Co-financed by the Connecting Europe Facility of the European Union

SCOOP@F Technical evaluation

Deliverable number: 2.3.3.2

Activity 2 - Studies

Sub-Activity 2.3 - Evaluation

Applicable version 0.01

Publication date:04/11/2019

Document information

- Publisher (organization): IFSTTAR
- Status (in progress, finalized, approved):

Publishing History

Date	Version	Contributor(s)	Main updates	Diffusion
10/12/2019	V0.01	IFSTTAR, URCA, TPT		SCOOP@F
31/12/2019	V0.04	IFSTTAR	Conclusions	SCOOP@F

TABLE OF CONTENTS

List of figures

List of tables

Acronym Table

CAM	Cooperative Aware Message
DENM	Decentralized Environmental Notification Message
FOT	Field Operational Test
ITS	Intelligent Transport System
ITS-G5	Adaptation of the IEEE 802.11p (wifi)
ITS-S	Intelligent Transport System Station
R-ITS-S	Roadside ITS Station
IVI	In Vehicle Information
Nfr-ITS-S	French National ITS Station
OEM	Original Equipment Manufacturer
PFro	Road Operator's Platform
PFcm	Car Manufacturer's Platform
KPI	key performance indicator
IVS	In vehicle Signage
POI	Point of Interest
TMS	Traffic Management System
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	V2V and/or V2I
V-ITS-S	ITS-S Vehicle (user or road operator)
Vro-ITS-S	ITS-S-V Road Operator
Vru-ITS-S	ITS-S-V User
VMS	Variable Message Sign

1 Introduction

SCOOP is a pilot project for the deployment of cooperative intelligent transport systems, i.e. systems based on the exchange of information between vehicles, and between vehicles and road infrastructure. Vehicles are equipped with sensors to detect events (such as a slippery road, an emergency brake, etc.) and transmit then to vehicles behind (V2V) and to road operator (V2I). Transmission is made from on-board units (V-ITS-S) to another one through (V2V) and to road side units (R-ITS-S) through (V2I). The road operator can also transmit information (roadworks, etc.) to the vehicles through their on board units (I2V).
The exchange of information between the vehicles and the infrastructure are based on ITS G5 (Figure 1), a short-range communication technology designed for cooperative ITS.

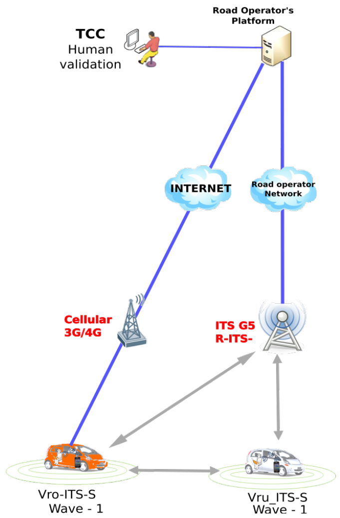


Figure 1: ITS G5 based architecture

In a second phase, new services were specified and a hybrid ITS G5/cellular technology was developed (Figure 2).
Technical Evaluation is dedicated to the first phase of SCOOP with only ITS-G5 for the access.

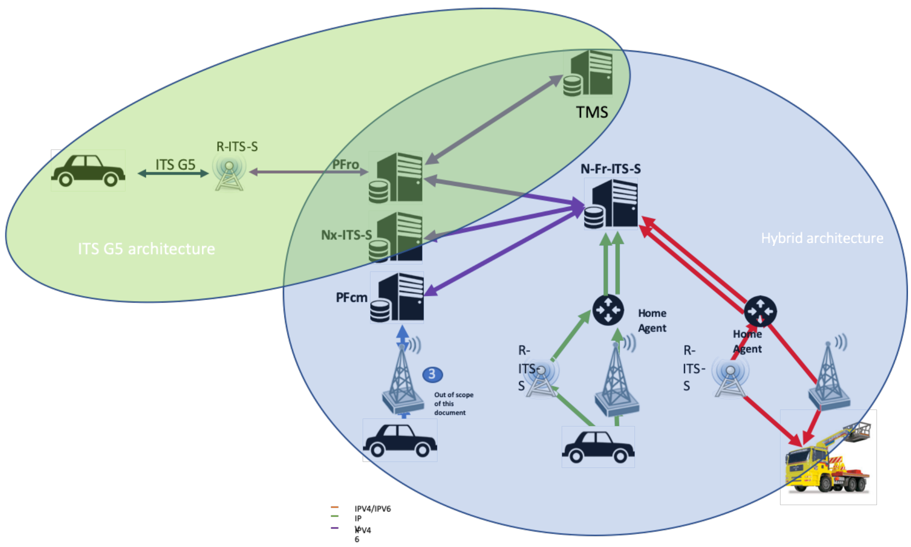


Figure 2: General SCOOP Architecture

Use Cases

Several use cases were specified, implemented, tested and evaluated in this project. Table 1 presents the complete list of SCOOP use cases.

List of SCOOP use cases
Traffic data collection
Data collection (automatic events)
Data collection (manual events)
Alert closure of part of a lane, whole lane or several lanes
Alert planned closure of a road or a carriageway
Alert planned road works – mobile
Alert Road operator in intervention
Alert end of queue by a road operator vehicle
Winter maintenance
Alert Temporary slippery road
Alert Animal or people on the road
Alert Obstacle on the road
Alert Stationary vehicle, breakdown
Alert Accident area
Alert Reduced visibility
Alert Unmanaged blockage of a road
Alert Emergency brake
Alert End of queue
Alert Extreme weather conditions
Alert Wrong-way driving
In-vehicle signage (embedded VMS)

Table 1: SCOOP use cases

The goal is to assess technical performances on access layer, facilities and application layer during naturalistic experimentations of C-ITS in the 5 test sites based on real data collected in real environment over a period of 1 year. The aim of this evaluation is to determine whether the functional and technical specifications are in line with what is expected from the system's behavior, whether at the application or radio level.
The expected outcome is represented by research questions listed in the methodology section. Tools for this evaluation are also presented.
Answering these research questions will be the challenge of the results section.

2 Methodology

According to the FESTA method, research questions and hypothesizes are defined for several topics:

- Technical functionality and performance evaluation
- Service evaluation

For each group, research questions lead to the definition of key performance indicators and at the end to the related collected data definitions (see deliverable 2.4.3.1 cataOfDataTlog.xls). Associated to the research questions, hypothesizes are given when it's relevant. Indicators will have to answer the questions and validate or not hypothesis.

2.1 Communication and ITS-G5 research questions

Research question	Hypotheses
What are the geographical distribution of events triggered by R-ITS-S?	Event are equally distributed in all region
What are the geographical distribution of events triggered by V-ITS-S ?	Event are equally distributed in all region
What are the percentage of events' type triggered by V-ITS-S?	Event are equally distributed between all use cases
What is the global volume of DENM sent by V-ITS-S?	
Is DE Repetition interval well defined for DENM sent by V-ITS-S?	Repetition interval is well defined in specifications for evaluated use cases
Is Update well defined for DENM sent by V-ITS-S	Updates is well defined in specifications for evaluated use cases
Is validity Duration well defined for DENM sent by V-IT-S? Is validity Duration well defined for for DENM sent by R-ITS-S?	Validity duration is well defined in specifications for evaluated use cases
What is the distribution of events for a week ? for a day?	Drivers are workers so they drive from Monday to Saturday and mostly during peak hours.
Are triggering conditions well defined for use cases? Nota: Stationary Vehicle use cases analysis Adverse weather condition – adhesion use cases analysis Adverse weather precipitation – Extreme weather condition	Triggering conditions are well defined in specifications for evaluated use cases
Do V-ITS-S receive Faulty messages?	We expect few messages at security level.
What are R-ITS-S locations communicating with V-ITS-S ?	All R-ITS-S will send at least one message to one V-ITS-S.
Do drivers go in all test sites ?	Cam sent are collected in all test site
How Messages are displayed to the driver?	The display duration is less than 1 minute per event. The display is equally distributed for all event.

What are the ITS-G5 performances for I2V, V2I, V2V?	Latency < 1s Range >300m

2.2 Tools

Data collection is based on the deliverable SCOOP_2.4.1.3_CataOfDataTlog. Each V-ITS-S and R-ITS-S collect all the sent or received messages each time there are in the range of another C-ITS station or each time a DENM is sent.

Table 2: Collection process for Data

TLog-UEVu-CAM-Sent	collect each CAM sent when there is another ITSS
Tlog UEVu-CAM received	collect each CAM revceived when there is another ITSS
Tlog-UEVu-DENM received	collect all DENM received
Tlog-UEVu-DENM sent	collect all DENM sent
TLog-UEVu-DriverRequest-Reception	collect all displayed message on HIMI
TLog-UEVu-DriverRequest-Sending	collect each time there is an action on HMI
TLog-UEVu-MapProjectionContext-DENMReceived	collect at each DENM received
TLog-UEVu-ClimaticEnvironmentContext	collect at each state changes
TLog-UEVu-NetworkAccessPerformance	collect every s durind a period activity + 30s before and 30s after
Tlog-UEVu-CAM-I	collect each CAM-I received
TLog-UEVu-DataStation	collect every 0.1s durind 15s before a new DENM sent
Tlog-UEVu-Radio	collect every s durind a period activity + 30s before and 30s after
Tlog-UEVu-faulty message	collect at each faulty message
uevu-SCOOPFunctionsSettingDriver	Collect at each function modification
uevu-MessagesDisplayedDriverStart	Collect at each displayed message
uevu-MessagesDisplayedDriverEnd	Collect at each end of displayed message
uevu-EventReportingContext	Collect of context associated to each record (3min before the event and 3minafter the event with a record every seconde.
Ulog-UEVu MultimediaReportingData	Collect at each state change

Data are sent by V-ITS-S through cellular with collection requirement defined in Table 2.

2.2.1 Tlog analyser

When receiving logs, they are converted in CSV files thanks to a specific tool developed by URCA, then stored in a Postgre database by IFSTTAR. Data are cleaned and intermediary indicators are calculated. Using SQL request, indicators are calculated and interpreted.
Different tools are developed to convert, extract relevant data and calculate indicators.
To help understanding data and indicators, a visual tool is also implemented. It permits to describe the path of several vehicles and received events. Each path and each message can be displayed separately (Figure 3). For a better understanding, a replay of events is also available.

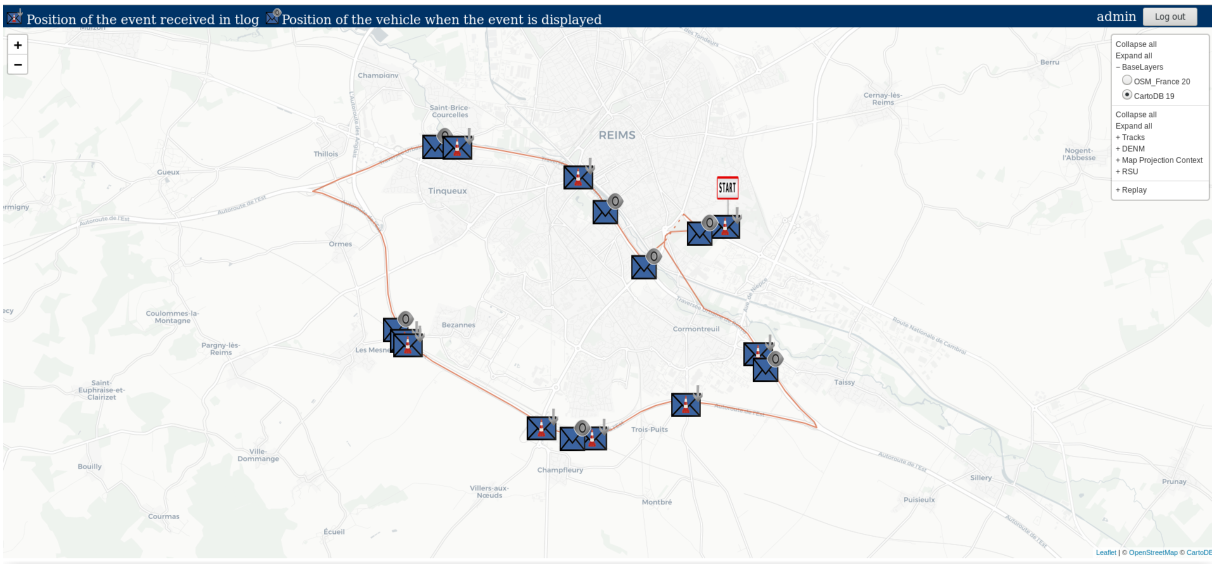


Figure 3: Visual tool

2.2.2 Security Log Analyser

Telecom ParisTech developed a Log analyser used to analyse the security Tlogs by extracting KPIs defined in the deliverable SCOOP_2.4.1.3_CataOfDataTlog_v13. More precisely, it takes as input (1) the ObjetsPKI Tlog file, (2) the Security Tlog File and (3) the SecurityIncident Tlog files. Then, it provides a cross analysis to extract the different KPIs defined in the SCOOP_2.4.1.3_CataOfDataTlog such as the number of sent messages, the number of received messages, the number of sent PC requests, the number of received PC requests, the rate of successfully signed messages, the number and rate of signed messages... Moreover, the log analyzer provides other indicators that can help in the detection of some attacks such as the Denial of Service (DoS/DDoS) attack.

2.3 Experimental Framework

A large number of equipped vehicle drives in SCOOP test sites from first of September 2018 until the 31st of August, 2019.

It's a naturalistic study so drivers have no driving instructions and real events are sent by road operators and drivers.

No baseline is needed in case of technical study as our research questions are independent of driver's behavior.

3 Results

3.1 General overview

Definition

Nota: To avoid any misunderstanding between event and use case, below, the definition considered in this document :

A use case is based on services defined in C-ITS French Use Cases Catalog deliverable.

We call an event when a DENM is sent with a dedicated action ID

For example stationary vehicle from a vehicle is the use case defined as:

« A vehicle detects that it has stopped for an undefined amount of time//has broken down and broadcasts an alert message to other vehicles. »

The event stationary vehicle is a DENM with a unique action ID and defined by Table 3.

Table 3: Extract of SCOOP_2.4.1.2 specification of DENM.

