Project Specific Technical Specification

Transport and Main Roads
PSTS013 ARLW Use Case Specification – Advanced Red Light Warning

October 2021

Queensland Government

Document control sheet

Contact for enquiries and proposed changes

If you have any questions regarding this document or if you have a suggestion for improvements, please contact:

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Version history

Version no.	Owner	Date	Nature of amendment
1.0	David Alderson	29/06/2018	Tender Issue
1.1	Kathy Mosley/ David Alderson	18/3/2019	Update to REQ_PSTS013_021
1.2	David Alderson	06/07/2019	Updates to match learnings from implementation
1.3	Zinah Tam	27/07/2020	Updated Table 7.2 to match final incorporation of HUET recommendations
1.4	Zinah Tam	06/10/2020	Updated Table 7.2 to match release 25.2
2.0	Nicholas Brook	28/01/2021	Final updates and adapt for external release
2.1	Jian Qin	06/10/2021	Overall System Architecture drawing update

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Contents

1 Introduction

The Advanced Red Light Warning (ARLW) use case specification is intended to provide future use case developers (including V-ITS-S vendors) with details of the Ipswich Connected Vehicle Pilot (ICVP) implementation as a guide. As use cases are expected to fall within the remit of original equipment manufacturers (car, application or device developers) it has been adapted from a prescriptive set of requirements for the pilot, to an example of potential operation within any future Cooperative ITS eco-systems. These are also not to be used directly as a specification for other Transport and Main Roads projects or integration, as they will either be adapted to be project specific or ratified and released as a formal Department Specification.

This specification includes:

- Objectives, general operation and applicable scenarios;
- System components and data flows;
- Life cycles;
- High level HMI requirements;
- Data and message examples; and
- Data definitions.

2 Definition of terms

Table 2.1 – Acronyms

Acronym	Term
ARLW	Advanced Red Light Warning
ASN.1	Abstract Syntax Notation One
CA	Conflict Area
C-ITS	Cooperative intelligent transport systems
C-ITS-F	Central ITS facility
DWT	Driver Warning Trigger
ETSI	European Telecommunications Standards Institute
EU	European Union
FOT	Field operational test
HMI	Human machine interface
ITS	Intelligent transport systems
MAP	Cooperative ITS message, broadcasting geography/topology of intersection
MAPEM	MapData extended Message
PDU	Protocol Data Unit
PSTS	Project Specific Technical Specification
R-ITS-S	Roadside ITS station
RTK	Real Time Kinematic
SCMS	Security credential management system
SPaT	Signal phase and timing (cooperative message)
SPATEM	Signal Phase and Timing Extended Message
TSC	Traffic Signal Controller
TTA	Time to Action
TTE	Time to Event
UPER	Unaligned Packed Encoding Rules

Acronym	Term
V-ITS-S	Vehicle ITS station
XML	eXtensible Markup Language

Table 2.2 – Definitions

Acronym/Term	Term Description
3G/4G	Cellular wireless network provided through a telecommunications company. 3G is the 3rd generation data network, 4G the fourth and LTE stands for Long Term Evolution.
AUSCORS	Australian Continuously Operating Reference Stations- the way that the NTRIP data is broadcasted by Geoscience Australia.
FOT	Field Operational Test – the period when the in-vehicle C-ITS systems are operational and logging data
HMI Presentation manager	Function of the V-ITS-S that arbitrates the information presentation requests to the HMI device
Monitoring system	Sub-system of the C-ITS-F that monitors the operation of the C-ITS Pilot system
STREAMS	TMR's integrated ITS operating platform

3 Reference documents

Table 3.1 – Referenced documents – External

Document ID	Document Name / Description
ISO/TS 19091:2017	Intelligent transport systems - Cooperative ITS - Using V2I and I2V communications for applications related to signalized intersections
ETSI TS 101 539-1 V1.1.1 (2013-08)	Intelligent Transport Systems (ITS); V2X Applications; Road Hazard Signalling (RHS) application requirements specification
ETSI TS 101 539-3 v1.1.1 (2013-11)	Intelligent Transport Systems (ITS); V2X Applications; Longitudinal Collision Warning (LCRW) application requirements specification

Table 3.2 – Referenced documents – Internal

Document ID	Document Name / Description
PSTS002	V-ITS-S Equipment
PSTS003	HMI Equipment
PSTS005	R-ITS-S Equipment
PSTS006	Data Entity
PSTS007	C-ITS Station Protocol Specification

4 Quality system requirements

4.1 Test Acceptance Criteria

Vehicle ITS Station (V-ITS-S) and Roadside ITS Station (R-ITS-S) devices shall demonstrate compliance to this specification in accordance with the test acceptance phases defined the *V-ITS-S Specification PSTS002* and *R-ITS-S Specification PSTS005*.

For each requirement, the selected test plan/s shall include criteria that clearly define how each requirement is met to the reasonable satisfaction of the Principal. Where appropriate, testing plans shall include:

1. Consideration of the primary scenarios identified in this specification and other scenarios identified by the Contractor or Principal.
2. Consideration of the sample SPATEM and MAPEM provided in the sample data pack and other Contractor or Principal defined sample data. Sample data is provided in the following encoding formats:
    a. JSON
    b. ASN.1 value notation
    c. XML
    d. UPER

5 Overview

The Advanced Red Light Warning (ARLW) use case provides a warning to a driver of a cooperative vehicle when they are likely to violate a red light at a signalised intersection. The aim is to allow drivers to safely stop in advance of the intersection conflict area (as denoted by the stop bar), and therefore reduce the occurrence of red light violations and resulting incidents in the conflict area.

The roadside equipment must broadcast the geometry (MAPEM) and the state and timing (SPATEM) of the intersection[1]. The vehicle must use its own (ego) position with lane level accuracy and confidence to determine which lane it is in relative to the intersection geometry. The vehicle subsequently uses its ego trajectory and its current lane's signal group to calculate the state of the relevant lights when the vehicle is likely to cross the stop bar. The V-ITS-S generates an ARLW warning that displays on the HMI on the approach to the intersection if the V-ITS-S determines the relevant signal group will be red and the vehicle trajectory will have it entering the conflict area during this red state.

Out of scope for the ALRW use case are warnings in similar use cases such as:

1. Attempt to warn surrounding cooperative vehicles of an ALRW event
2. Attempt to assess potential red light conflicts based on the movements of other vehicles.

[1] SPATEM and MAPEM are ETSI extended SPAT/MAP messages with a specific ETSI header. Thus, except for the ETSI header, the data frames and elements are interchangeable.

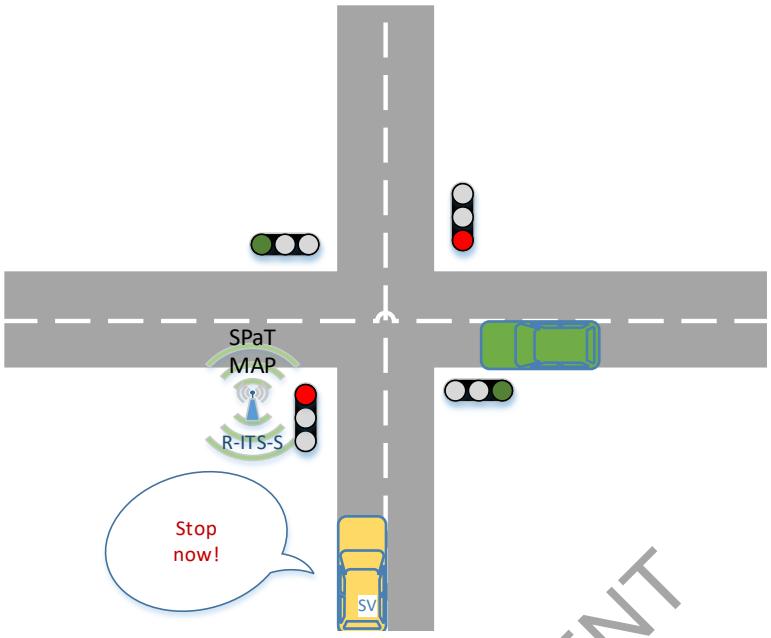


Figure 5.1 – ARLW operation

Requirement: The ARLW application shall identify if its own (ego) vehicle will drive through a traffic intersection while on a red signal and warn the driver to brake.

Requirement: The ARLW application shall process SPATEM at 100ms and MAPEM at 500ms for each R-ITS-S in range.

Requirement: The ARLW application shall identify and process SPATEM and MAPEM from up to 3 surrounding intersections at once. The most relevant intersection based on location and direction of travel shall have the highest priority when generating HMI warnings.

5.1.1 Primary Scenario

The vehicle approaches a signalised intersection, it recognises which lane it is in (from ego position compared to MAPEM) and determines during its approach that the vehicle will pass the stop bar (enter the conflict area) while the signal group relevant to its lane is red when unsafe (configurable value) braking is applied.

