



Technical Specification

**Intelligent Transport Systems (ITS);
V2X Applications;
Part 3: Longitudinal Collision Risk Warning (LCRW)
application requirements specification**

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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 3 of a multi-part deliverable. Full details of the entire series can be found in part 1 [3].

Introduction

ITS Stations (ITS-Ss) are interacting together to satisfy a large diversity of customers' services.

ETSI TC ITS WG1 has defined a basic set of applications (BSA) [i.1] with the purpose to scope the WG1 work. Driven by European safety and traffic management ITS directive, and within the scope of the European Mandate M/453 a subset of the BSA application requirements specifications, dedicated to road safety, are developed by ETSI TC ITS.

The present document provides specifications on the application requirements related to Longitudinal Collision Risk Warning (LCRW) application based on Co-operative Awareness basic service (CA basic service) [1] and Decentralized Environmental Notification basic service (DEN basic service) [2].

A communication technology may be used to realize this application, as long as the functional and operational requirements are satisfied. An ITS-S conforming to these functional and operational requirements are named conforming ITS-S.

The LCRW application functionalities are distributed in conforming ITS-Ss, two functional modes of the application are defined:

- The originating mode: including the triggering of DENM [2] transmission upon the detection of a longitudinal collision risk and the transmission of CAM according to the CAM transmission rules as specified in [1]. Functional and operational requirements for this functional mode are defined in accordance with the RHS application requirements specification [3].
- The receiving mode: referring to the analysis of longitudinal collision risks based on received information from other ITS-Ss and provision of warning to driver in case of a detected risk. The driver warning is a strong advice that requires an immediate action of the driver to avoid an imminent longitudinal collision.

1 Scope

The present document provides a description of the Longitudinal Collision Risk Warning application requirements and the specification of the necessary parameters and conditions to operate the application using CAM [1] and DENM [2]. It includes the specifications of functional requirements and operational requirements of the LCRW application.

2 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 reference document (including any amendments) applies.

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2.1 Normative references

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

- [1] ETSI EN 302 637-2 (V1.3.0): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".
- [2] ETSI EN 302 637-3 (V1.2.0): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service".
- [3] ETSI TS 101 539-1: "Intelligent Transport Systems (ITS); V2X Applications; Part 1: Road Hazard Signalling (RHS) application requirements specification".
- [4] ETSI TS 102 637-1 (V1.1.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 1: Functional Requirements".

2.2 Informative references

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] TISA specification TAWG11071 (2011-11-07, drafted to potentially become ISO/TS 21219 Part 15): "Intelligent Transport Systems (ITS) - Traffic and Travel Information (TTI) via Transport Protocol Experts Group, Generation 2 (TPEG2) - Part 15: Traffic Event Compact (TPEG2 TEC-3.1/001)".
- [i.3] ISO 17425: "Data exchange specification for in-vehicle presentation of external road and traffic related data ("embedded VMS")".
- [i.4] ETSI TS 101 539-2: "Intelligent Transport System (ITS); V2X Applications; Intersection Collision Risk Warning (ICRW) application requirements specification".
- [i.5] ETSI EN 302 665 (V1.1.1): "Intelligent Transport Systems (ITS); Communications Architecture".
- [i.6] ISO/CD 15623: "Road Vehicles - Forward Vehicle Collision Warning System - Performance requirements and tests procedures".

- [i.7] ETSI EN 302 895: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM)".
- [i.8] ETSI TS 102 894-1: "Intelligent Transport Systems (ITS); Users and applications requirements; Part 1: Facility layer structure, functional requirements and specifications".
- [i.9] ETSI EN 302 636-4-1: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media-Independent Functionality".

3 Definitions and abbreviations

3.1 Definitions

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

age of data: time elapsed since the time when a data is set at the originating ITS-S and a specific reference time

end to end latency time: age of data with a reference time at which the application processing result is effective

forward vehicle: vehicle in front of the ego vehicle along its itinerary

LCRW: application layer entity that implements at least one longitudinal collision risk warning use case

longitudinal alignment: two vehicles are considered as longitudinally aligned when their trajectories may lead to a forward or frontal collision whatever surface portion of the vehicles being in contact at collision time

primary road safety application: application with objective of preventing a potential collision

NOTE 1: Multiple means are possible, ranging from giving information to the driver to acting directly on the vehicle.

NOTE 2: Secondary and tertiary safety applications do not avoid collision. They respectively can mitigate the collision (pre-crash and post crash) or accelerate the emergency rescue.

Subject Vehicle (SV): vehicle that estimates the collision risk and provides information or warning to driver when necessary

Target Vehicle (TV): counterpart of the subject vehicle for the evaluation of collision risk

3.2 Abbreviations

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

ABS	Anti-lock Braking System
ADAS	Advanced Driver Assistance System
BSA	Basic Set of Applications
CA	Co-operative Awareness
CAM	Co-operative Awareness Message
CCH	Control Channel
DCC	Distributed Congestion Control
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
ESP	Electronic Stability Program
FR	Functional Requirement
GBC	Geo Broadcasting
HMI	Human Machine Interface
ICRW	Intersection Collision Risk Warning

ITS	Intelligent Transport System
ITS-S	ITS station
IVI	In Vehicle Information
LCRW	Longitudinal Collision Risk Warning
MAT	Maximum Action Time
MDRT	Maximum Driver Reaction Time
MLT	Maximum end to end Latency Time
OEM	Original Equipment Manufacturer
OR	Operational Requirements
RHS	Road Hazard Signalling
SHB	Single Hop Broadcasting
SV	Subject Vehicle
TPEG	Transport Protocol Experts Group
TTC	Time to Collision
TV	Target Vehicle

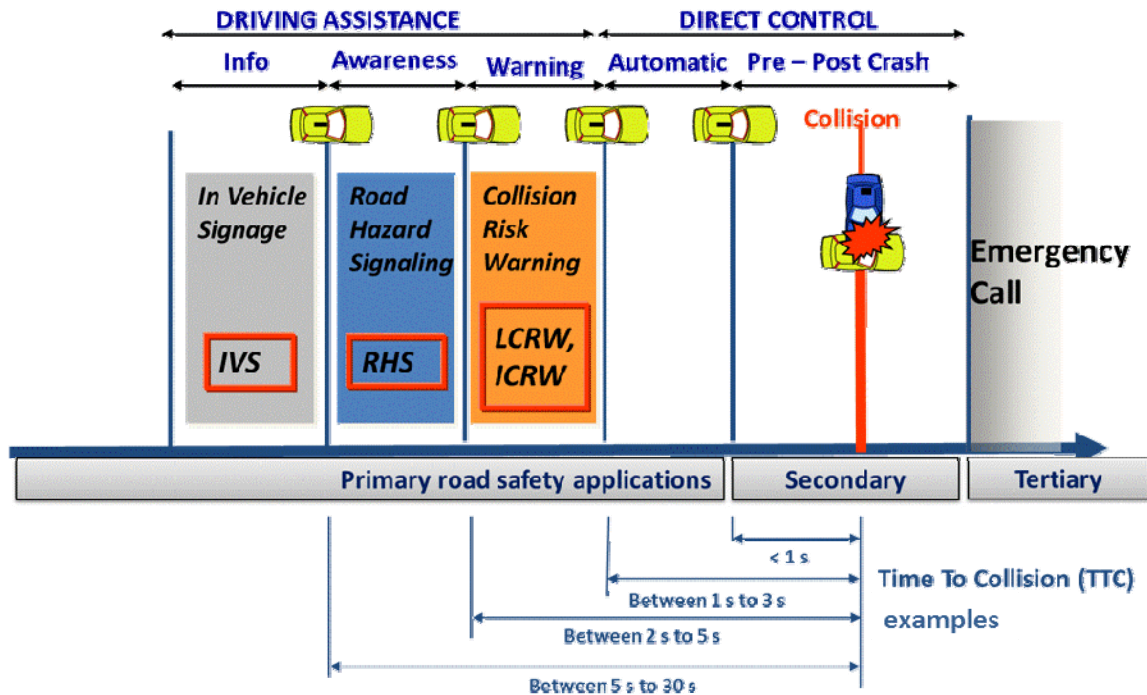
4 Conforming ITS-S performance class definition

Primary road safety applications are ITS applications that target at reducing the risk of collision and thus improving the road safety. Primary road safety applications may be realized with different technical means ranging from providing information about road hazard to driver up to acting on vehicle systems to avoid a potential collision.