Name	cause code	sub-cause code	Manu/ Auto	ValidityDuration (s)	Update	Termination	Repetition duration
Stationary vehicle, breakdown	94 : Stationary vehicle	0 : Unavailable	Auto	30s (correspond to transmission conditions)	If after an interval of 15 s, the trigger conditions are still fulfilled the following information is updated: - StationarySince - Quality -referenceTime -detection Time The time elapsed to validity duration is reinitialised.	only cancel, no negation Once of the following conditions is satisfied before the time set in the DE ValidityDuration is expired, the generation of the cancel shall be requested at the facilities layer within 100ms: a) the absolute value of the ego vehicle velocity is greater than 0 km/h for a duration of 5 seconds b) the hazard lights are disabled The cancellation message is sent with the same values of validityduration, repetitioninterval, repetitionduration than the new DENM.	1s

Stationary vehicle, breakdown	94 : Stationary vehicle	2 : Vehicle breakdown	Auto	30 s, re-armed for every update	If after an interval of 15 s, the trigger conditions are still fulfilled the following information is updated: - StationarySince --detection Time - Quality	only cancel, no negation Once of the following conditions is satisfied before the time set in the DE ValidityDuration is expired, the generation of the cancel shall be requested at the facilities layer within 100ms: a) the absolute value of the ego vehicle velocity is greater than 0 km/h for a duration of 5 seconds b) the hazard lights are disabled The cancellation message is sent with the same values of validityduration, repetitioninterval, repetitionduration than the new DENM.	30s

3.2 Experimental set-up

- Tlogs (technical logs) and Ulogs (Usage logs) (see deliberable SCOOP_2.4.1.3_catalogueofTlog) from 01/09/2018 to 31/08/2019 for Vru-ITS-S
- 5 test sites in France (see Figure 4)
- All data were converted from ASN1 UPPER to CSV and then to SQL Database

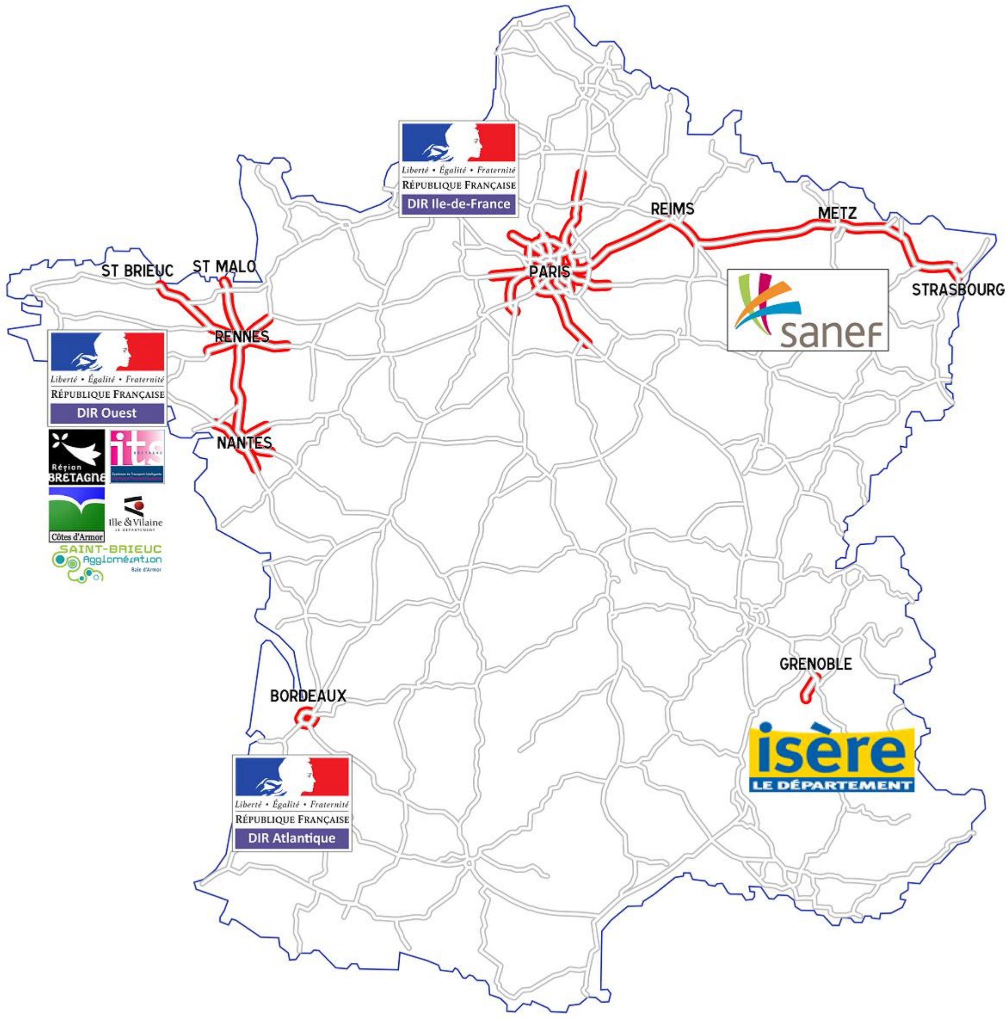


Figure 4: SCOOP@F test sites

3.3 A few statistics

Table 4: Messages count during a year

Number of CAMI received from R-ITS-S	586 700
Number of CAM sent by V-ITS-S	10 174 437
Number of CAM received by V-ITS-S	140 208
Number of DENM Sent (including repetitions and update) by V-ITS-S	572 993
Total Number of DENM received by V-ITS-S (including repetitions and update) from V-ITS-S or R-ITS-S	109 019
Number of DENM received by V-ITS-S (including repetitions and update) from V-ITS-S	7414
Number of Faulty message	1 159 033
Number of action ID received	698
Number of received Events (85% from R-ITS-S and 15% V-ITS-S)	554

Number of DENM received with a termination	132
DENM of termination without a related event sent by R-ITS-S	144 (20% of total DENM received)
Number of events sent by V-ITS-S	3117 (10% manually triggered)
Rate of CAM received/CAM sent	1,4%
Rate of DENM received from R-ITS-S or V-ITS-S / total of DENM exchanged	19%
Ratio : events received by V-ITS-S /sent events	18%

698 different actionID in DENM received including 554 event (132 with a termination and 422 without) and 144 termination and not the event.

Data analyses show that 3117 events were generated by V-ITSS (with 10 % manually triggered by the driver).
1,3% of event sent by a V-ITS-S were received by a V-ITS-S (V2V communication with eventually hop from V-ITS-S or R-ITS-S but the analysis is not able to discriminate direct messages or forwarded messages).
Among the 698 different actionID in DENM received, 554 were related to an event and 144 were related to a termination from a R-ITS-S with no received event by the V-ITS-S.
Knowing that :

- As described in section 3.11, validity duration can be up to 24h
- From SCOOP 2412Specifications of DENM:
  "The cancellation message is sent with the same values of validityduration, repetitioninterval, repetitionduration than the related DENM"

So if there is a termination of a long event, the duration of this event can also be up to 24H. there is a strong probability that a V-ITS-S received terminations with no event associated. To avoid network load, it could be interesting to optimize the ratio DENM sent/standalone termination. Specification of the termination need to be changed in order to have a validity duration of the termination that will not exceed the validity duration of the related event.
For example if a RWW is set to be sent during 10 hours, and finally ended after 5 hours, termination should be sent for maximum 5 hours.

109 019 DENM (update and repetition included) from R-ITS-S or V-ITS-S were received (554 events) by a V-ITS-S with 7% from a V-ITS-S.

If we consider also DENM sent by R-ITS-S, 19% of DENM were received by a V-ITS-S.
4% of DENM sent by V-ITS-S were a cancellation of a DENM and 31% of them were received by a V-ITS-S.
10 174 437 CAM were sent by vehicles and 1,4% were received by a V-ITS-S

3.4 Geographical distribution of events triggered by R-ITS-S

R-ITS-S have sent during this experimentation event related to 9 Use cases. 6 Sub cause code associated were not specified in SCOOP_2.4.1.2 Specification of DENM. If road operators triggered these new events, There is probably a need not covered actually.

Table 5: **Cause Code sent by R-ITSS**

eventtype _causecode	eventtype_ subcausecode	Label event type		Use case
2	0	Accident	unavailable(0): in case the information on the sub cause of the accident is unavailable,	Unprotected accident area
2	1		multiVehicleAccident(1): in case more than two vehicles are involved in accident,	Unprotected accident area – multi vehicle accident
2	2		heavyAccident(2): in case the airbag of the vehicle involving is accident is triggered, and accident requires important rescue and recovery work,	Unprotected accident area – heavy accident
2	3		accidentInvolvingLorry(3): in case the accident involves a lorry,	Unprotected accident areae – truck
2	4		accidentInvolvingBus(4): in case the accident involves a bus,	Unprotected accident area - Bus
2	5		accidentInvolvingHazardousMaterials(5): in case the accident involves hazardous material,	Unprotected accident area – hazardous material
3	0	Roadworks	Unavailable	Planned road works
3	1		majorRoadworks(1): in case a major roadworks is ongoing,	Not specified
3	2		roadMarkingWork(2): in case a road marking work is ongoing,	Not specified
3	3		slowMovingRoadMaintenance(3): in case slow moving road maintenance work is ongoing,	Planned road works - Slow moving Road Maintenance
6	0	Adverse weather condition - adhesion	unavailable(0): in case information on the cause of the low road adhesion is unavailable,	Temporary slippery road
6	1		heavyFrostOnRoad(1): in case the low road adhesion is due to heavy frost on the road,	Temporary slippery road - heavy frost on road
6	3		mudOnRoad(3): in case the low road adhesion is due to mud on the road,	Temporary slippery road - mud on road
6	4		snowOnRoad(4): in case the low road adhesion is due to snow on the road,	Temporary slippery road - snow on road
9	0	Hazardous location -	unavailable(0): in case further detailed information on the road surface condition is unavailable,	Not specified

9	1	Surface condition	rockfalls(1): in case rock falls are detected on the road surface,	Unsecured blockage of a road – rock falls
10	0	Hazardous location - Obstacle on the road	unavailable(0): in case further detailed information on the detected obstacle is unavailable,	Obstacle on the road
10	1		shedLoad(1): in case detected obstacle is large amount of obstacles (shedload),	Not specified
10	2		partsOfVehicles(2): in case detected obstacles are parts of vehicles,	Not specified
10	3		partsOfTyres(3): in case the detected obstacles are parts of tyres,	Not specified
11	0	Hazardous location - Animal on the road	unavailable(0): in case further detailed information on the animal on the road event is unavailable,	Animal on the road
11	1		wildAnimals(1): in case wild animals are detected on the road,	Animal on the road - Wild animal
11	2		herdOfAnimals(2): in case herd of animals are detected on the road,	Animal on the road - herd of animal
12	0	Human presence on the road	unavailable(0): in case further detailed information on human presence on the road is unavailable,	People on the road
12	1		childrenOnRoadway(1): in case children on the road event is detected,	Not specified
12	2		cyclistOnRoadway(2): in case cyclist presence is detected on the road,	Not specified
18	0	Adverse weather condition - visibility	unavailable(0): in case information on the cause of low visibility is unavailable,	Reduced visibility
94	0	Stationary vehicle	Unavailable	Stationary vehicle
94	2		Vehicle breakdown	Stationary vehicle, breakdown

Figure 5: Event sent by a R-ITSS in Ile-De -France

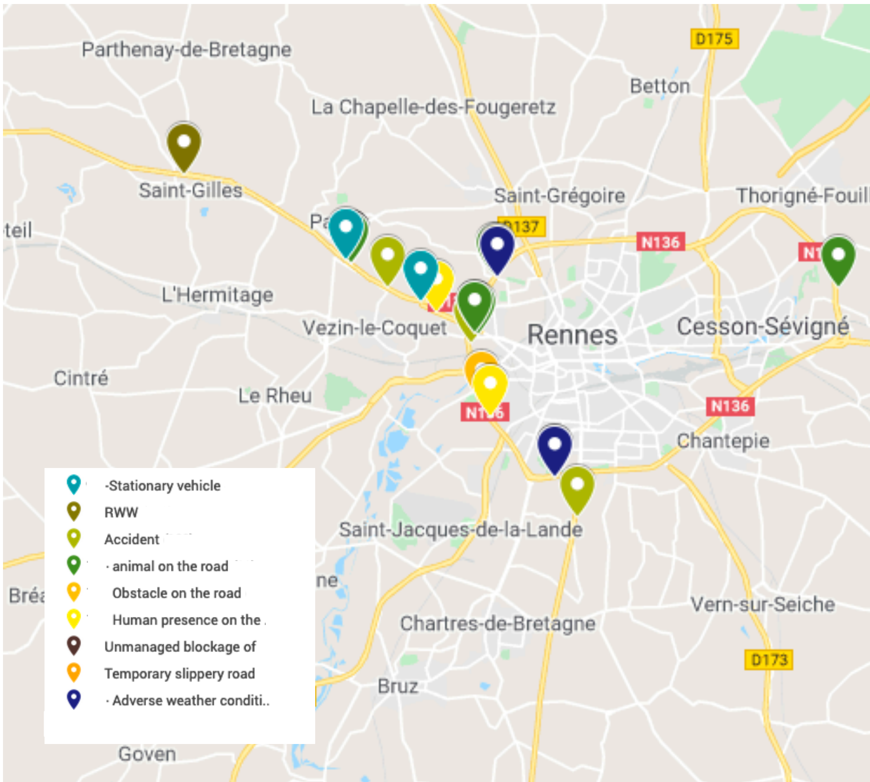


Figure 6: Event sent by a R-ITSS in Rennes

An event slow vehicle was sent by a R-ITSS located in the Rennes' ring road.

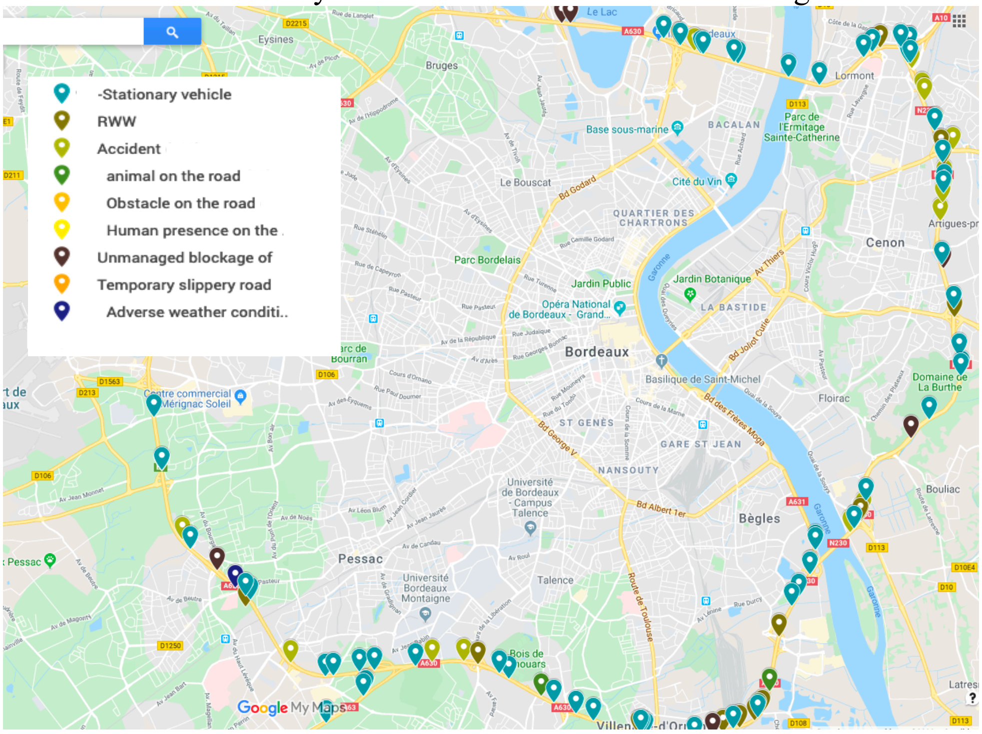


Figure 7: Event sent by a R-ITSS in Bordeaux

An action ID is supposed to define an event which mean a couple cause code/subcause code.

Among the 474 events generated by R-ITS-S and received by V-ITS-S, 13 action ID have 2 different cause codes or sub cause codes and one changed twice.

Table 6: example of cause code change for the same actionID

Cause code	sub causecode	originating station id	sequence number
2 - Accident	1	586172488	1
2 - Accident	2	586172488	1
12 – Human presence of the road	0	586172488	1

When a road operator triggers an event, he has the ability to change the nature of this event if he receives additional information.
Definition of an action ID is :

- From C-Road platform specifications: The actionID is the unique identifier of a DENM
- From the DENM standard: identifier of an detected event

Definition of an update: From DENM standard : indicate an evolution of the event
From these definitions, road operators consider they can change cause code and subcause code for one action ID where OEM consider that if it's the same action id, the event type is the same (same cause code/subcause code).

A clearer definition is needed so OEM and road operators have the same understanding; and at the end, the driver can have the relevant information on his HMI. At least V-ITS-S should be able to update the even type in the display of an action ID (modification of the text/panel).

3.5 Geographical distribution of events triggered by V-ITS-S

From DENM received by V-ITSS we are able to extract map of the different use cases and eventually define where are most often triggered event.

Figure 8 represents event distribution in France triggered manually or automatically by vehicles. We can notice that vehicles drive all around the country and also in Portugal, Italy and Belgium.