The V-ITS-S receives intersection information and the ARLW application determines the time required to stop the vehicle at a predetermined comfortable deceleration rate and the likelihood of exceeding this deceleration rate and entering the conflict area in a red phase. If V-ITS-S calculates the vehicles trajectory will require braking above the deceleration threshold, a HMI warning will be issued to the driver.

The vehicle will display HMI warnings in an escalating style with increased urgency indicated by warning image, wording and audio. The escalation logic is justified further in *PSTS003.*

The vehicle continues to display the HMI warning until the ARLW event is no longer appropriate. The ARLW event ceases to be appropriate when:

- Vehicle has passed through the conflict area, or
- Vehicle brakes sufficiently below the deceleration threshold, or
- Vehicle speed drops below speed clear, or
- Vehicle leaves the lane with a red signal (for example; into turn lane or side street), or
- Signal changes state, will not be red when entering the conflict zone (for example, turned to green or unavailable).

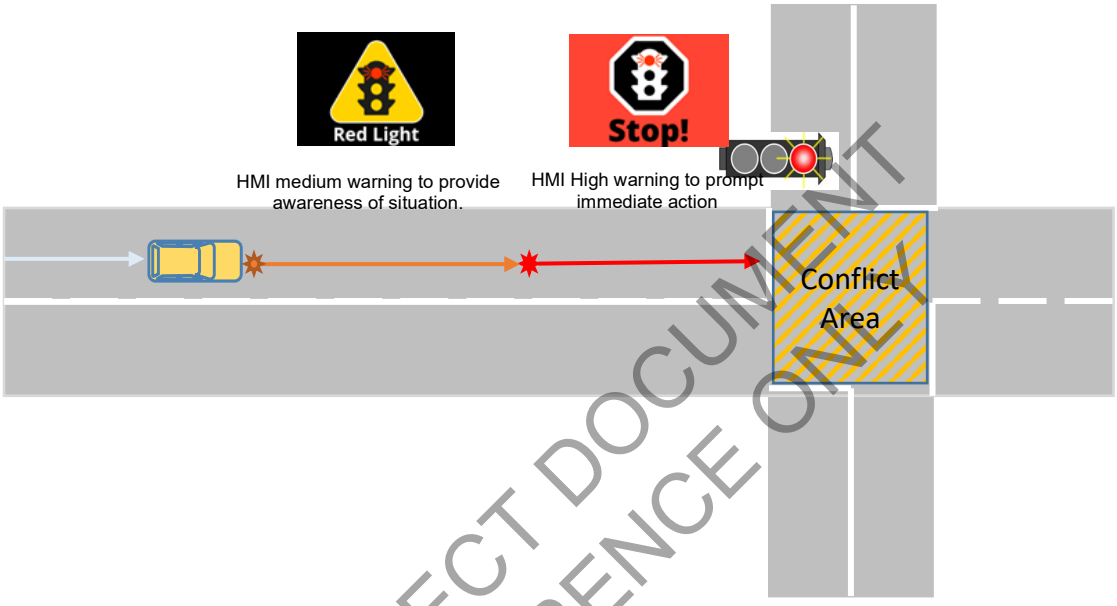
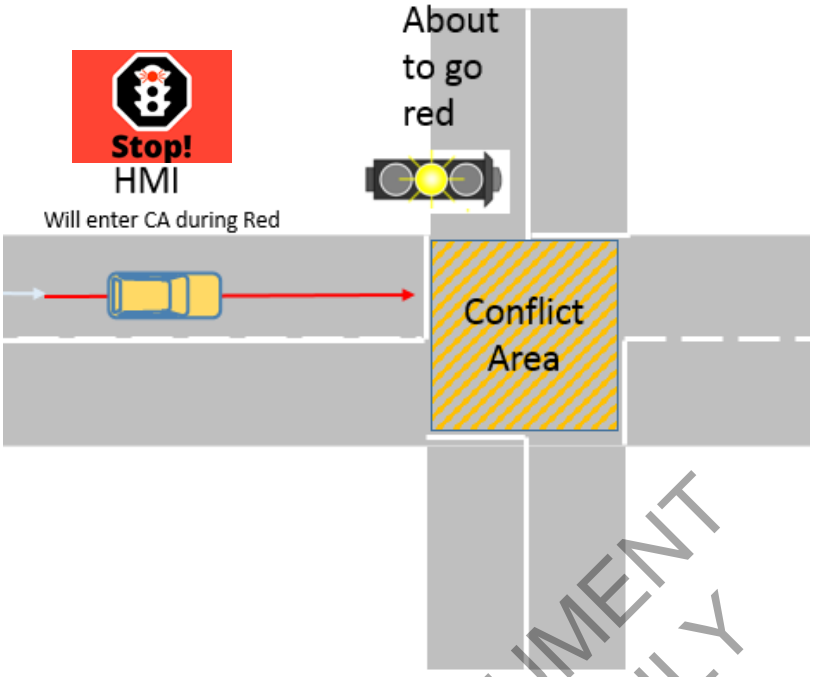
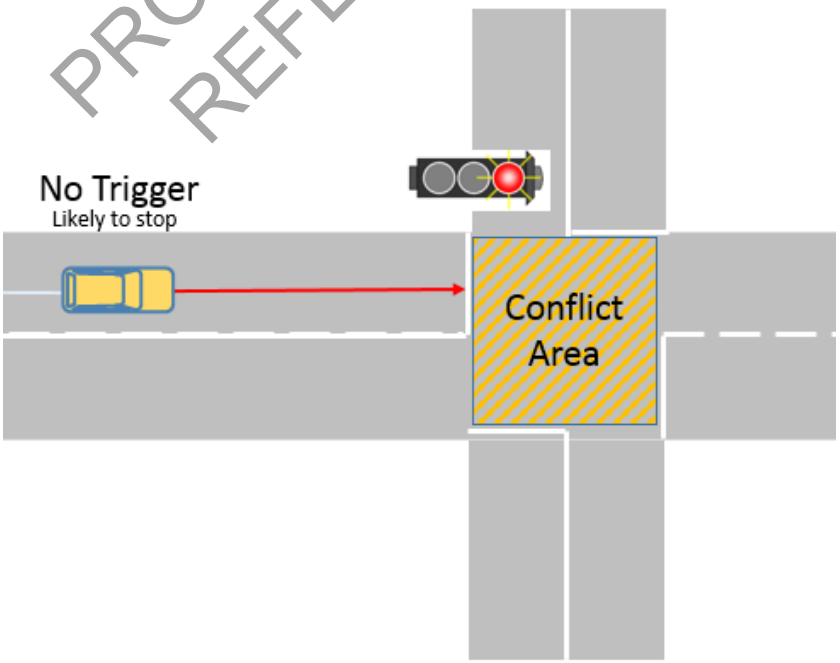


