Common C-ITS Service Definitions

Traffic Management

C-Roads Platform

Working Group 2 Technical Aspects

Taskforce 2 Service Harmonisation

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Publication History

Version	Date	Description, updates and changes	Status
1.0	27.10.2017	Started separate document for the use case Shockwave Damping (SWD). Hence, the overarching service still needs to be determined.	draft
1.1	13.11.2017	Included Use Case description, incorporated results of reviews.	draft
1.2	16.11.2017	Included comments from Hessen Mobile review. Included comments from SWD review call on 15.11.2017	draft
1.0.3	01.12.2017	Included changes from WG2 discussion in Paris on 24.11.2017	draft
1.0.4	15.01.2018	Included changes after TF2 Call on 12.01.2018	draft
1.0.5	17.01.2018	Correction of some writing errors	draft
1.0.6	26.01.2018	Included BE/FL comments from 18.01.2018	draft
1.0.7	18.12.2018	Included changes from WG2 review	draft
1.0.8	10.10.2019	Prepared for TF3 submission	draft

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Functional Description of service

1.1 Service Introduction (TBD)

Service introduction	
Summary	
Background **Objective** **Expected benefits**	
Use Cases	1. Shockwave Damping. 2. TBD

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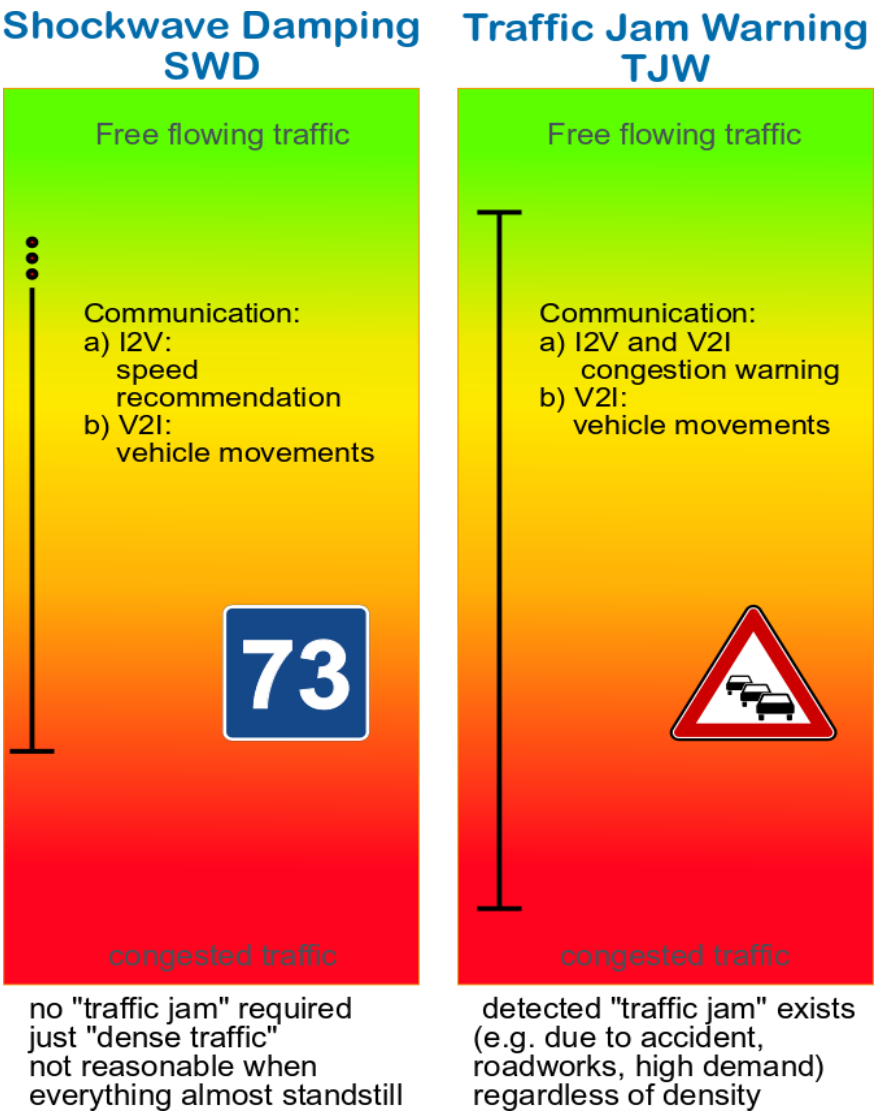
1.2 Shockwave Damping - high level description (SWD)