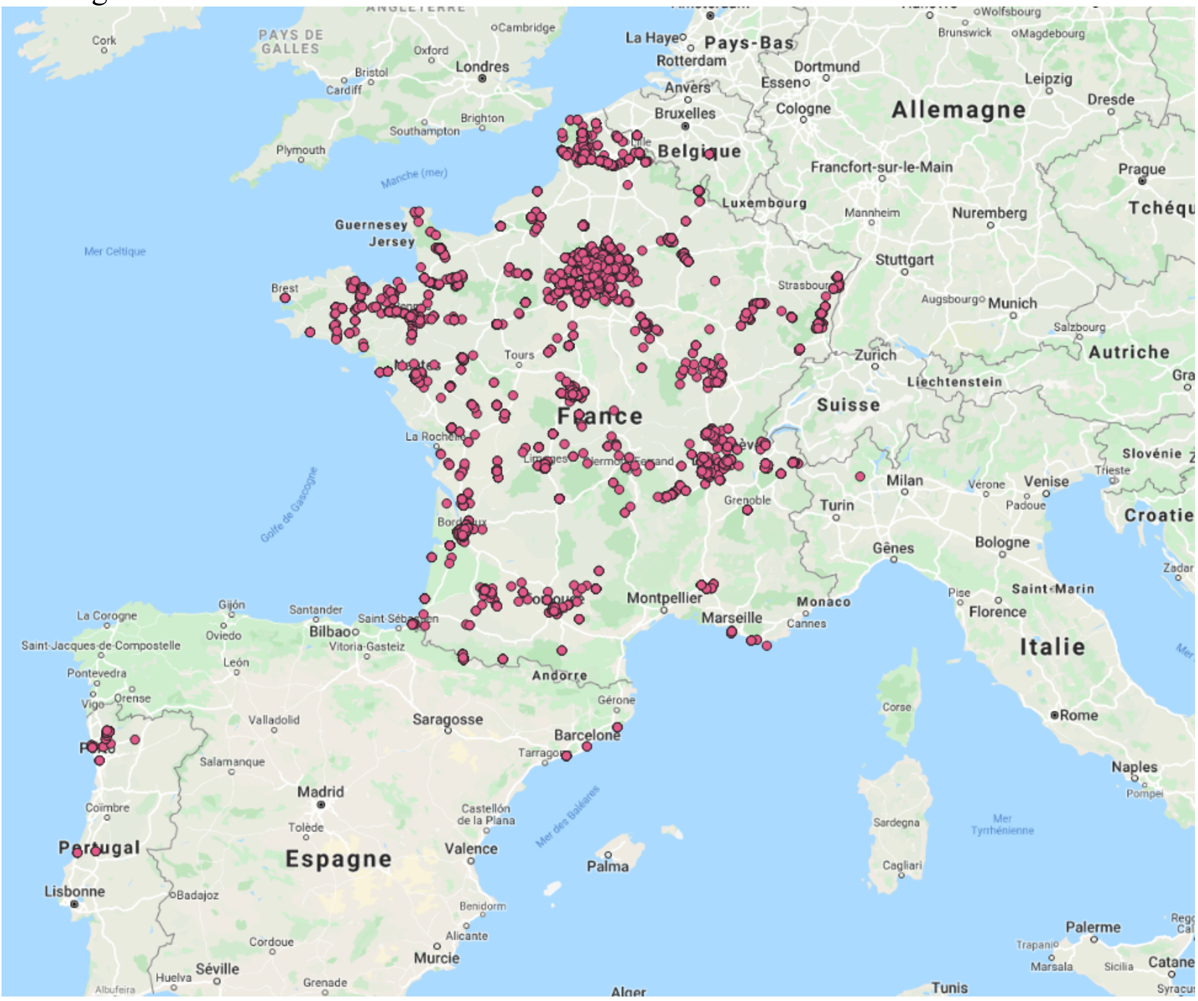


Figure 8: Event distribution in Europe during the experimentation all causecode combined

SCOOP Vehicles drove all around the territory but also in Spain, Portugal, Belgium and Italy. They triggered events even if the probability that another vehicles received it was low.
10 types of event were generated by V-ITS-S (see Table 7)

Table 7: event triggered by V-ITS-S

eventtype_causecode	eventtype_subcausecode	Event label		Use case Label
2	0	Accident	Unavailable	Unprotected accident area
6	0	Adverse weather condition - adhesion	Unavailable	Temporary slippery road
9	0	Hazardous location - Surface condition	Unavailable	Unsecured blockage of a road

10	0	Hazardous location - Obstacle on the road	Unavailable	Obstacle on the road
11	0	Hazardous location - Animal on the road	Unavailable	Animal on the road
12	0	Human presence on the road	Unavailable	People on the road
18	0	Adverse weather condition - visibility	Unavailable	Reduced visibility
19	0	Adverse weather precipitation – Extreme weather condition	Unavailable	Extreme weather conditions
94	0	Stationary vehicle	Unavailable	Stationary vehicle
94	2	Stationary vehicle	2 : Vehicle breakdown	Stationary vehicle, Breakdown
94	3	Stationary vehicle	3 : Postcrash	Unprotected accident area
99	1	Dangerous situation	Emergency Electronic Brake Light	Emergency break

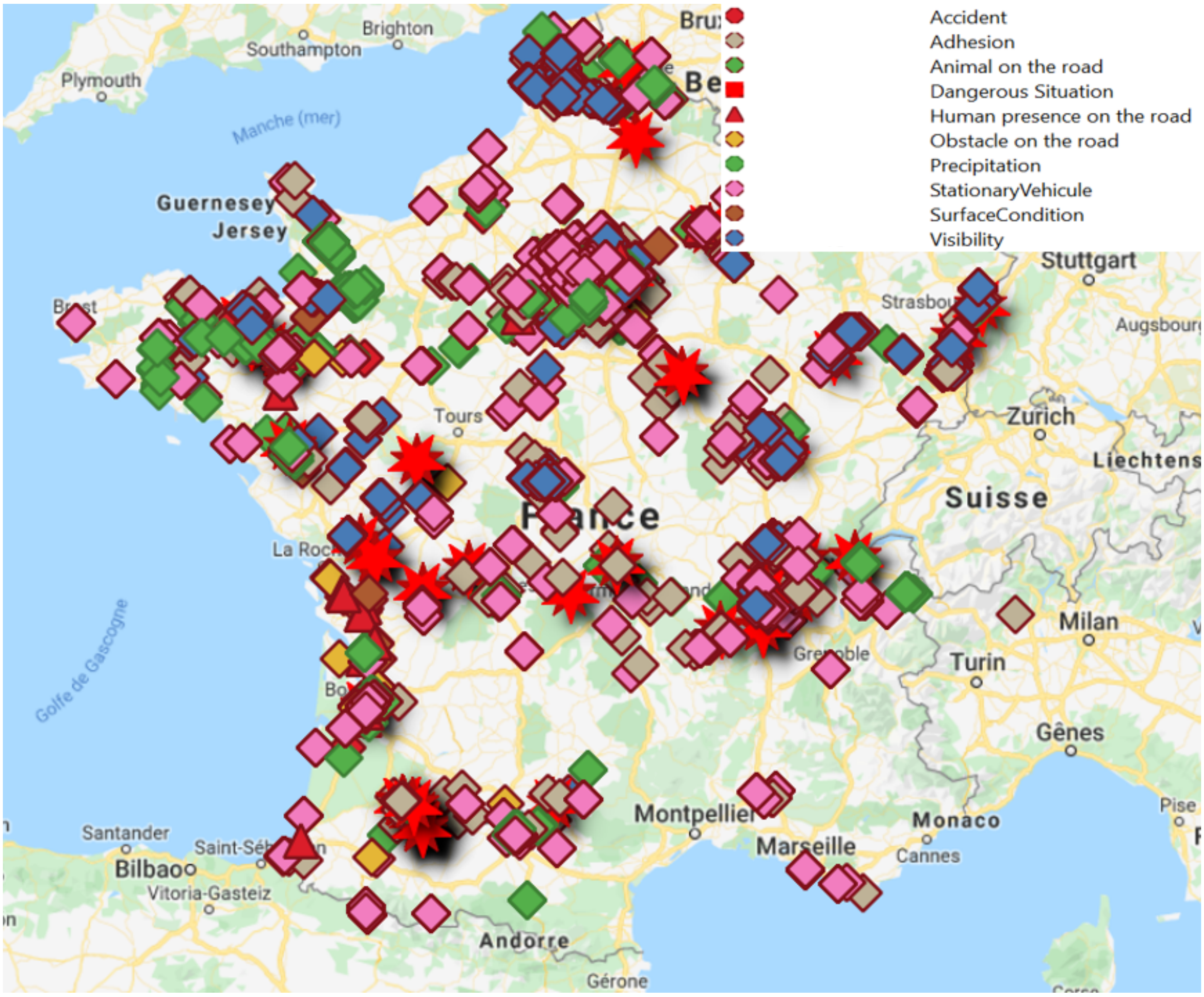


Figure 9: Event distribution in France during the experimentation

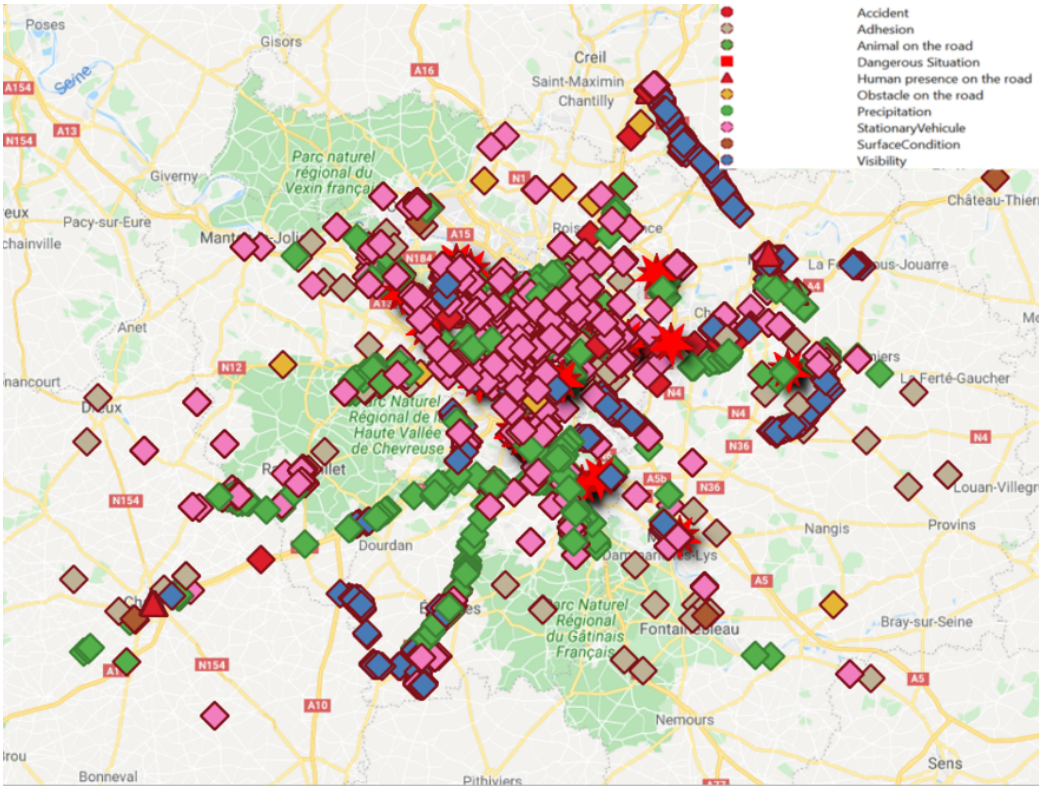


Figure 10: Event distribution in Ile-De- France during the experimentation

Stationary vehicle is the most triggered event (See Figure 10 and Figure 12). First thought is that this event is mostly related to traffic jam. Deeper analysis is made in section 3.14

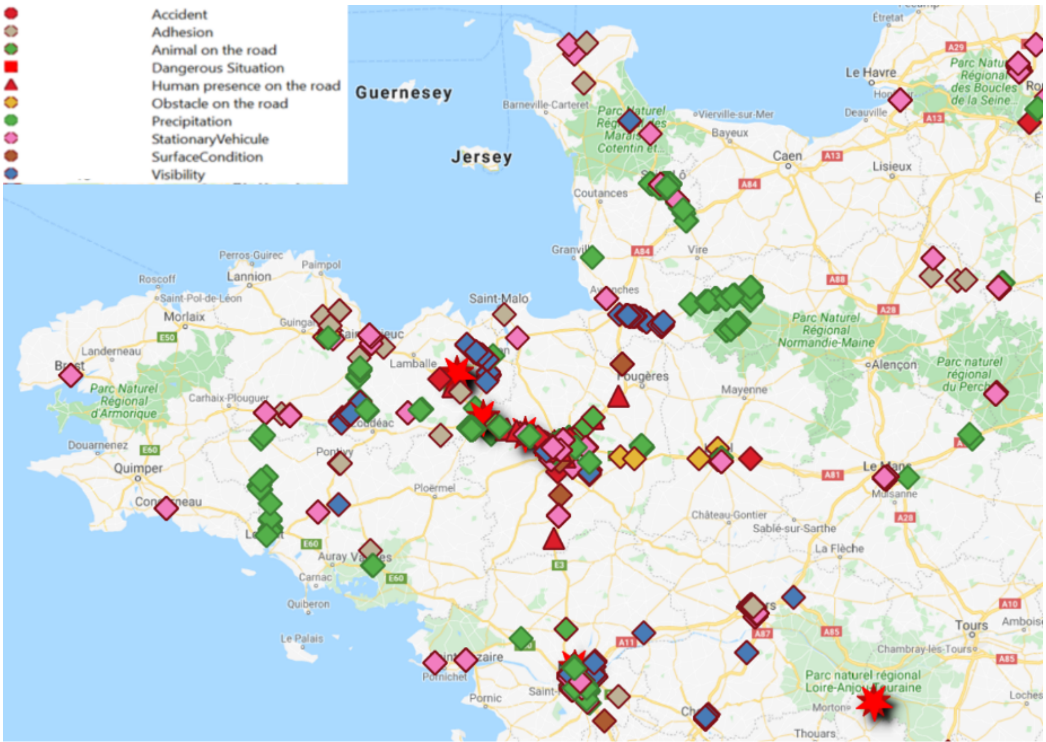


Figure 11: Event distribution in Brittany during the experimentation

Most events triggered in Brittani are linked to the weather (precipitation, Visibility and adhesion) (see Figure 11).

3.6 Events' type triggered by V-ITS-S

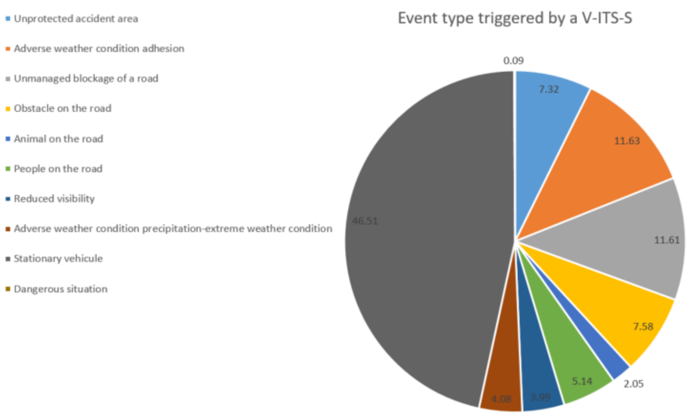


Figure 12: Event type distribution including repetition and update

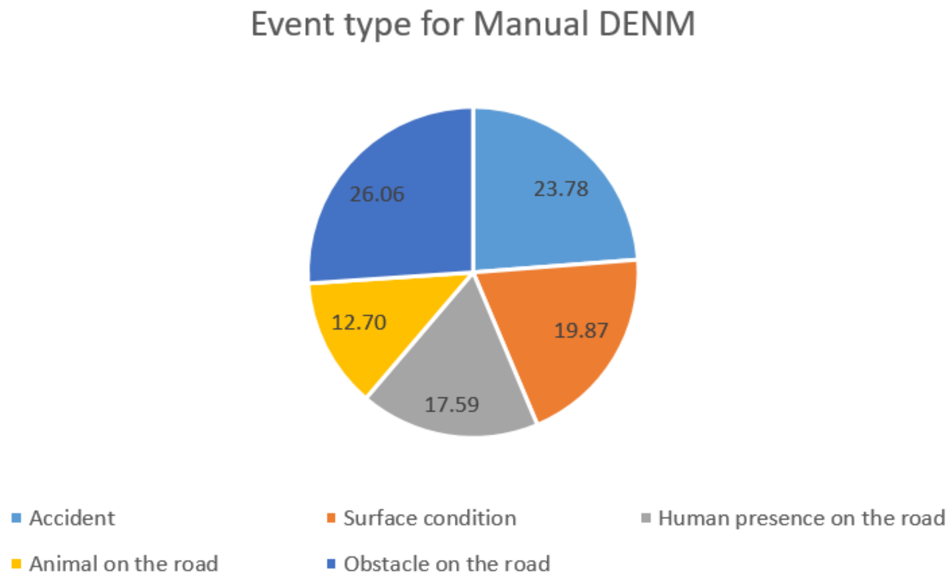


Figure 13: Manual event type distribution including repetition and update

Accident and Obstacle on the road are the most used by drivers to signal an event. The less used is animal on the road. Further analysis on HMI is needed to help understand drivers preferences on HMI signaling.

