting station
- Differentiation between RSU and vehicle
- Abstract descriptions possible (circular, polygon, rectangle, ellipse)
- Indication of free space detection capability → isotropic free space confidence
- Free Space can be derived on receiver, based on simple ray tracing approach

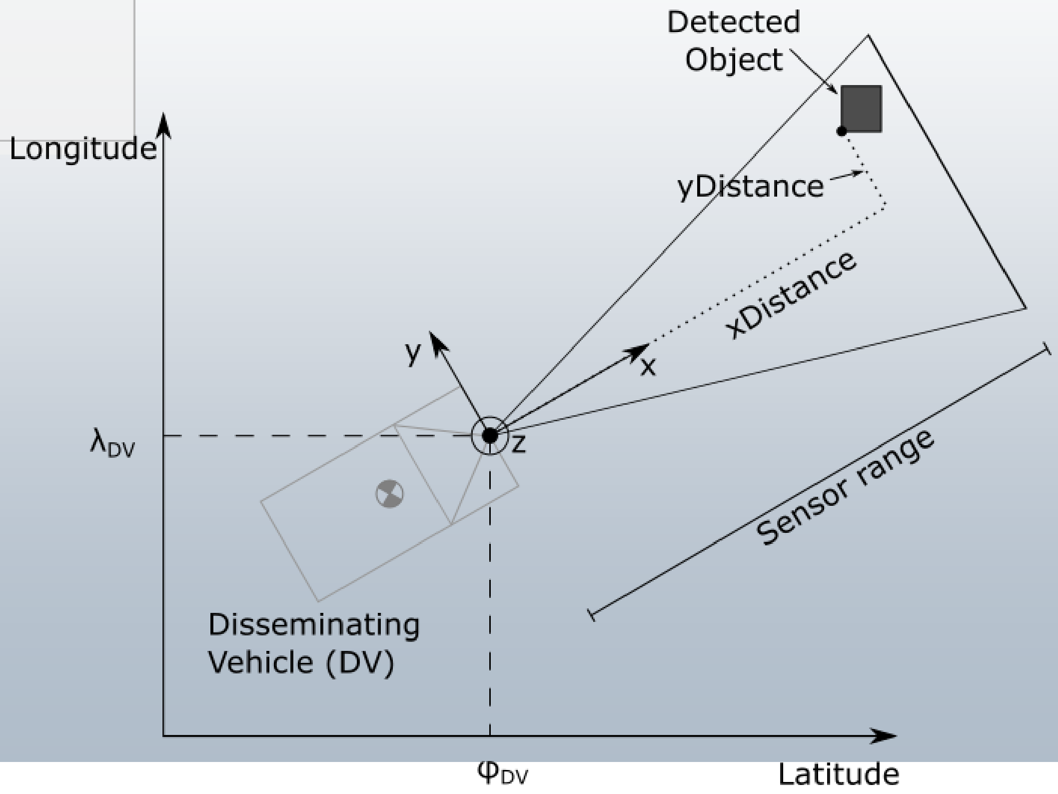


CP Message Format and Data Elements

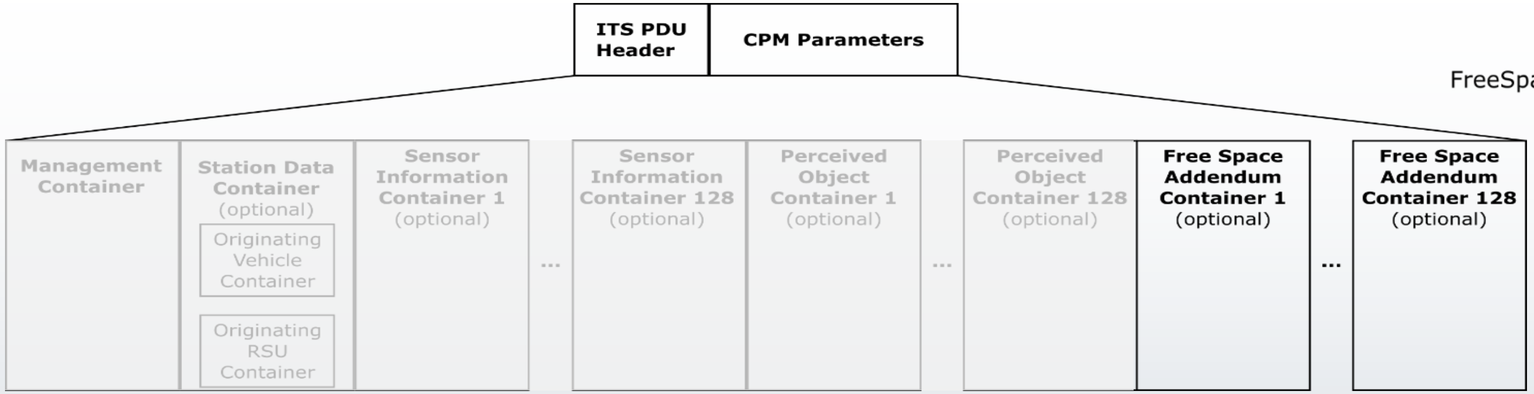


Perceived Object Container

- Provides timing, position and attitude information for detected objects
- (Multi-) Classification of objects supported (vehicle, person, animal, other)
- 3D representation of objects supported, along with variance
- Work in progress: how to encode meaningful object confidence
- Map matching result may be provided for RSUs
- Work in progress: Selection of suitable coordinate system, cooperation with POTI STF

