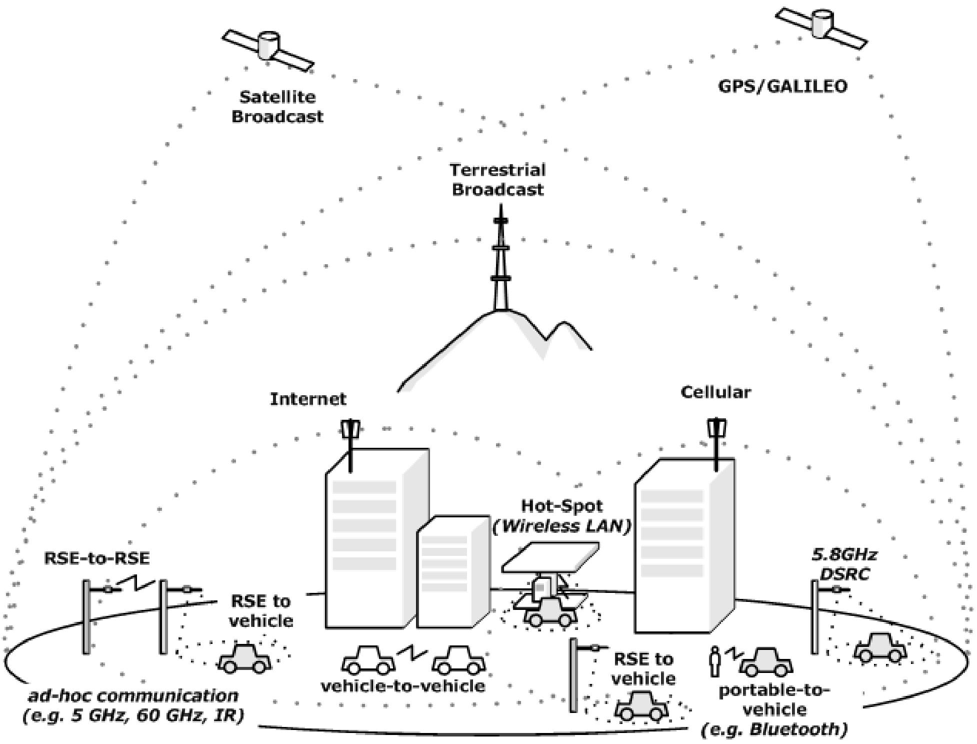
Guide about technologies for future C-ITS service scenarios.



Draft version 0.1

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Contents

1 Introduction

This guide about the technologies for ITS services scenario is to be considered as an extension of the ERTICO Task Force report on Communication Technologies for C-ITS services. This guide is made up of contributions from the task force members as a working material, which has laid the foundation for the report and its conclusions.

This guide is intended as a tutorial or guidance for those who need a more detailed insight in the ITS technologies, standards and initiatives. Some parts of the text in the task force report can also be found unchanged in this guide.

The pieces of information provided in this guide can possibly reflect some of the differences in the viewpoints of the task force experts involved in the task force. Never the less this guide is expected to be useful as a crash-course in ITS technologies.

