HOCHSCHULE
HANNOVER
UNIVERSITY OF
APPLIED SCIENCES
AND ARTS
–
Fakultät IV
Wirtschaft und
Informatik

Fahrzeugvernetzung – V2X

Lecture 2: Facilities Layer - Message Type, Format and Structure

Hugues Tchouankem, 06.10.2021

Lecture 2

Outline

- Facilities Layer
- Cooperative Awareness (CA) Basic Service
- Decentralized Environmental Notification (DEN) Basic Service
- Message Type
- Message Structure

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Previous Lecture

- Motivation behind Intelligent Transportation Systems (ITS)
- Some Road Safety Applications
- V2X Standardization Activities
- ITS Station Reference Architecture

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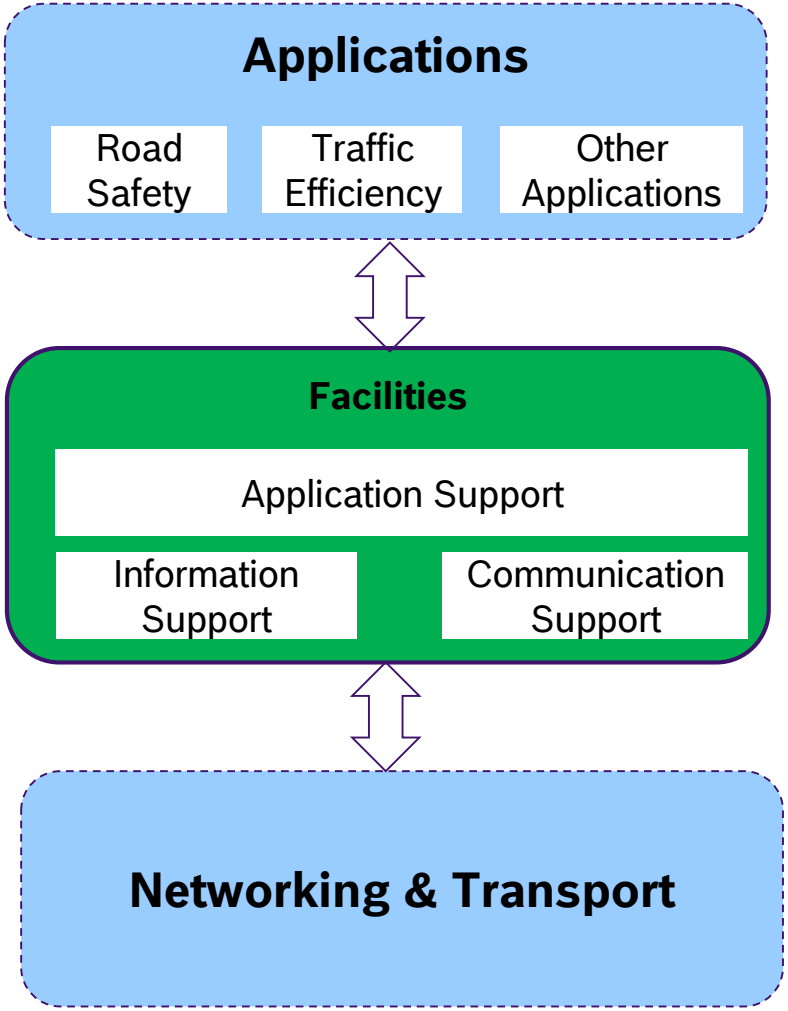
ITS Facilities Layer

- The facilities layer provides generic functionalities that can be shared by several applications and their assigned use cases
  - Application support
  - Information support
  - Communication support



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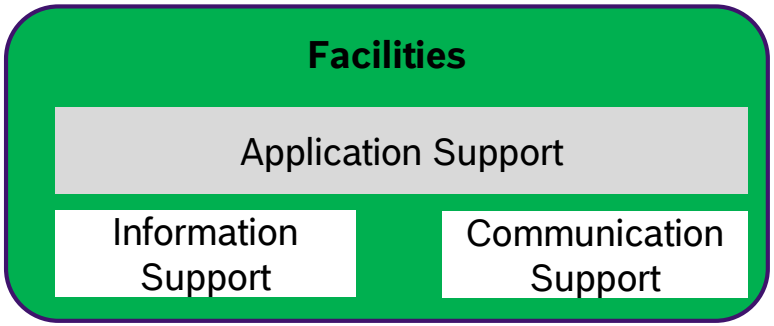
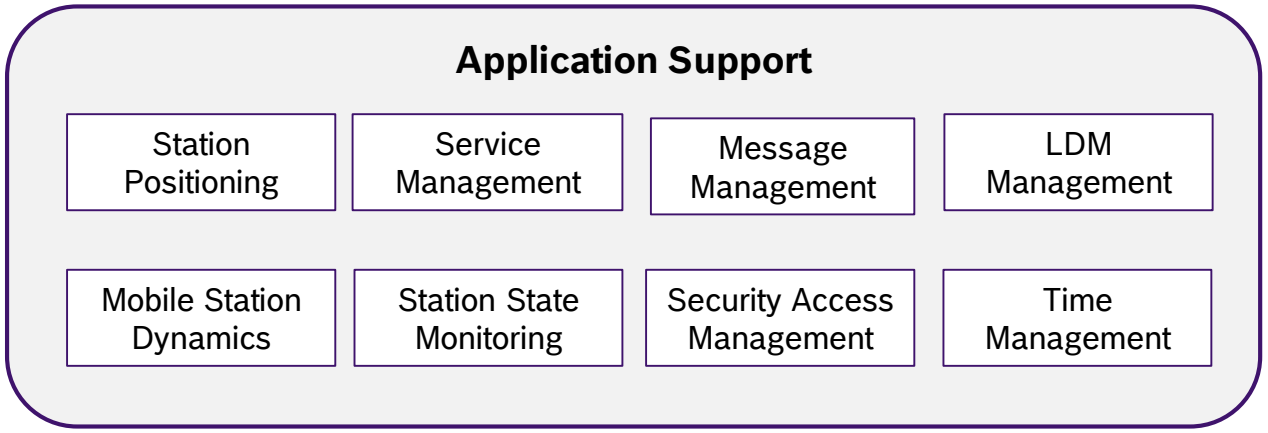
Application Support

The application support is the core of common functions supporting the applications





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Application Support – Station Positioning

- The station positioning provides absolute **3D position information** of the station
  - **Latitude, longitude, altitude**
- **Geographical data** is derived in real time from satellite position systems such as Galileo or GPS
- For some applications an high positioning accuracy of **less than 50 centimeter** is required
  - Obtained through a combination of GPS, odometer, gyro, etc.
- It permanently processes information received from several captors (GPS, vehicle sensors, etc.) and **fuse them** to get the mobile station position information

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Application Support – Mobile Station Dynamic Monitoring

- Only used for **ITS vehicle station** (due to mobility)

- It monitors permanently the **real time evolutions** of relevant vehicle electronic information

- It filters necessary variables allowing the update of the vehicle dynamic parameters
  - Vehicle speed
  - Acceleration control
  - Steering wheel angle
  - Yaw rate
  - Cylinder pressure
  - Stability control status

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Application Support – Station State Monitoring