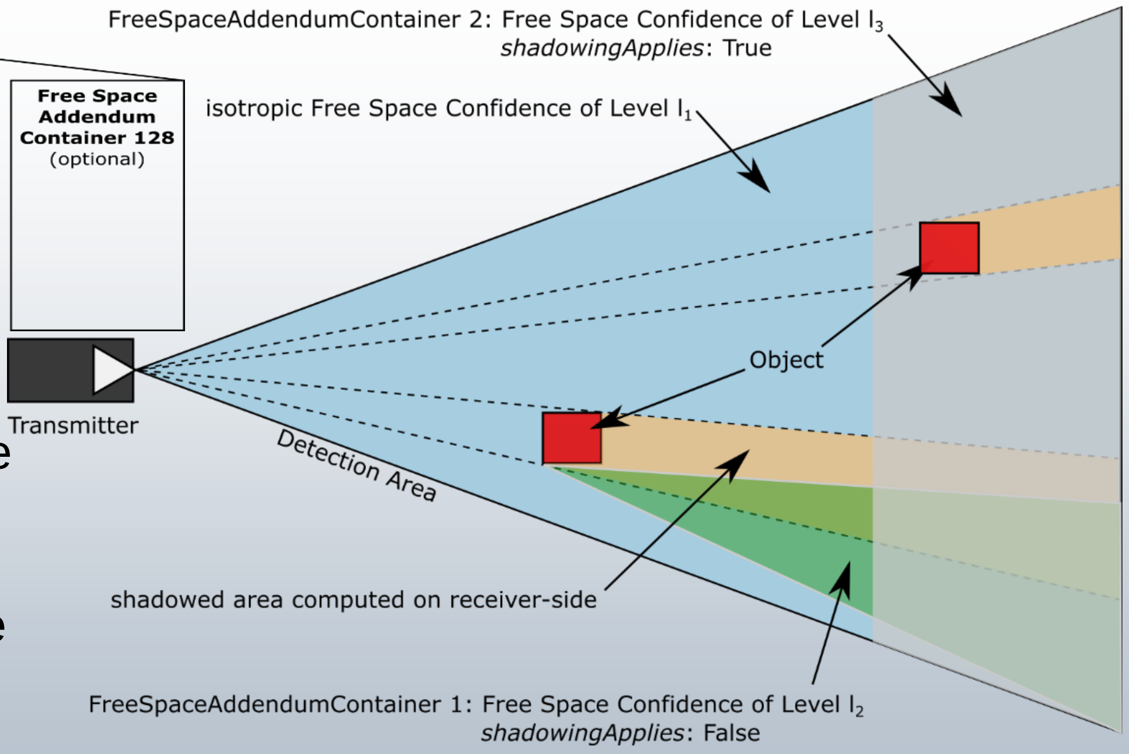


CP Message Format and Data Elements



Free Space Addendum Container

- May be added in case *derived* free space description will be inaccurate / not applicable, as determined by transmitter, e.g., if free space can only be detected in constrained area
- Indication if shadowing shall apply in the defined free space addendum container