2 Definition of Cooperative ITS (ISO 17465)

A co-operative ITS is a subset of the overall ITS that

- communicates and
- shares information

between ITS Stations*) to

- give advice or
- facilitate actions

with the objective of improving

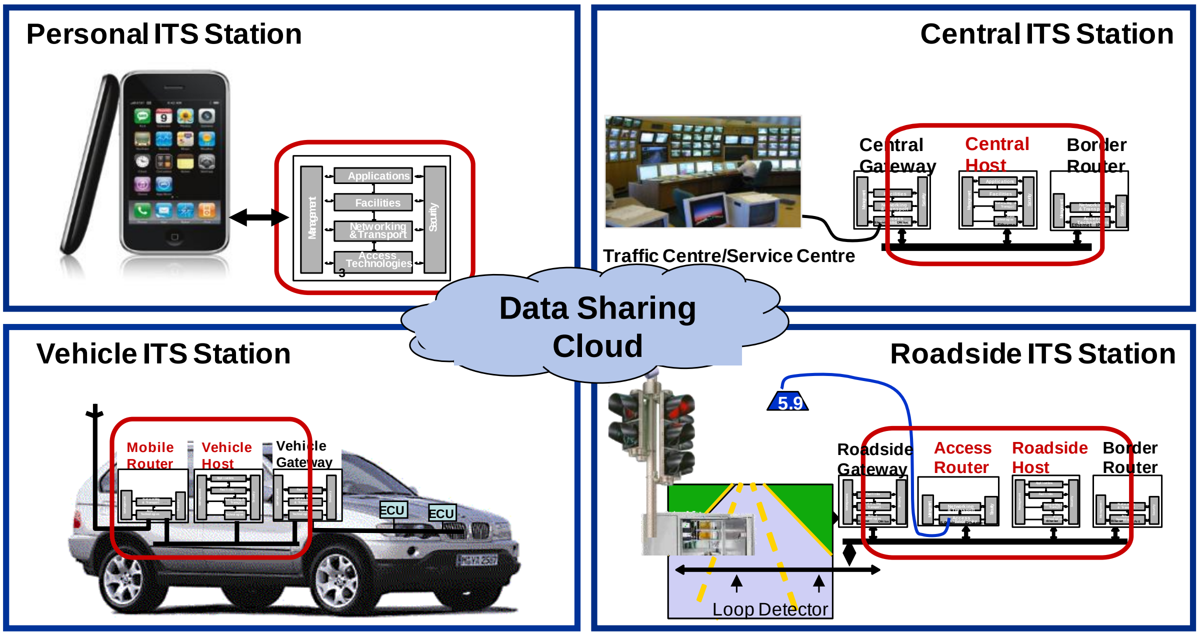
- safety, sustainability, efficiency and comfort

beyond the scope of stand-alone systems.