Figure 5.2 – Advanced Red Light Warning

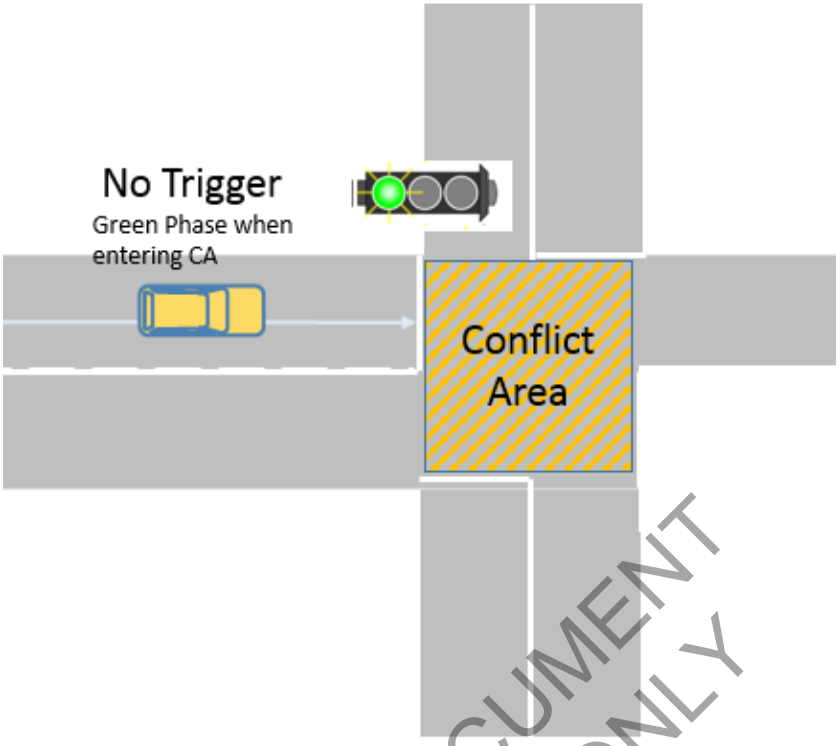
5.1.2 Scenario Equivalents

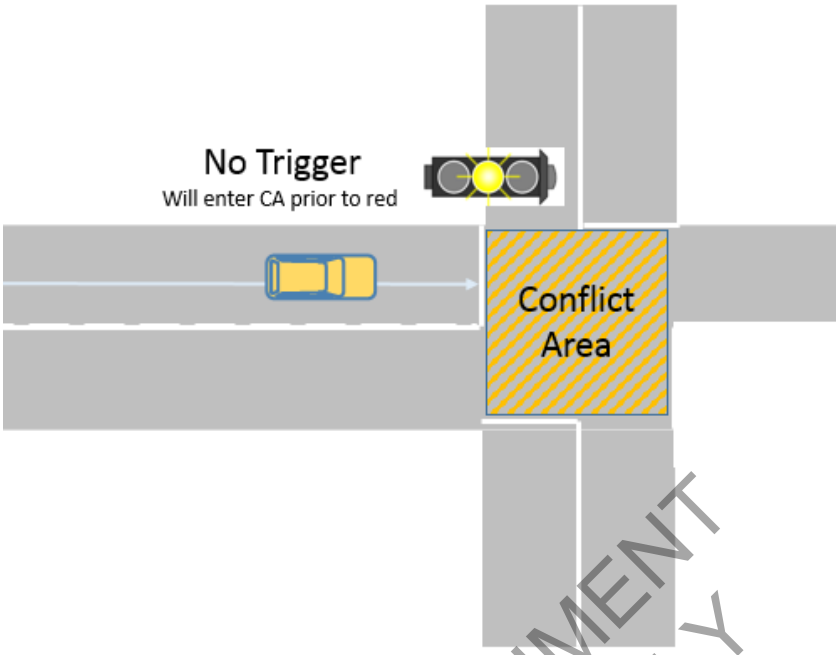
The following table describes the same primary scenario above but with several variants and the expected outcome. In each scenario, the V-ITS-S receives the MAPEM and SPATEM in advance of the intersection approach (as soon as in range of the R-ITS-S).

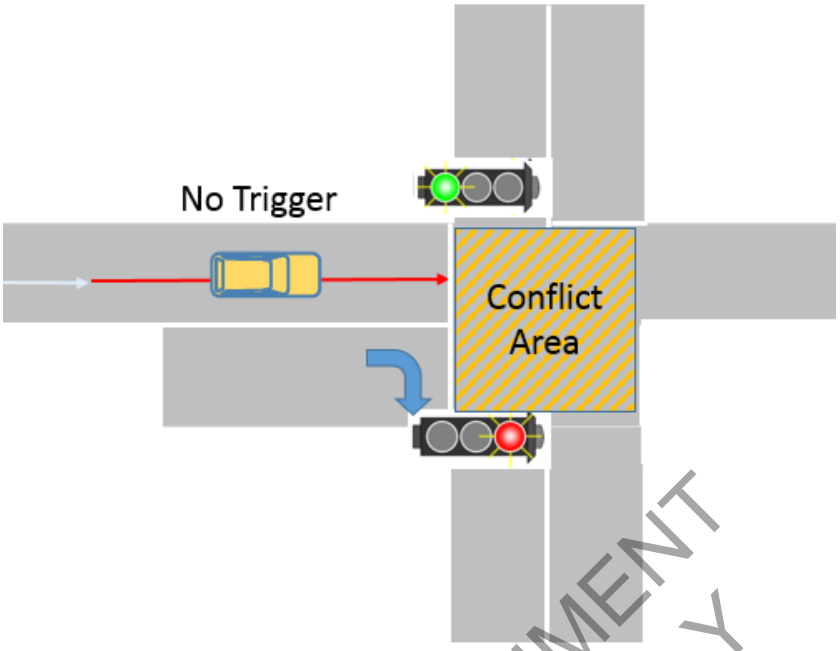
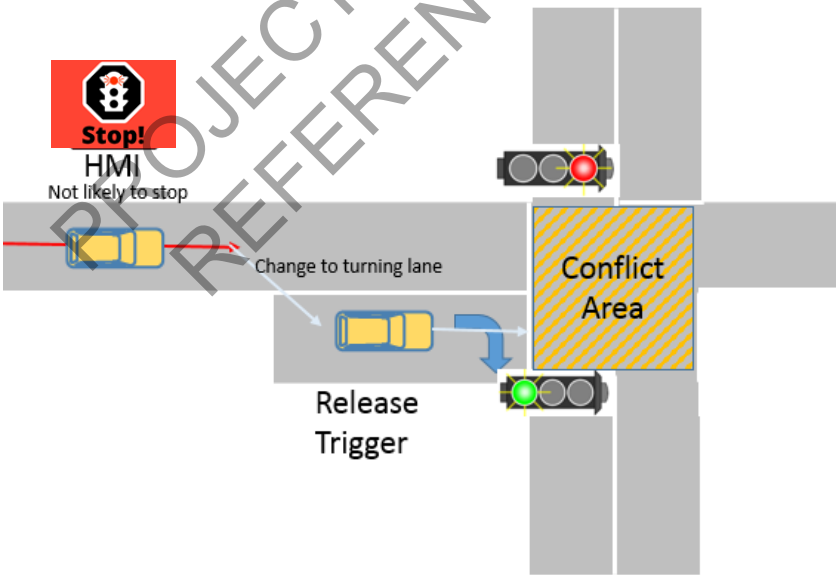
Table 5.1– Scenario Equivalents

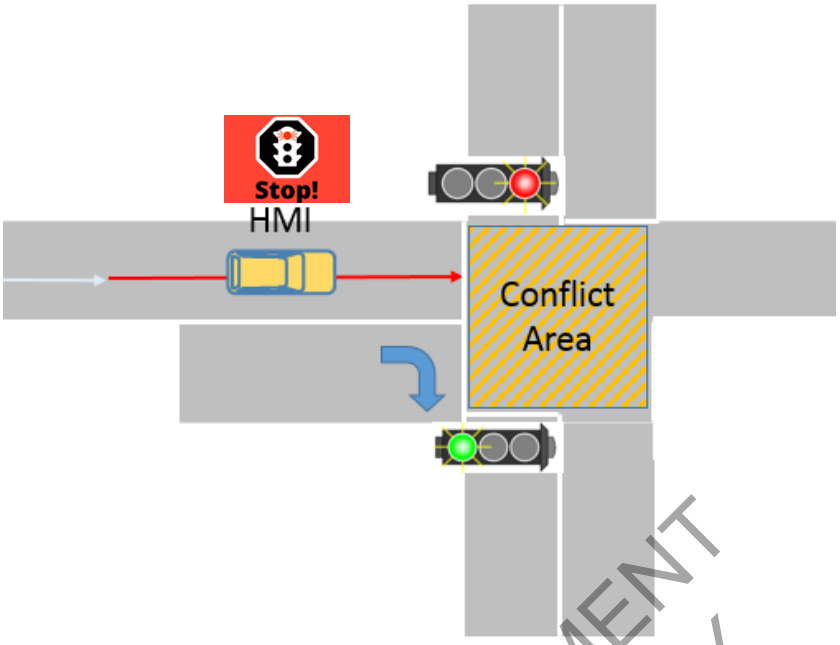
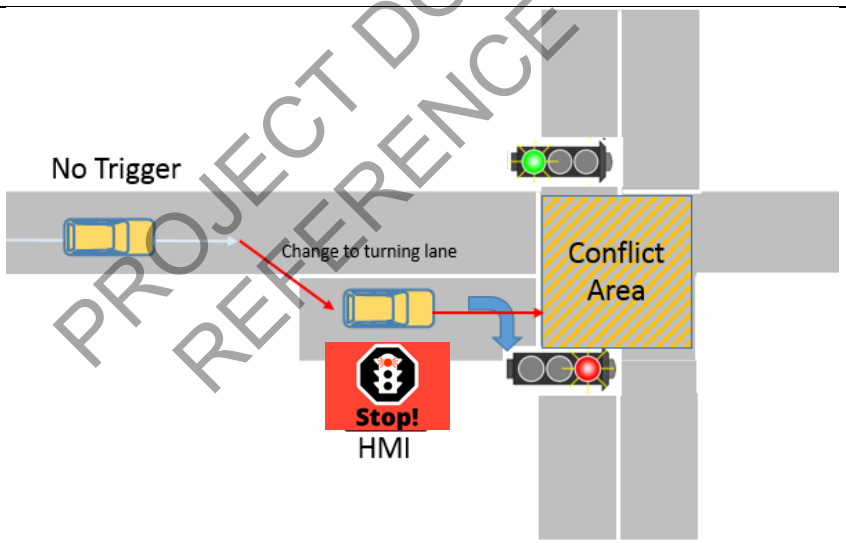
Variant	Visualisation and Comment
Vehicle likely to enter the conflict area after the signal has turning red	 HMI Warning: Yes Comment: The V-ITS-S assesses the vehicle trajectory to determine relevant lane and distance to the intersection through the use of MAPEM. Based on the SPATEM, the vehicle determines that the traffic light will be red for the vehicle's lane when it reaches the stop bar. The V-ITS-S provides an escalating warning through the HMI with enough time for the driver safely to stop prior to the stop bar as per primary scenario.
Vehicle likely to Stop on Red Signal	