3.7 Global volume of DENM sent by V-ITS-S

3.7.1 Number of received DENM (with repetition)

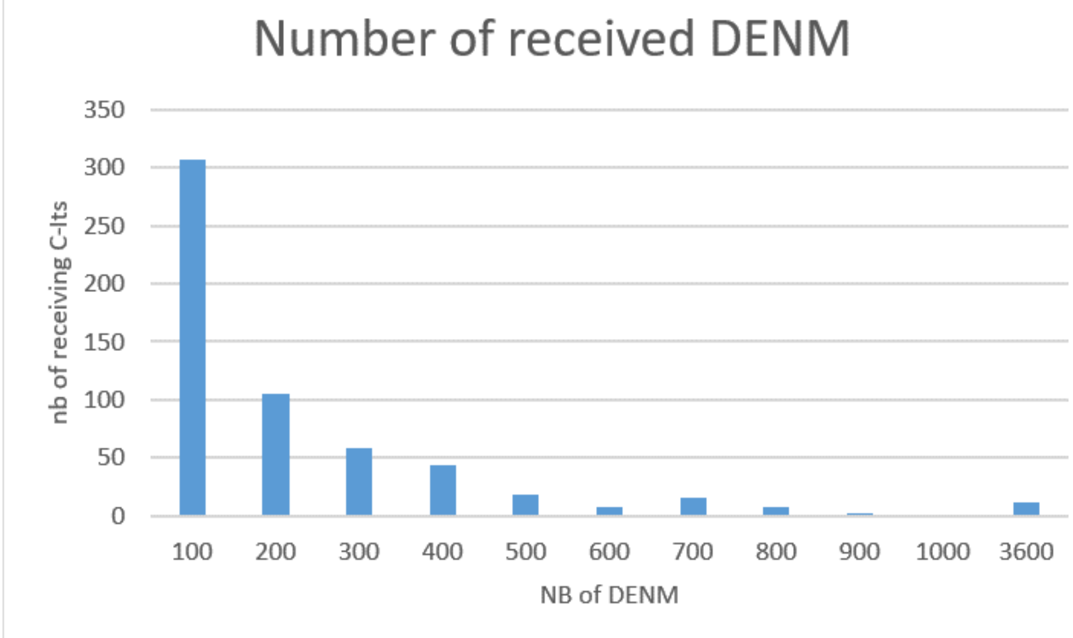


Figure 14: Number of received DENM per station

Figure 14 shows that 94% of stationID received less than 500 DENM and 6% receive between 501 and 3524 DENM during the experimentation.
As we are not able to associate stationID and V-ITS-S, no further analysis can be done.

3.7.2 Number of received Event

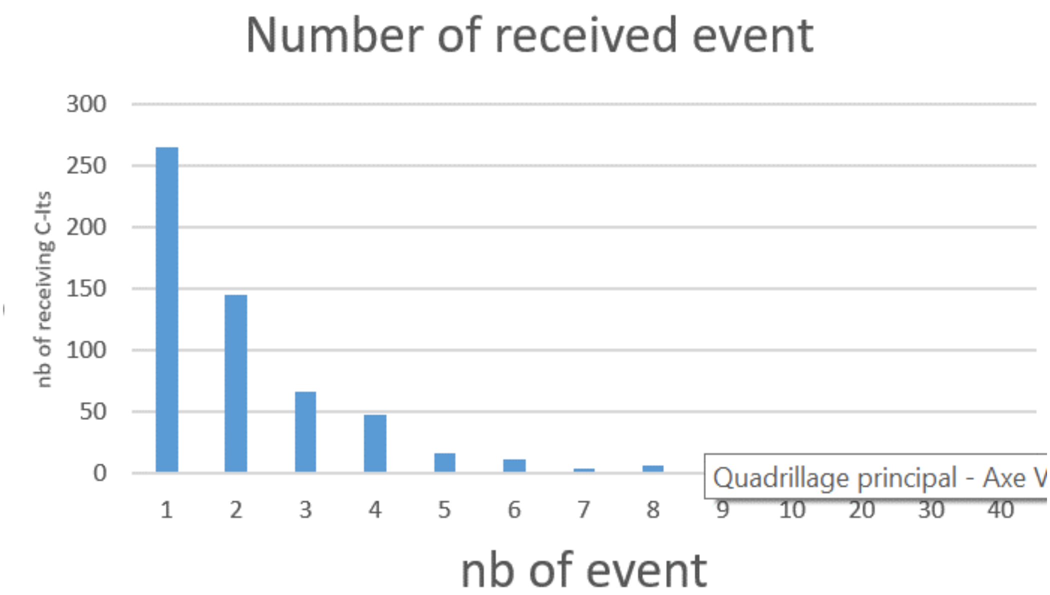


Figure 15: Event received by V-ITS-S

94% of stationID received between 1 and 5 events when 6 % received between 6 and 40 events.
As we are not able to associate stationID and V-ITS-S, no further analysis can be done.

3.7.3 DENM sent per cause code

The number of DENM sent per use cases is calculated including repetition and update. 45% of the global volume of DENM sent is dedicated to stationary vehicle. This corresponds too many DENMs given the unreliability of the information (see 3.14).

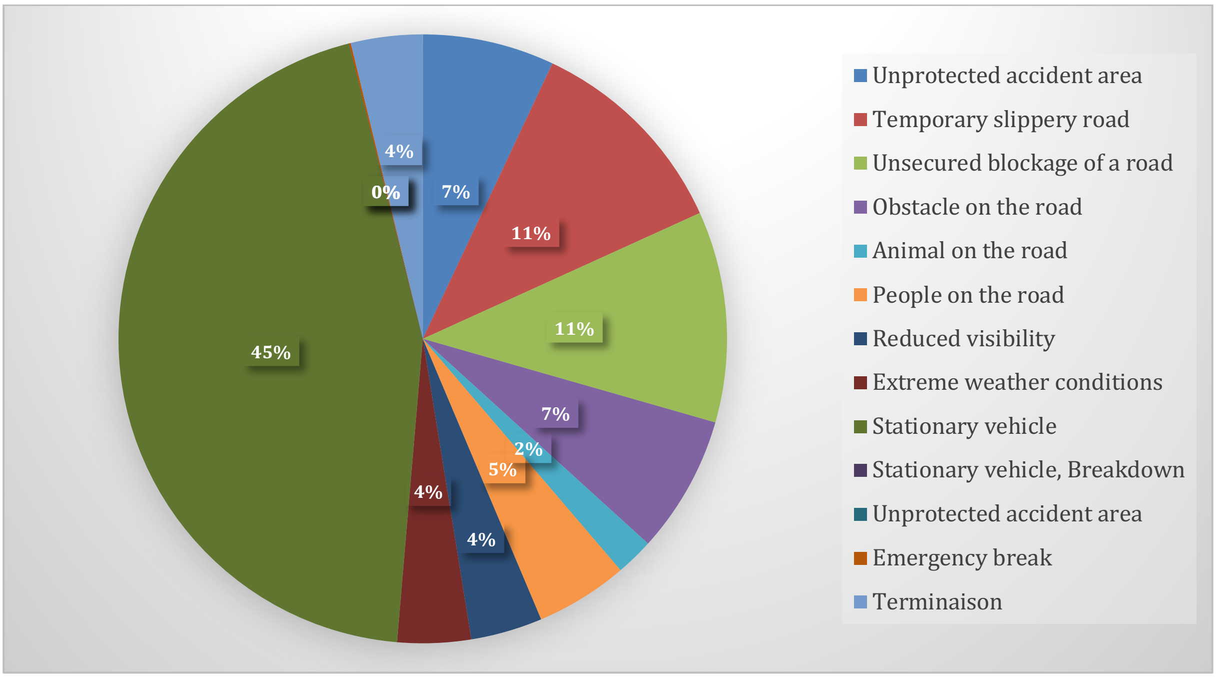


Figure 16: DENM repartition per use case

3.8 Repetition analysis for DENM sent by V-ITS-S

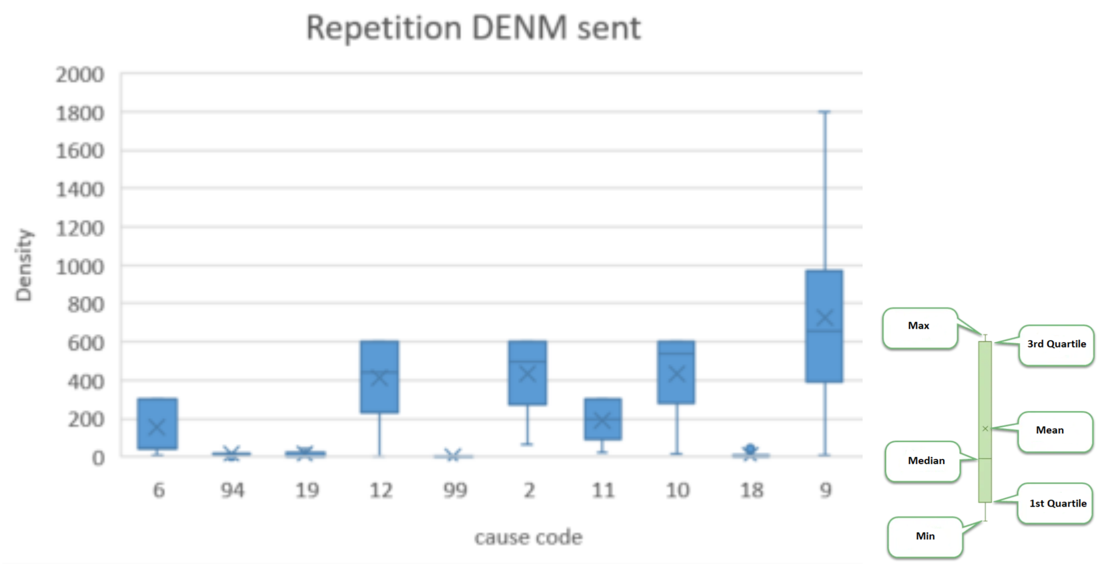


Figure 17: Density of repetition messages (including update) by cause code.

For example for the use case Unmanaged blockage of a road (manually triggered), the maximum of repetition sent is 1800 times with a mean value of 726 messages sent.
From the specifications (SCOOP_2.4.1.2_ Specifications of DENM fields) it appears that this DENM has to be repeated during 1800 s each s.
There is no cancellation for this DENM.

We have no further information to explain why this DENM is almost never repeated at the frequency specified. Cars may have stopped and turned off the engine each times the driver sent the information.

For all other cause code, results are closed to what is specified (see Table 8).

Table 8: Specifications for V-ITS-S about repetitions

Name	cause code	sub-cause code	Manu/ Auto	Repetition duration
Temporary slippery road	6 : Adverse weather conditions – Adhesion	0 : Unavailable	Auto	default value 600 s / in urban area, determined by digital map or onboard sensor algorithm: 300 s (If the vehicle has no information about the urban/non-urban status, the default value shall be used.
Animal on the road	11 : Hazardous Location - Animal on the road	0 : Unavailable	Manu	300S
People on the road	12 : Human presence on the road	0 : Unavailable	Manu	600s
Obstacle on the road	10 : Hazardous Location - Obstacle on the road	0 : Unavailable	Manu	600s
Stationary vehicle, breakdown	94 : Stationary vehicle	0 : Unavailable	Auto	30s
Stationary vehicle, breakdown	94 : Stationary vehicle	2 : Vehicle breakdown	Auto	30s
Unprotected accident area	2 : Accident	0 : Unavailable	Manu	600s
Unprotected accident area	94 : Stationary vehicle	3 : Postcrash	Auto	30s
Reduced visibility	18 : Adverse weather conditions - Visibility	0 : Unavailable	Auto	default value 600 s / in urban area, determined by digital map or onboard sensor algorithm: 300 s (If the vehicle has no information about the urban/non-urban status, the default value shall be used.
Unmanaged blockage of a road	9 : Hazardous location – Surface condition	0 : Unavailable	Manu	1800s
Emergency breake	99 : Dangerous situation	1 : Emergency electronic brake lights	Auto	2s
Extreme weather conditions	19 : Adverse weather precipitation – Extreme weather condition	0 : Unavailable	Auto	180s

3.9 Update analysis for DENM sent by V-ITS-S

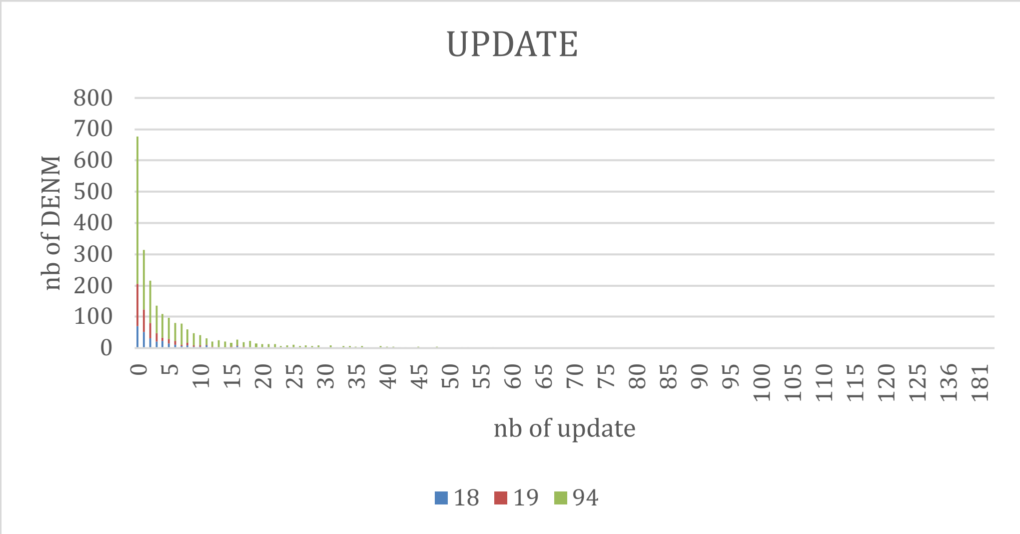


Figure 18: DENM versus count of update

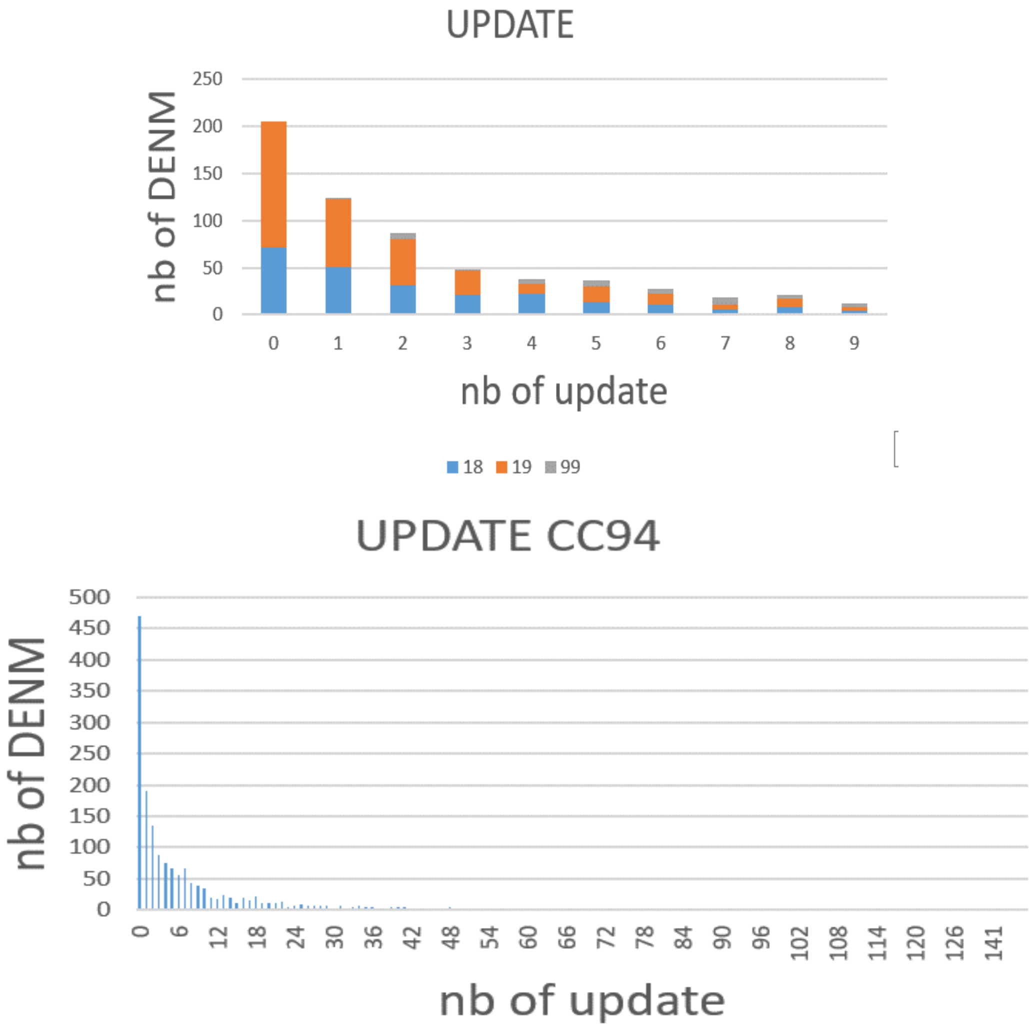


Figure 19: DENM versus count of update

0 means there is no update
Among all DENM, Almost 600 DENM were sent without any update.

