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Focus Group on AI for autonomous and assisted driving
(FG-AI4AD)

FGAI4AD-01

Automated driving safety data protocol – Specification

Technical Report ITU-T FGAI4AD-01

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Summary

This Technical Report is the result of an open collaborative pre-standardization activity of the ITU Focus Group on artificial intelligence (AI) for autonomous and assisted driving (FG-AI4AD).

This Technical Report will be reviewed and considered for future ITU-T Recommendations in the form of telecommunications and computer protocol specification documents that specifically relate to:

- the behavioural evaluation of artificial intelligence (AI) responsible for the dynamic driving task;
- the in-use assessment of AI driving behaviour using onboard vehicle system;
- the field monitoring of assisted and automated vehicles is required to ensure continual validation of safety performance.

Measurement is considered the gold standard evidence base for the assessment of acceptable safety for automated vehicles.

The use of real-time in-service monitoring provides a framework for the identification of collisions, near-miss events, and safety-critical performance degradations of the software's situational awareness, risk evaluation, decision making and execution of response.

This automated driving (AD) safety data protocol specification provides a standardized foundation for measuring safe interaction of road users using data gathered from automated and assisted systems which can perceive, understand and respond to road traffic situations.

Keywords

Assisted and automated vehicles, automated driving, dynamic driving task, artificial intelligence, data protocol, safety metrics, behavioural evaluation, field monitoring, in-use assessment, standardization.

Change Log

This document contains Version 1 of the ITU-T Technical Report on "***Automated driving safety data protocol – Specification***" approved at the ITU-T Focus Group meeting held online, 28-29 September 2022.

Note

This is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

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1 Scope

The automated driving (AD) safety data protocol is specifically designed for post-hoc monitoring of driving behaviour. It is focused on automated and assisted driving system outputs, outcomes, and the identification of real-world safety event occurrences.

It is only intended to monitor real-time *decision-making* processes of the automated or assisted driving systems and evaluate the safety of *actions* while not interfering in these processes themselves e.g., the real-time behavioural assessment is not designed to prevent a near-miss event from occurring, its purpose is to ensure the near-miss event can be detected, recorded, investigated and used to improve safety in the future.

The AD safety data protocol specification defines the minimum set of data elements (DEs) and data frames (DFs) required for analysing the safe interaction of road users over space and time. The data specification is aligned to exciting vehicle-to-everything (V2X) standards for connected and cooperative mobility in order to simplify system design and enable holistic safety evaluation across multiple vehicles and surrounding infrastructures.

The specification also defines a protocol for communicating, storing and processing the safety data in real-time which enables safety monitoring onboard the vehicle, at the edge or in the cloud. Data communication bandwidth and storage size are minimized by focusing on the perception system outputs in a standardized world model representation. This approach enables both continual re-codings and triggered based data recording scenarios.

The AD safety data protocol specification provides a standardized way for automated and assisted driving systems to expose data required for safety monitoring in an open, interoperable manner without constraining the architecture of the monitored system.

The AD safety data protocol specification defines a standardized data output from automated and assisted driving systems. The intent is that this data then acts as the input for a broad range of leading *safety metrics* that monitor safe driving behaviour against specific *safety thresholds* the details of which are expected to be covered in future standards and regulations.

The AD safety data protocol facilitates the creation of safety event *triggers* generated as *metrics* cross specified *thresholds*, which could be published in real-time by the monitoring system and may be consumed by the automated or assisted driving software to enhance safety e.g., a notification of a near-miss event may be considered within minimal risk manoeuvre *decision-making* which may consider it an appropriate response to the endangerment of other road users.

The scope of this Technical Report is limited to the specification of the *data* required as input to these *metrics* and related *thresholds*. The specification of *metrics* and *thresholds* are out of the scope of this Technical Report but may be referenced to provide context for the value of, or requirement for, specified *data*.

The scope of the *data* specification within this Technical Report is to define the minimum set of *data* required for making a meaningful safety assessment of driving behaviour whilst acknowledging the need for the protection of privacy and intellectual property.

2 References

[ITU-T X.680] Recommendation ITU-T X.680 (2021) | ISO/IEC 8824-1:2021, *Information technology – Abstract Syntax Notation One (ASN.1): Specification of basic notation.*

[Eclipse zenoh] Eclipse zenoh. <https://projects.eclipse.org/projects/iot.zenoh>
NOTE – Eclipse was recognized in 2022 as a publicly available specification (PAS) submitted by ISO/IEC JTC 1.