The performance of a primary road safety applications can be divided into three parts:

- The ITS-S originating part performance related to the transmission of Cooperative Awareness Messages (CAM) [1] and Decentralized Environmental Notification Messages (DENM) [2].
- The wireless communication performance, which may vary according to network characteristics, radio obstacles and network load.
- The ITS-S receiving part performance related to the processing of received information, presenting information to driver or acting on the in vehicle system.

An overview of ITS applications according to their proximity to potential collision (time to collision) is illustrated in Figure 1.



NOTE: The position of an application relative to the TTC are illustrated as examples. Exact TTC numbers are out of scope of the present document.

Figure 1: Overview of road safety applications

From user viewpoint, several services may be provided by the primary road safety application, in order to increase driver awareness and collision avoidance capabilities of vehicle, for example:

- An "information" may be provided by telematics service (e.g. TPEG [i.2]) using e.g. digital radio broadcasted channels or by cellular network.
- An "In-Vehicle Information" (IVI) may be provided by a road side ITS-S or a central ITS-S to provide static road signage or variable message sign information [i.3].
- A "Awareness" information may be provided by Road Hazard Signalling application as specified in [3], based on processing of received CAM [1] and DENM [2].
- A "warning" may be provided to driver by the Intersection Collision Risk Warning (ICRW) [i.4] and the LCRW applications, based on processing of received CAM [1], DENM [2] and other messages.
- An automatic action is taken by in vehicle system in order to avoid the imminent collision risk. User may or may not be warned.

The present document focuses on the LCRW applications.

One important quality parameter for receiving ITS-S to realize the primary road safety application is the age of data, in particular the age of highly dynamic data. The receiving ITS-S may take erroneous decision if the received data does not correspond to the latest situation of the originating ITS, e.g. trajectory, velocity of the target vehicle. Therefore, the quality of the offered customer' service by the LCRW application rely on the quality and the availability of data transmitted from the originating ITS-S.

The age of data estimated at the receiving ITS-S is denoted as end to end latency time as illustrated in Figure 2.

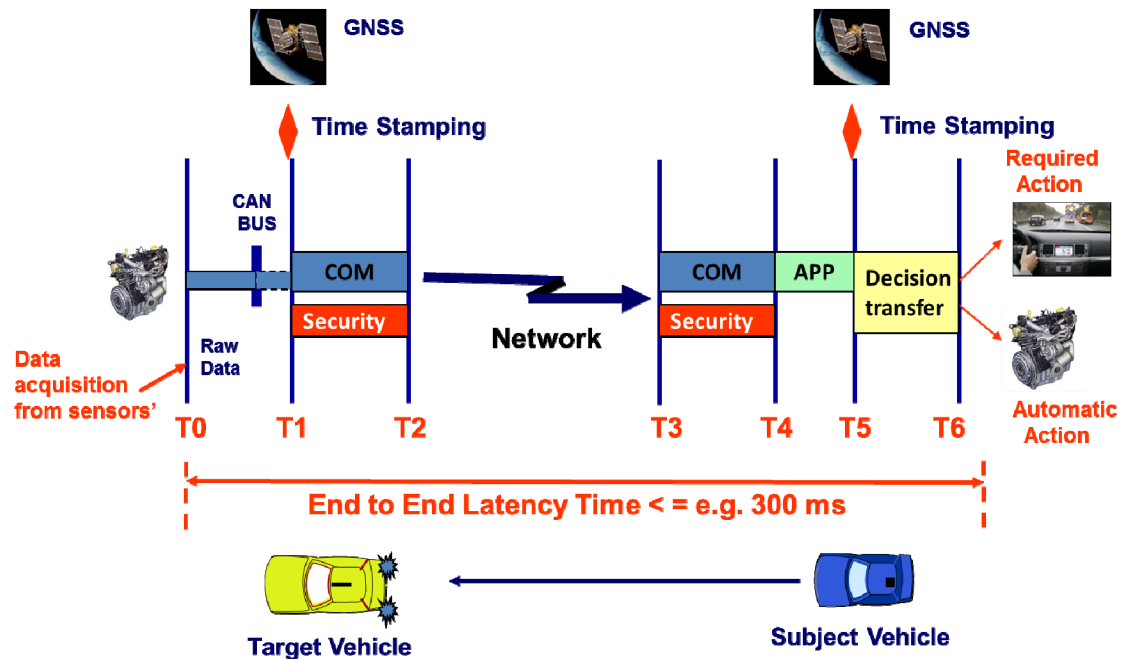


Figure 2: Application end to end latency time

For collision risk warning applications as illustrated in Figure 1, 300 milliseconds end to end latency time may be required to avoid false decision due to old data. This value corresponds to about 10 meters distance travelled by a vehicle moving at 130 km/hour.

In Figure 2, the following time parameters are defined:

- T0: Time at which the vehicle data is available at the vehicle electronic systems.
- T1: Time stamp information included in CAM, DENM. For CAM, this time stamp corresponds to the time at which the position information is updated, as specified in [1]. For DENM, the time stamp corresponds to the time at which an event is detected, as specified in [2].
- T2: Time at which the message is transmitted over the air by the originating ITS-S.
- T3: Time at which the message is received at the access layer (antenna level) of the receiving ITS-S.
- T4: Time at which the data of the received message is provided to the ITS facilities layer for processing.
- T5: Time at which the application processing is finished. The application may request a driver action, if applicable.
- T6: 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.

The end to end latency time is the time difference between T0 and T6. Even though the latency time T1 to T4 may be calculated by comparing the time at which the message is received at facilities layer (T4) and time stamp information included in CAM / DENM, the T0 - T1 latency time remains unknown for the receiving ITS-S.

Without knowledge on the T0 to T1 time the receiving ITS-S cannot predict vehicle trajectory and estimate the potential collision risk with originating ITS-S.

NOTE 1: The T4 - T6 latency time depends on the implementation. The required value is out of the scope of the present document.

For this purpose at least two ITS-S performance classes are defined for ITS-S originating part performance:

- Class A: a class A ITS-S shall guarantee a T0 to T1 less than 150 milliseconds.
- Class B: No requirement on T0 to T1.

NOTE 2: $T_0 - T_1$ reflects the freshness of in-vehicle data with regards to the message time stamp. For a class A system, the CAM generation intervals should be adjusted properly by the CA basic service to reflect the latest value of the in vehicle data.

NOTE 3: Additional performance class may be added in the future.

The conformance class information shall be transmitted by ITS-S, as long as the information is available. It is included in a data element in CAM as specified in [1], in order to enable the receiving ITS-S to estimate the age of received data (worst case age: $T_4 - T_1 + 150$ ms).

5 Longitudinal Collision Risk Warning application description

5.1 LCRW in the ITS architecture

Longitudinal collision refers to the collision between vehicles (or a vehicle and an obstacle) at any part on the front or rear side of vehicle. If a longitudinal collision risk is detected, a subject vehicle (SV) may issue a collision risk warning to driver. The counterpart vehicle or obstacle is called the target vehicle TV or target obstacle.

LCRW is an application layer entity that implements at least one longitudinal collision risk use case. In one possible implementation, an LCRW may include more than one longitudinal collision risk use cases into one application entity. The present document does not specify any implementation structure of the LCRW application.