- Permanently monitors the current **static state** of the station

- It filters some variable values allowing the update of the station state
  - Engine temperature
  - Gear status
  - Light bar in use
  - Siren in use
  - Tank filing level
  - Wiper rate

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Application Support – Services Management

- This facility manages the **station life cycle services** through **downloading of new customer services**, **up-grading** or **removing** of **existing services**

- Services provisioning servers advertise the **availability of new services** which can be contracted/downloaded by stations

- The application layer, after a local dialogue with the user if necessary, identifies **selected services** to be **installed**

- Capability to request the downloading of subscribed services to a **service provider** is required

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Application Support – LDM Management(1)

- The LDM management **permanently updates the LDM data base**, according to local information and information received **through** V2X communication messages

- Local Dynamic Map (LDM) is a **digital map** comprising
  - All **dynamic objects** that are directly sensed or which presence is indicated by other road users (co-operative awareness) should have a reference to the digital map
    - *V2X communication vehicles*
    - *Objects tracked by infrastructure (Camera, Radar)*

  - **Lane-specific information** including curves, pedestrian walking, bicycle paths and road furniture such as **traffic signs** and **traffic lights**

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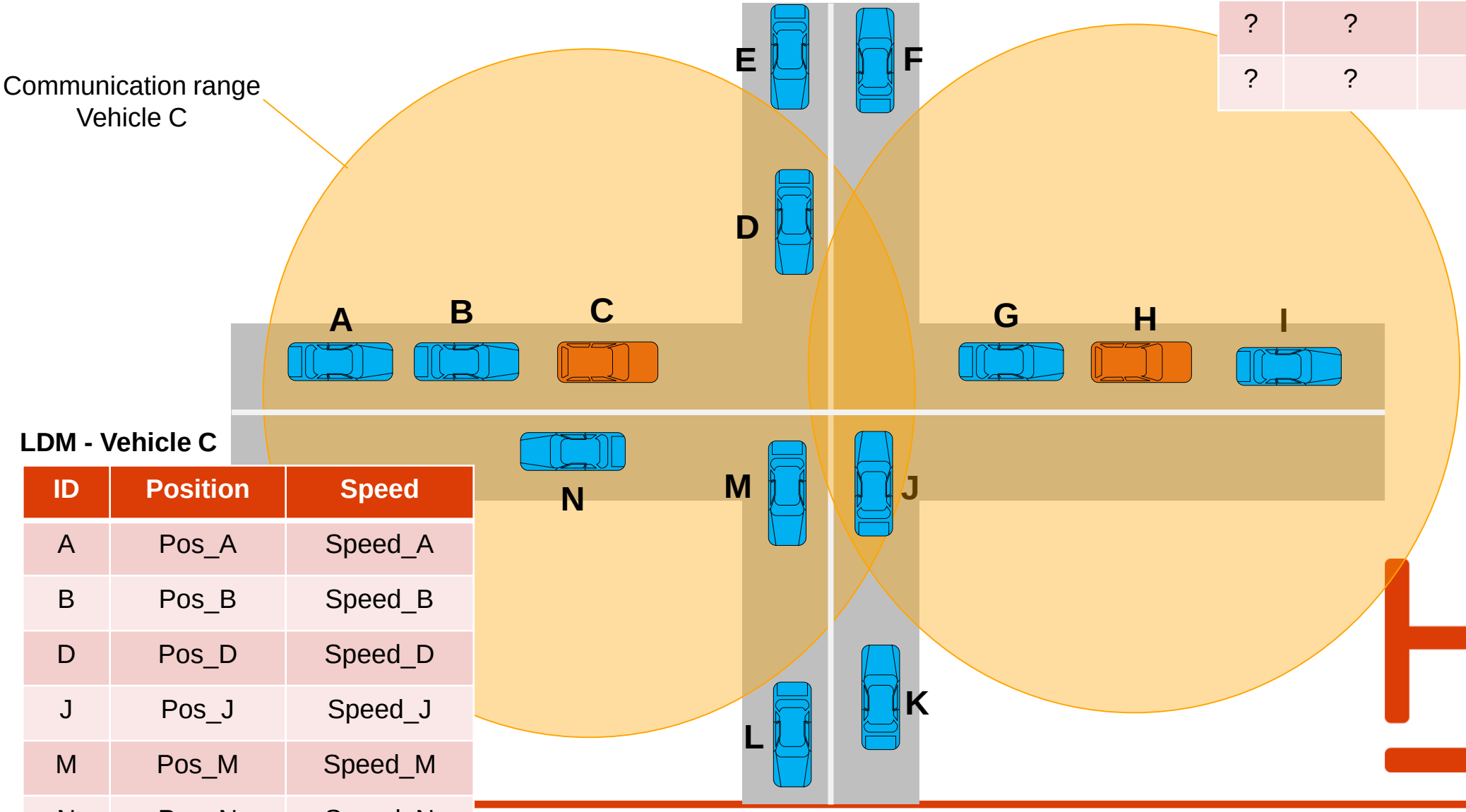
Application Support – LDM Management(2)

LDM - Vehicle H

ID	Position	Speed
?	?	?
?	?	?
?	?	?
?	?	?



LDM - Vehicle C

ID	Position	Speed
A	Pos_A	Speed_A
B	Pos_B	Speed_B
D	Pos_D	Speed_D
J	Pos_J	Speed_J
M	Pos_M	Speed_M
N	Pos_N	Speed_N

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Application Support – Message Management

- This facility **generates**, **structures** and **formats application messages** and passes them to the transport/network layer

- It receives V2X messages, analyzes their contents and dispatches relevant data to requesting applications and other local facilities (e.g. LDM management)

- It has the capability **to stop transmitting and forwarding** application messages according to **application requirements**

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Application Support – Time Management

- The task of the time management is to maintain a **global time reference**
- It extracts the GMT time provided by the GPS sensor and used **to synchronize a local real time** reference
- It provides the **time stamping information** at the end of message formatting process
- It requires the capability to maintain an **accurate global time clock** used for time stamping messages