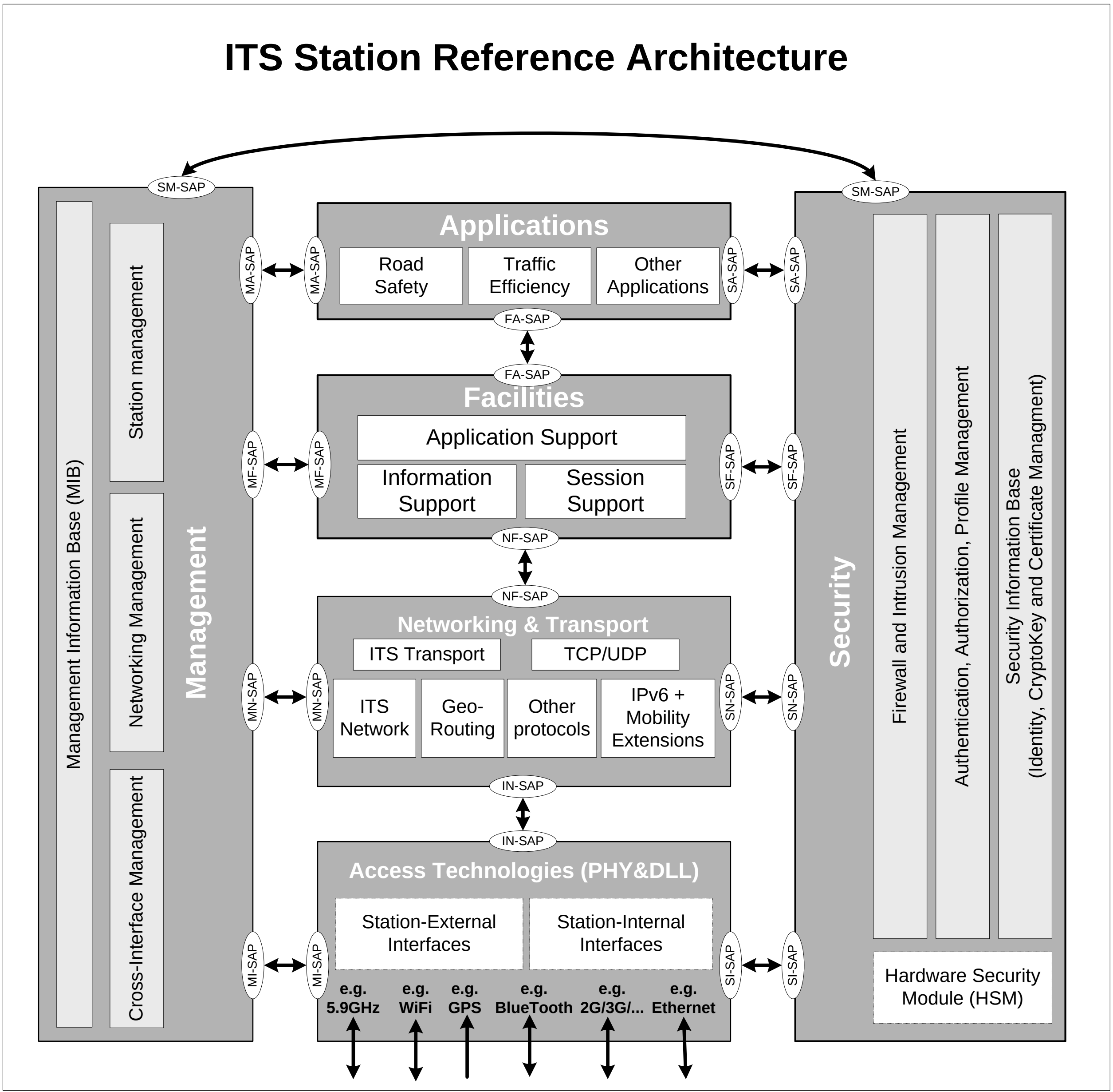
ITS Station defined in ISO 21217 / ETSI EN 302 665, e.g. units installed in vehicles, at the road side, in traffic control/management centres, in service centres, or in hand-helds.

2.1 ITS reference architecture

Architecture For Cooperative ITS



ITS Station reference architecture


ITS Station Reference Architecture
SM-SAP
SM-SAP
Management Information Base (MIB)
Station management
Networking Management
Cross-Interface Management
Management
MA-SAP
MF-SAP
MN-SAP
MI-SAP
Applications
Road Safety
Traffic Efficiency
Other Applications
FA-SAP
Facilities
Application Support
Information Support
Session Support
NF-SAP
Networking & Transport
ITS Transport
TCP/UDP
ITS Network
Geo-Routing
Other protocols
IPv6 + Mobility Extensions
IN-SAP
Access Technologies (PHY&DLL)
Station-External Interfaces
Station-Internal Interfaces
e.g. 5.9GHz
e.g. WiFi
e.g. GPS
e.g. BlueTooth
e.g. 2G/3G/...
e.g. Ethernet
SA-SAP
SF-SAP
SN-SAP
SI-SAP
Security
Firewall and Intrusion Management
Authentication, Authorization, Profile Management
Security Information Base (Identity, CryptoKey and Certificate Managment)
Hardware Security Module (HSM)

3 ITS Services

3.1 Common data definition

Using common data structure is necessary to ensure interoperability of the ITS services among the different ITS sub-systems.