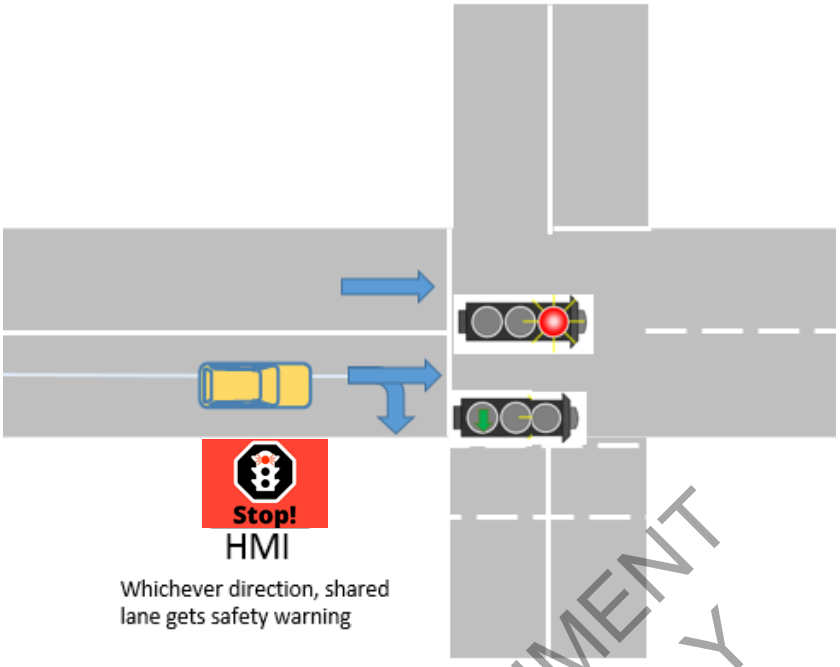
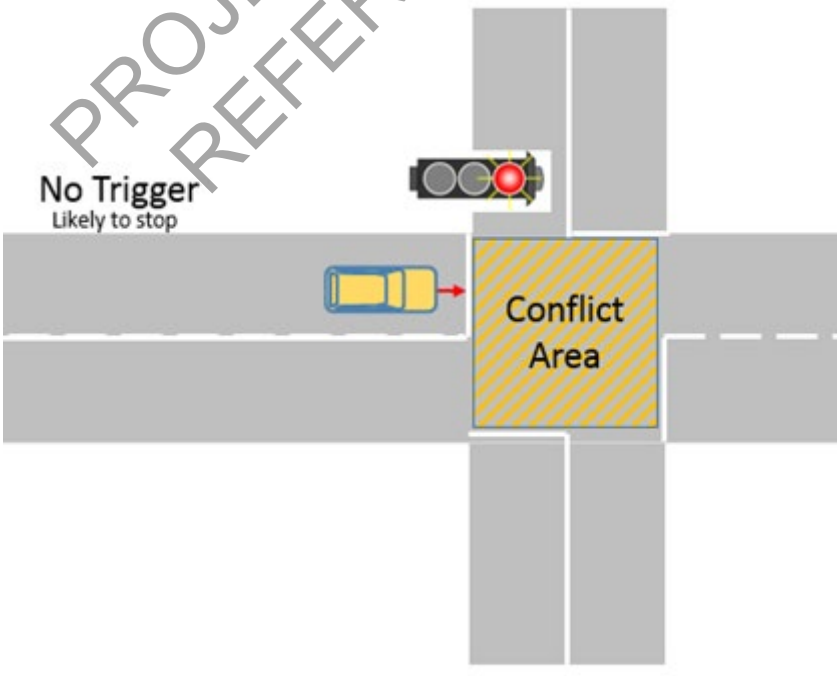
Variant	Visualisation and Comment
	HMI Warning: No Comment: The vehicle trajectory has it safely able to stop prior to the stop bar. The vehicle decelerates safely prior to the stop bar not warranting any warning.

Variant	Visualisation and Comment
Vehicle likely to enter conflict area on green	 HMI Warning: No Comment: The vehicle trajectory has it safely able to cross the stop bar during the Green light. This use case does not use predictive information for when a green light will become yellow. Not until it changes to Yellow can the time for entering the conflict zone during a Red light be calculated.

Variant	Visualisation and Comment
Vehicle likely to enter conflict area while Yellow	 HMI Warning: No Comment: The vehicle's current trajectory has it safely able to cross the stop bar during the Green light without accelerating. This calculation will include the known duration of Yellow. The intent of this is to not cause sudden and unexpected warning that could be a distraction or dangerous to the driver or surrounding vehicles.

Variant	Visualisation and Comment
Vehicle approaches an intersection in a straight through lane that remains green. Intersection has other lanes that have red signals.	 HMI Warning: No Comment: The vehicle trajectory has it in a lane that has a Green light and will safely cross the stop bar. This scenario emphasises the importance of lane level positioning with high confidence.
Vehicle approaches an intersection in a straight through lane that remains red, but turns into a lane that has green signals.	 HMI Warning: Possibly Comment: The warning may display when the vehicle is originally in a lane that has a Red light but will be removed once changing into a lane with Green Light. This scenario emphasises the importance of lane level positioning with high confidence.

Variant	Visualisation and Comment
Vehicle approaches an intersection in a straight through lane that remains red. Intersection has other lanes that have green signals.	 HMI Warning: Yes Comment: As per the primary scenario. This scenario emphasises the importance of lane level positioning with high confidence.
Vehicle approaches an intersection in a straight through lane that remains green but turns into a lane that has red signals.	 HMI Warning: Yes Comment: In original lane no warning will occur as the lane has a Green Light, when it changes into the turning lane the warning will occur as per the primary scenario. This scenario emphasises the importance of lane level positioning with high confidence.

Variant	Visualisation and Comment
Vehicle approaches an intersection in a shared lane with an inactive and active signal group in the same lane.	 HMI Warning: Yes. Comment: As the V-ITS-S in ICVP has no access to indicator or planned movement, and the lane has a movement possible that is associated to a Red Light, it will act more conservatively by warning. This could result in a potential false alarm for the driver, even though the V-ITS-S is performing as expected.
Vehicle Stopped on Red Signal and enters conflict area while signal remains Red	 HMI Warning: Yes

Variant	Visualisation and Comment
	Comment: When the vehicle enters the conflict area at any speed it will provide a warning. The intent of this scenario is to warn oblivious drivers stopped at the lights from taking off before they get to an unsafe part of the conflict area.

5.1.3 Vehicle entering conflict area from stopped position while red

The ARLW application shall consider the situation where the vehicle is stopped at the stop bar and begins accelerating whilst still in a red phase. This can happen if the driver mistakes the downstream signal or adjacent turning lane green signal as their green signal.

Requirement: The ARLW application shall monitor movement within the conflict area in having entered from a lane that aligns with a red phase.

5.1.4 Vehicle Location – Lane Association

The ARLW use case is based on the concept of the geometric topography (MAPEM), which details lane specifics including information about the signal groups relevant to each ingress (entry) lane as well as the egress (exit) lane it connects to. The vehicles position is matched to the MAPEM lane that it is most confidently in.

Requirement: The ARLW application assess the lane with most confidence based on the vehicle position relative to the MAPEM node paths.

5.2 MAPEM Logic

As illustrated in Figure 5.3, MAPEM data provides context of the intersection by defining lanes as a series of nodes at the centre of each lane. The space between the stop bars (ingress) and the start of new lanes (egress) is known as the conflict area. The MAPEM links the node at the stop bar with its corresponding exit(s) by defining the *connectsTo* data element and its associated signal group that enables this movement. The MAPEM provides the foundation by which V-ITS-S can interpret relevance of Signal Phase and Timing (SPaT). SPATEM data provides the real-time status of the intersection including state and timing of each signal group.