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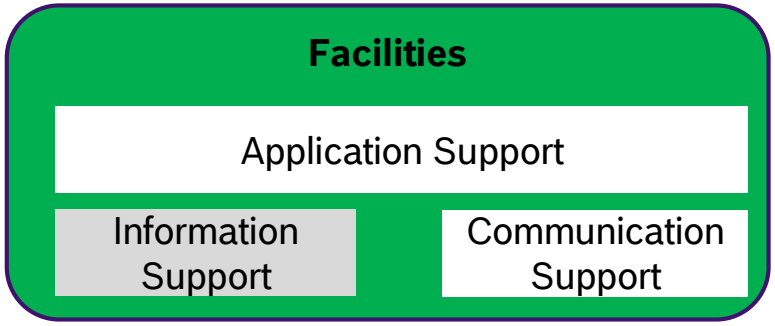
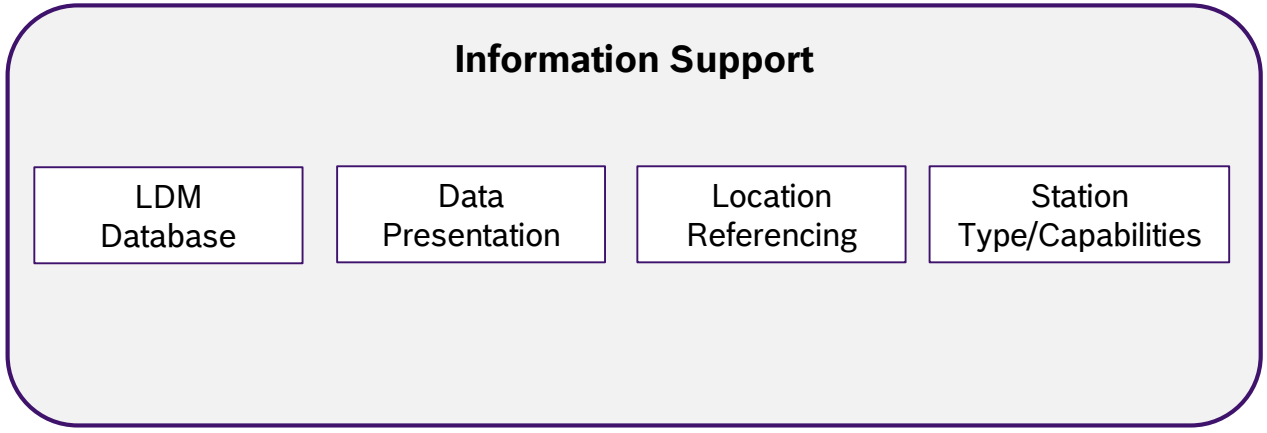
Information Support (1/2)

- The information support facility assures mainly the maintenance of Local Dynamic Map (LDM)
  - LDM database
  - Data presentation
  - Location referencing
  - Station type/capabilities





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Information Support (2/2)

- **LDM database** contains all the data necessary to build **a local map**
  - It is constantly updated in real time by the LDM management facility
- **Data presentation** codes and decodes messages according to formal language being used (e.g. ASN)
  - It corresponds to the presentation layer of the OSI reference model
- **Location referencing** provides the standard methods necessary to position static and mobile objects on a dynamic map
- **Station type/capabilities** provides static and dynamic information related to station (e.g. type of vehicle, vehicle size, RSU type, road link type, nearest RSU) and their respective capabilities (available services, networking resources, HMI)

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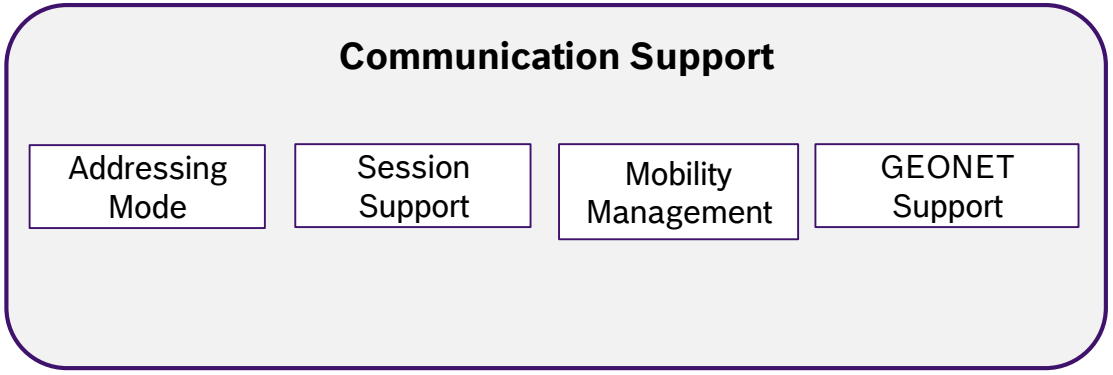
Communication Support

- It provides the capability to manage the **communication session** and **communication modes**
  - Broadcasting, Geocasting, unicasting
- It supports functions in cooperation with the transport/networking layer
  - Addressing of vehicles, areas and other multicast groups
  - Routing in ad-hoc fashion
  - Mobility management → While moving a vehicle might have to change the point of attachment to the Internet
  - Application-defined policies for the selection of communication technology



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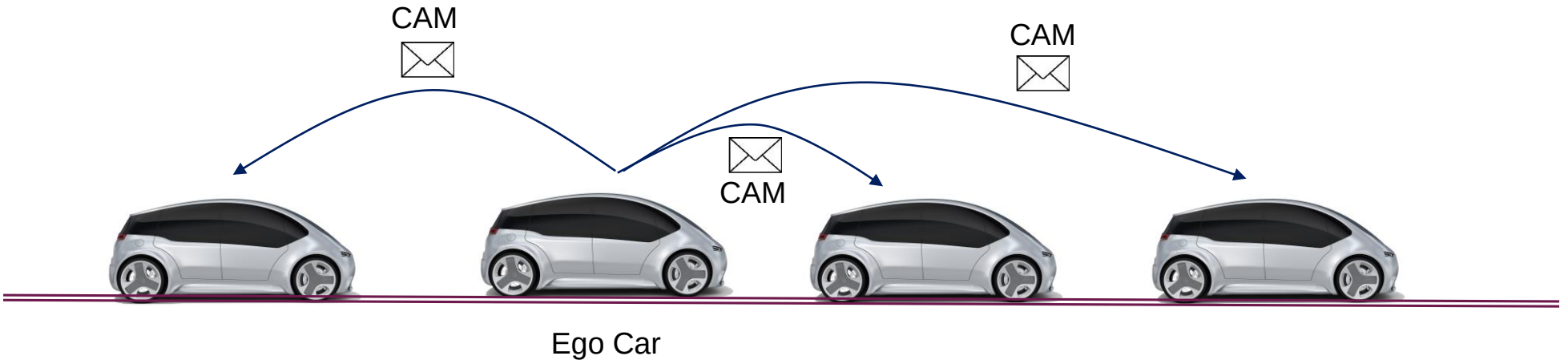
Cooperative Awareness Message (CAM)

- **Cooperative Awareness Messages (CAMs)** are messages exchanged between stations to create and maintain an awareness of each other
  - To support cooperative performance of vehicles using the road network

- A CAM contains status and attribute information of the originating station
  - For vehicle the status information includes **time**, **position**, **motion state**, **activated systems, etc.**



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Cooperative Awareness (CA) Basic Service

- The **CA basic service** is a facilities layer entity that operates the **CAM protocol**
- It provides two services: **sending** and **receiving** of CAMs
- The **CA basic service** uses the services provided by the protocol entities of the networking/transport layer to disseminate the CAM
- CAMs are generated **periodically** with a frequency controlled by the CA basic service in the originating station
- Upon receiving a CAM, the CA basic service makes the content of the CAM available to the **applications and/or to other facilities** within the receiving station, such as **Local Dynamic Map (LDM)**