[ETSI EN 302 637-2] ETSI EN 302 637-2 V1.3.0 (2013), *Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service*.

[ETSI TR 103 562] ETSI TR 103 562 V2.1.1 (2019), *Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Analysis of the Collective Perception Service (CPS); Release 2*.

[ETSI TS 102 894-2] ETSI TS 102 894-2 V1.2.1 (2014), Intelligent Transport Systems (*ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary*.

[ETSI TS 103 300-3] ETSI TS 103 300-3 V2.1.1 (2020), *Intelligent Transport Systems (ITS); Vulnerable Road Users (VRU) awareness; Part 3: Specification of VRU awareness basic service; Release 2*.

[ISO 3779] ISO 3779:2009, *Road vehicles – Vehicle identification number (VIN) – Content and structure*.

[ISO 3833] ISO 3833:1977, *Road vehicles – Types – Terms and definitions*.

[ISO 8855] ISO 8855:2011, *Road vehicles – Vehicle dynamics and road-holding ability – Vocabulary*.

3 Definitions

3.1 Terms defined elsewhere

This Technical Report uses the following terms defined elsewhere:

3.1.1 automated driving [b-BSI Flex 1890]: The full function of the dynamic driving task performed by the automated driving system within its operational design domain.

3.1.2 advanced driver assistance system (ADAS) [b-BSI Flex 1890]: Entity consisting of interdependent components that support human drivers by performing a part of the dynamic driving task or providing safety relevant information.

3.1.3 automated driving system (ADS) [b-BSI Flex 1890]: Hardware and software that are collectively capable of performing the dynamic driving task on a sustained basis, regardless of whether it is limited to a specific operational design domain.

3.1.4 dynamic driving task (DDT) [b-BSI Flex 1890]: Real-time operational and tactical functions required to operate a vehicle safely in on-road traffic.

3.1.5 driving automation system (DAS) [b-BSI Flex 1890]: Hardware and software that are collectively capable of performing part or all of the dynamic driving tasks on a sustained basis.

3.1.6 operational design domain (ODD) [b-BSI Flex 1890]: Operating conditions under which a given driving automation system or feature thereof is specifically designed to function.

3.1.7 vehicle [b-BSI Flex 1890]: Motorized, wheeled conveyance that is mechanically propelled and intended or adapted for use on roads.

3.2 Terms defined in this Technical Report

This Technical Report defines the following term:

3.2.1 assisted driving: The use of an advanced driver automation system such as forward collision warning (FCW) systems, lane keeping assistance (LKA) systems, and automatic emergency braking (AEB) to assist a human driver in the execution of the dynamic driving task.

4 Abbreviations and acronyms

This Technical Report uses the following abbreviations and acronyms:

AD	Automated Driving
ADS	Automated Driving System
AEB	Automatic Emergency Braking
ASN.1	Abstract Syntax Notation One
BSON	Binary JavaScript Object Notation
CAM	Cooperative Awareness Message
CDD	Common Data Dictionary
CPM	Collective Perception Message
DDS	Data Distribution Service
DE	Data Element
DF	Data Frame
ETSI	European Telecommunications Standards Institute
FCW	Forward Collision Warning
HTTP	Hypertext Transfer Protocol
ISO	International Standards Organization
ITS	Intelligent Transportation System
ITU-T	ITU Telecommunication Standardization Sector
JSON	JavaScript Object Notation
LaD	Lateral Distance
LAN	Local Area Network
LKA	Lane Keeping Assistance
LoD	Longitudinal Distance
MAN	Metropolitan Area Network
MQTT	MQ Telemetry Transport
MSLaD	Minimum Safe Lateral Distance
MSLoD	Minimum Safe Longitudinal Distance
MSVD	Minimum Safe Vertical Distance
TAI	International Atomic Time
TSN	Time-Sensitive Networking
VD	Vertical Distance
VDS	vehicle Descriptor Section
VIN	Vehicle Identification Number

VIS	Vehicle Indicator Section
VRU	Vulnerable Road Users
V2X	Vehicle-to-everything
WAN	Wide Area Network
WGS 84	World Geodetic System 84
WMI	World Manufacturer Identifier

5 Conventions

None.

6 Automated driving (AD) safety data protocol specification

The automated driving safety data protocol makes use of the European Telecommunications Standards Institute (ETSI) common data dictionary (CDD) as defined in [ETSI TS 102 894-2] to define format and coding rules in abstract syntax notation one (ASN.1) [ITU-T X.680].