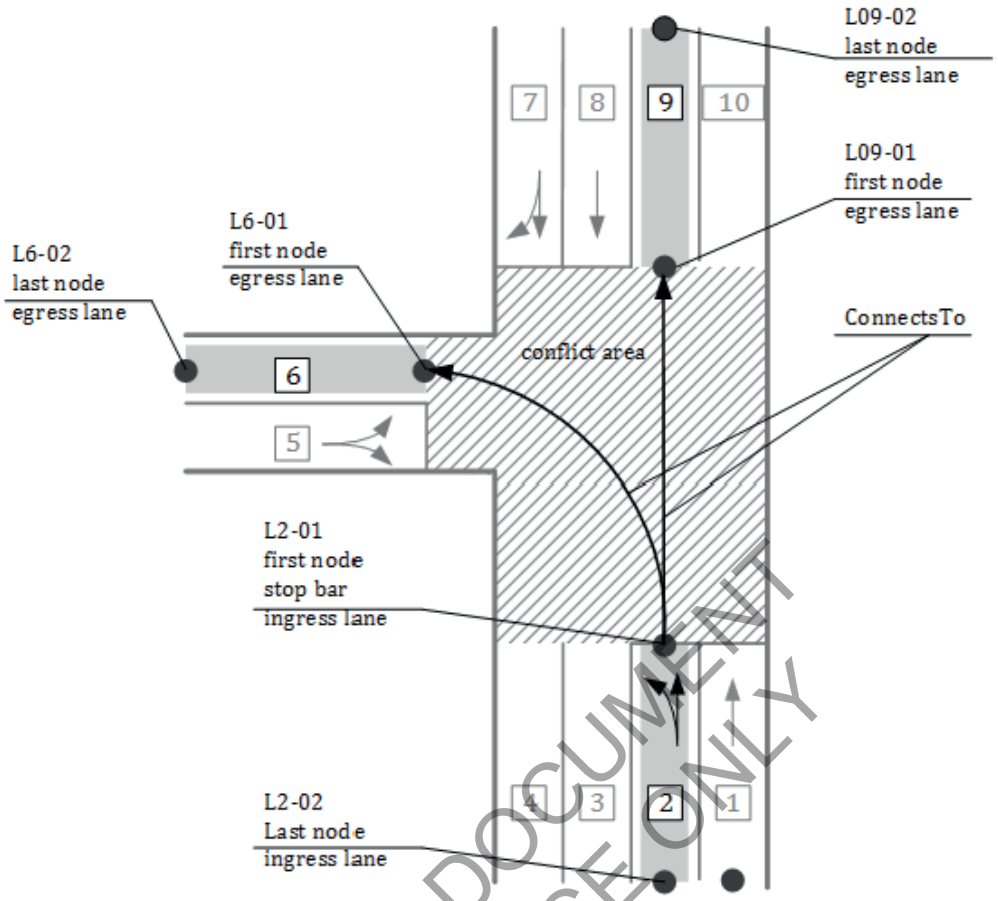


Figure G.4 — Vehicle lane

Figure 5.3 - Intersection MAPEM Layout (PD ISO/TS 19091:2017)

Requirement: The ARLW application shall use received MAPEM to determine the vehicle location against a lane and subsequently; *ingress*, *connectsTo, signal group* and *egress* paths.

5.3 SPATEM Logic

The list of available *eventState* options are listed in Table 5.2 along with their commonly used description. It is indicated if they are not expected to be applicable (NA) to the pilot.

Table 5.2 – SPAT Event States

***eventState* (enumerated value)**	**Common description**
unavailable (0)	Unknown or error
dark (1)	Traffic signal is unlit
stop-Then-Proceed (2)	Left turn on red **(NA)**
stop-And-Remain (3)	Red
pre-Movement (4)	Red+Yellow EU **(NA)**
permissive-Movement-Allowed (5)	Green (Filtered)

***eventState* (enumerated value)**	**Common description**
protected-Movement-Allowed (6)	Green (Controlled)
permissive-clearance (7)	Yellow (Filtered)
protected-clearance (8)	Yellow (Controlled)
caution-Conflicting-Traffic (9)	Flashing Yellow

The STREAMS Connect provides the timing information for the relevant phase as shown in Table 5.3.

Table 5.3 – SPATEM Timing

SPATEM Parameter	Description	Green	Yellow	Red
startTime	Determined as soon as the next <eventState> is known then revised at the actual start of the relevant <eventState> and does not change during the event state	Yes	Yes	Yes
minEndTime	All states have a known minimum time, for example; red event state represents the all-red parameter approx. 2 seconds, Yellow a locked minimum of approx 4 seconds	Yes	Yes	Yes
maxEndTime	Determined at the start of the Yellow for the Yellow event state. The next active signal group <startTime>, <minEndTime> and <maxEndTime> are also provided at the start of the Yellow event state. Hence - there is no predictive SPATEM data - the next phase change is only known at the beginning of Yellow Yellow event state, the <maxEndTime> is equal to the <minEndTime>		Yes	
likelyTime	optional, and not populated if the phase is in dwell (no demand for other phases) and the time exceeds the plan time. For the		Yes	

Requirement: The ARLW application shall determine the current signal state and timings based on the MAP node path.

6 System Components

The ARLW use case is an I2V application and as a result the primary path is through the intersection equipment (Traffic Signal Controller (TSC), STREAMS Connect and R-ITS-S) and the V-ITS-S (and HMI).

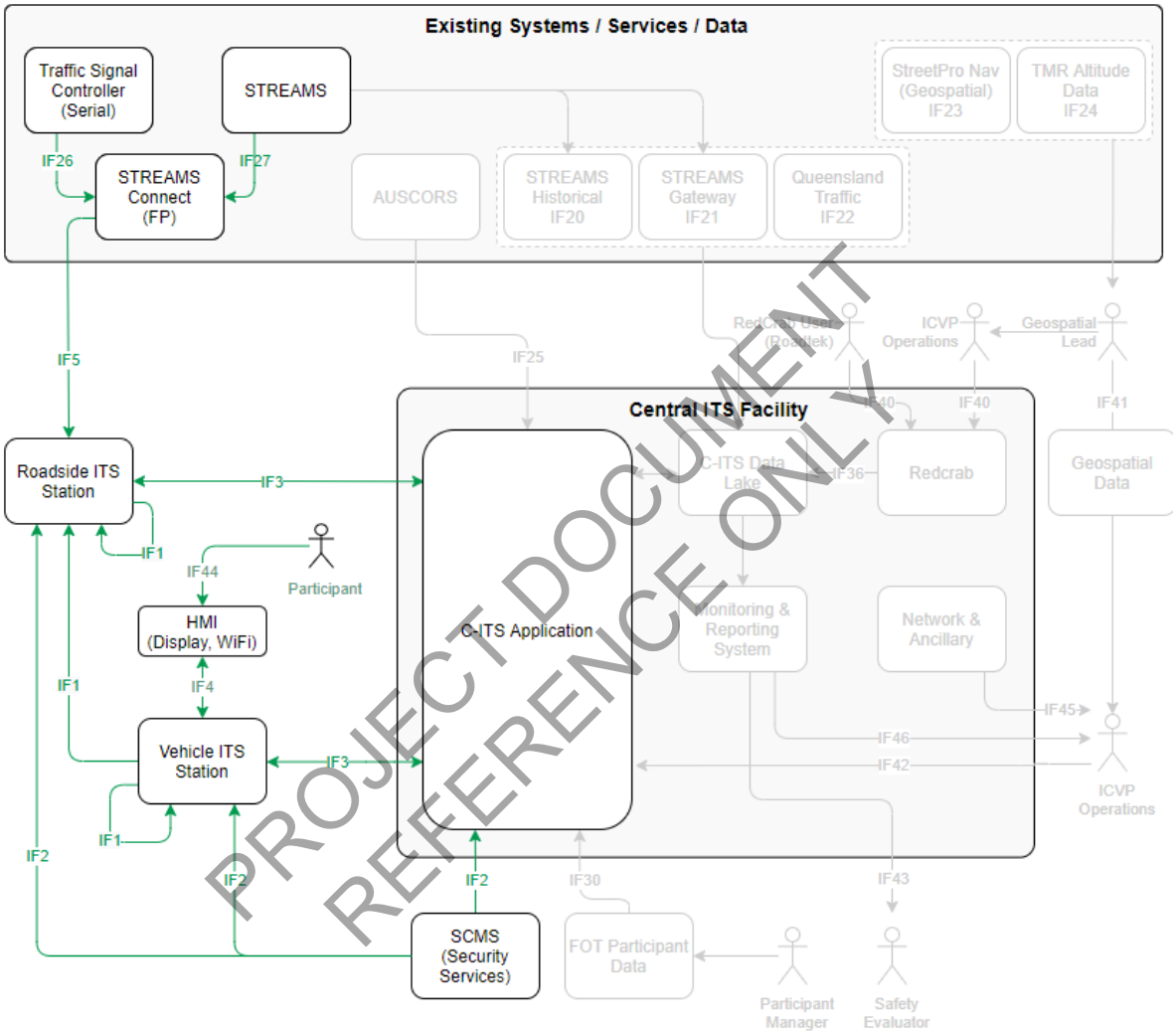


Figure 6.1 – Overall System Architecture

Table 6.1 describes the system components that interact for the overall operation of the ARLW application.