- Free space addendum provided along with confidence indication

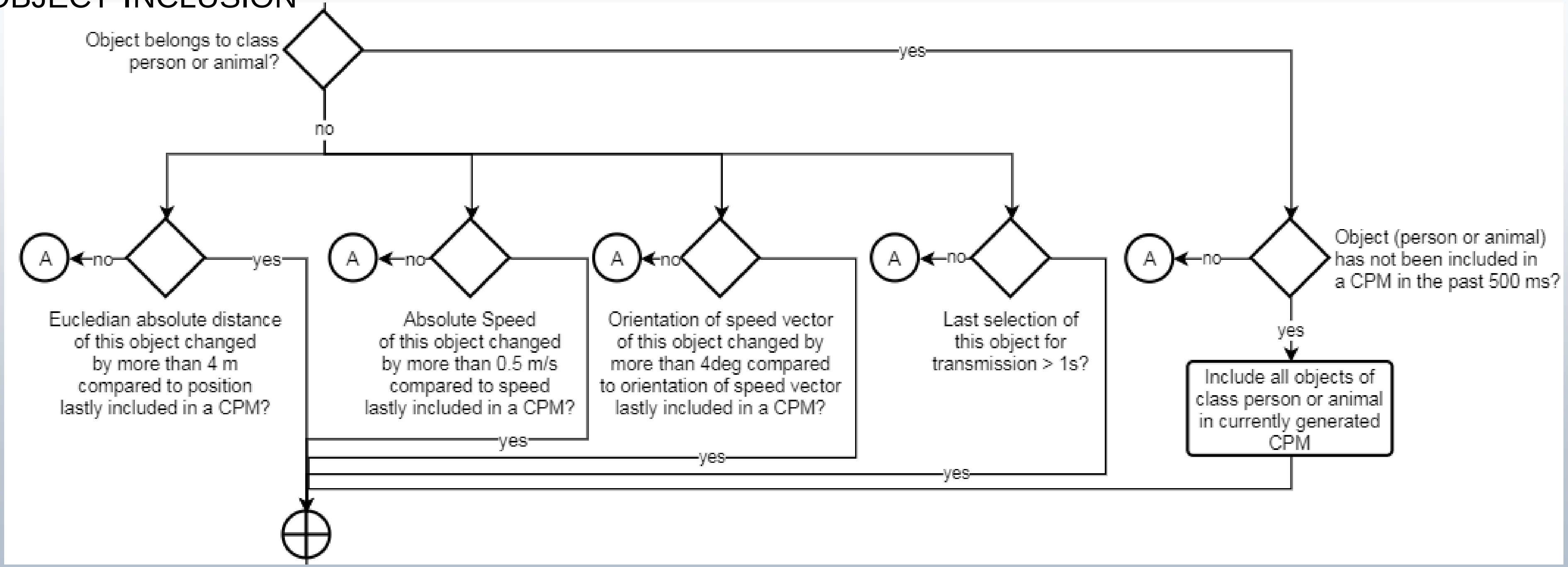


Generation Rules Overview

100 ms ≤ T_GenCPM ≤ 1000 ms

- CPM is generated dynamically between 10 Hz and 1 Hz
- DCC mechanisms may influence frequency of generation event
- Opposed to CAM, generation of CPM contingent on dynamics of detected objects, not on dynamics of disseminating station