3.10 Validity Duration analysis for DENM sent by V-IT-S

Figure 20: Validity duration for DENM sent by V-ITS-S

Table 9: ValidityDuration from SCOOP_Specifications of DENM

Name	cause code	sub-cause code	ValidityDuration (s)
Temporary slippery road	6 : Adverse weather conditions – Adhesion	0 : Unavailable	600 s, re-armed for every update
Animal on the road	11 : Hazardous Location - Animal on the road	0 : Unavailable	Estimated average duration 600s
People on the road	12 : Human presence on the road	0 : Unavailable	Estimated average duration 1200s
Obstacle on the road	10 : Hazardous Location - Obstacle on the road	0 : Unavailable	Estimated average duration 1200s
Stationary vehicle, breakdown	94 : Stationary vehicle	0 : Unavailable	30s (correspond to transmission conditions)
Stationary vehicle, breakdown	94 : Stationary vehicle	2 : Vehicle breakdown	30 s, re-armed for every update
Unprotected accident area	2 : Accident	0 : Unavailable	Estimated average duration 1200s

Unprotected accident area	94 : Stationary vehicle	3 : Postcrash	180 s, re-armed for every update.
Reduced visibility	18 : Adverse weather conditions - Visibility	0 : Unavailable	300 s, re-armed for every update
Unmanaged blockage of a road	9 : Hazardous location – Surface condition	0 : Unavailable	3600s
Emergency break	99 : Dangerous situation	1 : Emergency electronic break lights	2s, re-armed for every update
End of queue	27 : Dangerous end of queue	0 : Unavailable	V2V logic : C2C recommendation 20s
Extreme weather conditions	19 : Adverse weather precipitation – Extreme weather condition	0 : Unavailable	300 s, re-armed for every update

Slippery road is the only use case not in lined with specifications with a validyduration which varies between 300 and 600 s. With no other information we can nit conclude if it's relevant to have this two values.

3.11 Validity Duration analysis for DENM sent by R-ITS-S

Figure 21: Validity Duration for DENM sent by R-ITS-S

Validity duration chosen by road operators are not compliant with SCOOP_Specifications of DENM (Table 10).

Table 10: Validity Duration from SCOOP_Specifications of DENM

Name	cause code	sub-cause code	ValidityDuration (s)
Planned road works	3	0 : unavailable	duration of the RW
Planned road works	3	3 : Slow moving Road Maintenance	duration of the RW
Temporary slippery road	6	0 : Unavailable	1800
Temporary slippery road	6	1 : heavy frost on road	
Temporary slippery road	6	10 : roadsSalted	
Temporary slippery road	6	2 : fuel on road	
Temporary slippery road	6	3 : mud on road	
Temporary slippery road	6	4 : snow on road	
Temporary slippery road	6	6 : black ice	
Temporary slippery	6	7 : oil on road	
Temporary slippery road	6	8 : looseChippings	
Temporary slippery road	6	9 : instantBlackIce	
Animal on the road	11	0 : Unavailable	1800
Animal on the road - Wild animal	11	1: wild animal	
Animal on the road - herd of animal	11	2 : herd of animal	
Animal on the road - small animal	11	3: small animal	
Animal on the road – large animal	11	4 : large animal	
People on the road	12	0 : Unavailable	1800
Obstacle on the road	10	0 : Unavailable	1800
Stationary vehicle	94	0 : Unavailable	1800
Stationary vehicle, breakdown	94	2 : Vehicle breakdown	1800
Unprotected accident area	2	0 : Unavailable	3600
Unprotected accident area – multi vehicle accident	2	1 : multi vehicle accident	3600
Unprotected accident area – heavy accident	2	2 : heavy accident	7200
Unprotected accident areae – truck	2	3 : accident involving lorry	7200
Unprotected accident area - Bus	2	4 : accident involving bus	7200
Unprotected accident area – hazardous material	2	5 : accident invovlving	7200

		hazardous materials	
Unprotected accident area	2	7 : unsecured Accident	3600
Reduced visibility	18	0 : Unavailable	1800
Reduced visibility - fog	18	1 : fog	
Reduced visibility- smoke	18	2 : smoke	
Reduced visibility –heavy snow fall	18	3 : heavySnowfall	
Reduced visibility - heavy rain	18	4 : heavy Rain	
Reduced visibility - heavy hail	18	5 : heavy Hail	
Unmanaged blockage of a road – rock falls	9	1 : rock falls	3600
Unmanaged blockage of a road – subsidence	9	4 : subsidence	
Unmanaged blockage of a road – snow drifts	9	5 : snow drifts	
Unmanaged blockage of a road – burst pipe	9	7 : burst pipe	
End of queue	27	0 : Unavailable	1800
Extreme weather conditions - strong winds	17	1 : strong winds	1800
Extreme weather conditions - thunders torm	17	4 : thunderstorm	

Road operator send long event in order to compensate for possible connection faults with the R-ITSS, with a subsequent termination sending to close the event. But for Slippery road(cc=6), human presence on the road (cc=12) and animal on the road, that seems way too much. It's not necessary to increase de network load with messages that are no longer useful.
This way can be efficient if the termination hasn't the same validityduration which is not the case. At least termination duration need not to exceed the time set by the originating event validity duration.
The road operator need to choose validityduration by taking into account realities on the ground but also the usefulness of sending a message if it is no longer relevant and the induced network load.

3.12 The distribution of events

3.12.1 The distribution of events for a week

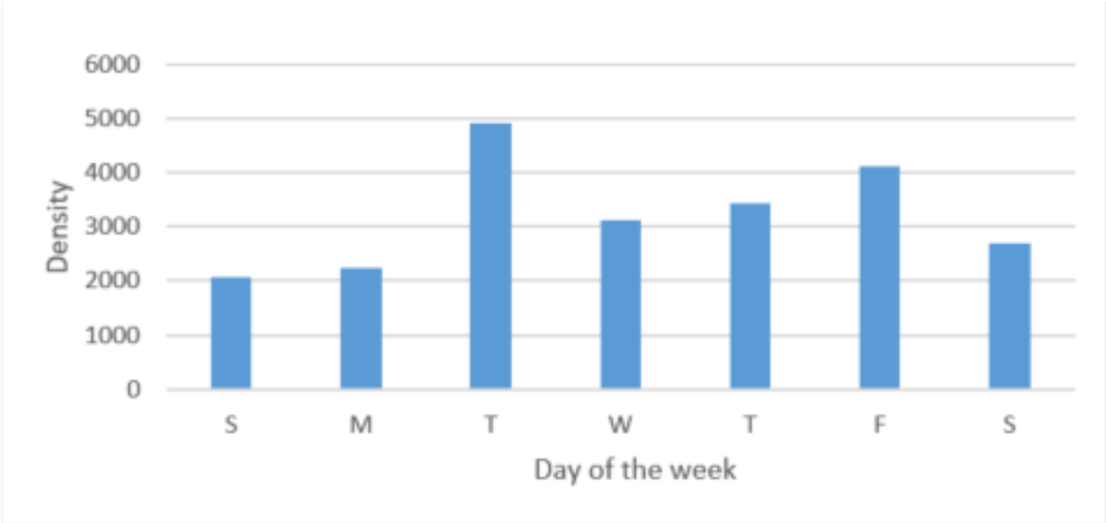


Figure 22: Events' per week

Density is related to the number of event sent by vehicles. DENM are sent mostly during work day.

3.12.2 The distribution of events for one day

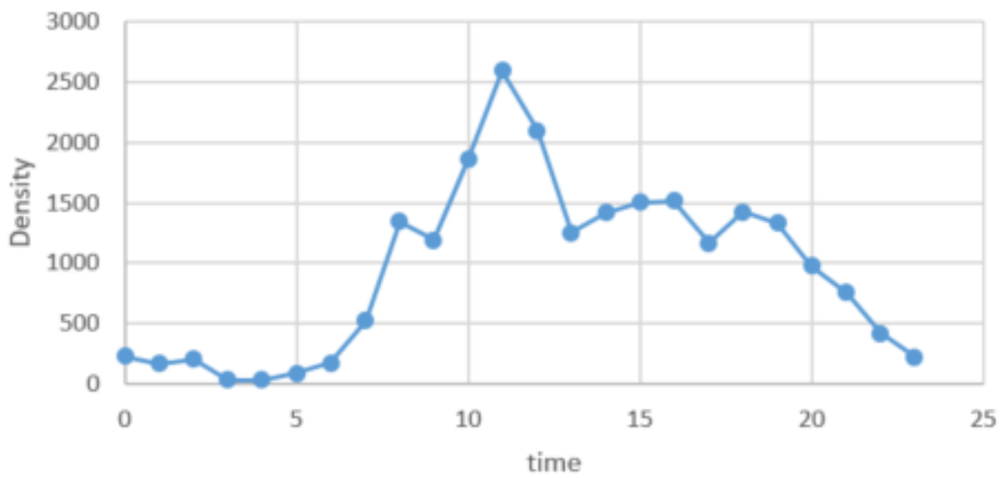


Figure 23: Events' per day

And during the day, they are mostly sent in the morning with a pic value around 11:00 A.M.. It seems that SCOOP vehicles are mostly cars company used for working activity.

3.13 Number of received DENM from an ITS-S (R- or V-)

In most case , 1 or 2 StationID received the same DENM sent by V-ITS-S or R-ITS-S. 90% of received DENM from R-ITS-S and the rest from V-ITS-S.
60% of DENM was received by 1 StationID.
19% of DENM was received by 2 stationID.
1.5% of DENM was received by more than 10 stationID.
In two cases, one DENM was received by 16 V-ITS-S.

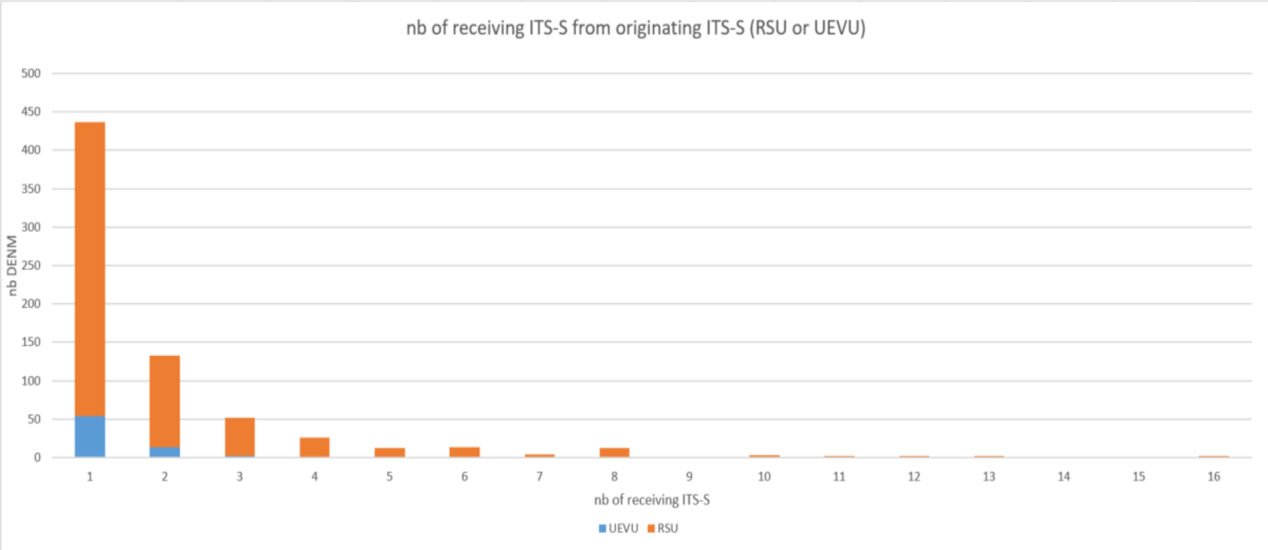


Figure 24: Receiving ITSS

3.14 Stationary Vehicle use cases analysis

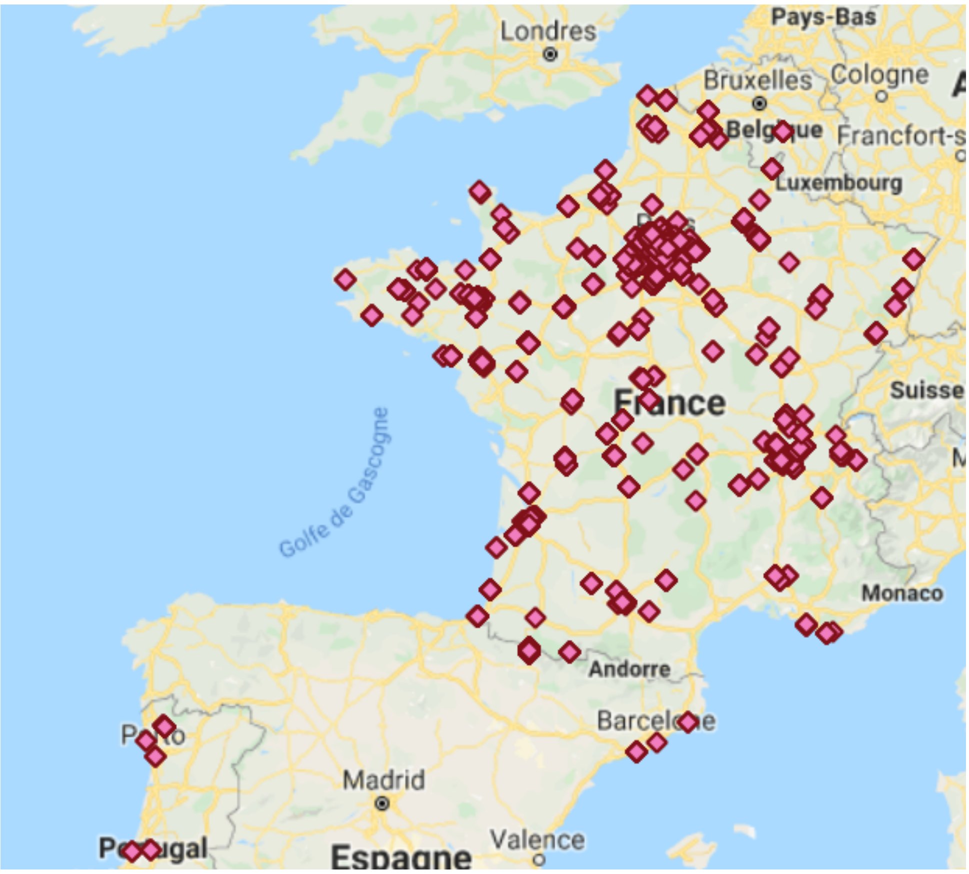


Figure 25: Stationary use case map Cause code 94.

Stationary use case have 2 possible cause codes (see Table 11).

Table 11: Cause code for Stationary vehicle

Subcausecode	percentage

0-Unavailable	99,9%
2 – Vehicle Breakdown	0,08

Vehicle Breakdown is not significant as it occurs once during this experimentation. So let's focus on the subcaucode 0.
From SCOOP@F specifications SCOOP_2.4.1_Common set of functional and technical specifications 3 possible levels of information quality (see Figure 26).

