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Part 2: Intersection Collision Risk Warning (ICRW) application requirements specification

Reference

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

The present document is part 2 of a multi-part deliverable. Full details of the entire series can be found in part 1 [i.4].

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The present document provides Intersection Collision Risk Warning Application requirements and specifies the necessary parameters and conditions to operate the application using CAM [1], DENM [2] and the intersection service messages [4]. It includes the specifications of functional requirements and operational requirements of the LCRW application.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

[1] ETSI EN 302 637-2 (V1.3.2): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".

[2] ETSI EN 302 637-3 (V1.2.2): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service".

[3] ETSI TS 101 539-3 (V1.1.1): "Intelligent Transport Systems (ITS); V2X Applications; Part 3: Longitudinal Collision Risk Warning (LCRW) application requirements specification".

[4] ETSI TS 103 301 (V1.1.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services".

[5] ETSI TS 102 636-4-2 (V1.1.1): "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 2: Media-dependent functionalities for ITS-G5".

2.2 Informative references

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 102 638: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions".

[i.2] ETSI EN 302 665 (V1.1.1): "Intelligent Transport Systems (ITS); Communications Architecture".

[i.3] ETSI TS 102 894-1 (V1.1.1): "Intelligent Transport Systems (ITS); Users and applications requirements; Part 1: Facility layer structure, functional requirements and specifications".

[i.4] ETSI TS 101 539-1 (V1.1.1): "Intelligent Transport Systems (ITS); V2X Applications; Part 1: Road Hazard Signalling (RHS) application requirements specification".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

age of data: difference between the time of a data element value setting at the originating ITS-S and the time the same data element value is used to undertake an appropriate action at a receiving ITS-S

NOTE: The age of data is an important quality parameter reflecting the freshness of highly dynamic data elements in particular when a collision risk is assessed at vehicles' receiving levels.

conflict zone: zone of an intersection where the trajectory paths of vehicles and other traffic participants (e.g. pedestrian, bicycles, vehicles) may cross

primary road safety application: ITS-S application which purpose is to prevent a collision

stop line: pavement marking line extending across lanes to indicate the point at which a stop is intended or required to be made

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

BSA	Basic Set of Applications
CA	Co-operative Awareness
CAM	Co-operative Awareness Message
CCH	Control Channel
DCC	Decentralized Congestion Control
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
HMI	Human Machine Interface
ICRW	Intersection Collision Risk Warning
ITS	Intelligent Transport Systems
ITS-S	ITS Station
IVI	Infrastructure to Vehicle Information
IVIEM	In Vehicle Information Extended Message
IVIM	Infrastructure to Vehicle Information Message
LCRW	Longitudinal Collision Risk Warning
MAPEM	Message with detailed road topology information used by RLT service
MAT	Maximum Action Time
MDRT	Maximum Driver Reaction Time
MLT	Maximum Latency Time
OEM	Original Equiment Manufacturer
OR	Operational Requirements
RHS	Road Hazard Signalling
RLT	Road and Lane Topology
SPAT	Signal Phase And Timing
SPATEM	Signal Phase And Timing Extended Message
TLM	Traffic Light Maneuver
TTC	Time To Collision
VRU	Vulnerable Road User

4 Conforming ITS-S performance class definition

Intersection Collision Risk Warning (ICRW) application is considered as a primary road safety application. As introduced in clause 4 of ETSI TS 101 539-3 [3], primary road safety applications are ITS applications that target at reducing the risk of collision and thus improving the road safety. An ICRW application provides intersection collision risk warning to drivers. The warning indicates the risk of potential intersection collision risk that requires an immediate action of the driver.

NOTE: It is not excluded to implement the ICRW with automatic assistance system, such as automatic braking system. In this case, the automatic assistance system will react directly on the braking system for the driver, enabling a quicker reaction towards the collision risk.