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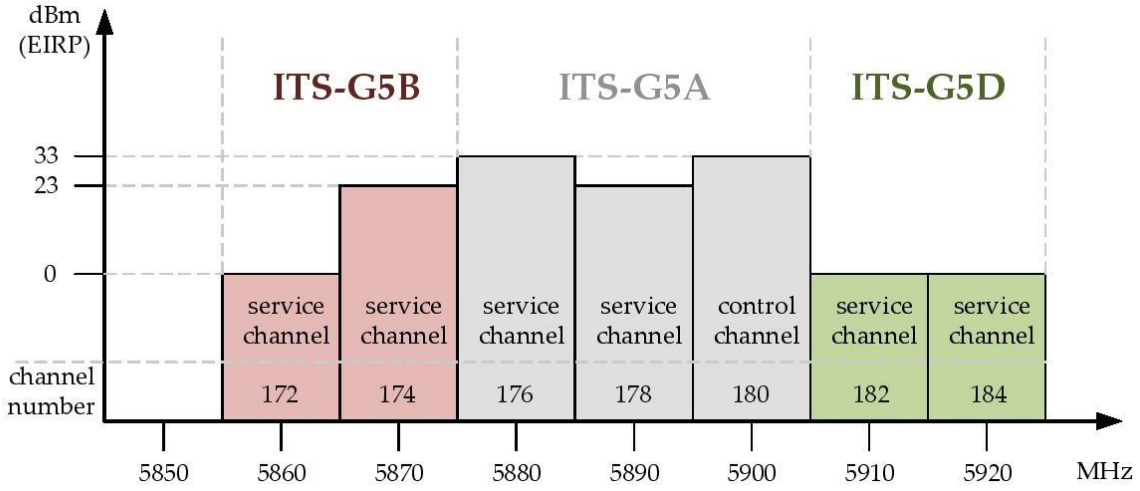
CAM Dissemination

- The **control channel (CCH)** is used for the dissemination of CAMs

- The CAM shall be transmitted **only** from the originating station in a single hop to the receiving station located in the direct communication range of the originating station

- A received CAM shall **not be forwarded** to other stations



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CAM Generation Rules for Mobile Stations

- CAM **generation trigger conditions** are as follows:
  - the absolute **difference** between the **current heading** of the originating station and the heading included in the CAM **previously** transmitted exceeds **4°**
  - the distance between the **current position** of the originating station and the position included in the CAM **previously** transmitted exceeds **4 m**
  - the absolute difference between the **current speed** of the originating station and the speed included in the CAM **previously** transmitted exceeds **0.5 m/s**

- Maximum time interval between CAM generations is **1000 ms**. It corresponds to the CAM generation rate of **1 Hz**
- Minimum time interval between CAM generations is **100 ms**. It corresponds to the CAM generation rate of **10 Hz**
- Main goal is to minimize the **load** on the **wireless channel**

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CAM Time Requirements

- The CAM **generation** and the **timeliness** of the data taken for the message construction are **decisive for the applicability** of data in the receiving station
  - Time required for a **CAM generation** must be less than **50 ms**

- The CAM generation time is the **time difference** between time at which CAM generation is **triggered** and time at which the **CAM is delivered** to **networking/transport layer**

- The **CAM time stamp** corresponds to the time at which the **reference position** of the **originating station** was determined

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CAM Format Specification

- A CAM is composed of **one common PDU header** and **multiple containers**

- CAM payload contains (for mobile stations)
  - one **basic container** (mandatory)
  - one **high frequent container** (mandatory) → Frequency >= 2 Hz
  - may also include one **low frequent container** (optional) → Frequency <= 2 Hz
  - one or more other **special containers** (optional)

- The container concept ensures a **flexible message format** that can be adapted to the needs of the sending and receiving vehicle while **minimizing** the **load** on the **wireless channel**

PDU: Packet Data Unit

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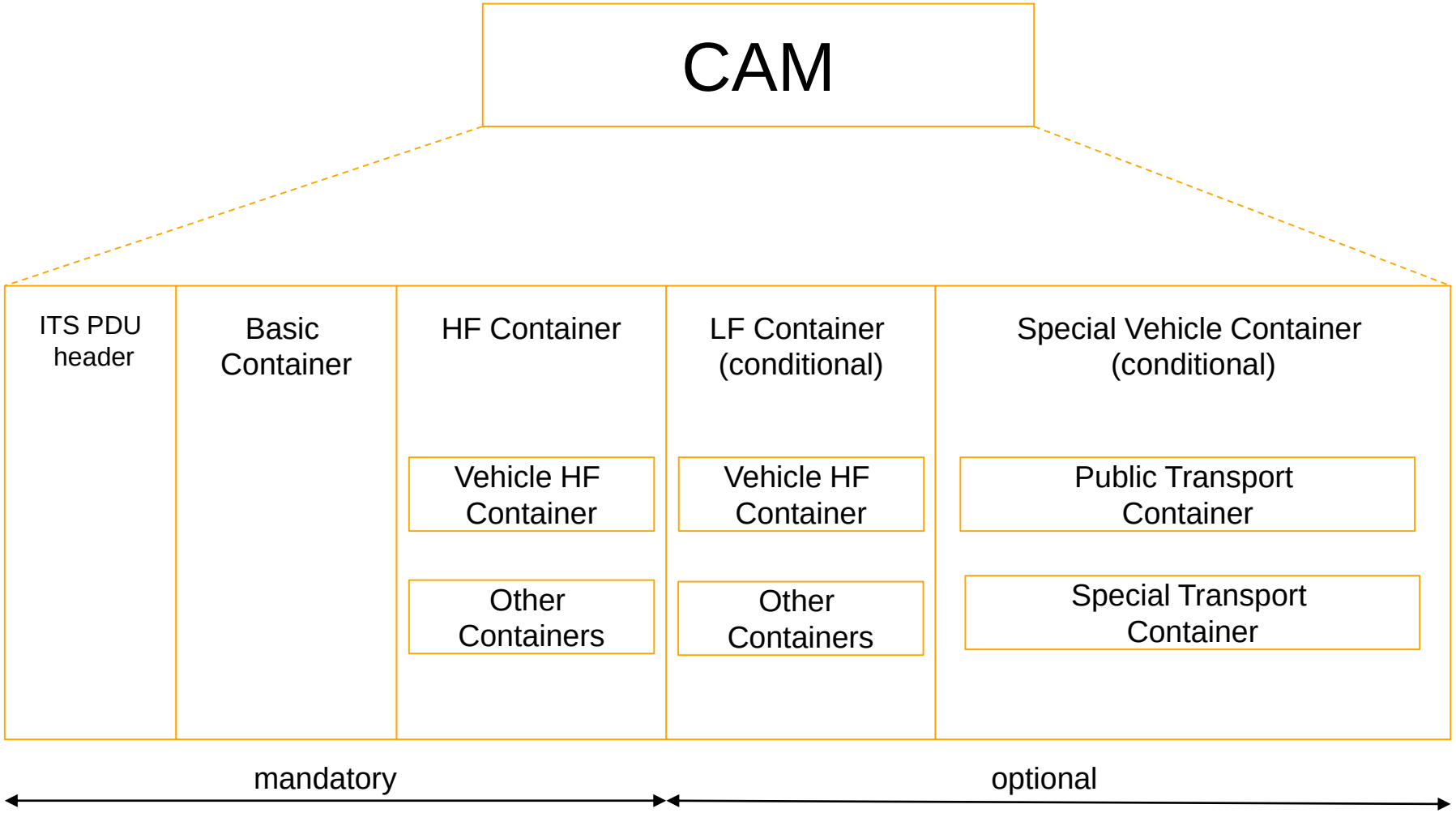
CAM Structure (1/2)