Figure 3 presents the LCRW in the ITS-S architecture as defined in [i.5] as well as its logical interfaces with other entities and layers.

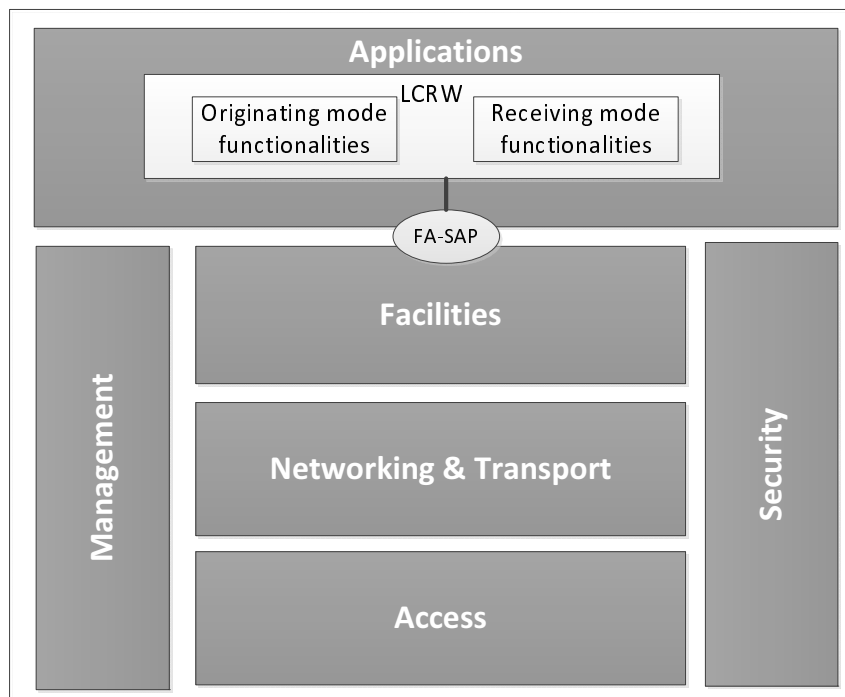


Figure 3: LCRW and logical interfaces

The LCRW application functionalities are distributed in conforming ITS-Ss, two functional modes of the application are included:

- The originating mode: including the triggering of DENM [2] transmission upon the detection of a road hazard or the detection of longitudinal collision risk, and the transmission of CAM according to the CAM transmission rules as specified in [1]. Some functional requirements are provided in [4] for traffic situations which may be leading to a longitudinal collision.

- The receiving mode: including the processing of received CAM and DENM from TV for the analysis of longitudinal collision risks and provides warning to the driver in case of a detected risk. A driver warning issued by an LCRW application is a strong advice that requires an immediate action of the driver to avoid an imminent longitudinal collision.

An ITS-S implementing LCRW shall implement both originating mode functionalities and receiving mode functionalities. Interactions may be required between these two modes.

The present clause describes LCRW functionalities of both modes.



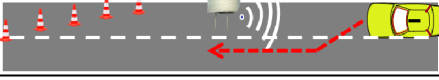



LCRW may include use cases as defined in Basic Set of Applications (BSA) [i.1], with their functional requirements defined in [4]. In summary, the following collision risks may be considered as the longitudinal collision risks:

- Forward collision: the SV detects the risk of a collision with a forward vehicle or an obstacle e.g. roadwork zone, in its trajectory. An immediate action e.g. emergency brake is required for the driver of the SV to avoid the collision.
- Forward / side collision: a vehicle wants to overtake a vehicle while a third vehicle has already started the overtaking manoeuvre and is approaching to the overtaking vehicle. The two overtaking vehicles detect a collision risk which each other. This scenario corresponds to a typical accident scenario for motorcycles approaching at high speed to a vehicle which intend to overtake another vehicle. In this case, both the overtaking vehicle and the approaching vehicle are considered as SVs as each one may initiate a warning to the driver requiring an immediate action to avoid the collision. In meanwhile, both vehicles are also considered as target vehicle to each other, since movement status and trajectory of each vehicle is analyzed by other vehicle in order to estimate the collision risk.
- Frontal collision: at least two SVs moving in opposite direction detect the risk of collision between themselves. Also in this scenario both vehicles may be considered as SV and TV. This may happen when one of the two vehicles is driving in a wrong direction on a one way road. A warning may be issued to both vehicles' drivers.

5.1.1 Forward and forward / side collision risk warning

The considered use cases related to forward and forward / side collision risk warning are summarized in Table 1.

Table 1: Relevant use cases description for forward and forward / side collision risk warning

Use case	Scenario illustration
Safety relevant lane Change	
Emergency electronic brake light / Traffic condition	
Roadworks	
Stationary vehicle	
Stability problem	
Collision risk warning from a third party	

Safety relevant lane change: in this use case, SV are two vehicles being involved, i.e. the first vehicle that signals its lane change and a second vehicle that is driving at high speed on the lane that the first is changing to. One possible example of the use case is the overtaking scenario, when the first vehicle starts an overtaking manoeuvre while a second vehicle is already driving in the overtaking lane.

If the first SV is effectively changing the lane, then the two considered vehicles would be aligned so creating a risk of longitudinal collision. In this situation the first vehicle should refrain to do it and stay in its lane (keep lane). The second vehicle should slow down. The LCRW application is to warn both involved vehicles' drivers to attempt avoiding the collision.

Emergency electronic brake light / Traffic condition: in this use case, the SV is heading in the direction of a TV which is abruptly slowing down (e.g. due to a traffic jam condition). The objective of the LCRW application is to warn the SV's driver, in due time, in order for him to adapt its speed to avoid a collision with the TV.

Roadworks: in this use case, the SV is driving at a speed that is not adapted to the road work situation ahead. The objective of the LCRW application is to warn the SV driver, in due time, in order for him to adapt its speed to avoid losing the control of vehicle or hitting workers / obstacles when entering the road work area.

Stationary vehicle: in this use case, the SV is heading in the direction of an immobilized TV (such as breakdown, accident etc.). The objective of the LCRW application is to warn the SV driver, in due time, in order for him to adapt its speed to avoid a collision with the immobilized TV.

Stability problem: in this use case a TV entering a slippery road area may partially or completely lose the traction. The objective of the LCRW application is to warn SVs approaching to the slippery road area based on the received CAM / DENM transmitted from the TV e.g. by analysing the yaw rate, Electronic Stability Program (ESP) status and/or Anti-lock Braking System (ABS) status of TV.

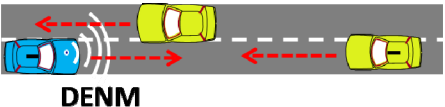
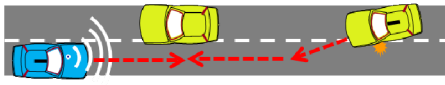
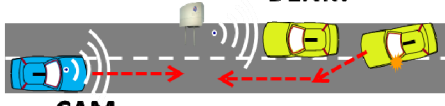
Collision risk warning from a third party: in this use case, the SV cannot perceive a risk of forward collision with the TV ahead due to radio obstacle. A third party ITS-S e.g. a road side ITS-S, a central ITS-S or another vehicle ITS-S, perceiving the risk of collision between the two vehicles may transmit "collision risk" DENMs as defined in [2]. Upon reception of such DENM, a SV driver should adjust the behaviour to avoid a forward collision. The road topologies that may benefit from this use case are for example:

- A curved road with radio obstacles, e.g. trees, building preventing direct communication between the SV and the TV.
- A road with altitude variations (slope) creating radio obstacle for direct V2V communications) between the SV and the TV.
- Intersections with a high accident risk. Specific detection means equipped at the intersection e.g. camera systems may detect collision risk between vehicles or between vehicles and obstacles e.g. pedestrians, then a road side ITS-S may transmit "collision risk" DENM.