Common data definitions are provided in the ITS standards:

- Cooperative ITS protocols:
  - CAM and DENM from ETSI, with ISO harmonisation,
  - SPAT/MAP for traffic light information
- eCall Minimum Set of Data (MSD)
- DATEX standards (see [1]) concerning the exchange of traffic information between traffic management centres, traffic information centres and service providers
- TPEG messages and frames broadcasted TPEG client devices (see [2])

DATEX II development and maintenance is supported by the EIP (European ITS platform) under the activity 4.3. DATEX II standards are currently drafted and published by CEN TC278, under the umbrella of the working group 8: Road Traffic Data. For harmonisation reasons, liaisons exist with TISA for TPEG and with ETSI for CAM and DENM.

DATEX II is the agreed communication protocol between Traffic Management Centers and to control traffic infrastructure installations like VMS-signs. A message stream is illustrated in figure 1 below

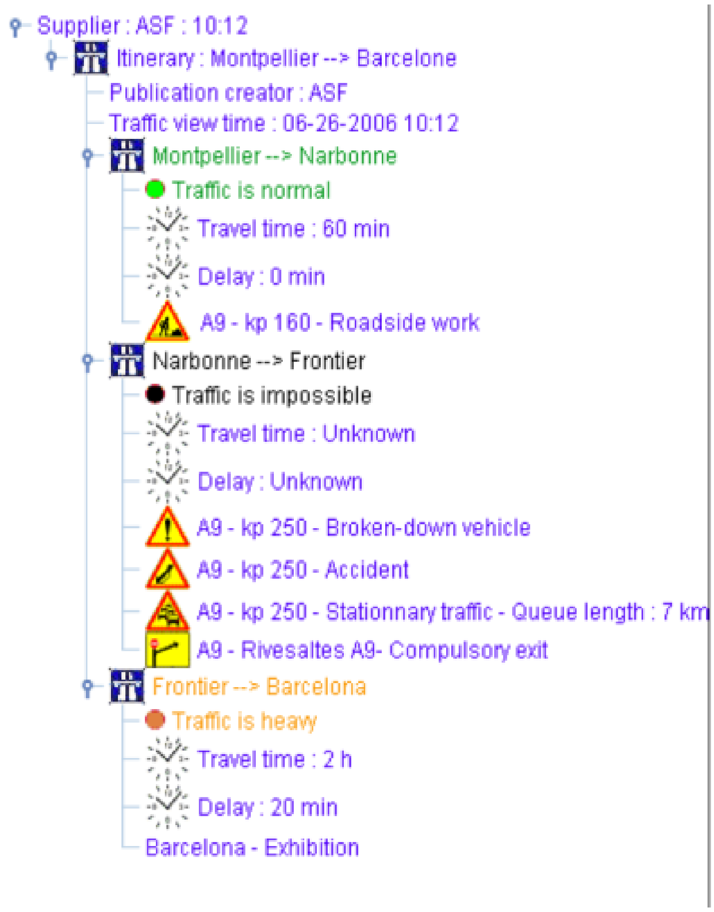


Figure 1 DATEX II message stream

[1] http://www.datex2.eu/
[2] http://www.tisa.org/technologies/tpeg/

Important notes:

- Concurrent DATEX standards are also published by ISO TC204, which are however diverging from the CEN DATEX standards on essential points. There is however a need to ensure global interoperability between CEN and ISO and thus to pay attention on the harmonisation of both set of standards in the future.

3.2 C-ITS standards and services

Cooperative ITS are Intelligent Transport Systems (ITS) where ITS stations (vehicles, roadside equipment, traffic control centres and nomadic devices) communicate and share information using a standardized communication architecture (the *ITS Station Reference Architecture*), to provide road users with better road safety, traffic efficiency, comfort, improved mobility and sustainability.

Cooperative ITS standards are developed by ISO technical committee 204, CEN technical committee 278 and ETSI technical committee ITS, following the European Commission ITS Directive and its Standardisation Mandate M/453 (65 standards developed between 2009 and 20120).

The ITS station reference architecture (ISO 21217) accommodates a diversity of ITS stations (vehicles, roadside infrastructure, control centres, personal equipment) and provides a diversity of communication means and technologies. The architecture unifies the technologies so that it can benefit to a diversity of applications (road safety, traffic efficiency and comfort/mobility) that are agnostic to the communications technologies.