PDU: Packet Data Unit

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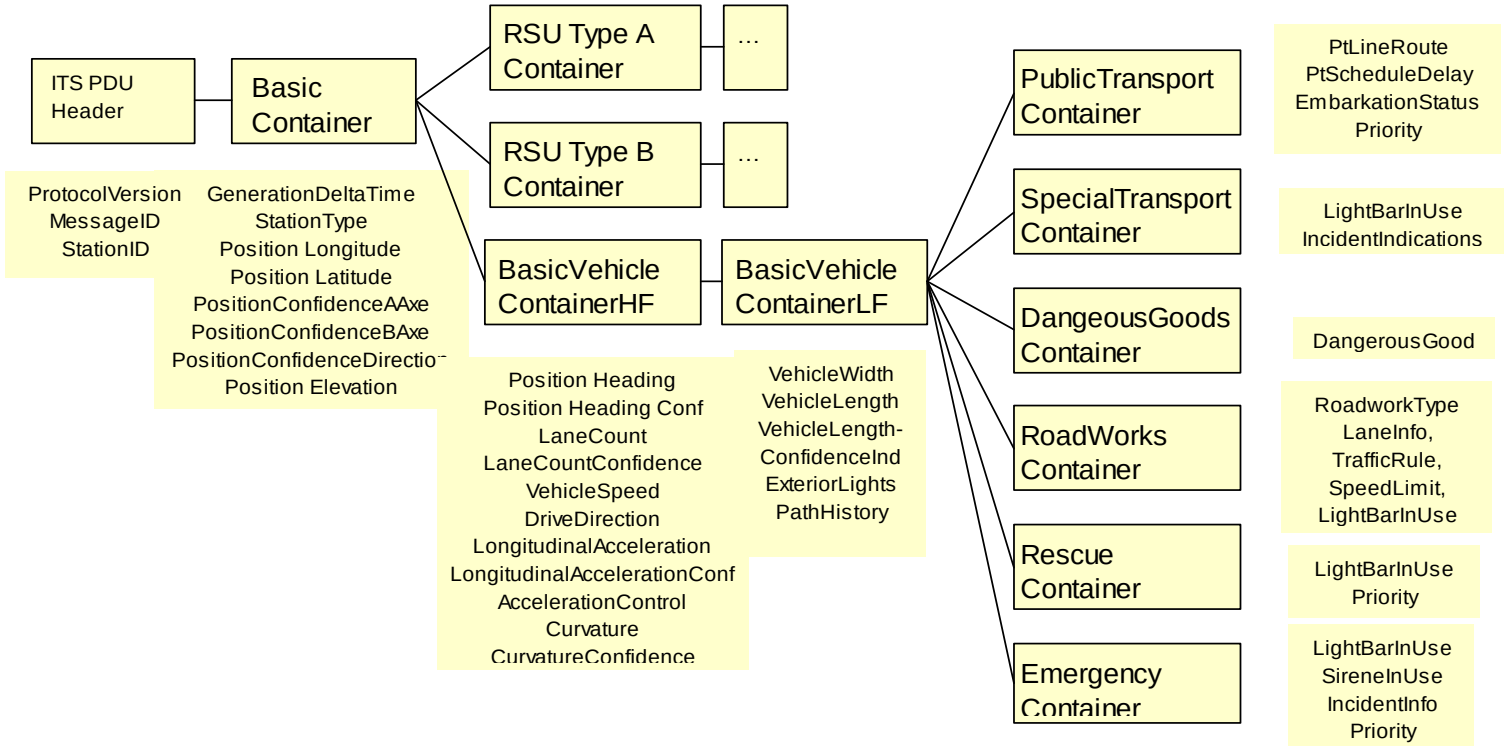
CAM Structure (2/2)



PDU: Packet Data Unit

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CAM Structure

- The **PDU header** includes the protocol version, message type and station identifier of the originating station
- The **basic container** provides basic information of the originating station
  - The **station type**
  - The **latest geographic position** as obtained at the CAM generation
- CAMs generated shall include at least a **high frequent vehicle (Vehicle HF)** container, and optionally a **low frequent vehicle (Vehicle LF)** container
  - **Vehicle HF container** contains all fast-changing (**dynamic**) status information of the vehicle station such as heading or speed
  - **Vehicle LF container** contains **static** or **slow-changing** vehicle data like the status of the exterior lights
- Vehicle stations which have a **specific role** in road traffic such as public transport could provide further status information in **special vehicle containers**

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Use Cases based on CAM

► The latency is defined as the time between the CAM generation and its reception by the CA basic service

Use Cases	Min. Frequency (Hz)	Max. Latency (ms)
Emergency Vehicle Warning	10	100
Slow Vehicle Indication	2	100
Intersection Collision Warning	10	100
Motorcycle Approaching Indication	2	100
Collision Risk Warning	10	100
Speed Limits Notification	1 to 10	100
Traffic Light Optimal Speed Advisory	2	100

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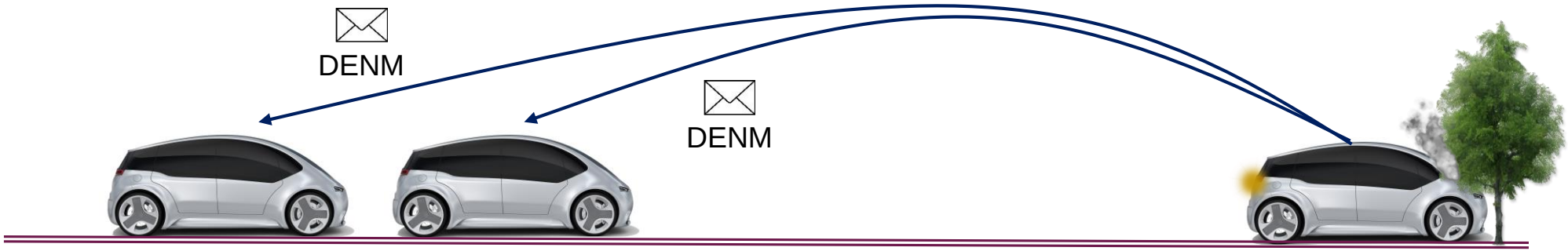
Decentralized Environmental Notification Message (DENM)

► **DENM** is mainly used by applications in order **to alert road users** of a **detected event**



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Decentralized Environmental Notification Message (DENM)

- **DENM** is an application-controlled, safety **event-triggered message**
  - Upon **detection of an event**, a station transmits a **DENM** in order to **disseminate** the **information about this event** to other stations located inside **an area of relevance**
  - **DENM transmission** may persist **as long as the event** is present and **may be repeated**
  - A **DENM** may be **forwarded** by **intermediate stations** in order to disseminate DENM to **receiving stations** which are **not located** in the **direct communication range** of the originating station

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Decentralized Environmental Notification (DEN) Basic Service

- The **DEN basic service** operates the **DENM protocol** and provides services to entities at the application layer
- At the originating station, an application may **trigger**, **update** and **terminate** the **transmission of DENMs**
- At the receiving station, the DEN basic service processes received DENMs and makes the **information available** for usage in **applications processes**