5.1.2 Frontal collision risk warning

The considered use cases related to frontal collision risk warning are summarized in Table 2.

Table 2: Relevant use cases description for frontal collision risk

Use case	Scenario illustration
Wrong way vehicle driving	 DENM
Safety relevant vehicle overtaking	 DENM
Collision risk warning from third party	 DENM CAM

Wrong way vehicle driving: in this use case the SVs are the countersense vehicle and vehicle driving in the normal direction. The objective of the LCRW application is to warn SVs' drivers, in due time, for them to slow down or even to stop their vehicles in order to avoid a frontal collision.

NOTE 1: Use case scenario should be compliant to legal requirements of the implementation environment.

NOTE 2: The SV may be only the countersense vehicle, or the oncoming vehicles.

Safety relevant vehicle overtaking warning: in this use case the SV is signalling its intent to overtake a slow vehicle and detects a collision risk with an oncoming vehicle on the opposite traffic direction. The oncoming vehicle may also be SV and may achieve an action to avoid the frontal collision. The objective of the LCRW application is to warn the SVs' drivers to stay in lane or to break in order to avoid a frontal collision.

NOTE 3: Detailed scenario of the use case should be compliant to legal requirements of the implementation environment.

NOTE 4: The SV may be only the countersense vehicle, or the oncoming vehicles.

Collision risk warning from third party: in this use case, the SV cannot perceive a risk of frontal collision with an TV due to e.g. radio obstacles. In such cases, a third party ITS-S e.g. a road side ITS-S or vehicle ITS-S, perceiving the risk of collision may transmit "collision risk" DENMs as defined in [2]. Upon reception of such DENM, the SV driver may stop a dangerous manoeuvre creating the risk of a frontal collision. The road topologies which benefit from to such use case are for example:

- A curved road with radio obstacles, e.g. trees, building preventing direct communication between the SV and the TV.
- A road with altitude variations (slope) creating radio obstacles to direct V2V communication between the SV and the TV.
- Intersections with a high accident risk. Specific detection means equipped at the intersection e.g. camera systems may detect collision risk between vehicles or between vehicles and obstacles e.g. pedestrians, then a road side ITS-S may transmit "collision risk" DENM.

5.2 LCRW originating mode functionalities

The LCRW shall provide the originating mode functionalities as defined in the present clause.

5.2.1 CAM & DENM transmission

Vehicle ITS-S implementing the LCRW application shall be able to transmit CAMs [1] and DENMs [2]. The triggering of CAM is as specified in [1]. The triggering of DENM transmission is as specified in [4].

5.2.2 Interaction with other ITS-S layers

LCRW application may interact with functionalities of other ITS-S layers:

- Optionally, adjusting the CAM time interval if necessary.

NOTE 1: Mechanisms for CAM rate control by application is defined in annex A of the present document.

- Controlling DENM transmission.
- Inhibiting or enabling the ITS-S pseudonym change.

NOTE 2: Interaction with security entity is out of scope of the present document.

- Optionally, providing requirements to Decentralized Congestion Control.

NOTE 3: Interaction of DCC with application is out of scope of the present document.

- Informs lower layers of the priority level, if necessary.

NOTE 4: The priority level is assigned by LCRW receiving mode, according to the criticality of the traffic situation perceived by the ITS-S, based on received CAM and DENM. The priority level and traffic safety critical situation are defined in clause 5.3.1.

5.2.3 Longitudinal collision risk from a third party

A third party ITS-S (e.g. a Roadside ITS-S or a Central ITS-S) is an ITS-S that is not directly involved in collision risk but may have the capability to detect it between two or several other vehicles.

A third party ITS-S may detect a risk of collision between several vehicles using multiple means such as by processing receiving CAM/DENM from these vehicles, radars, cameras etc.

When a collision risk is detected, the third party ITS-S may transmit "Collision Risk" DENMs as defined in [2] to the concerned Vehicle(s) ITS-S.

This functionality may be particularly useful in situation where direct communication between vehicles is limited.

5.3 LCRW receiving mode functionalities

The LCRW shall provide the receiving mode functionalities as defined in the present clause.

5.3.1 Traffic safety critical situation evaluation

The LCRW application receiving mode should monitor the criticality of the traffic safety situation to detect a risk of collision and act accordingly. The evaluation of a the traffic safety situation may be realized by processing received CAM/DENM from other ITS-Ss. In one possible implementation, the lower the estimated TTC, the higher the criticality of the traffic safety situation. Based on estimated criticality, an LCRW application may adjust accordingly its priority level. The priority level of an ITS application denotes the application priority relative to other applications of the ITS-S.

For primary road safety applications as illustrated in Figure 1, three priority levels are defined in Table 3.

Table 3: Priority levels set by the LCRW receiving mode

Criticality of the traffic safety situation	Priority level
Normal or driver awareness situation	2
Warning situation (Driver assistance or automatic action)	1
Pre-crash situation	0

The priority level may be communicated to other layers e.g. facilities, network & transport, Decentralized Congestion Control and security entities in order to satisfy the data quality requirements of class A, in particular in critical traffic safety situations.

5.3.2 Issuing warning to vehicle driver

The purpose of LCRW is to warn the vehicle driver about the risk of an imminent longitudinal collision. The driver may be alerted to take an immediate action, e.g. brake or keep/change lane to avoid the collision.

With respect to Figure 1, a driver assistance warning should be triggered before the predicted collision. This predicted time to collision (TTC) may be calculated according to the following elements by processing the received CAM [1] and DENM [2]:

- The distance separating the SV and TV.
- The longitudinal alignment of the SV and TV.
- The speed of the SV and TV.
- The vehicle type, mass of SV and TV.
- The estimated driver reaction time, which may take into account driver state / capabilities.
- Known driver's manoeuvring intentions, e.g. overtake or turn of SV and TV.
- Known deteriorated weather conditions or road hazard situation which may reduce the visibility of the driver or the stability of the vehicle.

6 Application functional requirements

The LCRW application warning is issued to driver in receiving ITS-S. However, the application is relying on the performances of the originating ITS-S which are transmitting CAMs and DENMs.

The present clause provides functional requirements of LCRW (denoted as FRxxx).

A machine state diagram of one possible receiving mode LCRW implementation is provided by annex B of the present document.

6.1 Longitudinal collision risk detection requirements

FR001: When a safety critical traffic situation is detected and the need of alerting the driver is established, the application priority level shall be set to "1" or higher.

FR002: When the application priority level is set to "1" or higher, application may request security to block the pseudonym change in order to avoid a temporary loss of the target vehicle.

FR003: For estimation of the longitudinal collision risk, the situation assessment shall be carefully performed regarding all relevant factors, e.g. the longitudinal alignment or the potential longitudinal alignment between the SV and TV.

NOTE 1: Longitudinal alignment of vehicles may require a certain level of positioning accuracy or map database.

NOTE 2: In case of insufficient positioning accuracy or no confidence in any positioning accuracy, the longitudinal alignment may be verified by positioning the SV and TV in lanes they are respectively located.

NOTE 3: If vehicle ITS-S is able to estimate the lane position with the required level of confidence. The longitudinal alignment of SV and TV may be verified by comparing its own lane position with the TV's lane position for the estimation of a longitudinal collision risk.

FR004: According to the situation assessment, the SV shall analyze a risk of longitudinal collision with TV. This may be realized by monitoring of relative distances and speeds between itself and the TV.

NOTE 4: LCRW application may stop the monitoring of the TV based on the situation assessment of relevant factors e.g. if the SV and TV is not any more longitudinally aligned. This may be detected by verifying the changing of itinerary of SV and TV. The changing of vehicle itinerary may be indicated by e.g. direction lights activated, the yaw rate or the steering wheel angle evolutions.