The architecture is defined in such a way that Cooperative ITS standards can be deployed using any existing and forthcoming access technologies. Currently supported access technologies comprise vehicular WiFi (IEEE 802.11p variants), urban WiFi (IEEE 802.11 a/b/g/n, cellular networks (2G, 3G, 4G/LTE), DSRC, infra-red, satellite, and short range radio for sensors (IEEE 802.15.4).

New access technologies can be added without changing the existing Cooperative ITS standards as long as an interface complying with the ITS station standards is developed. ITS applications in turn would benefit from the newly available access technologies as communication profiles are defined according to the communication requirements (expressed in a technology agnostic way) of the ITS applications and the current capabilities of the ITS station.

An agreed list of day one applications is fundamental to the initial deployment of cooperative ITS and the development roles & responsibilities, roll out plans, definition of hot spot areas, investment plans and the related business models.

For the agreement between Motorway operators within ASECAP – Road operators and authorities within CEDR – European Cities and regions networking within POLIS and Vehicle manufacturers within the Car 2 Car Communication Consortium deployment in a phased approach should be based on a list 'day one use cases /applications'. This list is tentative and non-exhaustive and applications may be provided in bundles of many applications to some extend using the same communication technology and message sets.

The list of day one use cases/applications is at this point in time deliberately not linked to specific communication technologies but it is realised that applications have different operational and functional requirements with for instance different latency requirements that would lead to specific communication technologies. In particular the safety related services but also traffic efficiency services and use cases based on the ad hoc network concept are focused on the ETSI G5 technology within the 5.9 GHz band. ISO 17423 provides the means for applications to express their communication requirements in a technology agnostic fashion so that the best available access technology and the most appropriate protocol stack can be selected according to the current communication capabilities (e.g. road traffic hazard such as black ice could be reported either direct non-IP broadcast from the roadside ITS stations to vehicle ITS stations using medium range vehicular WiFi or direct IP point-to-point from the control centre ITS station to registered vehicle ITS stations using long range cellular radio).

For the planned early deployment starting in 2015 it is important that the use cases are based on standardised message sets and have been tested and validated in field operational tests. ISO and CEN are currently specifying a generic data format that is designed to distribute information belonging to various message sets (ISO 17429) defined in distinct areas around the world or by distinct stakeholders.

It is important to agree on a set relatively simple and non-complex use cases which are easy to implement with limited costs but at the same time achieving high level of customer benefit to the end users in order to achieve a continued development and expansion of cooperative ITS. The use cases implemented and deployed with ITS G5 5.9 GHz technology are of course complemented by similar applications within smartphones, digital maps and other information provided to the end users. But for both automotive industry and infrastructure providers it is important to provide high quality and reliable information even if complementing applications are available by other means. For both safety and traffic management services liability provides a strong requirement for a high quality system.

For the initial deployment and probably also in the longer term it is anticipated that aftermarket equipment and to some extend nomadic devices will play a role for non-hard or less time-critical safety applications. Within the US deployment scenarios also 'crash avoidance' is planed with aftermarket equipment with the necessary performance requirements and certification process.

3.3 sim^TD list of use cases and car 2 car communication consortium (C2C-CC) use cases