Dynamic object Inclusion



Generation Rules Overview

100 MS ≤ T_GENCPM ≤ 1000 MS	• CPM is generated dynamically between 10 Hz and 1 Hz • DCC mechanisms may influence frequency of generation event
DYNAMIC OBJECT INCLUSION	• Opposed to CAM, generation of CPM contingent on dynamics of detected objects, not on dynamics of disseminating station
STATIC SENSOR INFORMATION	• Sensor Information Container included every 1000 ms
FREE SPACE ADDENDUM	• Free Space Addendum Container added on demand
MESSAGE SEGMENTATION	• Service-level message segmentation: In case encoded message size exceeds MTU of AL (minus overhead), message may be segmented. Standalone interpretation of each segment supported.
REDUNDANCY MITIGATION	• Number of objects per message may be controlled by redundancy mitigation techniques

Redundancy Mitigation Technique

- Object information transmission may be subjected to high redundancy, e.g., in case multiple stations observe the same object
- ETSI has been studying various redundancy mitigation techniques (RMT) and evaluated benefits and drawbacks of each technique
    - Frequency-based RMT
        - Aims at balancing the frequency at which an object is disseminated between stations
    - Dynamics-based RMT
        - Aims at applying and coordinating generation rules of chapter 4.3 for detected objects (i.e. multiple stations act as a common transmitter)
    - Confidence-based RMT
        - Station omits object from CPM if other station is able to provide higher confidence for same object
    - Entropy-based RMT
        - Anticipate reception state of objects on surrounding stations and include object if it is assumed that a station did not receive object
    - Object Self-Announcement RMT
        - Omit objects from CPM that are detected to transmit CAMs themselves
    - Distance-based RMT
        - Objects that are detected and shared from other stations within a certain range are omitted from a CPM

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C2C-CC Study on Object quality for CPM

Motivation / Starting point

- In context of CPM, a clear **definition of object quality** is missing
- Is a full **covariance matrix** required or is the current approach [diagonal (standard deviation)] sufficient?
- What **other quality components** need to be reflected in CPM?

Process – setup of an investigation study in C2C-CC

- Literature review and definition of terms
- Consideration of several options for object accuracy
- Development of a metric for object confidence
- Evaluation through a basic simulation setup
- Solution proposal (contribution) to ETSI

Details on the process and considerations of the CAR2 CAR Communication Consortium work are documented in *Technical Report on CPM Object Quality* which is available here: https://www.car-2-car.org/documents/general-documents/

Relevant terms and concepts

- For CPM, the two concepts „accuracy“ and „confidence“ need to be considered
- Accuracy:
  - „Closeness of agreement between a test result and the accepted reference value”
- Object confidence:
  - “Quantification of the confidence that a detected object actually exists, i.e., has been detected previously and has continuously been detected by a sensor.”

Object Accuracy [1/2]

Options taken into consideration

- Full covariance matrix
- Block covariance matrix
- LDL decomposition
- Variance (diagonal of covariance matrix)
- Standard deviation and correlation

Evaluation per option

- Required data size in the CPM
- Information degradation compared to full covariance
    - Volume of the resulting ellipsoid (scaled to 95%)
    - 95% percentile of the scaling factor (for the ellipsoid to contain the true object state)
    - Similarity to the full covariance matrix

Object Accuracy [2/2]

Main outcome:

- Extended kinematic attitude state for an object: $\text{state}_{\text{Obj}} = (d_x, d_y, d_z, v_x, v_y, v_z, a_x, a_y, a_z, \theta_{roll}, \theta_{pitch}, \theta_{yaw}, \omega_{roll}, \omega_{pitch}, \omega_{yaw}, \alpha_{roll}, \alpha_{pitch}, \alpha_{yaw})^T$
- Accuracy information provided through
  - **Standard deviation** per component (as before)
  - **Lower triangular correlation matrix**, size corresponding to the provided state space vector