Use case	Information Quality defined for SCOOP	Trigger conditions	Comments
A2-D4a Warning stationary vehicle	1	Warning + V=0 since 30s	Risk of traffic jam without data on the vehicle's position (lane or shoulder)
	2	Warning + V=0 since 30s (can be reduced to 20s if enough triggering conditions) + [Neutral OR parking brake OR seat belt unbuckled]	Risk of traffic jam without data on the vehicle's position (lane or shoulder), for the case of the vehicle in neutral
	3	Warning + V=0 since 30s (can be reduced to 0 s if enough triggering conditions) + [door open during at least 3s OR -APC]	

Figure 26: Quality Information for stationary vehicle/unavailable

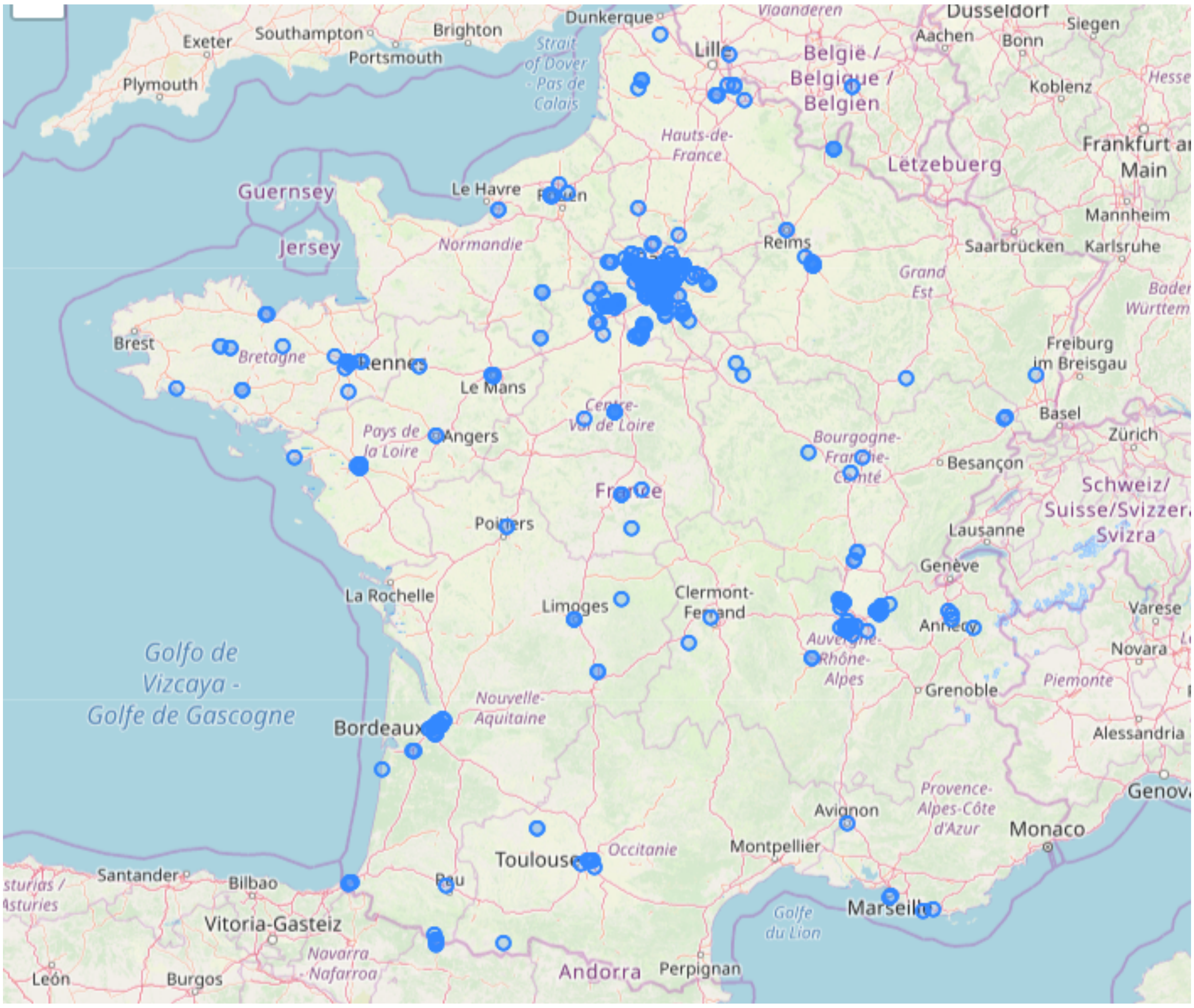


Figure 27: Stationary vehicle 94/0 and IQ=3

82% of stationary vehicle event are sent with an information quality of 3. From SCOOP@F specifications (Figure 26), Information quality of 3 is set if

- Warning
- an arbitrary number of doors is open for at least 3s or if the hood is open.

The high percentage of triggered event with IQ=3 is disturbing due to the fact that it represent almost 30% of all event generated by vehicles.
Among the multitude of triggers, we have double-lined vehicles, vehicles stopping at school or nursery level, parking on the side of the road with warning lights. These situations remain important to report in urban areas because they are dangerous.
In urban areas, the trigger can be crowded. But Stationary vehicle with an IQ=3 may also trigger events without a real associated danger.
In dense urban areas, the number of triggers is very high and may require future adaptation of the signage to the road situation. To consider such an adaptation, additional studies are necessary..

3.15 Adverse weather condition – adhesion use cases analysis

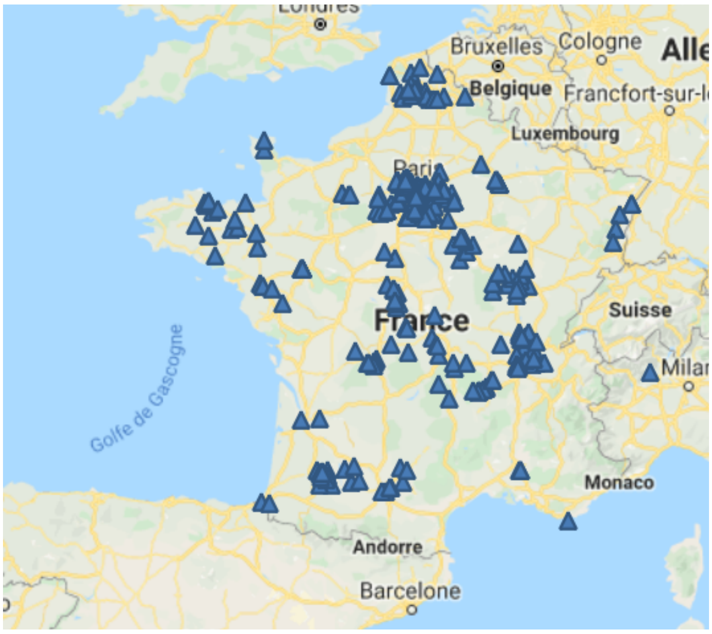


Figure 28: Adverse weather condition - adhesion map

Figure 28 show slippery road use cases automatically triggered by V-ITSS with an information quality of 5..

For this use case, no update was logged. Each time a vehicle triggered a slippery road, the DENM was sent during its validity duration. Triggering conditions was no longer fulfilled after the vehicle loose adhesion.

3.16 Adverse weather precipitation – Extreme weather condition

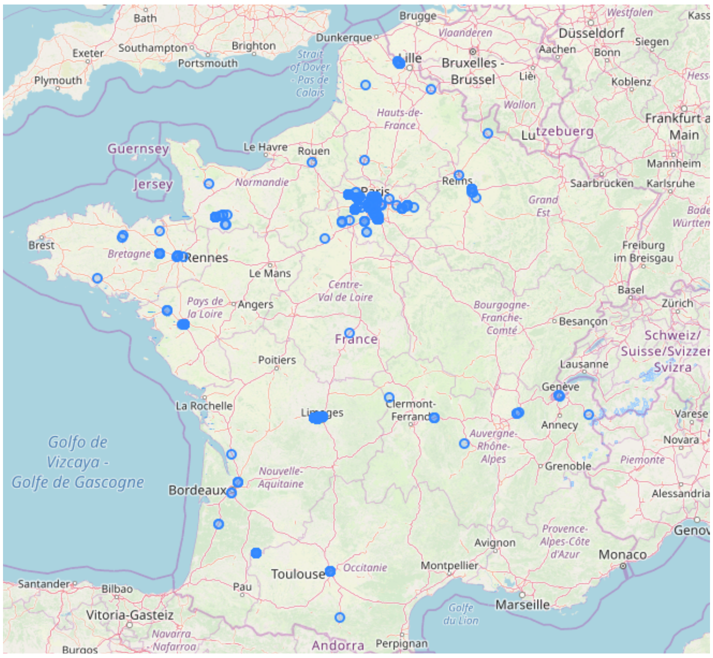


Figure 29: Adverse weather precipitation – Extreme weather condition location

For the period from 5/9/2018 to 27/8/2019, the event Warning exceptional weather was triggered 112 days /356 days (see Figure 30).

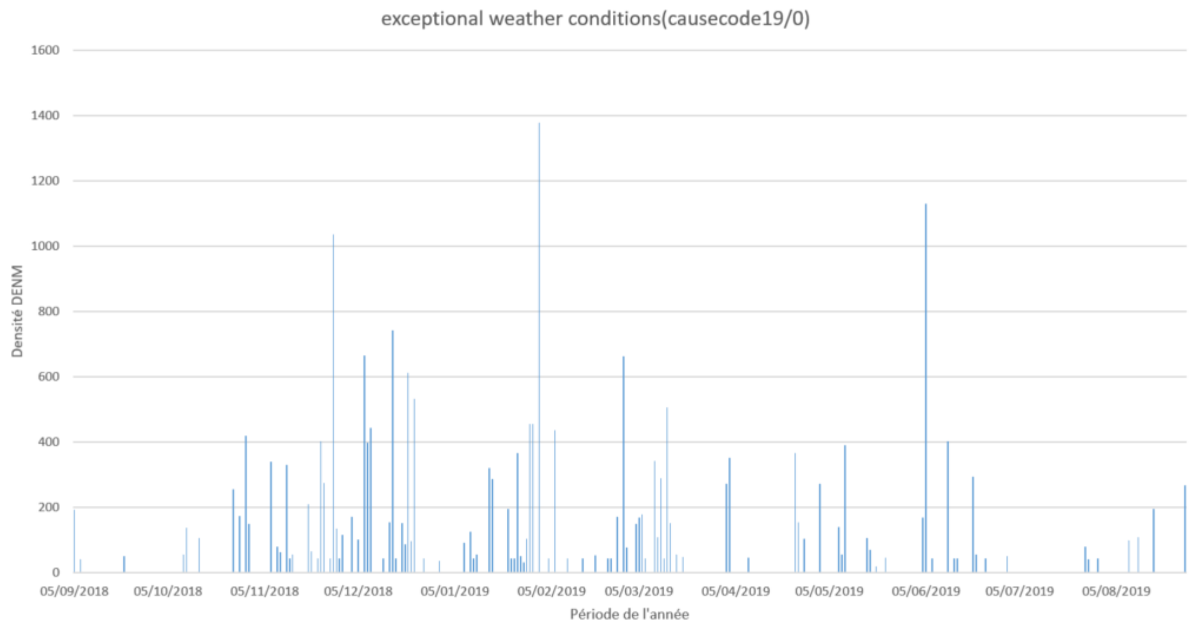
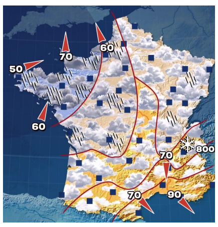


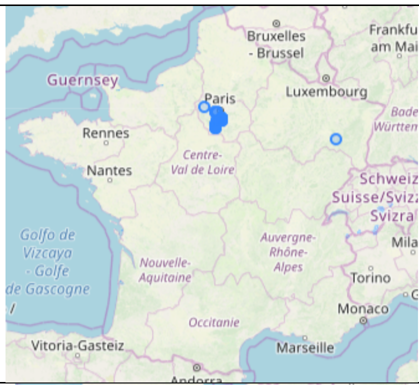
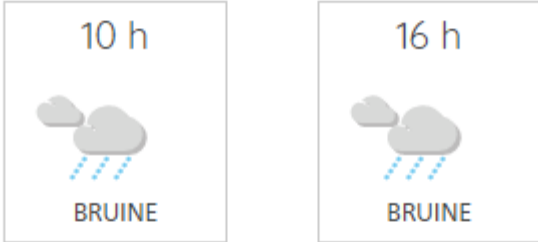
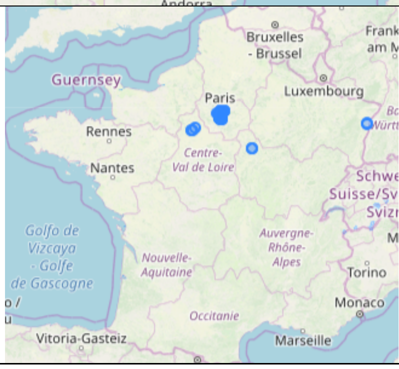
Figure 30: Density of sent DENM for Extreme weather condition

To define if the event is not a false positive, we cross check DENM sent with Meteo France database.

We consider three days when events were triggering by several stationID:

- 27/11/2018 with 1037 DENM (19 events)
- 01/02/2019 with 1379 DENM (13 events)
- 05/06/2019 with 1131 DENM (15 events)

Day	location	Meteo France data
27/11/2018		Event from 4 :21 P.M to 10:59 P.M. **Weather** 

01/02/2019		 **18 :38 à 22h47**
05/06/2019		 **12 :00 to 22 :46**

Differences observed are not representative because we do not have hourly rainfall data. Use cases are mostly consistent with the weather phenomena observed on those days..

3.17 Succession of use cases

We have 55 events for Emergency break light. 9 V-ITS-S sent other events just before or after
4 V-ITS-S triggered a CC=6 (adhesion) and then 99 (Emergency brake Light).
1 V-ITS-S triggered a CC=18 (Visibility) and then 99 (Emergency brake Light).
1 V-ITS-S triggered a CC= 99 (Emergency brake Light) then CC=18 (Visibility) and then 99 (Emergency brake Light).
3 V-ITS-S triggered a CC=99 (Emergency brake Light) and then 6 (adhesion).

Events' succession is logical as they occur close together

3.18 Faulty messages

Figure 31 shows that most errors come from a default in non-secured packed messages at Geonet level. The second higher percentage is related to unsupported BTP port.

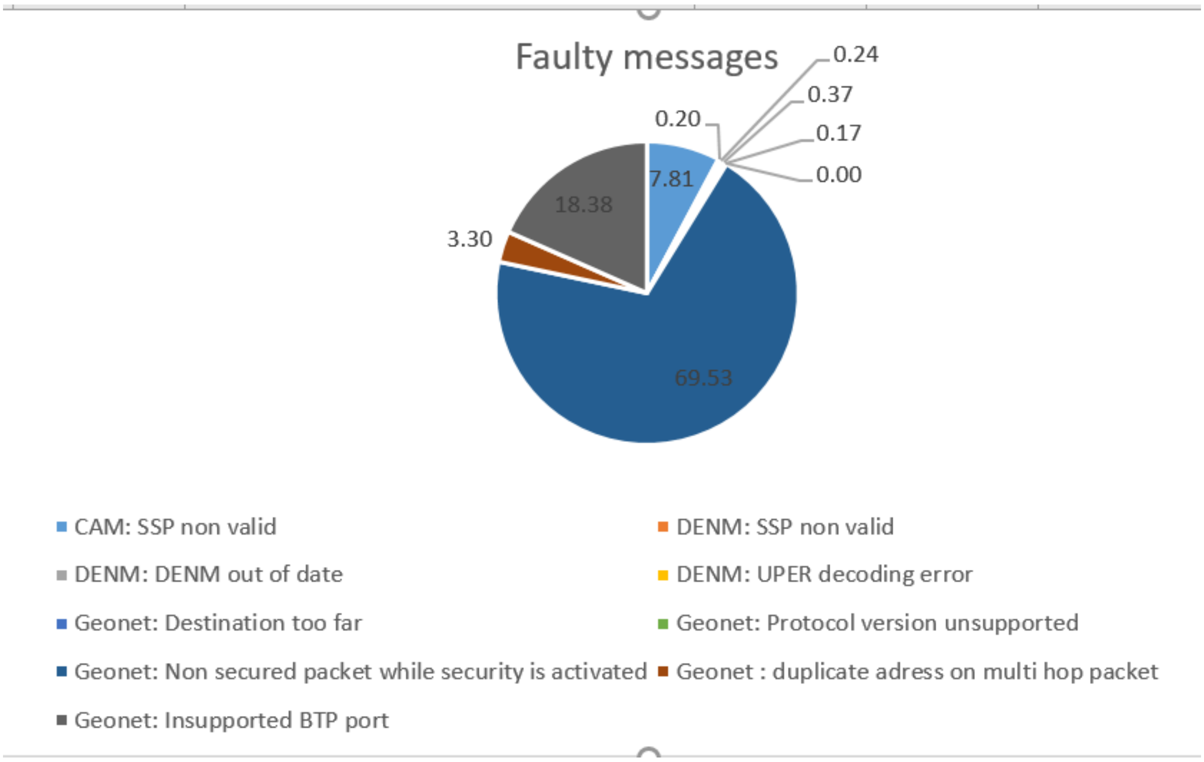


Figure 31 : faulty messages repartition

Most of errors occurs for a default of signature of the received message. SCOOP@F V-ITSS crossed V-ITS-S or R-ITS-S with different security specifications as seen in section XX, vehicles drive outside the SCOOP trust domain.