sim^TD use cases	C2C-CC Use-Cases
1. Traffic	**Scenario „Traffic Efficiency"**
1.1 Monitoring of traffic situation and complementary information/basic functions	
1.1.1 Data collection in the infrastructure side	
1.1.2 Data collection by the vehicle	
1.1.3 Identification of road weather	
1.1.4 Identification of traffic situation	
1.1.5 Identification of traffic events/incidents	
1.2 Traffic (flow) information and navigation	
1.2.1 Foresighted road/traffic information	2160 Decentralized Floating Car Data
1.2.2 Road works information system	
1.2.3 Advanced route guidance and navigation	6180 Enhanced Route Guidance and Navigation
1.3 Traffic Management	2180 V2I Traffic Optimization
1.3.1 Alternative route management	
1.3.2 Optimized urban network usage based on traffic light control	
1.3.3 Local traffic-adapted signal control	
2. Driving and Safety	**Scenario „Safety"**
2.1 Local danger alert	
2.1.1 Obstacle warning	6170 Safety Service Point 1011 Slow Vehicle Warning 1120 Hazardous Location V2V Notification 1121 I2V Hazardous Location Notification 3101 Wrong Way Driving Warning 6010 Post Crash Warning
2.1.2 Congestion warning	
2.1.3 Road weather warning	2110 Traffic Jam Ahead Warning
2.1.4 Emergency vehicle warning	1010 Approaching Emergency Vehicle Warning
2.2 Driving assistance	
2.2.1 In-vehicle signage/traffic rule violation warning	3020 Stop Sign Violation Warning 3109 Limited Access Warning
2.2.2 Traffic light phase assistant/ traffic light violation warning	6150 Green Light Optimal Speed Advisory 3010 Traffic Signal Violation Warning
2.2.3 Extended electronic brake light	1100 Emergency Electronic Brake Lights 2120 Cooperative Adaptive Cruise Control 4020 Cooperative Forward Collision Warning

sim[TD] use cases	C2C-CC Use-Cases
	3010 Pre-Crash Sensing/Warning
2.2.4 Intersection and cross traffic assistance	4010 I2V Intersection Collision Warning 4011 V2V Intersection Collision Warning 4050 V2V Highway-Rail collision Warning 4051 I2V Highway Rail Collision Warning
	2040 V2V Lange Change Assistance 3031 V2V Merging Assistance 3030 I2V Based Merging Assistance
	2100 Adaptive Drive Train Management
	3170 Cooperative Vehicle Highway Automation System (Platooning)
3. Additional services	**Scenario "Infotainment and Others"**
3.1 Internet-based usage of services	6100 Media Download
3.2 Location-dependent services	5080 POI Notification
	5070 Remote Diagnostics 6020 Safety Recall Notice 6030 Just in Time Repair Notification 6110 Vehicle Computer Program Update
	2060 Free Flow Tolling 5100 Drive Through Payment
	6080 Automatic Access Control
	5010 SOS Services
	6200 Fleet Management
	2080 Instant Messaging 5020 Map Downloads and Updates 5030 GPS Correction

Table 1 List of sim[TD] use cases matched with C2C-CC use cases (not exhaustive), source: sim[TD] deliverable D11.1, page 7,8 (adapted)[3]

3.4 Drive C2X use cases[4]

- Traffic jam ahead warning
- Road works warning
- Car breakdown warning
- Approaching emergency vehicle
- Weather warning
- Emergency electronic brake lights
- Slow vehicle warning
- Post crash warning
- Obstacle warning
- Motorcycle warning
- In-vehicle signage / Speed limit
- Green Light Optimized Speed Advisory (GLOSA)
- Traffic information
- Insurance and Financial Services
- Dealer Management
- Point of interest notification

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[3] sim[TD] results published on http://www.simtd.de/index.dhtml/deDE/backup_publications/Projektergebnisse.html
[4] http://www.drive-c2x.eu/use-cases