6.2 Warning triggering requirements

FR005: LCRW shall be able to trigger a warning to the driver by e.g. interaction with in vehicle human machine interface (HMI).

The warning triggering time may consider distance and TTC to the predicted collision. An example is described in annex C of the present document.

Recommendations on the warning presentation are provided in annex E of the present document.

6.3 Third party ITS-S warning functional requirements

A third party ITS-S e.g. an authorized road side ITS-S implementing the LCRW application shall satisfy the same receiving mode functional requirements as vehicle ITS-S as defined in clause 6.1.

NOTE: A third party ITS-S may not need to have the warning capabilities as described in clause 6.2.

For originating mode, a third party ITS-S shall satisfy the following requirements:

FR006: The LCRW application shall be able to trigger the transmission of "collision risk" DENM transmission.

FR007: The LCRW application shall be able to provide all required information for the generation of "collision risk" DENM, as defined in [2].

FR008: The third party ITS-S application shall request the termination of DENMs transmission upon detection of the collision risk disappearance.

FR009: The DENM data setting rules as defined in Table 4 shall apply to LCRW application of the third party ITS-S. Detailed requirements on interface between application and the DEN basic service are provided in [2].

Table 4: Data elements to be provided to the DEN basic service

Cause Code		
Data	Description	Mandatory (M) or Optional (O)
LCRW_CauseCode value	Collision Risk	M
Sub Cause Code		
Data	Description	Mandatory (M) or Optional (O)
LCRW_SubCauseCode value	One of: 0 Unavailable, 1 Longitudinal collision risk, 2 Crossing collision risk, 3 Lateral collision risk, 4 Collision risk involving vulnerable road user, 5 Frontal collision risk.	M
Traces		
Data	Description	Mandatory (M) or Optional (O)
Traces	Historical path of SV Historical path of TV	O (see note)
NOTE: The position of an application relative to the TTC are illustrated as examples. Exact TTC numbers are out of scope of the present document.		

7 Application operational requirements

The present clause defines the operational requirements of the LCRW in a normal driving situation (denoted as ORxxx). In case of bad weather conditions the operational requirements of LCRW may be adjusted to keep the necessary safety margins accordingly. Bad weather conditions may be known through the reception from other ITS-Ss of relevant DENMs.

7.1 Security and reliability requirements

The LCRW application design may consider the following failure situations in order to be fault tolerant:

- The issuing of a warning when no collision risk is detected (fail jabbering mode).
- The generation and transmission of "collision risk warning" DENM which does not correspond to collision risk.
- The interruption of processing the received CAMs and / or DENMs (fail silent mode).
- The abnormal silence (fail silent mode) of the LCRW application not warning the driver of a detected collision risk.

The security functionalities have impact on the overall system performance in terms of processing time, processing capacity, etc. Such impact may not be negligible for LCRW application operation, in which the Maximum Latency Time should be respected in order to provide warning to driver in time.

OR001: In between each pseudonym update, CAM and DENM generation shall use a common pseudonym.

NOTE 1: This allows LCRW application to properly detect the risk of longitudinal collision by processing CAM and DENM from the same TV.

OR002: The priority level of LCRW application may be used to properly manage the processing, storage, communication resources of the ITS-S in order to ensure the normal operation of the LCRW application.

OR003: In case of a detected abnormal behaviour of the LCRW application, the LCRW application shall not trigger any warning to user.

NOTE 2: In case of detected LCRW failure, an information may be presented to the driver.

7.2 System minimum performance requirements

7.2.1 Longitudinal alignment and vehicle position accuracy

One of the important factors of longitudinal collision risk estimation is the estimation of longitudinal alignment between SV and TV.

Figure 4 presents examples of false positive warning and false negative warning scenario for the emergency electronic brake light use case in which the longitudinally alignment of SV and TV is not properly perceived.

Figure 5 presents examples of false warning and false absence warning scenarios for the safety relevant lane change use case in which the longitudinally alignment of SV and TV is not properly perceived in case of a lane change of the SV.

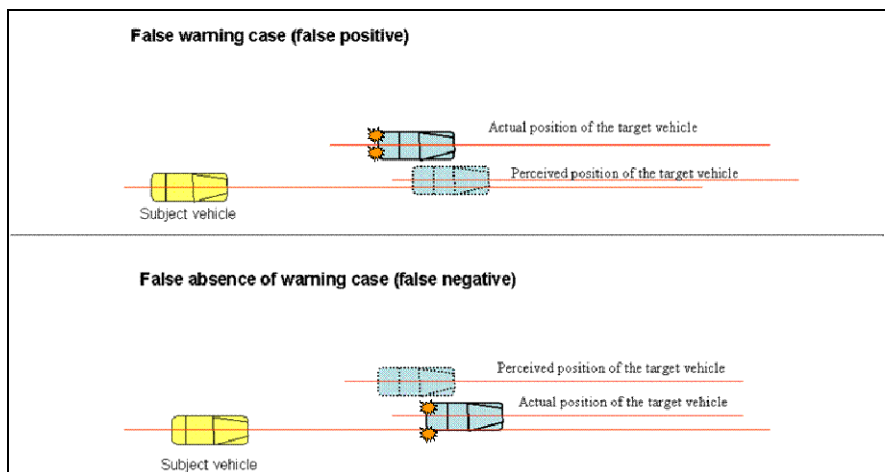


Figure 4: Errors on the longitudinal alignment: emergency electronic brake use case

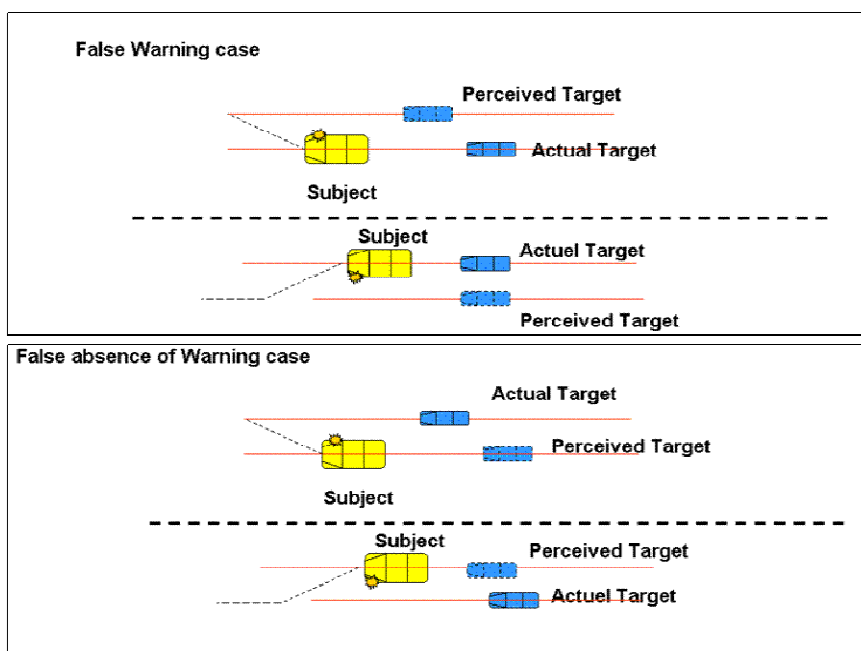


Figure 5: Errors on the longitudinal alignment: safety relevant lane change use case

OR004: The confidence level for the estimation of the actual or potential longitudinal alignment between SV and TV shall be at least 95 %.

NOTE 1: This level of confidence may be reached through combination of several means (vehicle positioning, path history, vehicles position in lanes, etc.).

OR005: In case position is used for longitudinal alignment estimation, the vehicle position accuracy shall be equal or less than one meter with a confidence level of 95 %.