3.19 R-ITS-S location

From DENM received by V-ITSS and sent by R-ITSS, a cartography of R-ITS-S was done (see Figure 32)

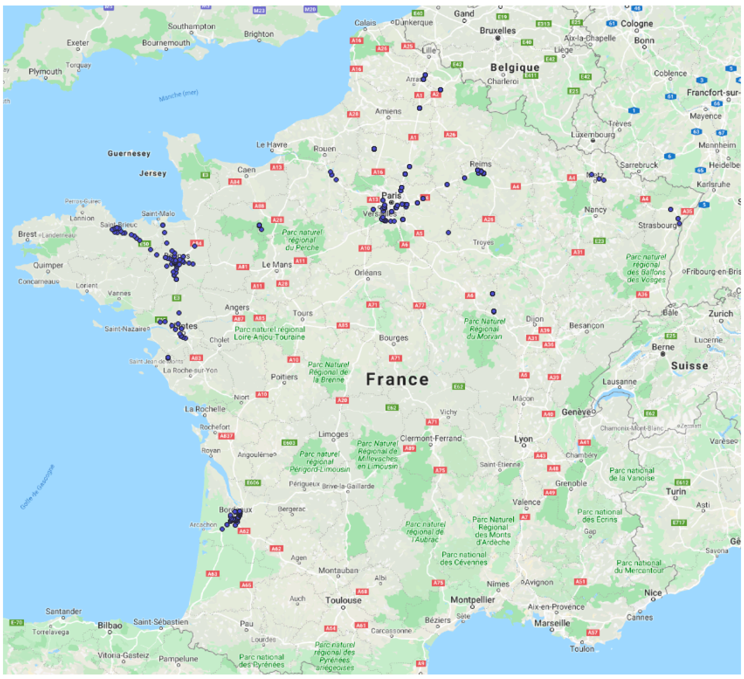


Figure 32: R-ITS-S (which sent DENM to V-ITS-S) location

R-ITS-S have their location calculated by GPS. As we can see Figure 33, multiple positions exist for one R-ITS-S. Maybe it will be more efficient to have a position manually written and not defined by the gps defined in the R-ITS-S to avoid this variation. For example R-ITS-S with the stationed 2628834093 has up to 200 positions.

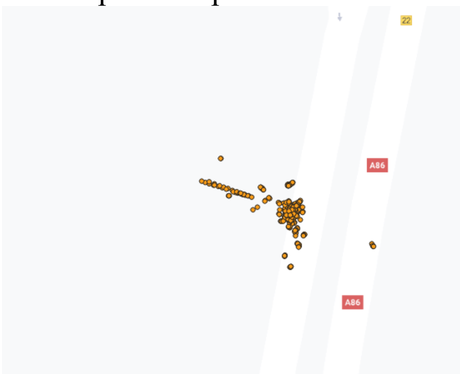


Figure 33: Positions of the R-ITSS 2628834093 in DIRIF test site

3.20 R-ITS-S Range

For 12 R-ITS-S, we calculated the range between them and V-ITS-S using CAMI and DENM received by V-ITSS from a R-ITSS(Figure 34). The highest range is for R-ITS-S located on highway with a long line of sight (Figure 35) : respectively 1461m and 1034 m.
Lowest value are for R-ITS-S located in urban area, near bridge or even in a curve (Figure 36 and Figure 37).

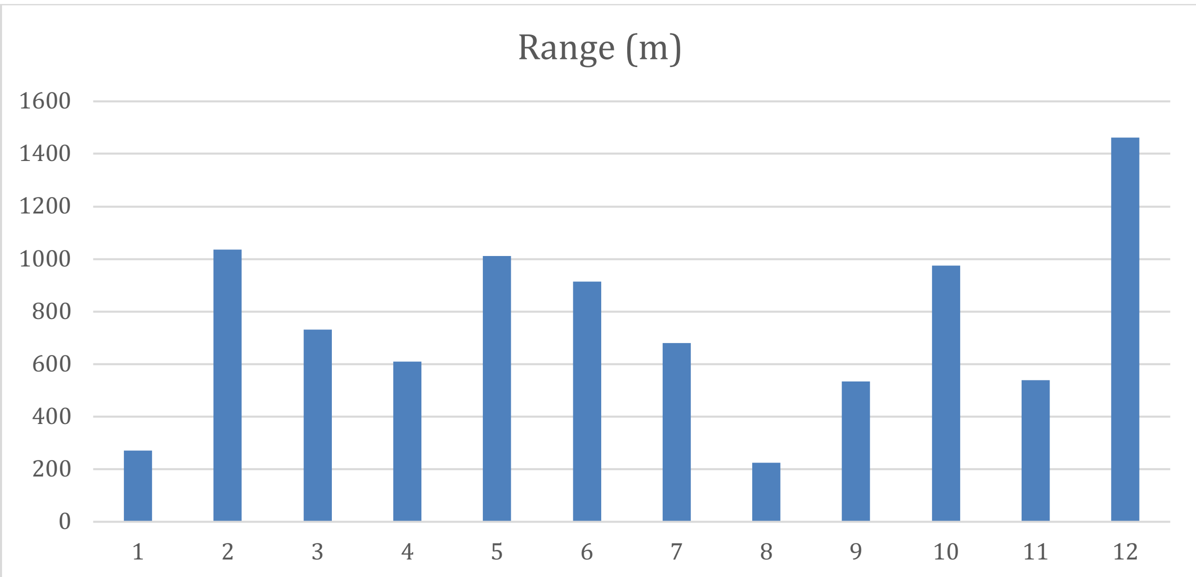


Figure 34: R-ITS-S range

Figure 35: Location of R-ITS-S with more than 1km range.

A R-ITSS located in a road interchange, in a curve, seems not to be a good location regarding the range (271m) (Figure 36) in fact event if the range is smaller due to geographical characteristic of the round-about, the R-ITSS is able to reach all V-ITSS that drive in or out the ring road.
Location choice for that R-ITSS was made due to that area is Accidentogenic. This R-ITS-S also makes it possible to relay vehicle or road operator information upstream of this area.

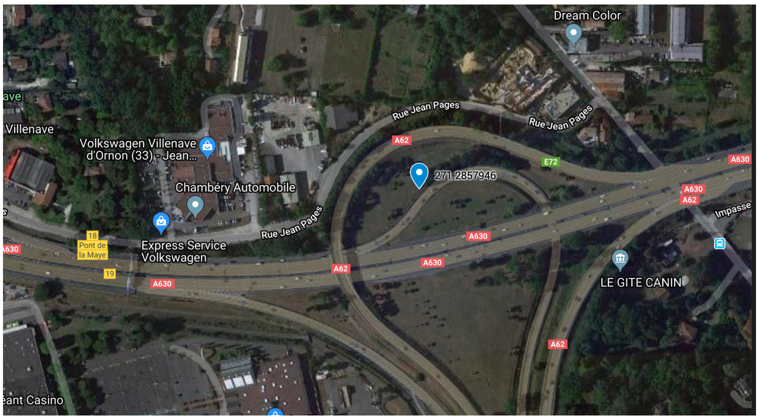


Figure 36: DIRA R-ITSS location

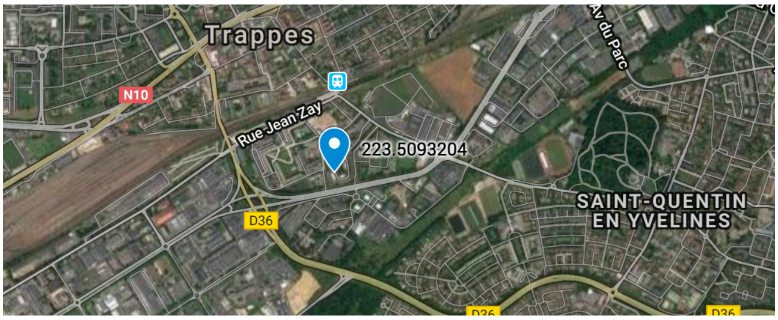


Figure 37: Urban R-ITSS

Most of R-ITS-S are not located near another R-ITS-S. In SCOOP, some road operator have made the choice to have R-ITS-S located closed enough to be able to communicate. This lead to have range of more than 3500 m due to the R-ITS-S forward.

3.21 V-ITS-S Range

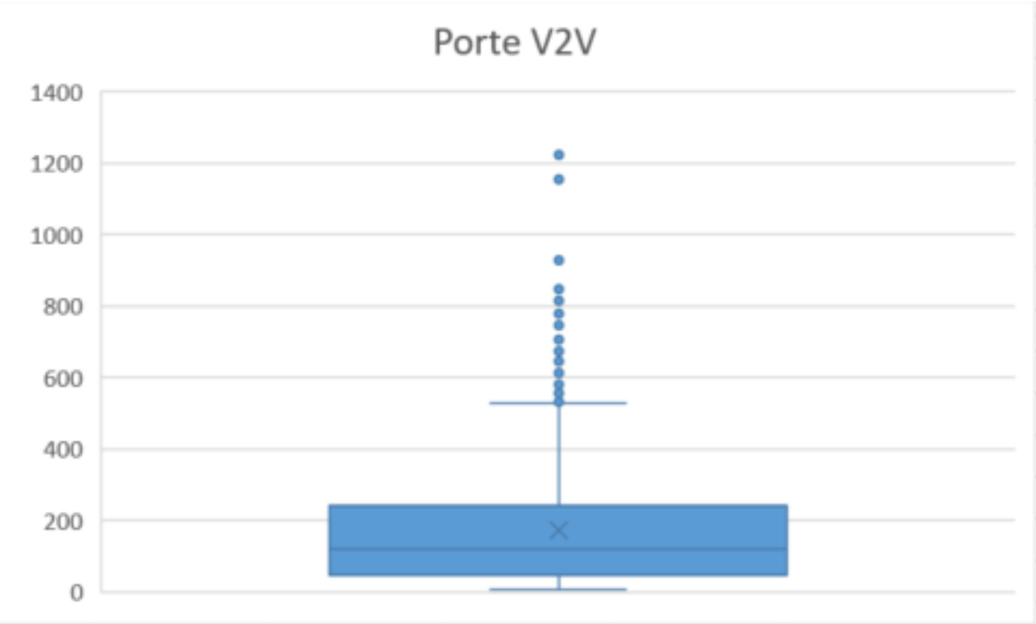


Figure 38: V-ITS-S range

Table 12Value for V-ITS-S range

	Distance in m
max	1829.584309
mean	227.2998289
median	147.0549974
1st quartil	63.27680925
3rd quartil	293.7348969

Range for V-ITS-s in real environment has no sense with no information of the road topology. A mean value of 227 seams a low value but if all V-ITS-S are located in urban area, it will make sense.
An interesting value is the max. It's not a real range but the result of forwarded messages by R-ITS-S.

3.22 Latency

Latency between V-ITSS was calculated using CAM and DENM. Latency between V-ITS-S and R-ITS-S was calculated using only CAMI.

3.22.1 Latency between V-ITS-S

For a V-ITS-S, we consider the reference time of the first DENM received and the first timestamp when the DENM is stored in the LDM.

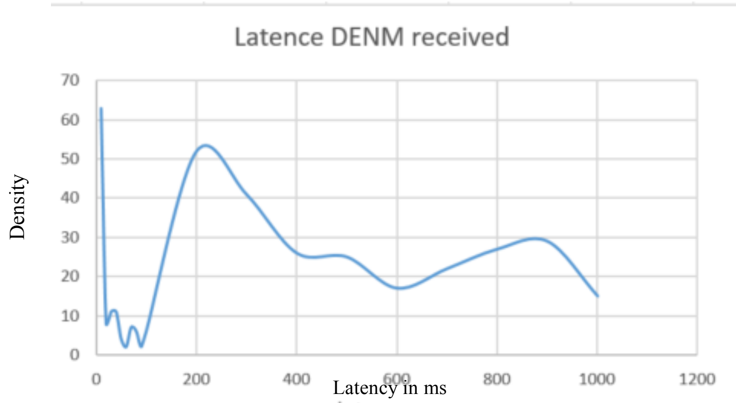


Figure 39: Latency density using DENM

Mean value for DENM latency between V-ITS-S is 331ms with a median value of 243 ms.

Latency considering the CAM exchanged between 2 V-ITS-S is calculated with the same method than DENM (timestamp when the CAM is stored in the LDM – generationtime).

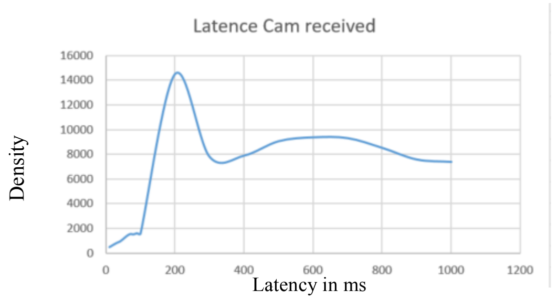


Figure 40: Latency density using CAM

Mean value for CAM latency between V-ITS-S is 457 ms with a median value of 453 ms. Differences between CAM and DENM latency is certainly due to treatment priorization by V-ITSS.
Latency are in line with standard requirement, 300 ms to 1 s depending on the use case.

3.22.2 Latency between V-ITS-S and R-ITS-S

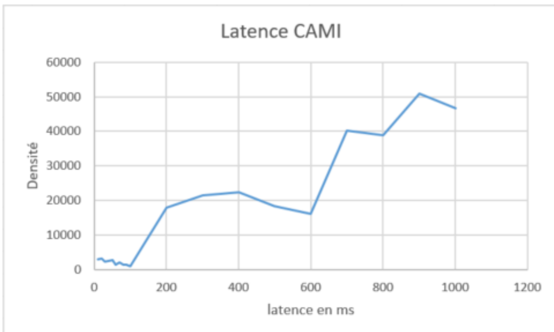


Figure 41: Latency density using CAMI

Mean value for latency between R-ITS-S and V-ITS-S is 458 ms. This results is obtained considering 20% of CAMI received. 80% present abnormal value (negative value for latency

or value closed to the modulo used for calculating the generationdeltatime :65535 ms). From this abnormal value, 11 couples R-ITS-S/V-ITS-S have more than 1s of latency for cumulative desynchronization duration up to 1 min. The maximum duration of desynchronization is 2min 38s between a R-ITS-S and a V-ITS-S.
To avoid such desynchronization, V-ITS-S and R-ITS-S need to share the same time referential.

3.23 CAM analysis

Figure 42 represents trajectory of all V-ITS-S based on CAM sent and recorded only when another C-ITS-S I is nearby. Most of travels are in Paris, DIRA and DIRO region (SCOOP@F test sites) but also in other regions (North, east and center).

Figure 42:Cam sent by V-ITSS

Figure 43: CAM received by V-ITSS

3.24 Message displayed to the driver

From data collect called ULog, we have 126 messages that have been displayed to drivers by 168 pop-up.
78 V-ITS-S displayed this messages.

Table 13: Display duration

	Display duration ms	Display duration
min	993	1s
max	443985	7, 4 min
mean	27043,6369	27 s

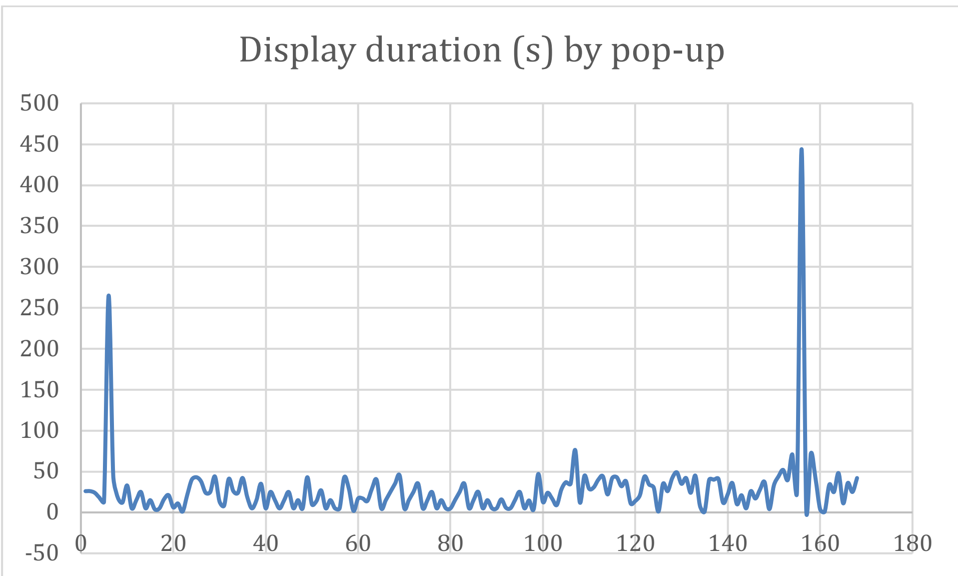


Figure 44: Display duration

Event were displayed by pop up with a mean display of 27s.