The data elements (DEs) and data frames (DFs) defined by [ETSI TS 102 894-2] are mapped to the Zenoh resources for communication and using JavaScript object notation (JSON), binary JavaScript object notation (BSON) or ASN.1 supported encodings for wire representation.

6.1 Applicable data elements (DEs) and data frames (DFs)

The primary objective of the applicable DEs and DFs defined below is to capture the time and space relationship between the ego vehicle and other road users.

These DEs and DFs can be extracted from the world model representation of the automated and assisted driving system. The fidelity of the world model may vary depending on the system design and function so the defined DEs and DFs can include optional fields and can be extensible.

The DEs and DFs would also be available directly from vehicle-to-everything (V2X) systems implementing the ETSI standards for cooperative awareness [ETSI EN 302 637-2], vulnerable road users (VRU) awareness [ETSI TS 103 300-3] and collective perception [ETSI TR 103 562].

The information contained in clauses 6.1.1 to 6.1.7 is considered the minimum set of data required for a wide range of safety metrics and their associated thresholds.

Clause 6.1.8 onwards covers optional DEs and DFs that provide additional context to the road traffic situation and environmental conditions in which the safety critical occurrences have been observed.

6.1.1 Time

The DE TimestampIts represents the number of elapsed (International atomic time-TAI) milliseconds since the intelligent transportation system (ITS) epoch. The ITS epoch is 00:00:00.000 UTC, 1 January 2004. "Elapsed" means that the true number of milliseconds is continuously counted without any interruption, i.e., it is not altered by leap seconds which occurs in UTC.

NOTE – International atomic time (TAI) is the time reference coordinate based on the readings of atomic clocks, operated in accordance with the definition of the second, the unit of time of the international system of units. TAI is a continuous time scale. UTC has discontinuities, as it is occasionally adjusted by leap seconds. As of 1 January 2022, TimestampIts is 5 seconds ahead of UTC since the ITS epoch on 1 January 2004 is 00:00:00.000 UTC, where a further 5 leap seconds have been inserted in UTC.

6.1.2 Global coordinate system

The World Geodetic System 1984 (WGS 84) is used as the 3-dimensional coordinate reference frame which is used for establishing DEs and DFs for latitude, longitude and altitude required for global positioning.

6.1.3 Vehicle identification

International Standards Organization (ISO) 3779:2009 specifies the content and structure of a vehicle identification number (VIN) to establish on a worldwide basis, a uniform identification numbering system for road vehicles.

This information is contained within the DF VehicleIdentification and the DE WMInumber for world manufacturer identifier (WMI) code and DE vDS for vehicle descriptor section.

NOTE – The vehicle indicator section (VIS) of the vehicle identification number (VIN) would need to be included as an extension to the current VehicleIdentification DF as specified in ETSI TS 102 894-2 ITS common data dictionary (CDD).

6.1.4 Vehicle coordinate system

ISO 8855:2011 (Road vehicles – Vehicle dynamics and road handling ability – Vocabulary) is used for the vehicle coordinate system and referenced DEs and DFs including; LateralAccelerationValue, LongitudinalAccelerationValue, VerticalAccelerationValue, SteeringWheelAngleValue, YawRateValue.

6.1.5 Vehicle types

ISO 3833:1977 (Road vehicles – Types – Terms and definitions) is used to define the DE Iso3833VehicleType. It defines 40 different types of vehicles including passenger cars, buses, commercialVehicle, semiTrailerTowingVehicle, motorcycles, etc.

6.1.6 Road user types

The DF ObjectClass indicates the class and associated sub-class that best defines an object. The sub-classes include; vehicleSubClass (object is a road vehicle), vruSubClass (object is a VRU), groupSubClass (object is a VRU group or cluster) and otherSubClass (object is of different types as the above).

```
VehicleSubClass ::= INTEGER {
   unknown           (0),
   passengerCar      (1),
   bus               (2),
   lightTruck        (3),
   heavyTruck        (4),
   trailer           (5),
   specialVehicles   (6),
   tram              (7),
   emergencyVehicle  (8),
   agricultural      (9)
} (0..255)
```