NOTE 2: In case this accuracy requirement cannot be fulfilled, longitudinal alignment estimation may be realized by comparing lane position of TV and SV.

OR006: When receiving a DENM, the LCRW receiving mode shall verify if the trajectory and heading of the vehicle will intersect with the relevance area in received DENM.

OR007: When receiving a "roadworks" DENM, the LCRW receiving mode may verify if it is running in a lane which is identified as being under work.

7.2.2 Communication coverage

OR008: The required communication range of a TV shall be set to 300 meters in a line of sight situation and when the channel load is at relaxed state, in order to enable the detection of a TV on time even when it is running at high speed.

OR009: When the used G5A channels are not congested, the current transmit power level requirements measured at the antenna level shall be at least 18 dBm.

The required communication range may be reduced in certain situation e.g. if the traffic around is slow e.g. less than 50 km/h, or in channel congested situation.

7.2.3 System end to end latency time

OR010: Performance class A system as defined in clause 4 shall be used for LCRW.

In a critical safety situation, the latency time T4 - T6 of 80 milliseconds as defined in clause 4 may be required.

7.2.4 Message processing performance

OR011: Vehicle ITS-S shall be able to decode and process the received CAM and DENM.

OR012: A conforming ITS-S shall be able to process at least 1 000 CAM and DENM per second. This corresponds realistically to the maximum of messages which can be transmitted in CCH of the G5 technology every second.

NOTE: The processing can be very basic consisting just to keep the messages which are relevant according to the traffic safety context. Security strategy can be adjusted in case of high messages rate e.g. validate on demand.

7.2.5 Congestion control for G5A

In case G5A is used for CAM/DENM transmission, the following requirements apply:

OR013: If the application priority is set to "1" or higher, CAM and DENMs shall be sent with a DCC Profile that minimize impact to the transmission interval in a congested state.

POTE 1: The Decentralized Congestion Control system for G5A may take into account the traffic velocity when acting on the transmission power control.

NOTE 2: In case a low traffic density in local lane, the required communication range of a TV may be set to 200 meters in a line of sight situation when the channel load is congested.

NOTE 3: If the traffic velocity is low e.g. less than 50 km/h around the vehicle, the transmit power control may be adjusted at its lowest acceptable value.

7.3 Third party ITS Station system performances requirements

A third party ITS-S e.g. an authorized road side ITS-S implementing the LCRW application shall satisfy the same operational requirements as vehicle ITS-S as defined in clauses 7.1 and 7.2.

OR014: A conforming third party ITS-S shall be able to process at least 1 000 CAM and DENM per second. This corresponds realistically to the maximum of messages which can be transmitted in CCH of the G5 technology every second.

NOTE: The processing can be very basic consisting just to keep the messages which are relevant according to the traffic safety context. Security strategy can be adjusted in case of high messages rate e.g. validate on demand.

OR015: When the priority level is set to "1" or higher, the LCRW application shall set the DENM transmission interval or repetition interval to 100 milliseconds.

Annex A (informative): CAMs interval adjustment based on critical safety situation

Multiple approaches are possible to adjust dynamically the CAMs interval:

- 1) Adjustment by the CA basic service based on the highly dynamic data evolutions of the originating vehicle ITS-S perception as specified in [1].
- 2) Adjustment by the road safety applications of the ITS-S, based on the perception of the criticality of the traffic safety situation around the vehicle ITS-S.

The option 1) may not take into account some particular critical traffic safety situations. For example, when a vehicle is moving slowly (stopped) without significant dynamic evolutions, it will result in a decrease of CAMs interval to 1 Hz, even when a critical traffic safety situation is observed with at least one of its neighbour ITS-Ss driving at high speed. For such situation, CAMs transmitted by this slow moving vehicle may not be received by other ITS-Ss in time, in order to take necessary actions to avoid potential collision risk.

The alternative solution 2) may be used to cover the above mentioned situation, taking into account the overall traffic situation perceived by ITS-S. In this solution, the ITS-S safety application may detect a critical traffic safety situation (e.g. through the monitoring of TTC with its neighbours) and then may request an adjustment of the CAMs interval accordingly. For example, an ITS application may request that the CAMs interval remain at its lowest value (100 ms or lower) as long as the priority level is set to "1" or higher.

It has been decided at ETSI TC ITS WG1 to pursue the study of solution 1 especially for some particular critical traffic safety situations, and keep the possibility in a future release of CA basic service to update the CAMs interval adjustment policy taking also into account the solution 2 or other solutions.

Annex B (informative): LCRW application state machine

Figure B.1 shows the state machine for an example of the receiving mode LCRW application implementation.

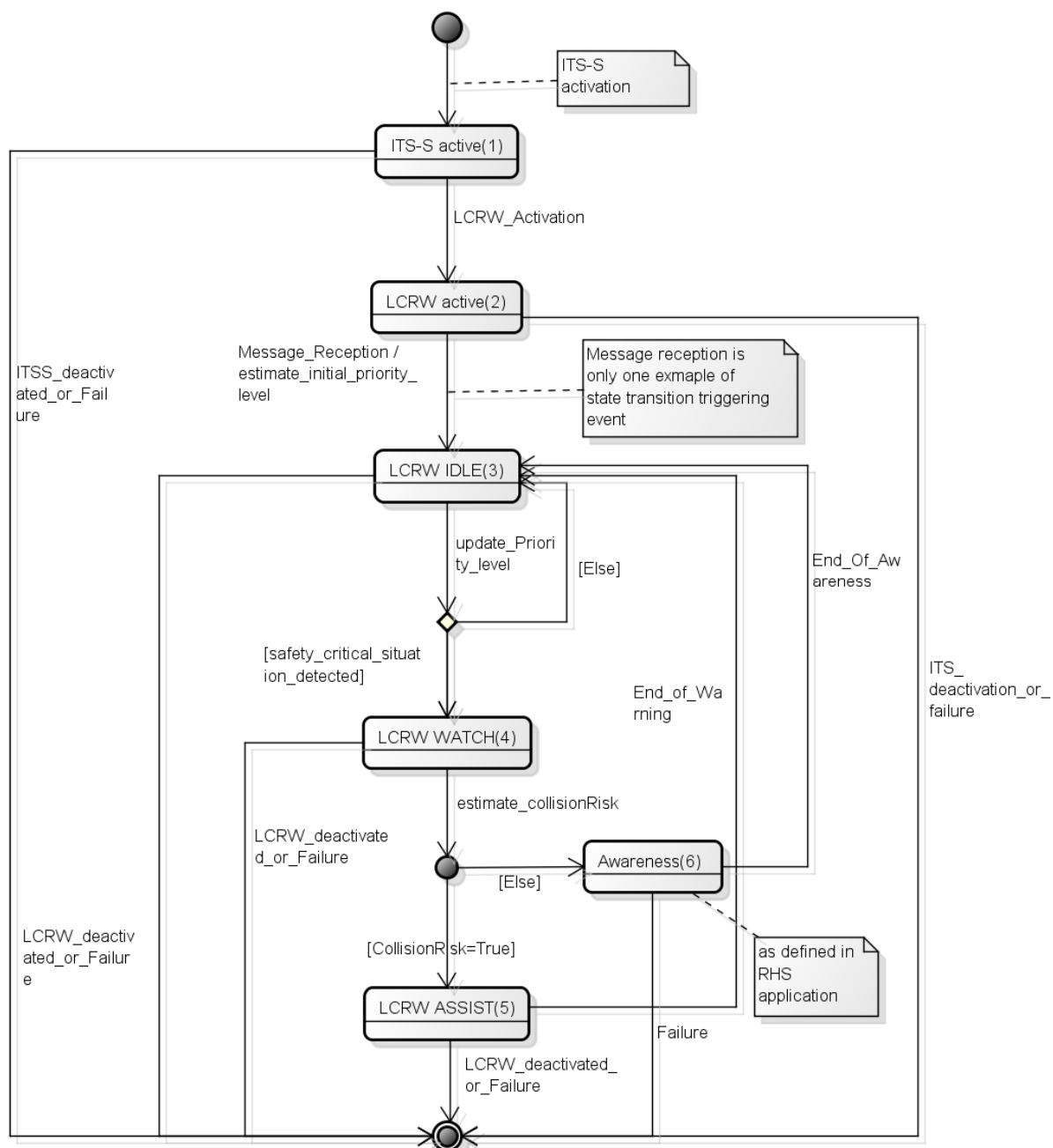


Figure B.1: LCRW application state machine example

In this implementation example of the LCRW application receiving mode functionalities, the following machine states are defined:

- ITS-S active (1): The ITS-S is activated.
- LCRW active (2): The LCRW application is activated. The application has finished the initialization phase. During this phase, all required functionalities of the application and facilities layer are activated, as well as their interfaces.