- **DEN basic service** may interact with other facilities layer entities, in particular the **Local Dynamic Map (LDM)**
  - LDM is updated with each received DEN

- Optionally, the **DEN basic service** may also provide **forwarding functionality**

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DENM Dissemination (1/4)

- **DEN basic service** uses the services provided by the protocol entities of the **networking/transport layer** to disseminate **DENMs**
  - **DENM** may also be disseminated over **a long distance** or to a central station, such as for vehicle rerouting or road traffic management purposes
  - The **control channel (CCH)** is used for the dissemination of **DENMs**

- A **DENM** contains information related **to an event** that has potential impact on road safety or traffic condition
  - An **event** is characterized by an **event type**, an **event position**, a **detection time** and a **time duration**

- **DENM** transmission is independent from the **originating station**
  - An event could **persist** even after the **originating station** has moved to a position far from the **event position**

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DENM Dissemination – DENM Types (2/4)

- **New DENM**
  - generated by the DEN basic service when an event is detected by an originating station for the first time. Each new DENM is assigned with a new identifier and contains information, such as event position, event type, event detection time
- **Updated DENM**
  - includes update information of an event transmitted by the originating station which had generated the new DENM
- **Cancelation DENM**
  - Transmitted by the **originating station** which has generated the new DENM to inform the termination of an event
- **Negation DENM**
  - Transmitted by an **another station** to inform the **termination** of an event for which the new DENM has been generated by a **originating station**

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DENM Dissemination (3/4)

- **DENM** is generated and transmitted when the **DEN basic service** receives a request from the **application**
- **DENM** is repeated by the **DEN basic service** at a pre-defined repetition interval, in order to inform new stations entering the destination area during the **event validity duration**

- **DENM** termination indicates the end of the detected event
  - **DENM termination** is either a cancelation or a negation
    - **Cancellation DENM** can only be transmitted by the originating station that originally requested the DENM trigger
    - **Negation DENM** can be transmitted by other stations

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DENM Dissemination (4/4)

- **DENM** should be disseminated to as many stations as possible located in an **area of relevance**
  - A **receiving station** makes use of the **relevance area** information to realize the relevance check
- DENM provides **location referencing information** of the event position as **traces**
  - A **trace** contains a list of **well-ordered waypoint**s that forms an itinerary approaching **towards the event position**
  - A receiving station have to compare its **own itinerary** with the trace in order to realize the **relevance check**
- **Destination area** is represented by the combination of one or several geometric **shapes** and **distance** information
  - Circular, rectangular or ellipsoid shape

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DENM Structure

- A **DENM** is composed of one **common PDU header** and **multiple containers**

- The DENM payload consists of four order parts:
  - **management** container (mandatory)
  - **situation** container (optional)
  - **location** container (optional)
  - **à la carte** container (optional)

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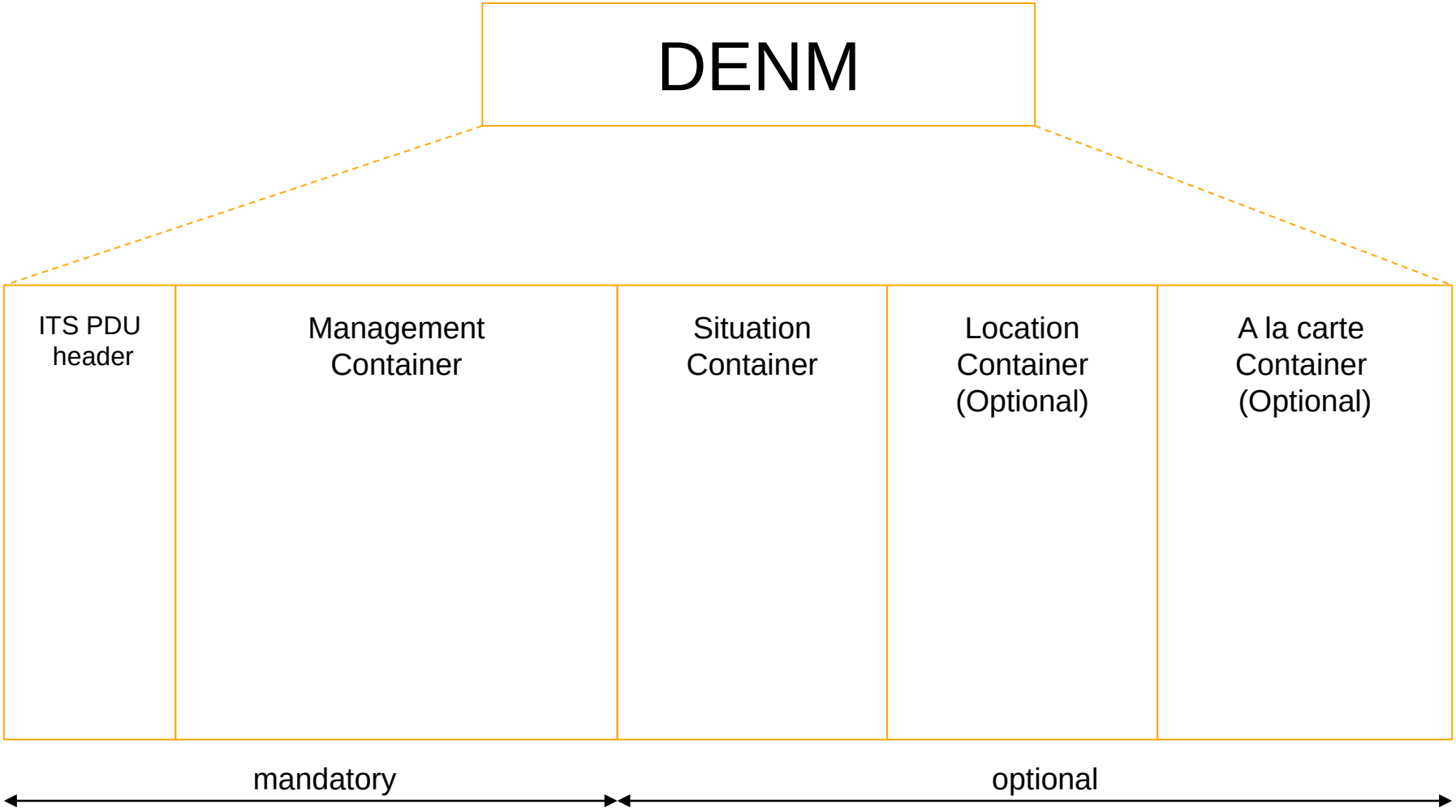
DENM Structure



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DENM Structure (1/2)

- The **message management container** holds administrative information of the messages, e.g. the message ID, data version, security, etc.
  - A **cancel mechanism** is also included in this container in order to cancel the detected situation

- The **situation container** includes information that describes the detected event
  - Event type, information quality - from lowest (1) to highest (7) -

- **Location container** consists mainly of three parts:
  - **Event location** describes the position where the event is detected
  - **Destination area** describes the geographic area that the messages shall be sent
  - **Location referencing method** is necessary at both sender and receiver sides, this will help to improve the correlation precision