- Fleet management
- Transparent leasing

3.5 ETSI Basic Set of Application (BSA)

Basic Set of Applications definitionApplications Class	Application	Use case
Active road safety	Driving assistance - Co-operative awareness	Emergency vehicle warning
		Slow vehicle indication
		Intersection collision warning
		Motorcycle approaching indication
	Driving assistance - Road Hazard Warning	Emergency electronic brake lights
		Wrong way driving warning
		Stationary vehicle - accident
		Stationary vehicle - vehicle problem
		Traffic condition warning
		Signal violation warning
		Roadwork warning
		Collision risk warning
		Decentralized floating car data - Hazardous location
		Decentralized floating car data - Precipitations
		Decentralized floating car data - Road adhesion
		Decentralized floating car data - Visibility
		Decentralized floating car data - Wind
Cooperative traffic efficiency	Speed management	Regulatory / contextual speed limits notification
		Traffic light optimal speed advisory
	Co-operative navigation	Traffic information and recommended itinerary
		Enhanced route guidance and navigation
		Limited access warning and detour notification
		In-vehicle signage
Co-operative local services	Location based services	Point of Interest notification
		Automatic access control and parking management
		ITS local electronic commerce
		Media downloading
Global internet services	Communities services	Insurance and financial services
		Fleet management
		Loading zone management
	ITS station life cycle management	Vehicle software / data provisioning and update
		Vehicle and RSU data calibration.

Table 2 ETSI Basic Set of Applications (BSA), Source: ETSI TR 102 638 V1.1.1 (2009-06) 18

3.6 USA architecture and use cases

On http://www.iteris.com/cvria/ the Connected Vehicle Reference Implementation Architecture homepage, there is material on US architecture and use cases.

3.7 Day one applications for deployment of cooperative ITS in Europe.[5]

Within the Amsterdam group (ASECAP – CEDR - POLIS and the Car 2 Car Communication Consortium (C2C-CC))[6], it is generally agreed to follow a phased deployment approach with an initial deployment of simple – non-complex use-cases where user benefits are achieved even with limited penetration of C-ITS in vehicles and equipped road side ITS-stations in hot spot areas. In the following phases the complexity of use cases will increase including crash avoidance and other "hard safety" applications with increased penetration of vehicles with C-ITS equipment and increased infrastructure coverage.

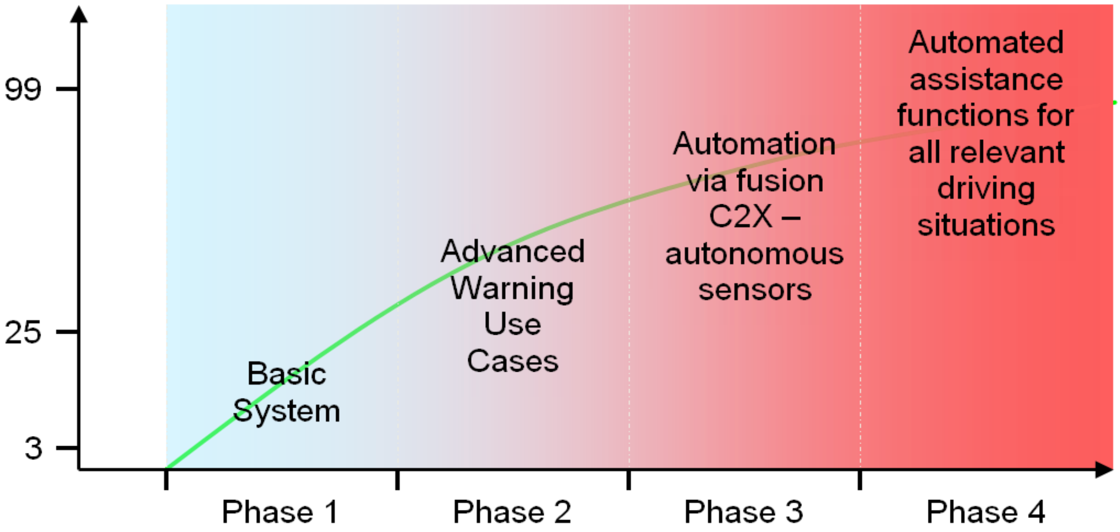

Figure 2: Deployment roadmap by the C2C-CC, part of MoU of OEM and suppliers[7] commonly introducing the day one use cases with ETSI ITS-G5 based C-ITS.