Table 6.1 – System Component Summary

Component	Role	Requirement	Detailed component lifecycle
V-ITS-S	Event Creator and Processor	An ARLW use case application must be enabled in the vehicle components. The conflict assessment off intersection information must be performed in the V-ITS-S.	The process for managing the ARLW use case is defined in section 7.1
HMI	Driver Interface	HMI must be on and able to interact with the V-ITS-S for display and status	HMI Warnings are defined in section 7.3
R-ITS-S	Enabler	Broadcast intersection status including real-time SPATEM information at 100ms and geometry MAPEM at 500ms	Update repeat. Sends broadcasts based on inputs from STREAMS Connect and C-ITS-F
STREAMS Connect	Enabler	Generates C-ITS appropriate SPATEM from TSC and sends to the R-ITS-S	Repeated updates of SPATEM at 100ms
TSC	Data Source	Provides traffic signal state and timing	Repeated update of signal status to STREAMS Connect
SCMS	Enabler	Provide secure communications	Defined in *C-ITS-S Station Protocol Specification PSTS007*
C-ITS-F	Monitoring	Interface for monitoring and use case logging and MAPEM updates	Defined in *V-ITS-S Specification PSTS002*
AUSCORS	Positioning Augmentation	Provides data to the V-ITS-S through the C-ITS-F that allows greater positioning accuracy for the operation of the use case	Defined in *V-ITS-S Specification PSTS002*
FOT	Evaluation	Evaluation of use case events log data	Not applicable. Managed by C-ITS-F

Requirement: The V-ITS-S shall meet the requirements of *V-ITS-S Specification PSTS002* as a basis for enabling the ALRW use case operation. Communications between components using 3G/4G and ITS-G5 are detailed in *V-ITS-S Specification PSTS002* including communications interface, security management and protocols to enable the data transfers described in Figure 6.2.

Requirement: The HMI shall meet the requirements of *HMI Specification PSTS003* as a basis for enabling the ARLW use case HMI warnings.

Requirement: The R-ITS-S shall meet the requirements of *R-ITS-S Specification PSTS005* as a basis for enabling the ARLW use case operation.

6.1 Typical Process Flow

The process flow for the ARLW event is shown in Figure 6.2. This describes the normal steps for the event through the relevant system components. The component lifecycles in section 7 describe the detailed creation, management, validation and completion states of the use case.

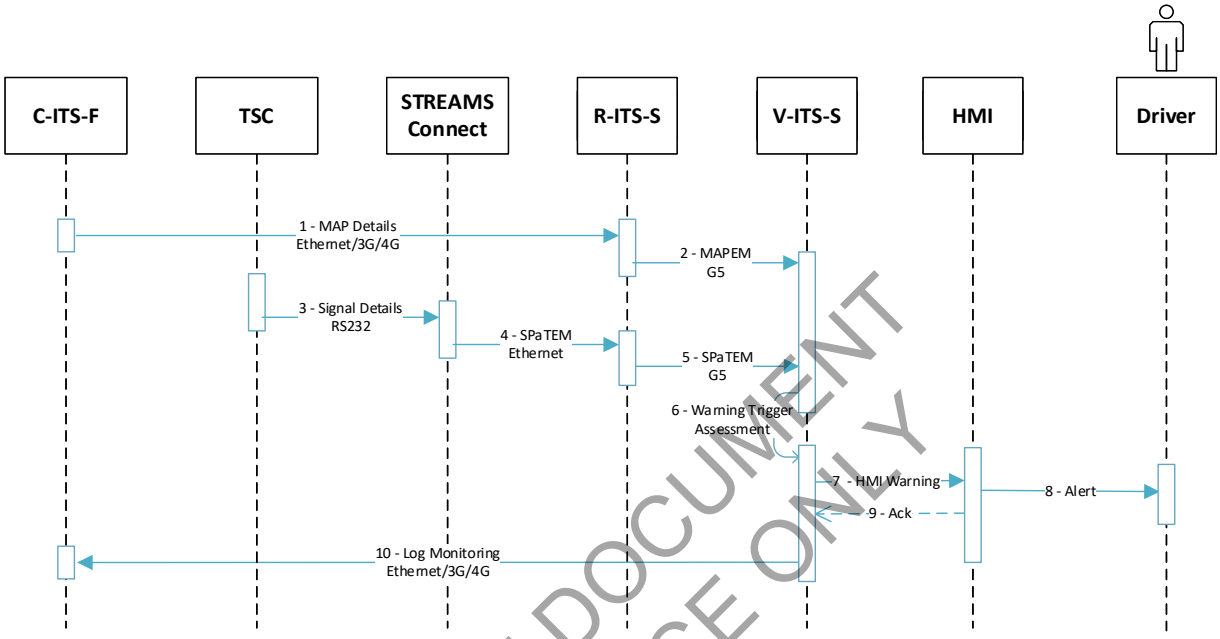


Figure 6.2 – Typical Flow of Data

7 Lifecycles

The ARLW event is identified and generated in the V-ITS-S application. Therefore, the event life cycle for this use case matches the V-ITS-S application lifecycle.

7.1 V-ITS-S Application Lifecycle

The following diagram shows a process flow expected from the V-ITS-S to receive SPATEM and MAPEM and determine use case behaviour.

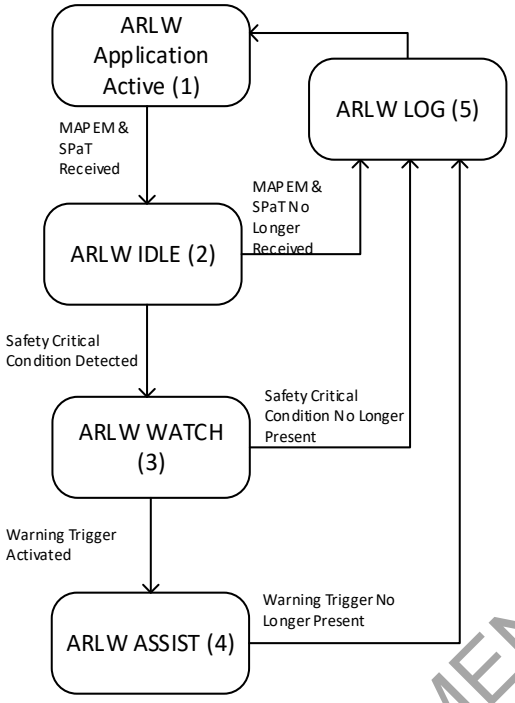


Figure 7.1 – V-ITS-S Lifecycle (modified from ETSI TS 101 539-01:2013)

Requirement: The V-ITS-S shall apply the lifecycle states and transitions in the ARLW application (or proven equivalent operation). A critical failure (as defined by the Contractor) in any state or transition shall cause the application to attempt to restart from state (1) to continue normal operation.

Requirement: ARLW application shall start up if enabled and monitor for MAPEM and SPATEM on ITS-G5 while the V-ITS-S is powered on (see *ucArlwEnabled* in *V-ITS-S Specification PSTS002* for application enabling and disabling). *(State 1)*

Requirement: The ARLW application shall receive MAPEM and SPATEM for the assessment by the ARLW application. *(Transition 1 to 2)*

Requirement: ARLW application shall compare the vehicle trajectory (location, speed and direction) to the intersection information (MAPEM) to determine if the safety critical conditions are met. In order to meet the safety critical conditions, the vehicle shall be: *(State 2)*

1. Travelling between the minimum (*speedMin*) and maximum speed (*speedMax*), and
2. Within a lane node path defined in the MAPEM (based on confidence)

Requirement: If the SPATEM is considered old (nominally 1s since last update), the ARLW application shall consider the intersection as no longer relevant and return to waiting for a new MAPEM and SPATEM. *(Transition 2 to 5)*

Requirement: To meet the safety critical conditions, the vehicle shall be: *(Transition 2 to 3)*

1. Travelling between the minimum (*speedMin*) and maximum (*speedMax*) speed; and
2. Following the node path (based on vehicle offset defined in section 5.1.4) in the same direction

Requirement: ARLW application shall assess the state of the signals and the likelihood of red-light violation by the vehicle entering the intersection as defined in section 7.2. *(State 3)*

Requirement: ARLW application shall determine that the vehicle safety critical conditions are no longer met if: *(Transition 3 to 5)*

1. The vehicle stops; or
2. The vehicle departs from the node path of the MAPEM; or
3. The vehicle departs from the conflict area; or
4. The traffic signal state is not currently or expected to be Red for the signal group of the vehicle's lane.