The vruSubClass includes:

```
VruSubProfilePedestrian ::= ENUMERATED {
    unavailable         (0),
    ordinary-pedestrian (1),
    road-worker         (2),
    first-responder     (3),
    max                 (15)
}

VruSubProfileBicyclist ::= ENUMERATED {
    unavailable          (0),
    bicyclist            (1),
    wheelchair-user      (2),
    horse-and-rider      (3),
    rollerskater         (4),
    e-scooter            (5),
    personal-transporter (6),
    pedelec              (7),
    speed-pedelec        (8),
    max                  (15)
}

VruSubProfileMotorcyclist ::= ENUMERATED {
    unavailable                   (0),
    moped                         (1),
    motorcycle                    (2),
    motorcycle-and-sidecar-right (3),
    motorcycle-and-sidecar-left  (4),
    max                           (15)
}

VruSubProfileAnimal ::= ENUMERATED {
    unavailable    (0),
    wild-animal    (1),
    farm-animal    (2),
    service-animal (3),
    max            (15)
}
```

The otherSubClass includes;

```
OtherSubClass ::= INTEGER {
   unknown      (0),
   roadSideUnit (1)
} (0..255)
```

6.1.7 Ego vehicle and other road users

Ego vehicle data is aligned with the DEs and DFs related to cooperative awareness (ETSI EN 302 637-2) and collective perception (ETSI TR 103 562).

Other road user data is aligned with the DEs and DFs related to collective perception (ETSI TR 103 562).

Ego vehicle data references the cooperative awareness message (CAM) which includes a BasicVehicleContainerHighFrequency with the following DEs and DFs.

```
heading                        Heading,
speed                          Speed,
driveDirection                 DriveDirection,
vehicleLength                  VehicleLength,
vehicleWidth                   VehicleWidth,
longitudinalAcceleration       LongitudinalAcceleration,
curvature                      Curvature,
curvatureCalculationMode       CurvatureCalculationMode,
yawRate                        YawRate,
accelerationControl            AccelerationControl OPTIONAL,
lanePosition                   LanePosition OPTIONAL,
steeringWheelAngle             SteeringWheelAngle OPTIONAL,
lateralAcceleration            LateralAcceleration OPTIONAL,
verticalAcceleration           VerticalAcceleration OPTIONAL,
```

Ego vehicles that include a trailer (such as a semi-trailer towing vehicle) reference the collective perception message (CPM) which includes a TrailerData DF with the following DEs and DFs.

```
TrailerData ::= SEQUENCE {
   refPointId                  Identifier1B,
   hitchPointOffset            StandardLength1B,
   frontOverhang               StandardLength1B OPTIONAL,
   rearOverhang                StandardLength1B OPTIONAL,
   trailerWidth                VehicleWidth OPTIONAL,
   hitchAngle                  CartesianAngle,
   ...
}
```

Other road user data also references the collective perception message (CPM) which includes a PerceivedObject DF, within the perceived object container. The PerceivedObject DF includes the following DEs and DFs to information about a perceived object including its kinematic state and attitude vector in a pre-defined coordinate system.

```
PerceivedObject ::= SEQUENCE {
    objectId                                Identifier2B OPTIONAL,
    timeOfMeasurement                       DeltaTimeMilliSecondPosNeg,
    xCoordinate                             CartesianCoordinateWithConfidence,
    yCoordinate                             CartesianCoordinateWithConfidence,
    zCoordinate                             CartesianCoordinateWithConfidence OPTIONAL,
    velocityMagnitude                       SpeedExtended OPTIONAL,
    velocityDirection                       CartesianAngle OPTIONAL,
    xVelocity                               SpeedExtended OPTIONAL,
    yVelocity                               SpeedExtended OPTIONAL,
    zVelocity                               SpeedExtended OPTIONAL,
    accelerationMagnitude                   Acceleration1d OPTIONAL,
    accelerationDirection                   CartesianAngle OPTIONAL,
    xAcceleration                           Acceleration1d OPTIONAL,
    yAcceleration                           Acceleration1d OPTIONAL,
    zAcceleration                           Acceleration1d OPTIONAL,
    rollAngle                               CartesianAngle OPTIONAL,
    pitchAngle                              CartesianAngle OPTIONAL,
    yawAngle                                CartesianAngle OPTIONAL,
    rollSpeed                               CartesianAngularSpeed OPTIONAL,
    pitchSpeed                              CartesianAngularSpeed OPTIONAL,
    yawSpeed                                CartesianAngularSpeed OPTIONAL,
    rollAcceleration                        CartesianAngularAcceleration OPTIONAL,
    pitchAcceleration                       CartesianAngularAcceleration OPTIONAL,
    yawAcceleration                         CartesianAngularAcceleration OPTIONAL,
    lowerTriangularCorrelationMatrixColumns LowerTriangularPositiveSemidefiniteMatrix OPTIONAL,
    planarObjectDimension1                  ObjectDimension OPTIONAL,
    planarObjectDimension2                  ObjectDimension OPTIONAL,
    verticalObjectDimension                 ObjectDimension OPTIONAL,
    objectRefPoint                          ObjectRefPoint DEFAULT 4,
    objectAge                               DeltaTimeMilliSecondPosNeg (0..1500) OPTIONAL,
    objectConfidence                        ObjectConfidence OPTIONAL,
    sensorIdList                            SequenceOfIdentifier1B OPTIONAL,
    dynamicStatus                           ObjectDynamicStatus OPTIONAL,
```

```
    classification              ObjectClassDescription OPTIONAL,
    mapPosition                 MapPosition OPTIONAL,
    ...
}
```