The ICRW application relies on the processing of Cooperative Awareness Message (CAM) as specified in ETSI EN 302 637-2 [1] and Decentralized Environmental Notification Message (DENM) as specified ETSI EN 302 637-3 [2] transmitted from vehicle ITS-Ss or road side ITS-S. If applicable, an ICRW application may in addition rely on the roadside infrastructure services such as Traffic Light Maneuver (TLM) service, Road and Lane Topology (RLT) service and Infrastructure to Vehicle Information (IVI) service as specified in ETSI TS 103 301 [4]. These messages enable a receiving vehicle ITS-S be informed of the movement status of other vehicles in the intersection as well as the traffic light status, intersection access priority status, and topology of the intersection. This receiving ITS-S is therefore able to estimate the potential collision risk and inform driver when necessary.

The ICRW application requires a short end-to-end latency time. This latency time is the time difference between T0 and T6 and shall be as defined in ETSI TS 101 539-3 [3] and illustrated in Figure 1, in order to provide timely warning to driver. T0 is denoted as time at which the vehicle data is available at the vehicle electronic systems. For message transmitted from road side ITS-S, T0 is denoted as time at which the data is available at data source e.g. traffic light status data available at traffic light controller system. T6 is denoted as time at which the warning is presented on the vehicle HMI or time at which a direct action is requested to the vehicle electronic system, if applicable. Typically, 300 ms end to end latency time is required.

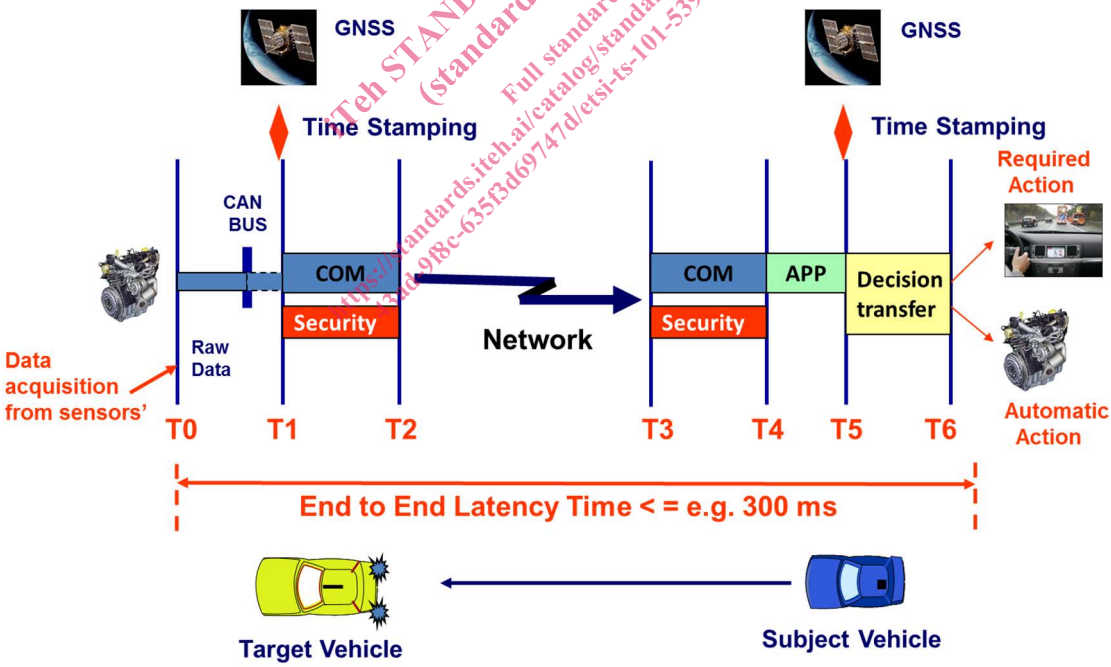


Figure 1: Application end to end latency time

In particular, time difference from T0 to T1 reflects the freshness of the data provided by a message with regards to the message time stamp. ETSI TS 101 539-3 [3] has defined two performance classes (class A and class B) based on this time difference, indicating the capability of a vehicle ITS-S to provide up-to-date information in CAM and DENM within a threshold value (e.g. 150 ms).

Road side ITS-S mounted within an intersection provides up-to-date information on intersection traffic light status (SPATEM), road topology (MAPEM) and infrastructure to vehicle Information (IVIM) in order to enable the receiving ITS-S be informed about the allowed maneuvers, the access rights to execute the maneuvers (e.g. "green", "yellow", "red"). The freshness of road side information may vary depending on the information update rate. Typically, such update rate is configured by road side ITS-S application, as described in ETSI TS 103 301 [4].