Use case introduction	
Summary	Providing I2V in-car information to avoid emerging or ideally even accomplish the elimination of shockwave situation in highway traffic.
Background	Shockwaves can occur in dense traffic when on some highway points the vehicles are driving relatively close to each other and/or change their speed or driving lane abruptly. In addition, it can be a result of a temporary overload on a highway ramp (due to traffic lights e.g. at the junction). In such situations, a braking action by a single vehicle may lead to a disturbance that propagates or even amplifies in upstream direction, ultimately bringing the upstream vehicles to a full stop. In traffic jams, shockwaves can propagate during vehicles constantly alternate between 'free flow' and 'congested' traffic.
Objective	UC SWD is aimed at damping or dissolving shockwaves on the roadmap with help of C-ITS concepts. Therefore - the main goal is - to lessen or prevent shockwaves and to avoid occurrence of a traffic jam (TJ). If nevertheless the TJ takes place, the Use Case (UC) - Traffic Jam ahead Warning (TJW) becomes relevant.



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Desired behaviour	**The ITS system**: is analysing input data - cooperative vehicles data, conventional sensors data and data from existing infrastructure (e.g. Traffic Control Centre (TCC), gantries) and discover relevant situation (shockwave occurrence). Then it generates cooperative output messages (for example IVI/DENM). Vehicle On-board Unit (OBU or V-ITS-S) receives the recommended or mandatory speed or other advice for SWD. This information is aligned and then forwarded to end users (ACC, HMI) **The road operator**: discovers shockwave situation on HMI at ITS Central Station (C-ITS-S). **The vehicle driver**: adapts his/her driving behaviour/speed compliant to the applicable driving regulations and any advice or guidance provided. **Adaptive Cruise Control (ACC) system**: automatically adapts speed/driving lane to avoid traffic jam occurrence.
Expected benefits	Homogenous traffic flow without traffic jams/congestions leads to: Economic benefits: saving resources, money and time, achievement of maximum road capacity utilization. Social benefits: traffic safety, reduced incidents. Personal benefits: more comfortable driving. Environment benefits: reduced CO_2 emissions and environmental pollution.
Use case description	
Situation	1. A vehicle brakes abruptly in dense traffic -> upstream traffic is affected -> shockwave situation occurs -> ITS system tries to regulate situation 2. A slow vehicle changes lane in dense traffic -> upstream traffic is affected -> shockwave occurs -> ITS system tries to regulate situation 3. Temporary overload on a highway ramp takes place -> upstream traffic is affected -> shockwave situation occurs -> ITS system tries to regulate situation
Logic of transmission	V2I – broadcast I2V- broadcast

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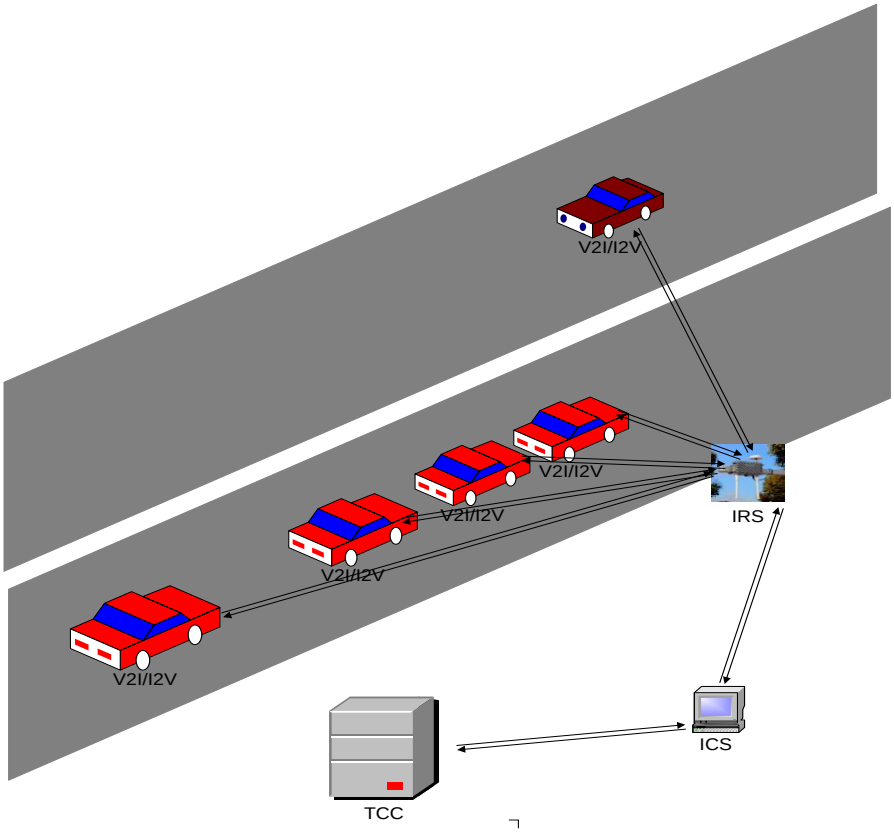