Requirement: A threat analysis shall be active if action is required within the safety thresholds as defined in section 7.2 *(Transition 3 to 4)*

Requirement: The ARLW application shall request a HMI warning display based on advanced red-light warning risk being active as defined in section 7.3.The ARLW application shall monitor acknowledgements and the status of the HMI while the display request is active. *(State 4)*

Requirement: ARLW HMI warning request shall be cleared if: *(Transition 4 to 5)*

1. The safety critical conditions are no longer met (see transition 3 to 5 above)

Requirement: The ARLW application shall log event information in accordance with *V-ITS-S Specification PSTS002* and send to C-ITS-F on via cellular logging process. *(State 5)*

Requirement: The ARLW application shall confirm the event is logged and event completed. *(Transition 5 to 1)*

7.2 Warning Trigger

When the vehicle enters any lane (node path) of the intersection, the vehicle must determine the current state of the traffic signal relevant to the signal group that lane is aligned. If the signal state is yellow or red, the vehicle must determine whether there is a risk of entering conflict area based on the Time-To-Event area (TTE) and the minimum driver warning triggering time as shown in Figure 7.2. If the signal state is red and the vehicle enters the event zone (conflict area), the HMI warning must alert the driver.

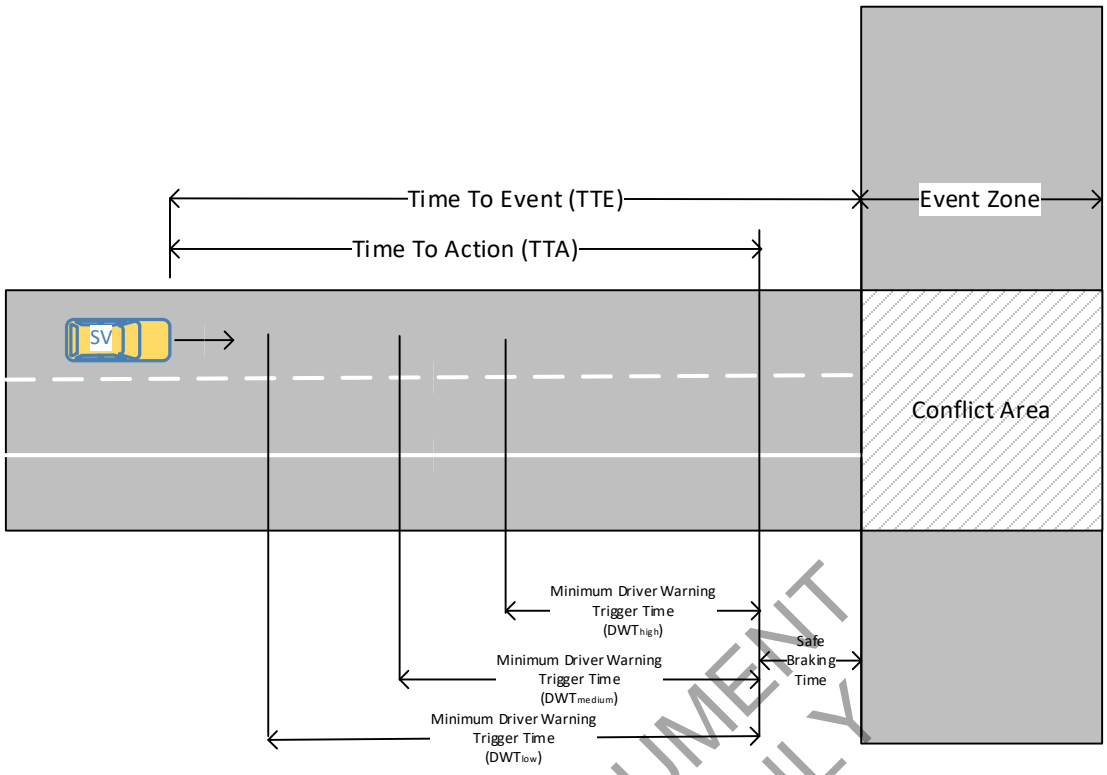


Figure 7.2 – Minimum Warning Trigger Time

Based on the TTA, the trigger is determined based on the graph in Figure 7.3.

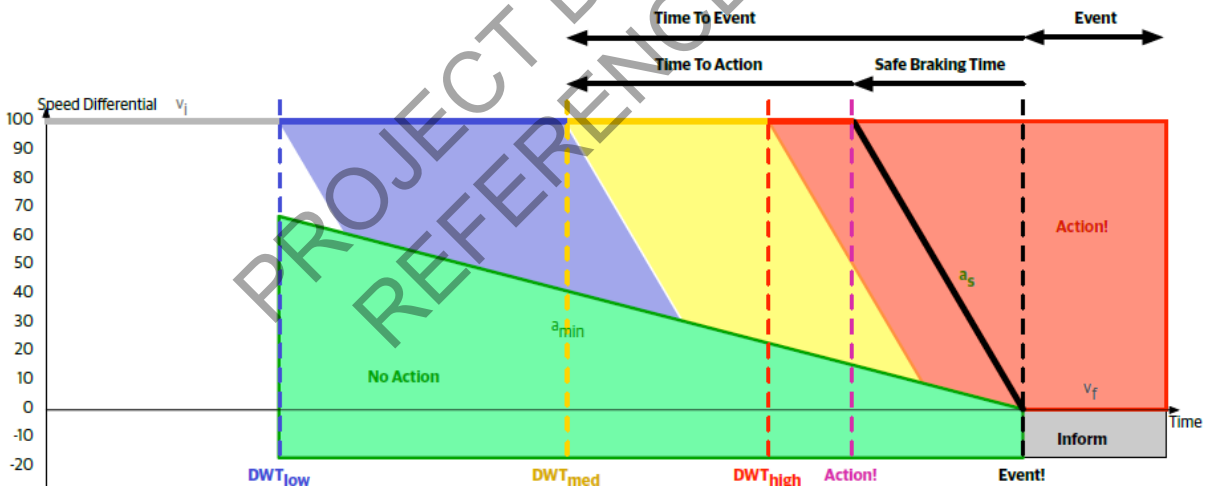


Figure 7.3 – Determining triggers from TTA

Requirement: Distance (d_{TV_INT} in metres) to the stop bar shall be calculated based on the MAPEM and the vehicle ego-location.

Requirement: While the application is in ARLW WATCH, it shall assess safe braking time, safe braking distance and TTA based on the following calculations:

$$\text{Safe Braking Time} = t_{safe} = -v_i / a_{safe}$$

$$\text{Safe Braking Distance} = d_{safe} = v_i * t_{safe} + ½ * a_{safe} * t_{safe} * t_{safe}$$

$$\text{Time-To-Action} = TTA = (d_{TV\_INT} - d_{safe})/ v_i$$

Where:

v_i = Current Speed

a_{safe} = Safe braking deceleration speed (*decelerationSafe*)

Requirement: The TWVR application shall consider the TTA as not applicable (no warning required) if:

1. a significant amount of time for braking is available; and
2. a significant distance for braking is available; and
3. A TTA based on the following calculations:

$$\text{No Action Time} = t_{no\_action} = -v_i / a_{min}$$

$$\text{No Action Distance} = d_{no\_action} = v_i * t_{no\_action} + ½ * a_{min} * t_{no\_action} * t_{no\_action}$$

$$\text{Time-To-Action at minimum braking} = TTA_{min} = (d_{TV\_INT} - d_{no\_action})/ v_i$$

Where:

v_i = Current Speed

a_{min} = Minimal braking deceleration speed (*decelerationMin*)

Requirement: Based on the TTA and TTA_{min} calculations, the ARLW application shall associate a HMI warning identifier.

Requirement: The ARLW application shall apply the following rules while the vehicle is in the event zone (conflict area):

1. No HMI Warning shall occur if the vehicle entered the conflict area during a yellow phase
2. A high level HMI warning shall persist for the whole conflict area if the vehicle entered the conflict area while currently in a HMI warning unless the signal group state changes from Red.
3. A high level HMI warning shall be created if the vehicle enters the conflict area while the ingress signal group is in a red state. This may only be detected once in the conflict area due to the speed of the vehicle which may have been stopped just prior to the conflict area. If the vehicle then stops it will be removed (even if in the conflict area).

Requirement: Based on the traffic signal state, vehicle location, DWT min calculation and TTC, the V-ITS-S shall associate a HMI warning identifier.