5 Intersection Collision Risk Warning application overview

5.1 ICRW in the ITS architecture

5.1.1 Overview

The objective of an ICRW application is to detect potential collision risk between two or more vehicles or obstacles inside an intersection area. In addition, the ICRW may detect potential traffic sign violation at an intersection area. When a collision risk or traffic sign violation risk is detected, the vehicle may issue a warning to the driver.

If the collision risk is detected by the roadside ITS-S, it may trigger the transmission of corresponding collision risk warning DENM to approaching vehicles. A vehicle receiving such DENM may issue a warning to driver, when the information is estimated relevant. One example use case is that a road side ITS-S equipped with sensors capable of detecting the intersection collision risk or traffic sign violation risk may transmit an intersection collision risk warning DENM to vehicles approaching to or inside the intersection area.

ICRW is an application layer entity that implements at least one intersection collision risk use case. In one possible implementation, an ICRW may implement more than one intersection collision risk use cases into one ITS-S application entity. The present document does not specify any implementation structure of the ICRW application.

Figure 2 presents an ICRW application in the ITS-S architecture as defined in ETSI EN 302 665 [i.2] as well as its logical interfaces with other entities and layers.

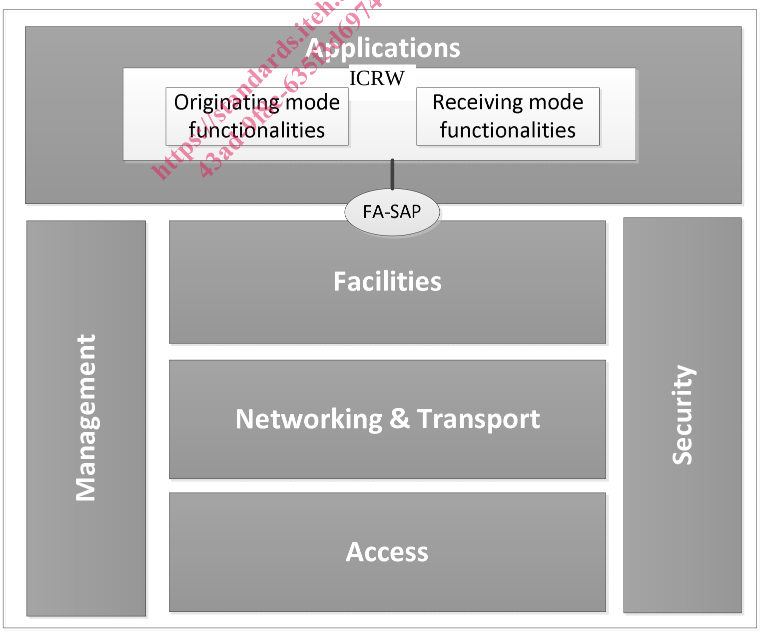


Figure 2: ICRW and logical interfaces

The ICRW application functionalities are distributed in conforming ITS-Ss. The following functional modes of the application are included:

- Vehicle ITS-S originating mode: This mode refers to functionalities implemented by a vehicle ITS-S, including the triggering of DENM transmission as specified in ETSI EN 302 637-3 [2] upon the detection of an intersection collision risk or traffic sign violation risk, and the transmission of CAM according to the CAM transmission rules as specified in ETSI EN 302 637-2 [1]. Some functional requirements are provided in ETSI TS 102 894-1 [i.3] for traffic situations which may be leading to an intersection collision.

- Minimum Vehicle ITS-S receiving mode: This mode refers to functionalities implemented by a vehicle ITS-S, including the processing of received ICRW DENM and providing warning to the driver in case based on the evaluation of the DENM.

- Full Vehicle ITS-S receiving mode: This mode refers to functionalities implemented by a vehicle ITS-S, including the processing of received CAM, DENM, SPATEM, MAPEM and IVIM for the analysis of intersection collision risks and provides warning to the driver in case of a detected risk. A driver warning issued by an ICRW application is a strong advice that requires an immediate action from the driver to avoid an imminent intersection collision.