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DENM Structure (2/2)

- The **à la carte container** contains additional information that **is not provided** by other containers
  - It provides the possibility for applications to include application specific data in a DENM
  - **Lane position** → To indicate the corresponding lane position of the event position
  - **External temperature** → Useful for the adverse weather condition use case
  - **Road works** → For the roadwork use case and includes information of the roadwork zone and specific access conditions
  - **Positioning solution** → It indicates the type of positioning solution being used for the resolution of the event position
- **Remarks**
  - For a cancelation or a negation DENM, the **situation container** and the **location container** are not present
  - If the **situation container** is present, the **location container** should be present

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Signal Phase and Timing Message (SPATEM) (1/3)

- **SPATEM** is used to inform drivers about the **current status** and **change** of the **traffic signal** ahead as well as when the **next signal stage** change
  - It will also provide information about **approaching traffic** to optimize the **signal system**
- It is most relevant for cities and/or urban areas and could improve the aspect of mobility in city environments
- Could be used to provide priority to **selected groups** like **emergency vehicles** and **public transportation**
- **SPAT application** have a positive effect on traffic flow and safety minimizing the number of stops resulting in less head-tail accidents

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Signal Phase and Timing Message (SPATEM) (2/3)

- **SPATEM** contains information about the status of the traffic light controller, traffic lights and intersection traffic information
  - **SPATEM** is sent over the service channel (SCH)

- **TLM (Traffic Light Maneuver)** service running at the facilities layer is one instantiation of the infrastructure services to manage the generation, transmission and reception of **SPATEMs**

- **I2V/V2I applications** using **SPATEM**
  - Green light optimal speed advisory
  - Signal violation warning
  - Remaining red and green traffic times
  - Roadworks information

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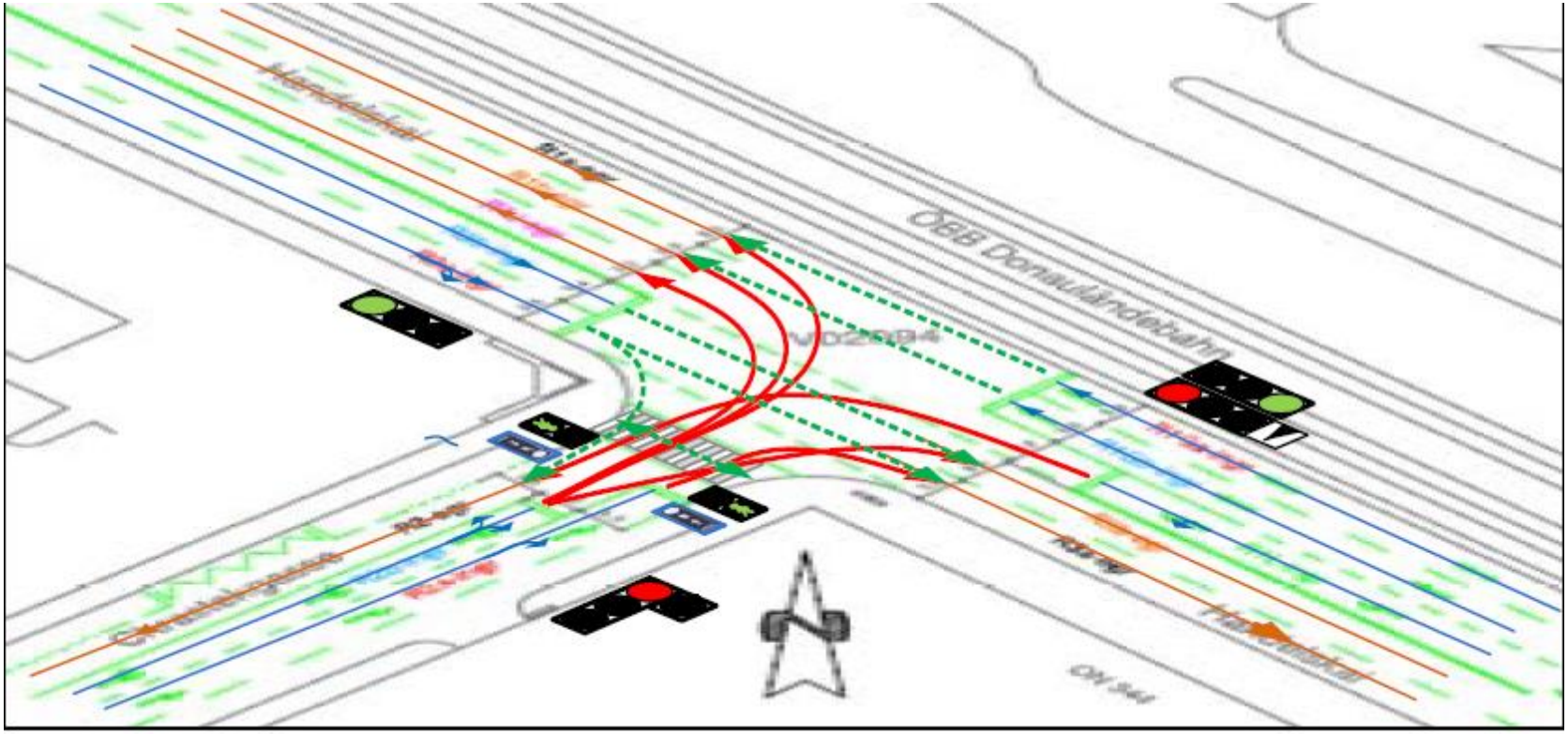
Signal Phase and Timing Message (SPATEM) (3/3)

- The connection lanes which describe the allowed maneuver, are highlighted based on the signaling status of the traffic light controller. The status information (e.g. "stop", "go") transmitted by the traffic controller is depicted in with red and green connection lines, respectively



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Map Data Message (MAPEM) (1/2)

- **MAPEM** provides **digital topological map**, which defines the topology of an infrastructure area
  - It includes the **lane topology** for e.g. vehicles, bicycles, parking, public transportation and the **paths for pedestrian crossings** and the **allowed maneuvers** within an intersection area or a road segment

- **MAPEM** is transmitted continuously together with the **SPATEM** to inform the traffic participant about the status of **allowed maneuvers** within the **intersection conflict area**
- The same **MAPEM** content is retransmitted continuously in a broadcast fashion, unless the application indicates to transmit a new **MAPEM**, e.g. if anything about the road and lane topology has changed

- **MAPEM** is sent over the service channel (SCH)