NOTE – A number of the DEs and DFs included in the ETSI TS 102 894-2 ITS common data dictionary (CDD) for cooperative awareness message standard (ETSI EN 302 637-2) have been kept for backwards compatibility reasons only. It is recommended to use the updated DEs and DFs referenced by the collective perception service standard (ETSI TR 103 562) for ego vehicle safety data.

6.1.8 Road type and lane type

The DE RoadType covers four types defining urban or non-urban roads with or without structural separation between lanes carrying traffic in opposite directions.

The DE LaneType represents 20 different types of lanes including; traffic, through, reversible, acceleration, deceleration, leftHandTurning, rightHandTurning. It also includes reference to dedicated lanes such as bus, taxi, cycleLane and pedestrian (for footpaths).

The DE LaneWidth represents the width of a lane measured at a defined position.

6.1.9 Traffic event cause code

The DF CauseCodeV2 represents the cause code value of a traffic event and includes various DE sub cause code values including:

```
AccidentSubCauseCode
::= INTEGER {
    unavailable (0),
    multiVehicleAccident (1),
    heavyAccident (2),
    accidentInvolvingLorry (3),
    accidentInvolvingBus (4),
    accidentInvolvingHazardousMaterials (5),
    accidentOnOppositeLane (6),
    unsecuredAccident (7),
    assistanceRequested (8)
} (0..255)

AdverseWeatherCondition-AdhesionSubCauseCode
::= INTEGER {
    unavailable (0),
    heavyFrostOnRoad (1),
    fuelOnRoad (2),
    mudOnRoad (3),
    snowOnRoad (4),
    iceOnRoad (5),
```

```
    blackIceOnRoad (6),
    oilOnRoad (7),
    looseChippings (8),
    instantBlackIce (9),
    roadsSalted (10)
} (0..255)

AdverseWeatherCondition-ExtremeWeatherConditionSubCauseCode
::= INTEGER {
    Unavailable (0),
    strongWinds (1),
    damagingHail (2),
    hurricane (3),
    thunderstorm (4),
    tornado (5),
    blizzard (6)
} (0..255)

AdverseWeatherCondition-PrecipitationSubCauseCode
::= INTEGER {
    unavailable (0),
    heavyRain (1),
    heavySnowfall (2),
    softHail (3)
} (0..255)

CollisionRiskSubCauseCode
::= INTEGER {
    unavailable (0),
    longitudinalCollisionRisk (1),
    crossingCollisionRisk (2),
    lateralCollisionRisk (3),
    vulnerableRoadUser (4)
}(0..255)

DangerousSituationSubCauseCode
::= INTEGER {
```

```
    unavailable (0),
    emergencyElectronicBrakeEngaged (1),
    preCrashSystemEngaged (2),
    espEngaged (3),
    absEngaged (4),
    ebEngaged (5),
    brakeWarningEngaged (6),
    collisionRiskWarningEngaged (7)
} (0..255)

HazardousLocation-ObstacleOnTheRoadSubCauseCode
::= INTEGER {
    unavailable (0),
    shedLoad (1),
    partsOfVehicles (2),
    partsOfTyres (3),
    bigObjects (4),
    fallenTrees (5),
    hubCaps (6),
    waitingVehicles (7)
} (0..255)

HazardousLocation-SurfaceConditionSubCauseCode
::= INTEGER {
    unavailable (0),
    rockfalls (1),
    earthquakeDamage (2),
    sewerCollapse (3),
    subsidence (4),
    snowDrifts (5),
    stormDamage (6),
    burstPipe (7),
    volcanoEruption (8),
    fallingIce (9),
    fire (10)
} (0..255)
```

```
HumanPresenceOnTheRoadSubCauseCode
::= INTEGER {
    unavailable (0),
    childrenOnRoadway (1),
    cyclistOnRoadway (2),
    motorcyclistOnRoadway (3)
} (0..255)

PostCrashSubCauseCode
::= INTEGER {
    unavailable (0),
    accidentWithoutECallTriggered (1),
    accidentWithECallManuallyTriggered (2),
    accidentWithECallAutomaticallyTriggered (3),
    accidentWithECallTriggeredWithoutAccessToCellularNetwork (4)
} (0..255)

RoadworksSubCauseCode
::= INTEGER {
    unavailable (0),
    majorRoadworks (1),
    roadMarkingWork (2),
    slowMovingRoadMaintenance (3),
    shortTermStationaryRoadworks (4),
   streetCleaning (5),
   winterService (6)
} (0..255)

SignalViolationSubCauseCode
::= INTEGER {
    unavailable (0),
    stopSignViolation (1),
    trafficLightViolation (2),
    turningRegulationViolation (3)
} (0..255)

StationaryVehicleSubCauseCode
```

```
::= INTEGER {
   unavailable (0),
   humanProblem (1),
   vehicleBreakdown (2),
   postCrash (3),
   publicTransportStop (4),
   carryingDangerousGoods (5),
   vehicleOnFire (6)
} (0..255)

VehicleBreakdownSubCauseCode
::= INTEGER {
   unavailable (0),
   lackOfFuel (1),
   lackOfBatteryPower (2),
   engineProblem (3),
   transmissionProblem (4),
   engineCoolingProblem (5),
   brakingSystemProblem (6),
   steeringProblem (7),
   tyrePuncture (8),
   tyrePressureProblem (9),
   vehicleOnFire (10)
} (0..255)

WrongWayDrivingSubCauseCode
::= INTEGER {
   unavailable (0),
   wrongLane (1),
   wrongDirection (2)
} (0..255)
```