- Road side ITS-S originating mode: This mode refers to functionalities implemented by a road side ITS-S, including the triggering of DENM transmission upon detection of potential collision risk at intersection.

- Road side ITS -S receiving mode: This mode refers to functionalities implemented by a road side ITS-S, including the processing of received CAM, DENM and/or sensor data for the detection of potential collision risk at intersection.

A vehicle ITS-S implementing ICRW shall comply with one of the following compliance levels:

- Level 1: the minimum vehicle receiving mode functionality shall be implemented.

- Level 2: according to Level 1 and the full receiving mode functionality shall be implemented.

- Level 3: according to Level 2 and the vehicle ITS-S originating mode functionality shall be implemented.

A road side ITS-S implementing ICRW shall comply with both the road side ITS-S originating and receiving mode functionalities.

The present clause describes ICRW functionalities of both modes.

ICRW may include use cases as defined in Basic Set of Applications (BSA) ETSI TR 102 638 [i.1], with their functional requirements defined in ETSI TS 102 894-1 [i.3]. In summary, the following collision risks may be considered as intersection collision risks:

- Crossing collision: the collision risk is detected between vehicles whose trajectories may cross in the conflict zone. In most cases, the crossing collision results in a lateral collision. The vehicle may issue a warning to the driver if it detects crossing collision. An immediate action e.g. emergency brake is required for the driver of the vehicle to avoid the collision.

- Traffic sign violation: the traffic sign violation at an intersection area refers to either a traffic light violation at a signalled intersection, or a priority violation at a non-signalled intersection (e.g. stop sign violation). The conditions under which a violation is considered to be true may vary according to regional regulations. Therefore, the violation risk detection algorithm of the ICRW should be compliant to such regulations.

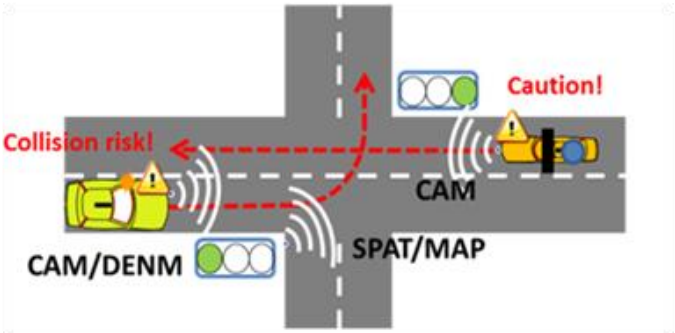
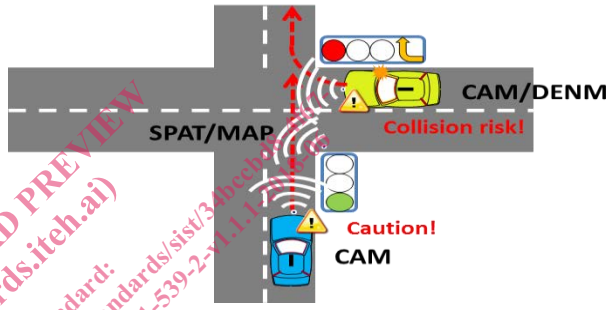
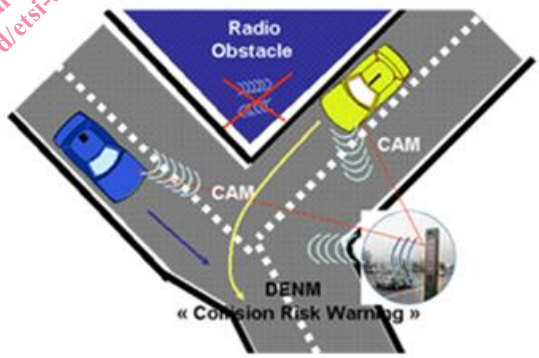
- Collision involving Vulnerable Road Users (VRU): this collision risk refers to risk of collisions between vehicles and Vulnerable Road Users e.g. bicycles, pedestrians inside the intersection area. A warning may be issued to the vehicle driver if a collision risk is detected. If the VRU is equipped with ITS-S implementing the ICRW e.g. a personal ITS-S, a warning may also be issued.