Table 7.1 – Driver Warning Trigger Time to HMI Warning

Vehicle Location	Current Signal State	TTE	Likely Signal State at time of entering conflict area	Conflict Risk	HMI Warning ID
Approach	Green	N/A	Not provided in SPaT	N/A	No HMI change
	Yellow	TTE < $Yellow_{max\ end\ time}$	Yellow	N/A	No HMI change
	Yellow	TTE > $Yellow_{max\ end\ time}$	Red	TTA < *thresholdHigh*	ARLW_HIGH
				thresholdHigh< TTA < *thresholdMedium*	ARLW_MEDIUM
				thresholdMedium< TTA < *thresholdLow*	ARLW_LOW[1]
				TTA > *thresholdLow*	No HMI change
				TTA_{min} > 0	No HMI change
	Red	N/A	Red	TTA < *thresholdHigh*	ARLW_HIGH
				thresholdHigh< TTA < *thresholdMedium*	ARLW_MEDIUM
				thresholdMedium< TTA < *thresholdLow*	No HMI change
				TTA > *thresholdLow*	No HMI change
				TTA_{min} > 0	No HMI change
Event Zone	Green	N/A	N/A	N/A	No HMI change
	Yellow	N/A	N/A	N/A	No HMI change
	Red	N/A	N/A	N/A	ARLW_HIGH_EVENT

[1]Note: In ICVP implementation the *thresholdMedium* and *thresholdLow* were configured to the same value based on HMI experiments and optimisation from field testing. The result is that only ARLW_MEDIUM, ARLW_HIGH and ARLW_HIGH_EVENT are displayed.

7.3 HMI Warning

The HMI warning display provides information in the vehicle that allows the driver to take suitable evasive action. The HMI warning is based on the vehicle location, trigger calculations and the resulting threat analysis. The library of ARLW use case HMI warnings includes the threat analysis stages and an associated image and sound.

Requirement: The HMI shall display the image and play the audio sound based on the information presented in Figure 7.2. The HMI warning requested from the ARLW application shall be through the HMI Presentation Manager (defined in *V-ITS-S Specification PSTS002*).

Requirement: The V-ITS-S and HMI shall allow image and audio sound configuration updates based on the HMI Warning ID.

Table 7.2 – HMI Warning Lookup

HMI Warning ID	Description	Image	Audible Sound
ARLW_LOW	Comfort warning	None[1]	None
ARLW _MEDIUM	Safety warning		None
ARLW _HIGH	Critical warning		ARLW_HIGH.wav[2]
ARLW_HIGH_EVENT	Critical warning		ARLW_HIGH_EVENT.wav[2]

The audio for ARLW HIGH warnings are a sharp audio given the criticality of the warning for a driver action. This is because: (1) unlike other use cases, the safety behaviour is immediately come to a stop, not slow down; (2) there is a higher level of accuracy with ARLW compared to other use cases and (3) the ARLW have been optimised to warn the driver only when at a critical decision point rather than other more informative use cases.

7.4 Continuity

Requirement: The HMI warning shall remain valid while the V-ITS-S preconditions and trigger conditions remain valid for the latest SPATEM received. If the vehicle receives a new SPATEM from the same R-ITS-S, the trigger conditions shall be reassessed against the new parameters in the SPATEM in accordance with the ARLW application lifecycle.

Requirement: Other C-ITS equipped vehicles in between the vehicle and intersection conflict area shall not affect the operation of the use case. SPATEM and MAPEM forwarding is not required.

Requirement: The ARLW HMI warning request escalates immediately (for example from medium to high warning level) as defined in *V-ITS-S Specification PSTS002*. However, an ARLW event shall not deescalate (for example from high to low warning level) for the duration of that event.

Requirement: On completion of the ARLW HMI warning, the HMI shall return to any lower priority use case HMI warning currently active (if no other HMI warnings are active, the HMI shall return to the default state as defined in *V-ITS-S Specification PSTS002*).

8 Key Configurable Parameters

Requirement: The following key configurable parameters shall be configurable from the C-ITS-F in accordance with *V-ITS-S Specification PSTS002*. These parameters shall be used through the use case to allow adjustments to the operation and timing.

Table 8.1 – ICVP Default Configurable Parameters

Reference Clause	Description	Unit	Factory Default	Min	Max	Device(s), systems affected
7.1	*speedMin*	km/h	30	0	200	V-ITS-S
7.1	*speedmax*	km/h	130	0	200	V-ITS-S
7.1	*speedClear*	km/h	30	0	200	V-ITS-S
7.2	*decelerationSafe*	0.1m/s/s	48	0	100	V-ITS-S
7.2	*decelerationMin*	0.1m/s/s	8	0	100	V-ITS-S
7.2	*threshholdHigh*	ds	12	0	250	V-ITS-S
7.2	*threshholdMedium*	ds	40	0	250	V-ITS-S
7.2	*threshholdLow*	ds	40	0	250	V-ITS-S
7.3	Images and Audio per HMI Warning ID		N/A			V-ITS-S and HMI

Note: a value of 0 disables the function associated with the parameter.

9 Data Definitions

The message structures of SPATEM Figure 9.1 and MAPEM in Figure 9.2, describes the overview of the ARLW SPATEM AND MAPEM which is subsequently detailed in data element level in the *Data Entity Catalogue PSTS006*. The message structure identifies the following data components:

1. ITS PDU container
2. Message set
3. Data frame
4. Sequence of data frame
5. Variable data frame identifier
6. Data element

Requirement: The ARLW application shall use SPATEM and MAPEM data elements in accordance with the *Data Entity Catalogue PSTS006*.

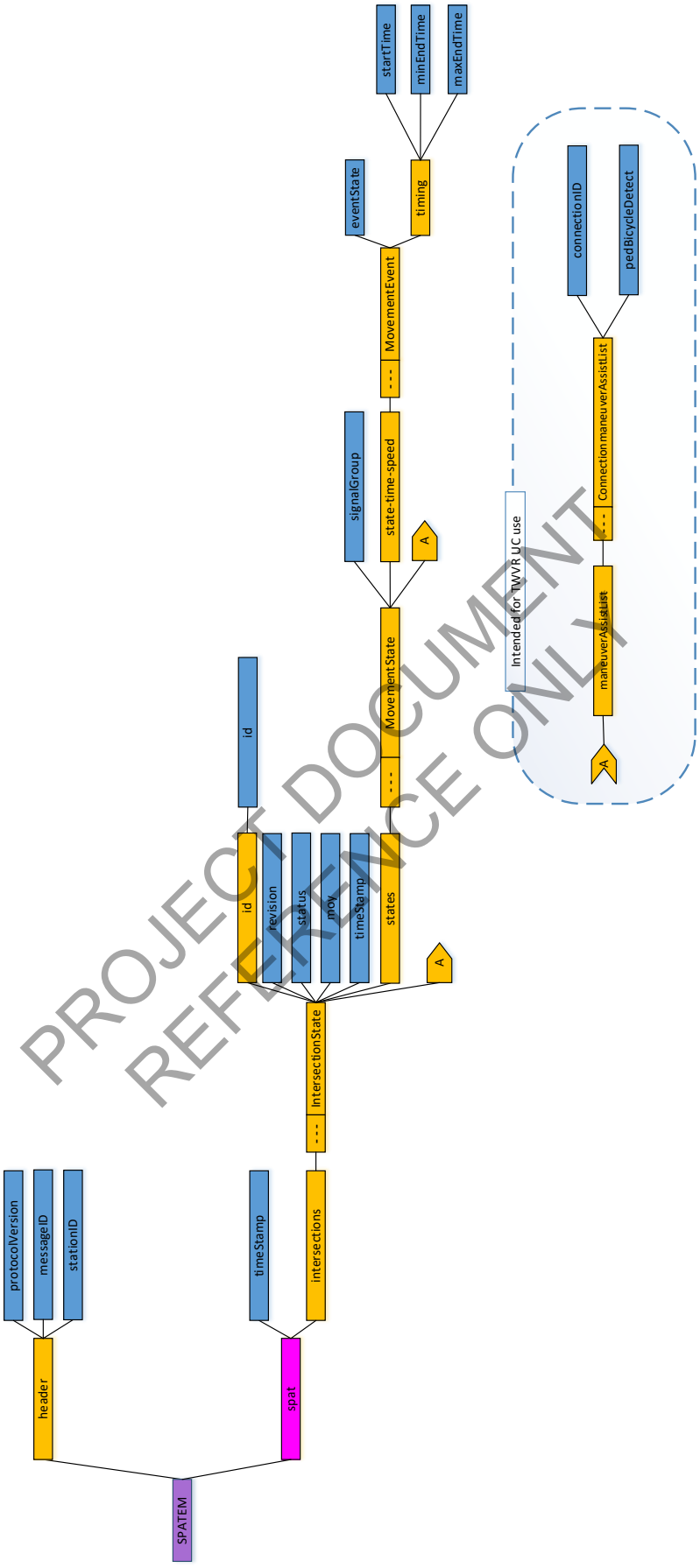


Figure 9.1 – ARLW SPATEM Structure

Figure 9.2 - ARLW MAPEM Message Structure