- LCRW IDLE (3): At the reception of the first CAM/DENM after the activation, the LCRW application starts evaluating the traffic safety critical situation and set a priority level. This may be realized by monitoring the movements of the ego vehicle and compares it to the movement of neighbour vehicles. In this state, no collision risk is detected.
- LCRW WATCH (4): The LCRW application detects a critical traffic safety situation with a target vehicle. It is watching carefully the evolutions of the SV and the TV to estimate the TTC. In this state the application priority level is set to "1".
- LCRW ASSIST (5): The application is assisting the driver to avoid a collision. A warning is issued to driver. This state is triggered when a collision risk with a TV is confirmed. In this state, the application priority level is set to "1" until the critical safety situation has been eliminated. If appropriate driver action has not been taken, the application priority level may be set to "0" when TTC continues to decrease and SV enters the "pre-crash" phase with TV.

State transitions are defined as follows:

- (Start to 1): The ITS-S is activated.
- (1 to end): ITS-S is deactivated or failure of ITS-S.
- (1 to 2): LCRW is activated. For a Vehicle ITS-S, the LCRW application may be activated as long as the ITS-S is active.
- (2 to 1): LCRW is deactivated or fault condition.
- (2 to end): ITS-S is deactivated or failure of ITS-S.
- (2 to 3): First CAM or DENM is received.
- (3 to end): LCRW is deactivated or fault condition.
- (3 to 4): Safety critical traffic situation is detected. Accurate watch of vehicle trajectory is required. In this example, the safety critical traffic situation is determined using a safety shield concept. The safety shield concept is presented in annex D of the present document.
- (3 to end): LCRW is deactivated or fault condition.
- (4 to 5): Longitudinal collision risk is detected.
- (4 to 6): Road hazard is relevant to the SV but no collision risk is detected, an information is provided to driver as defined in [3].
- (5 to 3): End of warning.
- (6 to 3): End of awareness.
- (5 to end): LCRW is deactivated or fault condition.
- (6 to end): LCRW is deactivated or fault condition.

Annex C (informative): Minimum time for warning issuing

The minimum time required for triggering of a driver warning may be derived with the following equation:

$$DWT_{min} = MLT + MDRT + MAT + \text{Margin}$$

DWT_{min} denotes minimum required TTC to avoid a collision. It may include a margin time in order to e.g. compensate the position error of SV and TV.

The time elements for DWT_{min} calculation are indicated in Figure C.1. Certain time elements requirements are given in [i.6].

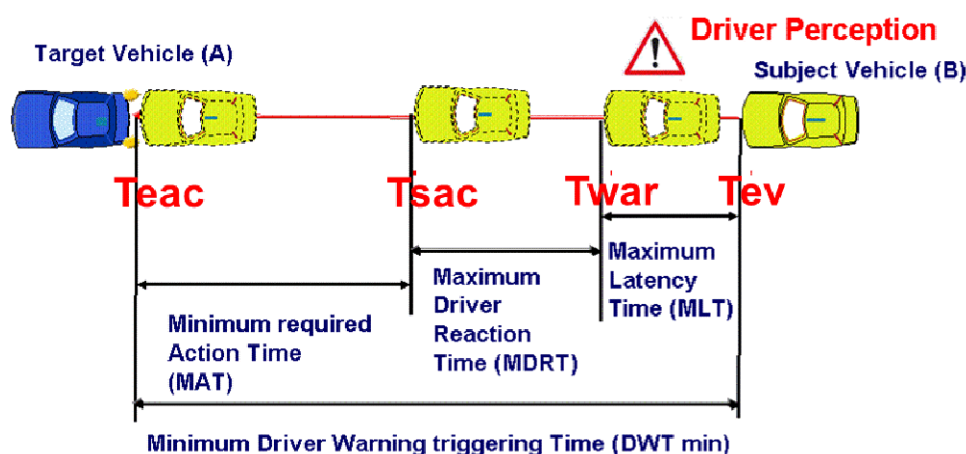


Figure C.1: Timing elements to take into account to avoid a collision

T_{ev} denotes time at which vehicle data of TV is available for CAM/DENM generation. It corresponds to T_0 as defined in Figure 2.

NOTE 1: In case of a third party warning, T_{ev} denotes time at which the third party ITS-S detects SV and TV.

T_{war} denotes time at which a LCRW warning is issued to driver. It corresponds to the T_6 as defined in Figure 2.

Total system maximum end to end latency time (MLT) denotes difference between T_{ev} and T_{war} . It corresponds to $T_6 - T_0$ as defined in clause 4. It may be set to 300 ms.

T_{sac} denotes time at which SV's driver starts collision avoidance action.

Minimum Driver Reaction Time (MDRT) denotes difference between T_{war} and T_{sac} . It corresponds to the time required for driver to perceive, interpret, and take corresponding action on the warning.

NOTE 2: The MDRT depends on driver capabilities and vigilance level.

T_{eac} denotes time at the collision avoidance action is finished.

Minimum required Action Time (MAT) denotes the difference between T_{sac} and T_{eac} . It corresponds to the time for SV to undertake collision avoidance action.

NOTE 3: MAT is impacted by the deceleration capabilities of the two vehicles and other variables such as their masses and the driver braking behaviour. The MAT estimation is under the responsibility of OEM. Margin takes into account some possible positioning errors and some processing time.

Annex D (informative): Safety shield concept

A possible method for detecting potential collision with TV is "Dynamic Safety Shield" concept. This method has been validated by the SAFESPOT research project. This concept is illustrated in Figure D.1.

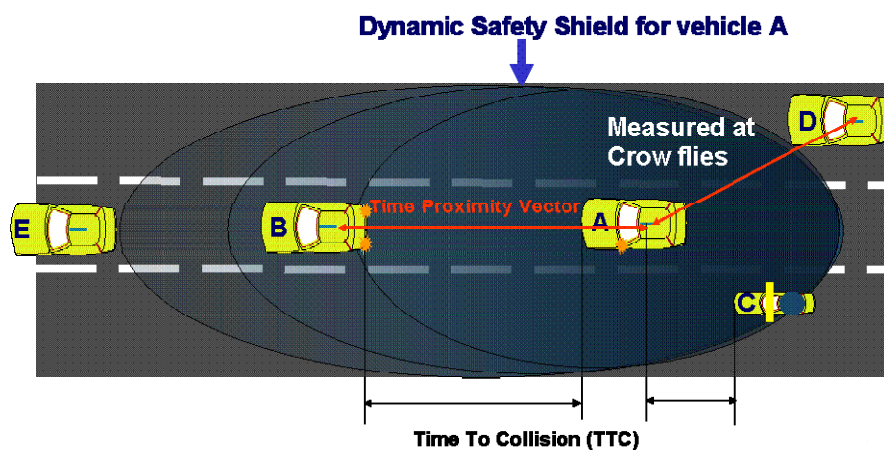


Figure D.1: Safety Shield concept

In this concept, when a SV (vehicle A) detects that a TV is within a predefined TTC threshold, this TV is located inside the dynamic safety shield of the SV.