- Rear end collision: rear end collision may happen inside or near an intersection area, for example, at intersection queues.

5.1.2 Crossing collision warning

The considered use cases related to crossing collision warning are summarized in Table 1 and described below.

Table 1: Relevant use cases description for crossing collision risk warning

Use case	Scenario illustration
Turning collision risk warning	
Merging collision risk warning	
Collision risk warning for vehicles with missing radio connectivity	

Turning collision risk warning:

Detection by vehicle:

The collision risk is detected between vehicles, whose trajectories cross in the conflict zone of an intersection. In the example scenario as presented in Table 1, a first vehicle is turning to the left and another vehicle is going straight across the intersection. Both vehicle ITS-Ss receive SPATEM and MAPEM from road side ITS-S, allowing both of them entering the intersection area. Both ITS-Ss transmit CAMs. The left turning vehicle is able to monitor continuously the straight driving vehicle and calculates the associated Time Proximity Vector / Safety Shield (see annex A) with it. Once the value is within a limit (the straight driving vehicle is within the safety shield), the left turning vehicle may increase the CAM generation and transmission rate. Similar estimation may be done at straight driving vehicle, who in its turn increases the CAM generation and transmission rate. Cooperatively, two vehicles are able to monitors more precisely each other's kinematics status changes and detects the potential collision risk. If the collision risk probability reaches a predefined threshold, a warning is issued to the driver.

In one other possible ICRW implementation, the vehicle detecting the potential crossing collision risk (e.g. using embedded sensors) may trigger a DENM transmission. Other vehicle ITS-S receiving such DENM may evaluate the collision risk with transmitting vehicle ITS-S and accordingly issue a warning to the driver.

NOTE: In regions where left hand traffic rules apply, the turning collision may be detected between right turn vehicles with other vehicles.

Detection by roadside:

The roadside ITS monitors the straight driving and left turning trajectories of the two vehicle. Thus the roadside ITS is able to estimate a potential collision risk in real time. Upon detection of collision risk the roadside ITS shall issue a DENM to the traffic participants (e.g. vehicles, pedestrians, bicycles).

Merging collision risk warning:

Detection by vehicle:

The merging collision risk is detected between a vehicle with at least one other vehicle whose trajectory is merging with the trajectory of the first vehicle. In the example scenario as presented in Table 1, the right turning vehicle is authorized to make right turn with yellow phase, and the other vehicle is going straight across the intersection. Both vehicles receive SPATEM and MAPEM from road side ITS-S, allowing the entrance to the intersection. The straight driving vehicle is able to monitor (based on CAMs) constantly the turning vehicle and assess the collision risk probability. If the collision risk probability reaches a predefined threshold, the vehicle issues a warning to the driver requesting immediate action to avoid the collision.

Detection by roadside:

The roadside ITS monitors the straight driving and right turning trajectories of the two vehicles. Thus the roadside ITS-S is able to analyse the potential collision risk in real time. Upon detection of collision risk the roadside ITS shall issue a DENM to the traffic participants (e.g. vehicles, pedestrians, bicycles) within the intersection area.

Collision risk warning for vehicles with missing radio connectivity:

In this use case, an roadside ITS-S detects collision risk between at least two other vehicles inside the intersection area and transmits a collision risk warning DENM. In the example scenario as presented in Table 1, a vehicle cannot receive CAM from other vehicles because of non-line-of sight radio propagation due to obstacle. A road side ITS-S is positioned at the intersection that has a line-of-sight condition with all road sections of the intersection. This road side ITS-S receives CAMs from vehicles at both directions, enabling it to detect the collision risk of these two vehicles. Optionally the roadside ITS-S uses additional technical means to detect the collision risk (e.g. radar, camera). Upon the detection of a collision risk, the ICRW application of the roadside ITS-S triggers the transmission of "collision risk warning" DENMs until the collision risk is eliminated. Upon reception of a DENM, a vehicle ITS-S may estimate the relevance of the collision risk with its own trajectory and movement state, and triggers a warning to driving if applicable.

5.1.3 Traffic sign violation warning

The considered use cases related to traffic sign violation are summarized in Table 2 and described below.