<u>Example</u>

- Sender provides distance and speed in the x-y-plane and the yaw angle: $(d_x, d_y, v_x, v_y, \theta_{yaw})^T$
- Corresponding correlation matrix:

$$Corr = \begin{bmatrix} 1 & corr_{\{d_x d_y\}} & corr_{\{d_x v_x\}} & corr_{\{d_x v_y\}} & corr_{\{d_x \theta_{yaw}\}} \\ corr_{\{d_x d_y\}} & 1 & corr_{\{d_y v_x\}} & corr_{\{d_y v_y\}} & corr_{\{d_y \theta_{yaw}\}} \\ corr_{\{d_x v_x\}} & corr_{\{d_y v_x\}} & 1 & corr_{\{v_x v_y\}} & corr_{\{v_x \theta_{yaw}\}} \\ corr_{\{d_x v_y\}} & corr_{\{d_y v_y\}} & corr_{\{v_x v_y\}} & 1 & corr_{\{v_y \theta_{yaw}\}} \\ corr_{\{d_x \theta_{yaw}\}} & corr_{\{d_y \theta_{yaw}\}} & corr_{\{v_x \theta_{yaw}\}} & corr_{\{v_y \theta_{yaw}\}} & 1 \end{bmatrix}$$

- Representation in CPM:

LowerTriangularPositiveSemidefiniteMatrix = [

$[corr_{\{d_x d_y\}}, corr_{\{d_x v_x\}}, corr_{\{d_x v_y\}}, corr_{\{d_x \theta_{yaw}\}}],$

$[corr_{\{d_y v_x\}}, corr_{\{d_y v_y\}}, corr_{\{d_y \theta_{yaw}\}}],$

$[corr_{\{v_x v_y\}}, corr_{\{v_x \theta_{yaw}\}}],$

$[corr_{\{v_y \theta_{yaw}\}}]$

],

Object confidence

Initial thoughts and requirements

- Simple, single-value, generic indication of the quality of an object
- Applicable to both vehicles and infrastructure
- Low computational complexity
- Cope with OEM- and sensor-manufacturer-specific object detection mechanisms
- Harmonized representation of existence confidence

Identified input parameters: object age, sensor/system specific detection confidence, detection success

Core proposal:

- Computation of an **exponential moving average** for detection confidence and detection success
- Discrete rating for the object age
- Computation of object confidence as a **weighted average of the ratings** for object age, detection confidence and detection success

This object confidence is not necessarily intended as input for sensor fusion processes, rather for potential pre-filtering

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C2C-CC Documentation

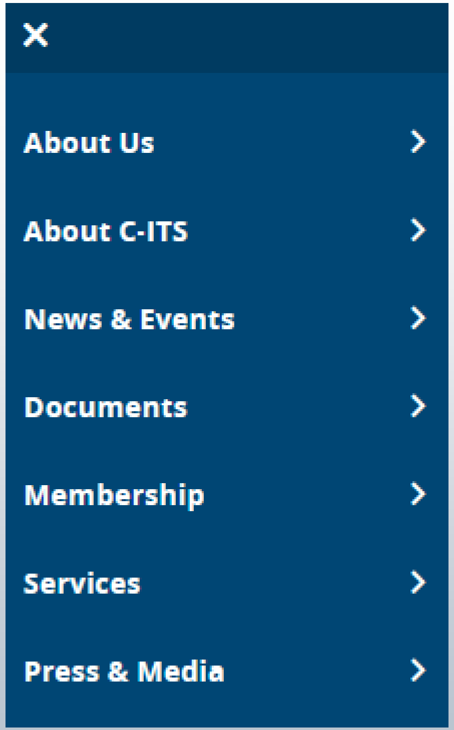
- released documents are published on the C2C-CC website
  www.car-2-car.org

  - **Basic System Profile**
    https://www.car-2-car.org/documents/basic-system-profile/

  - **White Papers and Position Papers**
    https://www.car-2-car.org/documents/general-documents/?L=-1

  - **Other Documents**
    https://www.car-2-car.org/documents/publications/

  - **Press & Media**
    https://www.car-2-car.org/press-media/



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