Table 14: display percentage by event.

cc/sc	Label	Display percentage by cause code (%)
3/0	Alert planned closure of a road or a carriageway	21
9/0/1/4/5/7/	Alert Unsecured blockage of a road	2
6/0	Alert Temporary slippery road	1
6/4	Alert Temporary slippery road - snow	0
11/0/1/3/4	Alert Animal on the road	13
12/0	Alert people on the road	10
10/0	Alert Obstacle on the road	4
94/0	Alert Stationary vehicle, breakdown	3
94/2	Alert Stationary vehicle, breakdown	22
2/0/1/2/3/4/5/6/7	Alert Accident area	24
18/0	Alert Reduced visibility	1

4 Conclusion

In terms of technical evaluation, the challenge was to assess technical performances of the ITS stations (V-ITS-S and R-ITS-S) as well as that of the use cases.

Despite the number of vehicles below our expectations, the substantial volume of data generated by vehicles over 1 year allowed us to carry out an in-depth statistical analysis and thus answer our research questions. However, some analyses require further investigation because of missing background information that we were not able to collect (road situation, stationID-vehicle correlation, fine weather data, etc.).

Through the statistical analysis of the data collected by vehicles, we were able to observe that :

- The performances in terms of latencies and range are in line with what is expected thanks to the extensive work carried out in terms of validation of the systems prior to experimentation.

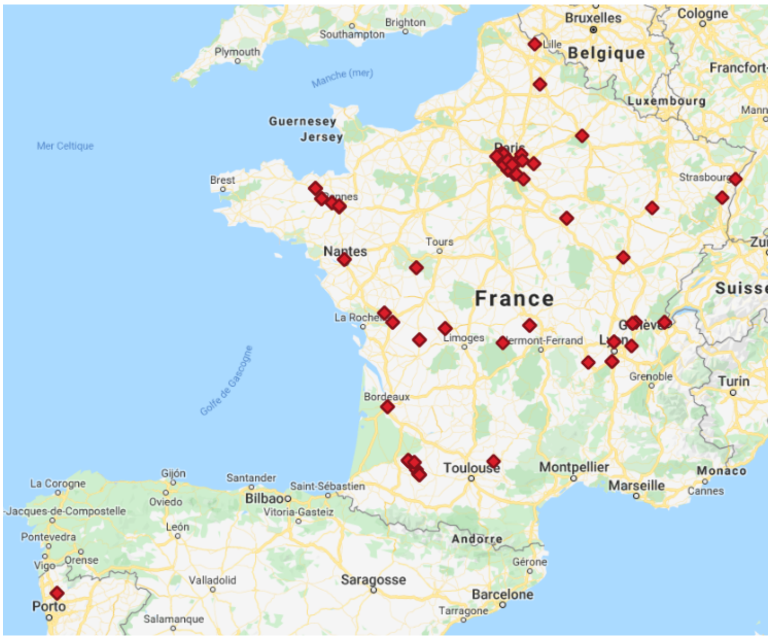
- A more in-depth analysis of the triggering conditions of the stationary vehicle use case must be carried out in order to avoid an overload of information for the driver.

Despite the harmonisation work in France and within the C-Roads platform, definitions of actionID and termination need to be discussed between C-ITS Actors in order to have harmonised specifications, avoid unnecessary network overload and allow a consistent display for the driver.

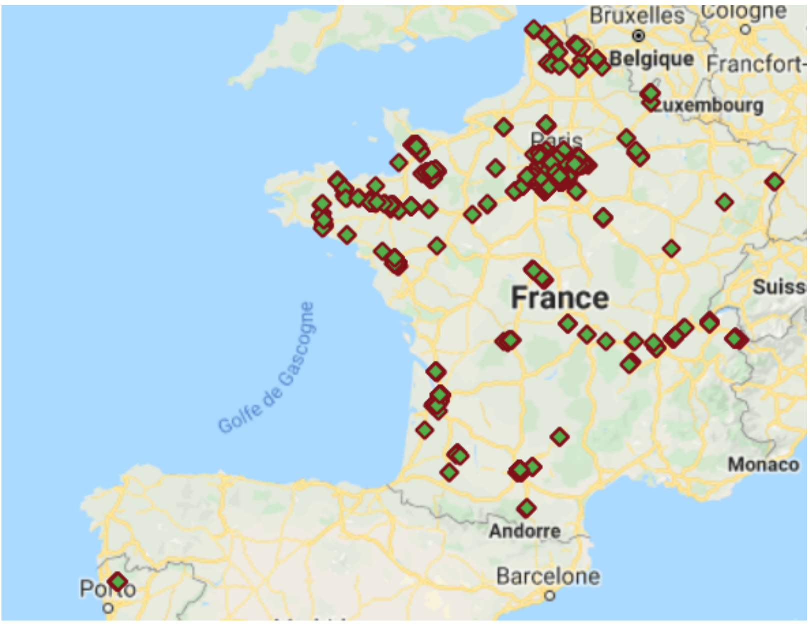
Thanks to this analysis, requests for modifications of specifications or requests for additional reflections have been made and brought back to the project level.

Annex : Use Cases Map for events sent by vehicles

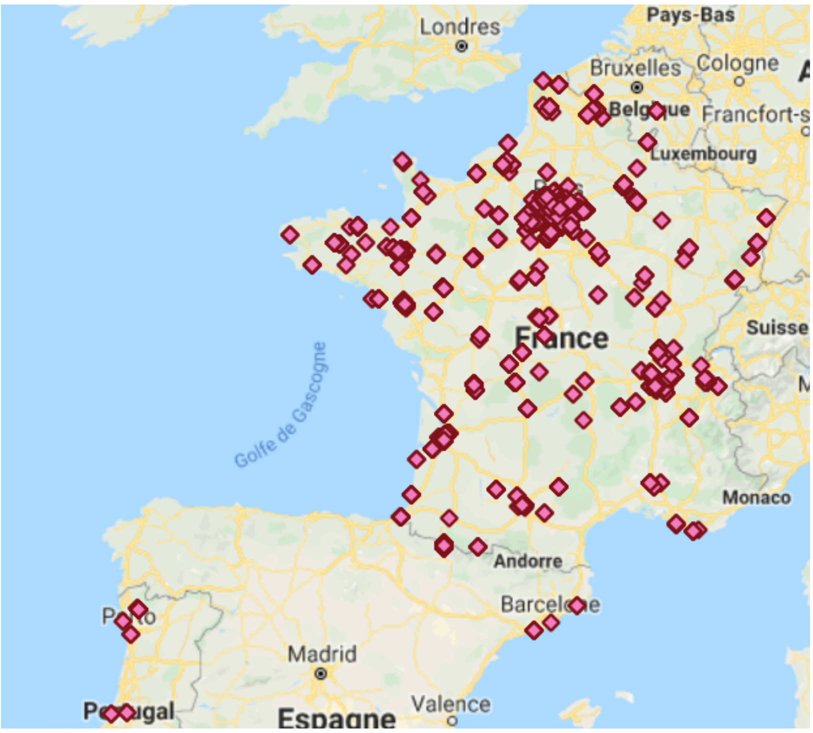
4.1 Dangerous situation



4.2 precipitation

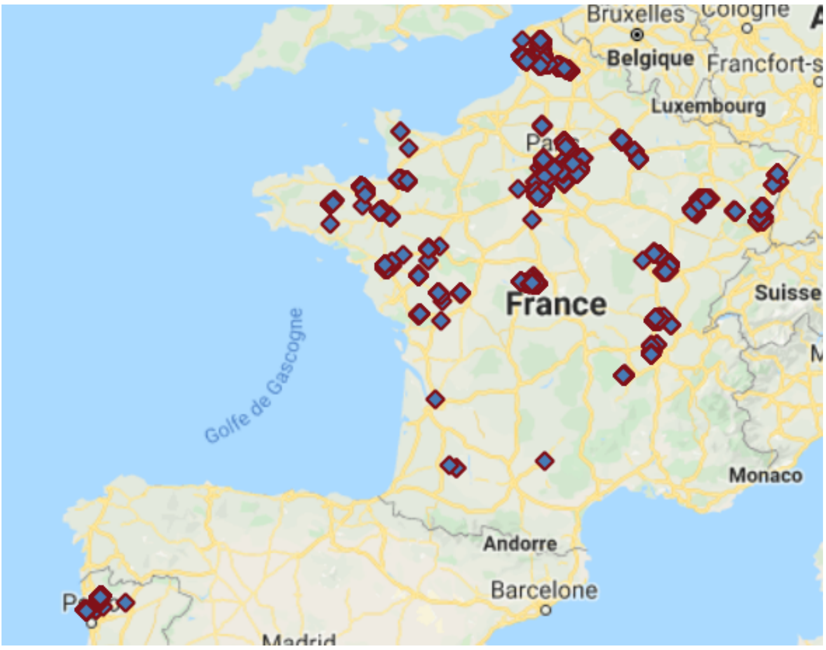


4.3 Stationary vehicle



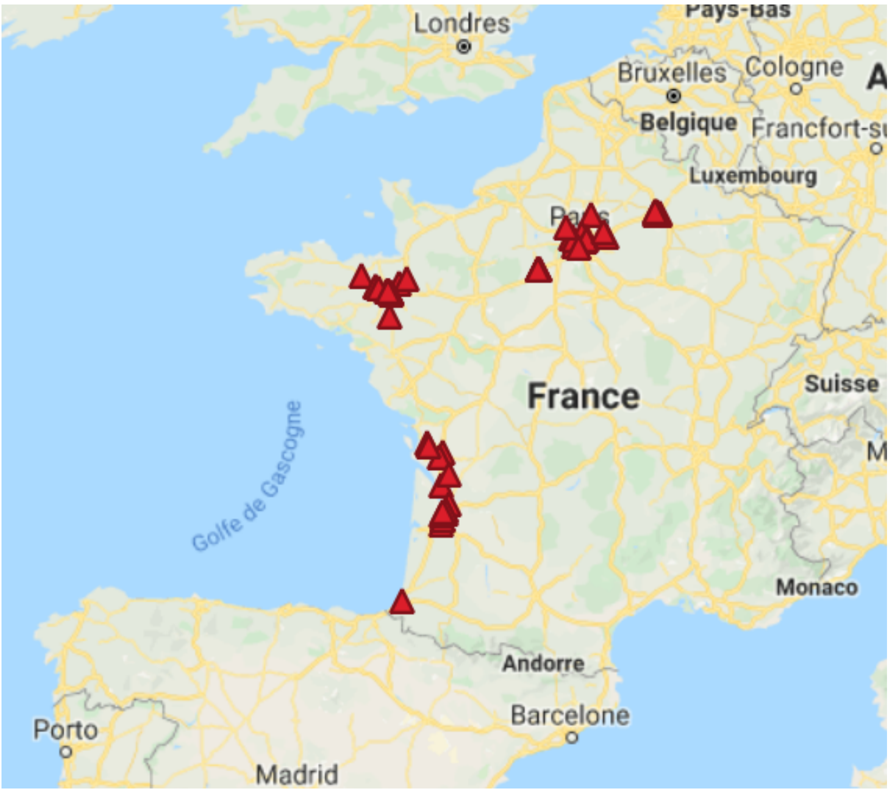
4.4 Surface condition

4.5 Visibility



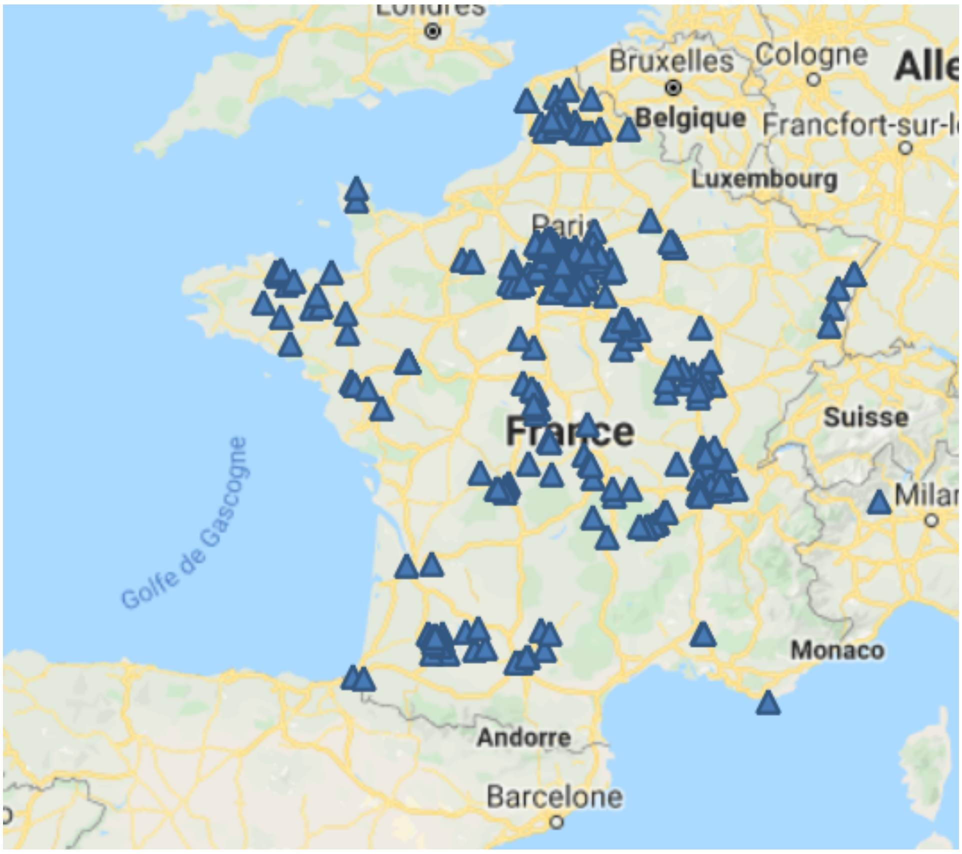
4.6 Obstacle on the road

4.7 Human presence on the road

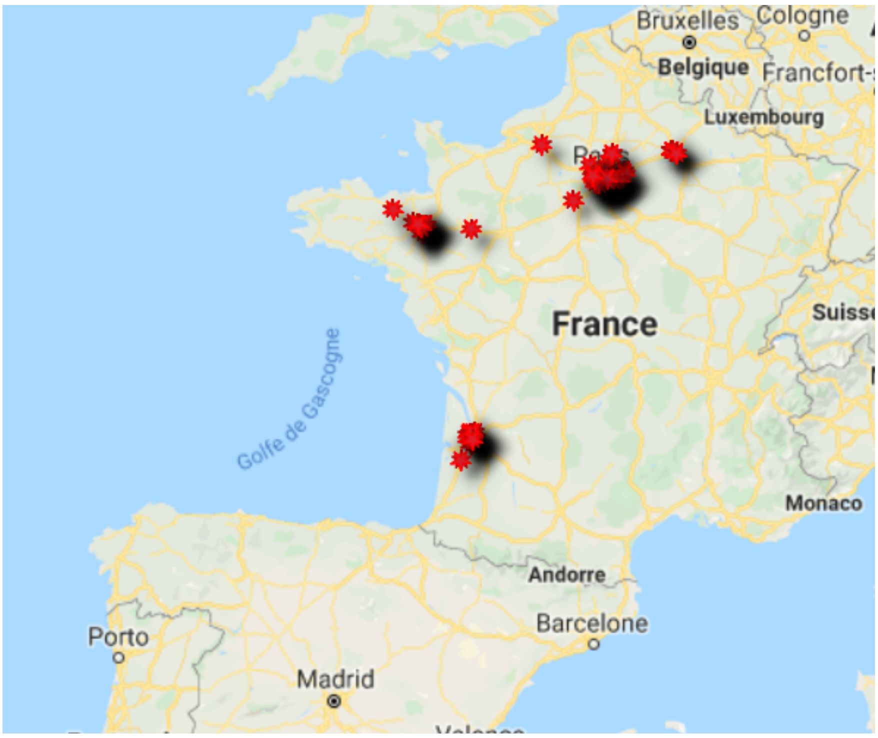


4.8 Animal on the road

4.9 Adhesion



4.10 Accident



4.11 For all cause code