6.1.10 Safety metrics

The SafeDistanceIndicator DE indicates if a distance is safe.

This DE is FALSE if the triple {LaD, LoD, VD} < {MSLaD, MSLoD, MSVD} simultaneously satisfied with confidence of 90% or more. Otherwise, stationSafeDistanceIndication is set to TRUE.

Metrics

Lateral Distance (LaD)

Longitudinal Distance (LoD)

Vertical Distance (VD)

Thresholds

Minimum Safe Lateral Distance (MSLaD),

Minimum Safe Longitudinal Distance (MSLoD),

Minimum Safe Vertical Distance (MSVD)

6.1.11 Vehicle control and signalling

The DE AccelerationControl indicates the current controlling mechanism for the longitudinal movement of the vehicle.

The data may be provided via the in-vehicle network. It indicates whether a specific in-vehicle acceleration control system is engaged or not. Currently, this DE includes information on the vehicle brake pedal, gas pedal, emergency brake system, collision warning system, adaptive cruise control system, cruise control system and speed limiter system.

The DE SteeringWheelAngleValue represents the steering wheel angle in units of 1.5 degrees.

AccelerationControl and SteeringWheelAngleValue are representations of longitudinal and lateral control inputs.

The DE ExteriorLights describes the status of the exterior vehicle lights indicating:

```
ExteriorLights ::= BIT STRING {
   lowBeamHeadlightsOn      (0),
   highBeamHeadlightsOn     (1),
   leftTurnSignalOn         (2),
   rightTurnSignalOn        (3),
   daytimeRunningLightsOn   (4),
   reverseLightOn           (5),
   fogLightOn               (6),
   parkingLightsOn          (7)
} (SIZE(8))
```

NOTE – This DE was originally conceived as ego vehicle centric with data originating from the light switch status and therefore did not indicate if the corresponding lamps are alight or not. This DE may also be used for indicating the exterior light status of a perceived vehicle. For this, DE should be extended to include a brake light.

6.1.12 Precipitation intensity

The DE PrecipitationIntensity represents the total amount of rain falling for one hour. It is measured in mm per hour at an area of 1 square metre.