There are three main data streams:
Data stream 1:
On the roadside, ITS communication technology (e.g. ETSI G5 or Cellular) is used to receive vehicle information on ITS Roadside Station (R-ITS-S) and to send information from R-ITS-S directly to vehicles equipped with compatible ITS Vehicle Stations (V-ITS-S).

a) *Uplink data*:
V-ITS-S->R-ITS-S
Vehicles send data such as:
- speed
- position
- other Probe Vehicle Data (PVD) raw data (e.g. brake state)

b) *Downlink data:*
R-ITS-S->V-ITS-S
- Regulatory speed limit (if exists)
- Speed recommendation
- Driving lane information

Data stream 2:
Communication between R-ITS-S and ITS Central Station (C-ITS-S)

a) *Uplink data*:
R-ITS-S -> C-ITS-S
R-ITS-S sends data such as:
- PVD aggregated data
- Control flow data

b) *Downlink data:*
C-ITS-S->R-ITS-S
C-ITS-S sends data such as:
- existing speed limit information

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	• speed recommendation as a result of performing SWD algorithm • driving lane information Data stream 3: Communication between C-ITS-S and Traffic Control Centre (TCC) *Downlink data*: TCC -> C-ITS-S • conventional sensor data (cross-section measurement data) • VMS data (if available)
Actors and relations	• **Vehicle ACC**: receives SWD related input information, speed recommendation. Automatically adapts car driving behavior to the scenario or/and forwards warning information to HMI. • **Vehicle driver**: receives SWD related information, speed recommendation on the in-vehicle display. Adapts his/her driving behavior to the scenario. • **Road operator**: Registers (if exist) shown at C-ITS-S HMI shockwave information. • **Service provider**: disseminates SWD related information, to/from vehicles/drivers. • **End user**: trip planners may use speed information, and expected delays caused by these, to optimize their trip planning.
Scenario	**Pre-Operation:** • System Start and Initialisation, • Road segment configuration. **Operation:** • Cooperative Vehicles send PVD raw data. • Existing highway infrastructure sends sensor and VMS data to TCC. • R-ITS-S and TCC prepare and send data to SWD module on C-ITS-S. SWD module analyses input data and generate dependent on road situation following control output. *Depending on situation:* - Low probability of shockwave: • normal traffic flow - no action - High probability/occurrence of shockwave: • C-ITS-S sends relevant speed recommendations to R-ITS stations allocated in shockwave affected segment of the highway. • R-ITS stations disseminate ITS SWD messages • V-ITS-S analyses and prepares information for end user (ACC, car driver). - Traffic jam took place: • Use Case TJW will be activated. **Post-Operation:** • End user (car driver, ACC) takes relevant actions • Shockwave is mitigated. • Traffic flow is harmonised.
Display principle / Alert logic	Triggering condition is – shockwave situation recognition on ICS. Displayed Information - Speed recommendation on V-ITS-S display or ACC activation on car control system.