The predefined TTC threshold should be equal or higher than DWT_{min} as defined in annex C.

A dynamic safety shield is a virtual dynamic area surrounding the SV. The size of this field is dynamically estimated by the SV as the TTC between the SV and TV. The TTC is estimated as the distance between SV and TV divided by the relative speed of these two vehicles along the bird view vector between the TV and SV. When a TV is detected to be inside the safety field of SV, the LCRW application enters the LCRW WATCH (4) state as defined in annex A.

Then, the following conditions are further checked:

- The SV and TV are longitudinally aligned or will be longitudinally aligned.
- The relative speed of SV and TV is equal or higher than a threshold.

If the two above conditions are true, the LCRW application may enter the LCRW ASSIST (5) state, a warning request is issued by the LCRW application to HMI device of SV.

Annex E (informative): Warning presentation recommendations

A vehicle ITS-S detecting a risk of collision has to warn the driver in time in order to start appropriate action to avoid the collision.

On the other hand, as multiple applications may be cohabitating in a given Vehicle ITS-S, it could be necessary to include an arbitration function (in HMI support for example) in order to manage the information provided to driver. A driver warning delivery should limit the distraction to driver, in particular in critical safety situation. Following non-exhaustive aspects may be considered for warning management:

- Distance separating the subject vehicle from the road hazard
- Speed of the subject vehicle
- Confidence level in the received information
- Started drivers actions
- Consistency of the simultaneous requests
- Possibility to merge several requests into one consistent assistance advice

Collision risk may be presented to the vehicle driver in the means of vehicle warning. The presentation of warning may be realized by a visual signal, audible signal, haptic warning or direct action on autonomous braking system. Warning presentations may apply requirements as provided by [i.6].

NOTE 1: The visual information is particularly necessary in case of noisy environment and for hearing impaired drivers.

When used, an audible warning tone should be easily heard.

NOTE 2: In case of similar warning issued by different sources, it is left to the OEM or equipment supplier to ensure the consistency and efficiency of the resulting warning.

The warning starting and ending time is at the discretion of vehicles manufacturers. The warning starting time should not be later than DWT_{min} as defined in annex C.

In case of a LCRW application failure, an information may be provided to driver. This signalling is at the discretion of vehicles manufacturers.

Annex F (informative): LCRW application interfaces

This annex presents an example of the main facilities functions and other applications that may be interfaced with the LCRW application, as illustrate in Figure F.1.

NOTE 1: Application interfaces are implementation dependent.

NOTE 2: An interface may be standardized, in order to enable development of hardware/software modules from suppliers.

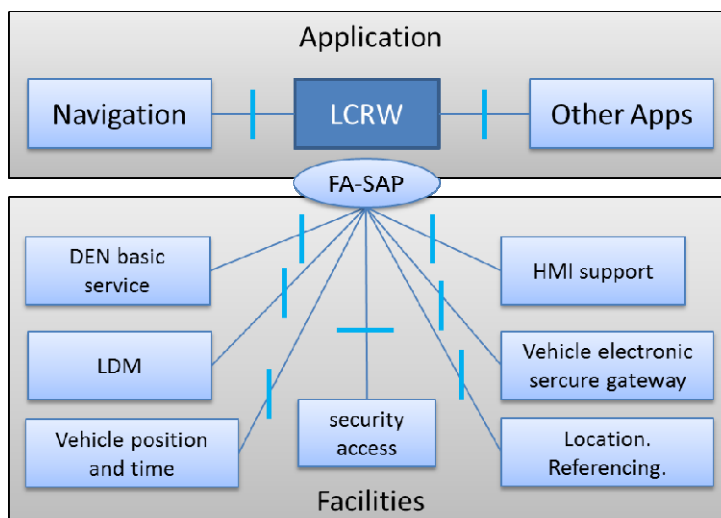


Figure F.1: LCRW application interfaces (example)

- The map matching functionality of the navigation application may be invoked by LCRW SV and TV on a digital map in order to estimate if the trajectories of the two vehicles may cross with each other.
- LCRW application may invoke the location referencing facility in order to improve the positioning perception of SV and TV within the road topology.
- The LCRW application may retrieve information of TV from Local Dynamic Map.

NOTE 3: LDM is specified in [i.7].

- The LCRW may invoke the interface provided by the DEN basic service for the transmission of DENM.
- When a collision risk is detected, the LCRW sends a request to HMI support to issue a warning to driver. The HMI support may include some arbitration function to manage the HMI information, as described in annex E.
- The LCRW application may restrict the pseudonym change via the security access while being in the "WATCH" and "ASSIST" states.
- The LCRW may access some other ADAS functions, e.g. a lane keeping / lane departure camera in order to verify the longitudinal alignment of the subject vehicle with the target vehicle.

NOTE 4: Facilities Layer functional architecture and functional description of facilities layer entities are specified in [i.8].

Annex G (informative): G5 based exchange profile for LCRW

LCRW application may rely on G5 communication and BTP/GeoNetworking protocol stack for communication between ITS-Ss.

In an example communication profile as illustrated in Figure G.1. The following communication profiles are used for CAM and DENM:

- CAM is generated by CA basic service of TV, then transmitted over BTP/GeoNetworking protocol stack. Single Hop Broadcasting (SHB) protocol is used for CAM dissemination. CAM packet is transmitted over Control Channel of ITS G5A.
- DENM is triggered by LCRW application of TV, and constructed by the DEN basic service of TV. DENM is transmitted over BTP/GeoNetworking protocol stack. Geo Broadcasting (GBC) protocol is used for DENM dissemination. DENM packet is transmitted over Control Channel of ITS G5A.
- CAM/DENM security processing is realized by GeoNetworking layer entity. End to end security is supported.

NOTE: Security processing for BTP/GeoNetworking stack is specified in [i.9].

This profile setting is implemented by the European Field Operational Test project DRIVE C2X.

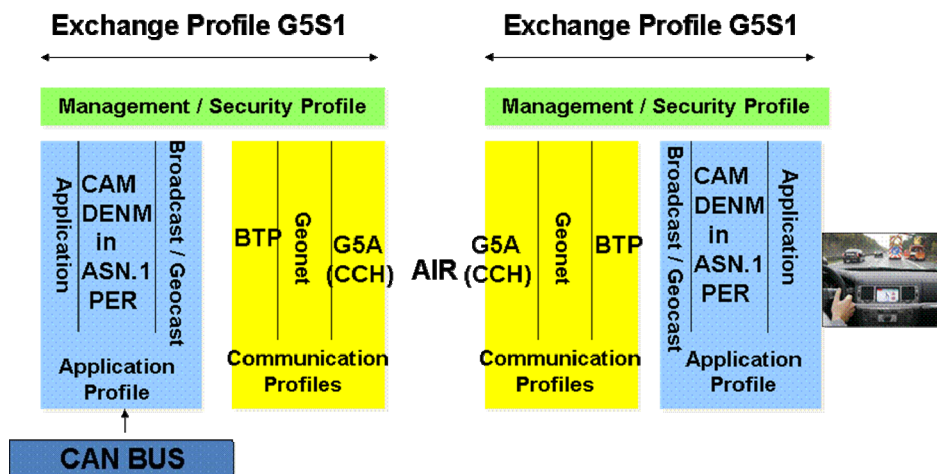


Figure G.1: Example of an exchange profile based on G5A used for LCRW

Annex H (informative): Bibliography

Directive 2010/40/EU of European parliament and the council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport.

Mandate M/453: Co-operative systems for Intelligent Transport in the field of information and communication technologies to support interoperability of cooperative systems for intelligent transport in the European Community.

History

Document history		
V1.1.1	November 2013	Publication