6.1.13 Vulnerable road users

The DE VruEnvironment indicates whether a VRU is located on an intersection crossing, zebra crossing, sidewalk, in the vehicle road or in a protected geographic area.

The DE VruMovementControl indicates the status of human control over a VRU vehicle including braking, braking hard, stopping the pedalling, braking and stopping the pedalling and no reaction.

The DF VruClusterInformation and the DE VruClusterProfile enables the clustering of pedestrians, bicycles, motorcycles, or animals into single object groups.

6.1.14 Vehicle role

The DE VehicleRole indicates the role played by a vehicle at a point in time. It includes the following values:

```
VehicleRole ::= ENUMERATED {
   Default (0),
   publicTransport (1),
   specialTransport(2),
   dangerousGoods  (3),
   roadWork       (4),
   rescue         (5),
   emergency      (6),
   safetyCar      (7),
   agriculture    (8),
   commercial     (9),
   military       (10),
   roadOperator   (11),
   taxi           (12),
   reserved1      (13),
   reserved2      (14),
   reserved3      (15)
}
```

7 Automated driving safety data using the Zenoh protocol

Zenoh [Eclipse zenoh] is a communication middleware designed to work across communication technologies such as Ethernet, time-sensitive networking (TSN), Wi-Fi and 4G / 5G. It can operate at different geographical scales such as a local area network (LAN), metropolitan area network (MAN) and a wide area network (WAN), and in various topology configurations such as peer-to-peer, mesh, brokered and routed. Zenoh also provides a plugin mechanism to integrate with other middlewares like MQ telemetry transport (MQTT), data distribution service (DDS) and hypertext transfer protocol (HTTP), as well as to integrate with many storage technologies like InfluxDB, RocksDB, and MariaDB.

Zenoh provides a standard communication protocol that enables automated and assisted driving systems to publish safety data that can be subscribed to by the safety monitoring system. The safety monitoring system can run on the same virtual or physical computer, a separate computer on the vehicle network, or a remote computer at the edge or in the cloud.

Zenoh unifies data in-motion, data in use, data at rest and computations providing a single protocol to enable new edge-centric paradigms where data is stored and processed and makes the most sense for performance, energy efficiency and security matters.

Zenoh is a Pub/Sub/Query protocol that supports extremely efficient and scalable publish / subscribe, and queries on geo-distributed data sources – which produce such data by querying storage or triggering a computation. Zenoh data is represented by means of resources, where each resource is identified by a name and a value. Besides interoperability, resource naming has a key role in facilitating and optimising, routing, storing and querying data. As such, the recommended format for naming CDD resources is:

`itu/its/cdd/<version>/<category>/<id>/<sub-category>`

This representation allows to ensure that the version of the data model is embedded in the resource name and can be used for matching one or a set of versions depending on the compatibility.

Additionally, this organization clearly captures the identity of a generic ITS as well as its structure and allows one to subscribe / query any portion of it.

Examples of the proposed Zenoh resource naming scheme are provided in Appendix I.

Appendix I

Zenoh examples

This appendix contains some examples showing how to apply the resource naming scheme recommended in clause 7.

As a running example it will take the VehicleIdentification DF as specified in the ETSI TS 102 894-2 ITS common data dictionary (CDD) including the proposed extension for a vehicle indicator section (VIS), then for this information the resources would be named as:

```
itu/its/cdd/<version>/vehicle/<vehicle-id>/geometry/length
itu/its/cdd/<version>/vehicle/<vehicle-id>/geometry/width
itu/its/cdd/<version>/vehicle/<vehicle-id>/path-history
itu/its/cdd/<version>/vehicle/<vehicle-id>/role
itu/its/cdd/<version>/vehicle/<vehicle-id>/…
```

This naming scheme allows queries such as:

```
get itu/its/cdd/<version>/vehicle/<vehicle-id>/geometry/*
get itu/its/cdd/<version>/vehicle/*/path-history?(some location)
get itu/its/cdd/<version>/vehicle/<vehicle-
id>/role?kind="specialTransport
…
```

Likewise, subscriptions can leverage wildcards to denote a set of resources of their interest related to a vehicle, or a set of vehicles.

Bibliography

[b-BSI Flex 1890] BSI Flex 1890 v4.0:2022-03, *Connected and automated vehicles – Vocabulary*. <https://www.bsigroup.com/globalassets/localfiles/en-gb/cav/pass-and-flex-pdfs/bsi-flex-1890-v4-2022-03.pdf>