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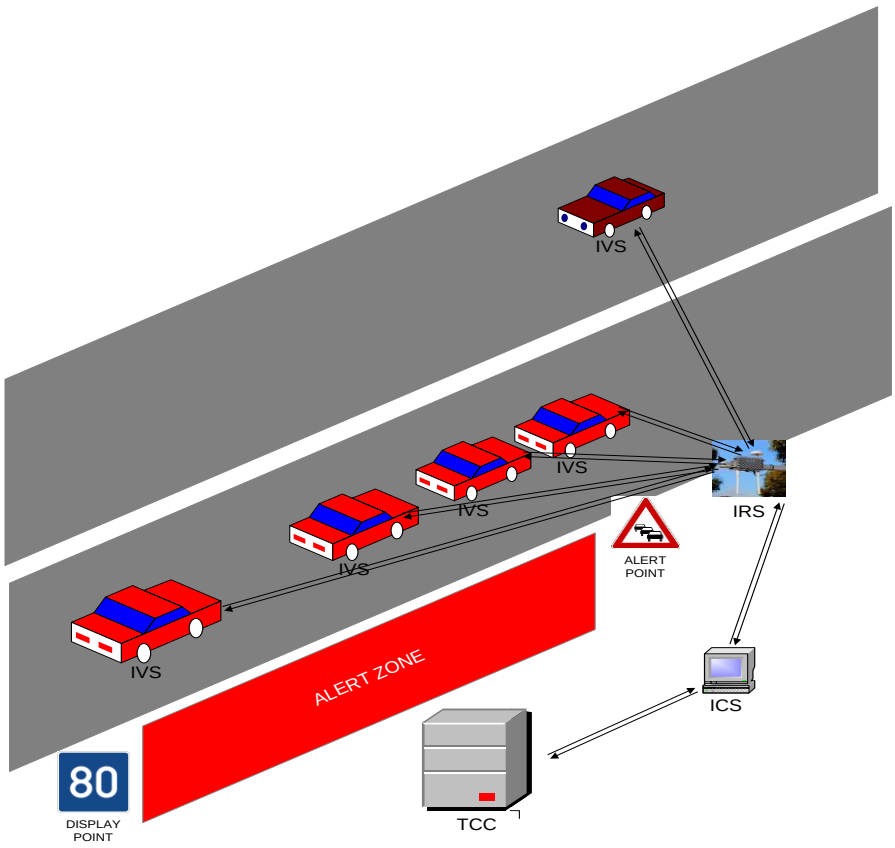

Constraints / Dependencies	Detecting shockwave requires sufficient historical and real-time data The location information needs to be accurate on road and lane level, and be related to the physical location of the measurement cross-sections and display cross-sections. Advisory speeds should match or be lower than the legal speed limit (static and dynamic speed limits). Advisory speed should not be too much higher/lower than the current speed of vehicle and speed of the surrounding traffic (might create dangerous situation). Advisory speed should be as high as possible, to prevent slow traffic. The coverage of users participating should be large enough to have a real impact (Testing with a smaller group, can be difficult).
Example of Use Case implementation	

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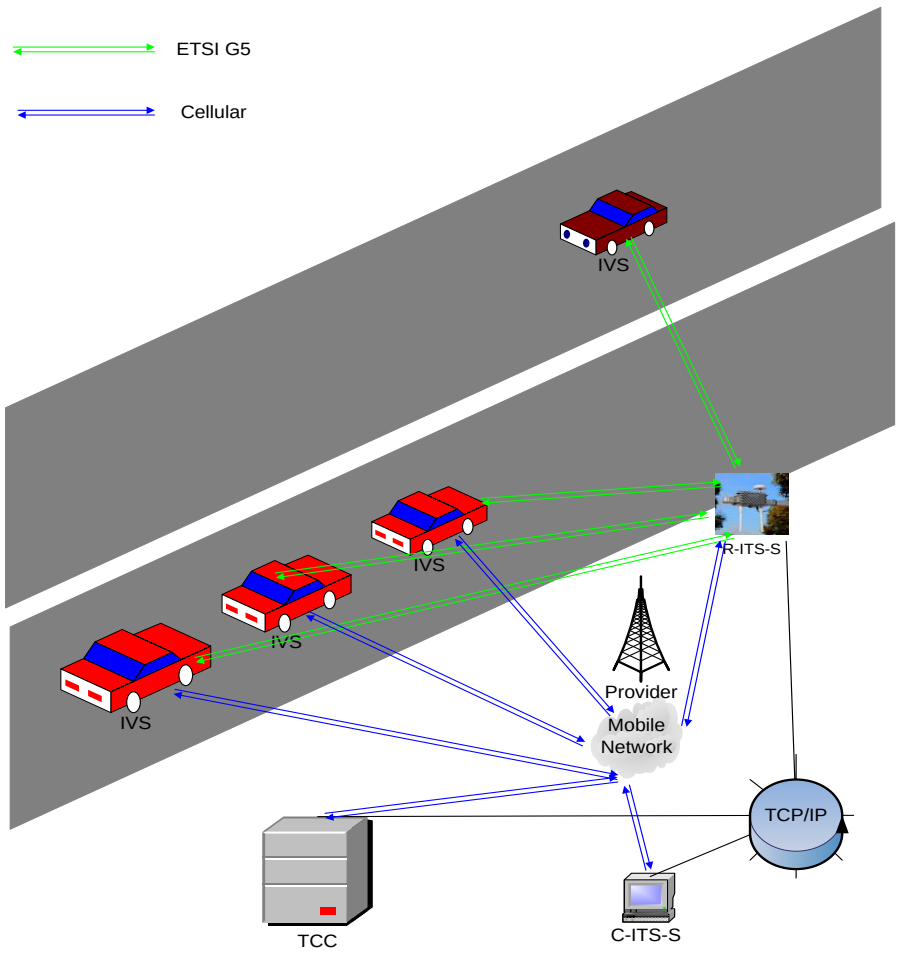
Model implementation