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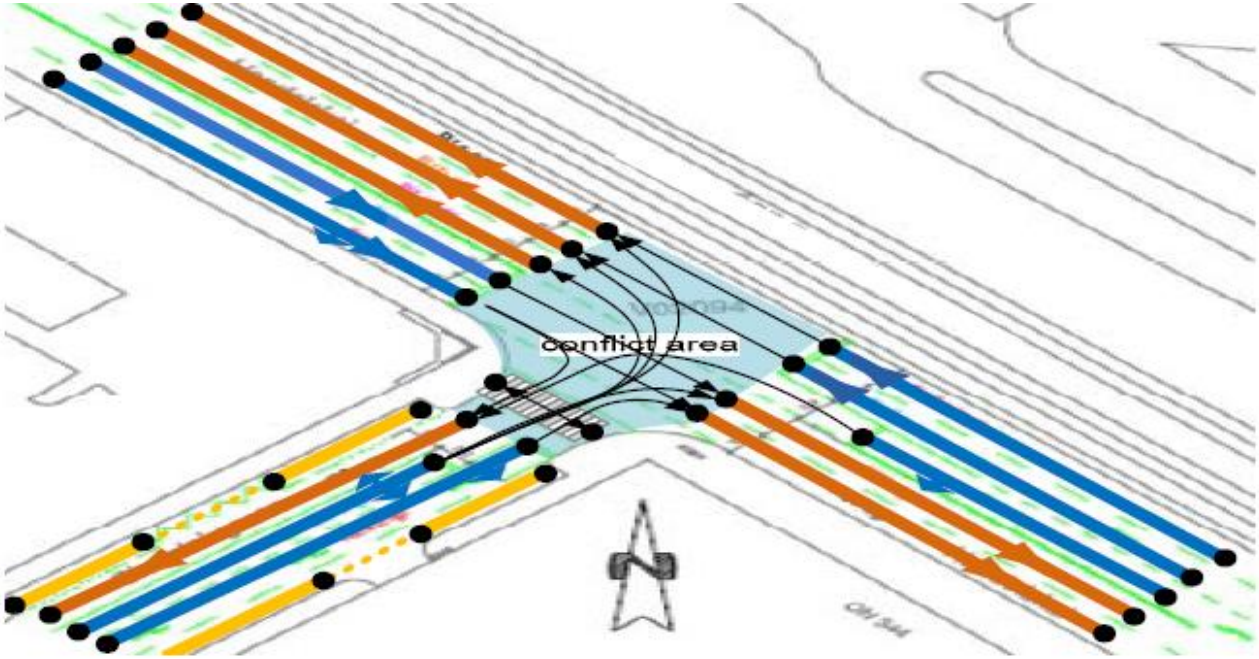
Map Data Message (MAPEM) (2/2)

- The topology is organized in several approaches and a "conflict area" in the junction of the approaches. Each approach holds "ingressing" (driving direction towards the conflict area) and "egressing" lanes (driving direction away from the "conflict area"). Each lane (e.g. vehicle, pedestrian, etc.) consists of two or more waypoint (positioned in the middle of the lane)



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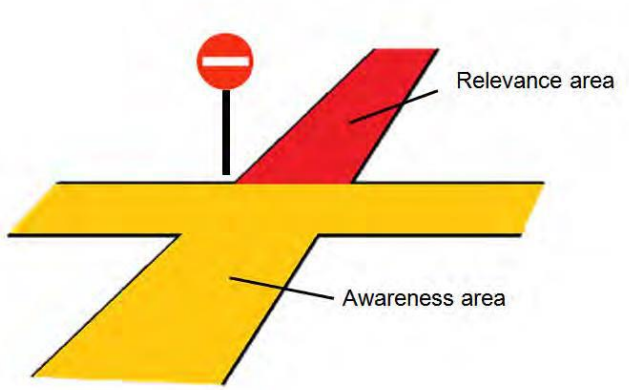
Infrastructure to Vehicle Information Message (IVIM) (1/3)

- **IVIM** provides information of **physical road signs** such as static or variable road signs, **virtual signs** or **road works**
- **IVI service** running at the facilities layer is one instantiation of the infrastructure services to manage the generation, transmission and reception of the **IVIM**



- An **IVIM** shall be transmitted if applicable, e.g. when it is **applicable in time** (e.g. a speed limitation only valid between 8:00 and 20:00) and due to the context as determined by the sending station (e.g. a speed limitation applicable in case of fog)

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Infrastructure to Vehicle Information Message (IVIM) (2/3)

- Most relevant containers of the **IVI message**
  - **General container**
    - Signage information to be processed by receiving vehicles
  - **Management container**
    - Mandatory and contains information necessary to handle the entire IVI message
      - Identification number, status and time validity of message content
  - **Geographic location container**
    - Where and how the information provided applies

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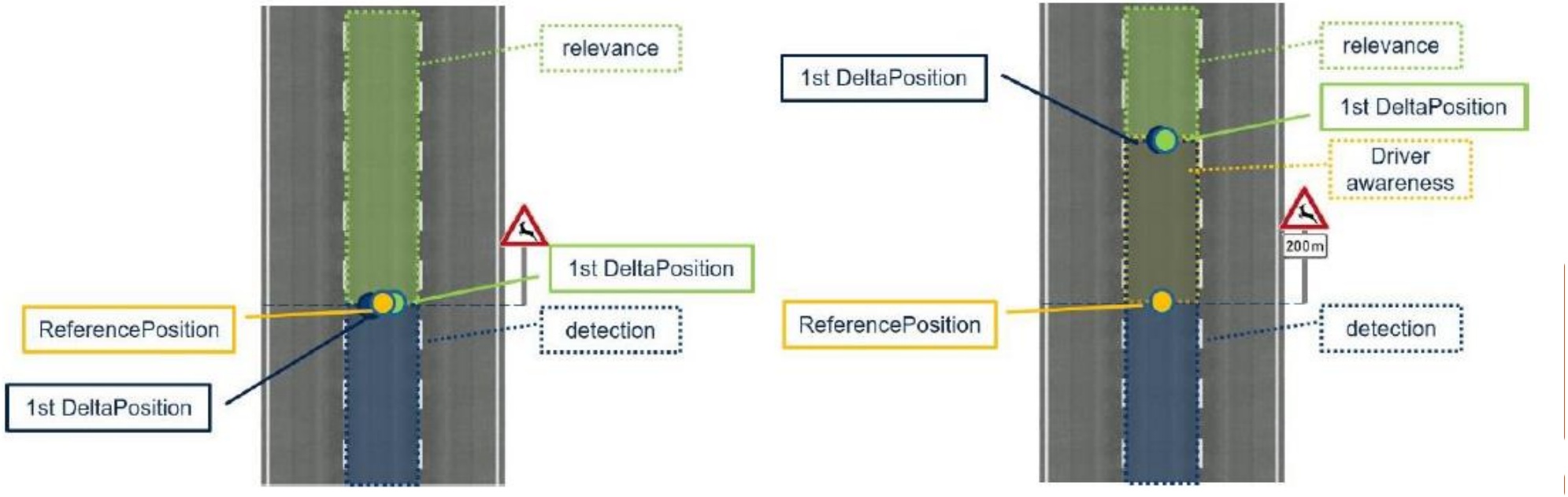
Infrastructure to Vehicle Information Message (IVIM) (3/3)

- Location of the vehicle information when assuming a **physical sign/gantry**
  - **Reference position** located in the **middle of the carriageway** at the position of the sign/gantry
  - **Detection zone** is defined in such a way that it leads up to the corresponding **relevance zone**



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Literature

- ETSI TR 102 638 (V1.1.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions"
- ETSI TS 102 637-3: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service”
- ETSI EN 302 637-2: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service“
- ETSI TS 103 301 (V1.2.1): ”Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services”
- CAR 2 CAR Communication Consortium:”Automotive Requirements for IVIM Document”