In this realization, ETSI Message Set (CAM, IVI and DENM) in combination with ETSI G5 or Cellular communication technology is used. A "hybrid" solution with utilization of both technologies is also possible.

Following functionalities are to be implemented:

V-ITS-S:

- sends CAM
- receives IVI(IVS)
- forwards aligned information to ACC and/or HMI

TCC:

- provides conventional sensor data (e.g. from measurement cross sections)
- provides VMS states (if exist)

R-ITS-S:

- receives CAM's
- aggregates CAM (ACAM)
- sends (ACAM) to ICS
- receives IVI messages from ICS
- checks validity of the messages
- sends IVI to V-ITS-S
- provides PKI security implementation

C-ITS-S (SWD Module)

- receives ACAM
- receives conventional sensor data and VMS states (if exist)
- analyses situation and if necessary generate IVI
- sends IVI to R-ITS-S

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<table>
<tr><td>Example architecture</td><td>

provides logging for operational monitoring
performs ITS management & configuration

PKI-Server (incorporated in TCC or C-ITS-S)

provision of certificates
provision of European Certificate Trust List (ECTL)

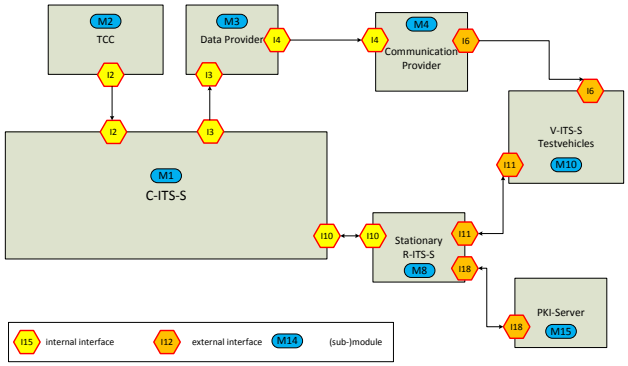

Figure 1: Example - system architecture (Hessian pilot of C-Roads Germany)
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<tr><td colspan="2">Functional and non-functional requirements (Example)</td></tr>
<tr><td>Sources of traffic information</td><td>

Measurement Cross-Section (conventional sensors)
Virtual detection zones (CAM)
Display Cross-section data (VMS)
Topology of zones, sensor and detection areas (TCC/C-ITS-S)
Traffic statistic data (TCC/C-ITS-S)

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<tr><td>Standards</td><td>
<table>
<tr><th>Topic</th><th>Document title</th></tr>
<tr><td>CAM</td><td>ETSI EN 302 637-02, ETSI TS 102 894-02</td></tr>
<tr><td>DENM</td><td>ETSI EN 302 637-3</td></tr>
<tr><td>IVI</td><td>ISO TS 102 321</td></tr>
</table>
</td></tr>
<tr><td colspan="2">Additional information</td></tr>
<tr><td>Sources used</td><td>
EU Documents: (https://www.c-roads.eu/platform.html)
National Documents:

Dutch C-ITS Corridor (https://itscorridor.mett.nl)
Talking Traffic Innovation Partnership (http://www.beterbenutten.nl/talking-traffic).
C-Roads_BE-Flanders UseCases.pdf (currently only in controlled circulation)
Activity 3_C-ROADS_Hessen_Sub-Activity_Specification_3.5 – Shockwave Damping.doc (currently only in controlled circulation)
C-ROADS SPAIN Mediterranean Pilot (Catalan sub pilot) Shockwave Damping

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	&Travel Time Estimation (draft versionv4) (currently only in controlled circulation)

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