Applications have different operational and functional requirements with for instance different latency requirements that would lead to specific communication technologies. In particular, the hard safety related services but also traffic efficiency services and use cases based on the exchange of information between vehicles and the roadside infrastructure (V2X) are currently focused on the vehicular WiFi technology (ETSI ITS G5 within the 5.9 GHz band). This is in no way contradictory to establishing a "hybrid" system with complementing technologies.

The list of day one use cases/applications, shown in table 3, is agreed between Amsterdam Group and C2C-CC, signed in different MoU and linked to V2X communication with ITS-G5 in Europe[8].

---

5 Day one applications – Final version 28 February 2013/ AmsterdamGroup, (Car2Car, CEDR, POLIS, ASECAP)

6 The Amsterdam Group is a strategic alliance of committed key stakeholders with the objective to facilitate joint deployment of cooperative ITS in Europe. It includes the umbrella organisations CEDR – ASECAP – POLIS and C2C-CC, source https://amsterdamgroup.mett.nl

7 MoU of C2C-CC, Car-2-Car Communication Consortium (Press Release of 10 October 2012): "European vehicle manufacturers working hand in hand on deployment of cooperative Intelligent Transport Systems and Services (C-ITS)"

8 The V2X communication based on WLAN technology in 5.9 GHz is called ITS-G5 in Europe and WAVE in US and use both EU-US harmonized set of standards.

Use case
Hazardous location warning
Slow vehicle warning
Traffic Jam ahead warning
Road works warning
Stationary vehicle warning
In vehicle signage including speed management
Probe Vehicle Data
Signal Phase and time
Emergency vehicle warning
Emergency brake light
Motorcycle approaching indication

Table 3 Day one use cases of deployment ITS-G5, agreed between C2C-CC and Amsterdam Group, source: Amsterdam Group

3.8 European Activities to roll-out ITS-G5

3.8.1 Standardization

ETSI has developed a GeoNetworking protocol for ITS G5, sending a message to a specific area instead of a specific receiver. This enables multi hop communications up or downstream between vehicles up to 20 km (if there is an unbroken chain of equipped vehicles/R-ITS-S´s).

The European Commission further mandated the development of European ITS standards.[9] TR 101 607 includes the standards developed under the mandate 453 and was agreed in early 2013 as the Release 1 for ITS-G5.

Release 1 is finalized and further harmonization C-ITS standardization is ongoing both in ETSI and CEN. ETSI ITS-G5 has been chosen by the automotive industry OEMs as the optimum solution for V2V and V2I communication with triggering conditions, minimum performance requirements and security framework towards a common system specification providing general interoperability.[10]

ETSI has standardized messages where CAM and DENM are considered for first deployment:

CAM (Cooperative Awareness Message) that is a periodic message sent one to ten times per second with data on the vehicles position, direction, speed etc.

DENM (Distributed Environmental Notification Message) that is a warning message about for example slippery road conditions, crash or approaching emergency vehicle. The message is send with high priority and is based on information from the vehicle or the infrastructure. Multi hopping for DENM´s will also increase the reach, when possible.

Standardization of applications based on communication between the road side and the vehicles is made in ISO204/WG18 (CEN278/WG16) and one example is Signal Phase and Timing (SPAT), a standard that give information on traffic light signals state and future state changes.

Some Past and ongoing activities until market introduction of ITS-G5 applications are illustrated below

[9] European Commissions Mandate M/453: "Standardisation mandate addressed to cen, cenelec and etsi in the field of information and communication technologies to support the interoperability of co-operative systems for intelligent transport in the European community", Brussels, October 2009.

[10] See also press release from ETSI "CEN and ETSI deliver first set of standards for Cooperative Intelligent Transport Systems (C-ITS)", http://www.etsi.org/news-events/news/753-2014-02-joint-news-cen-and-etsi-deliver-first-set-of-standards-for-cooperative-intelligent-transport-systems-c-its

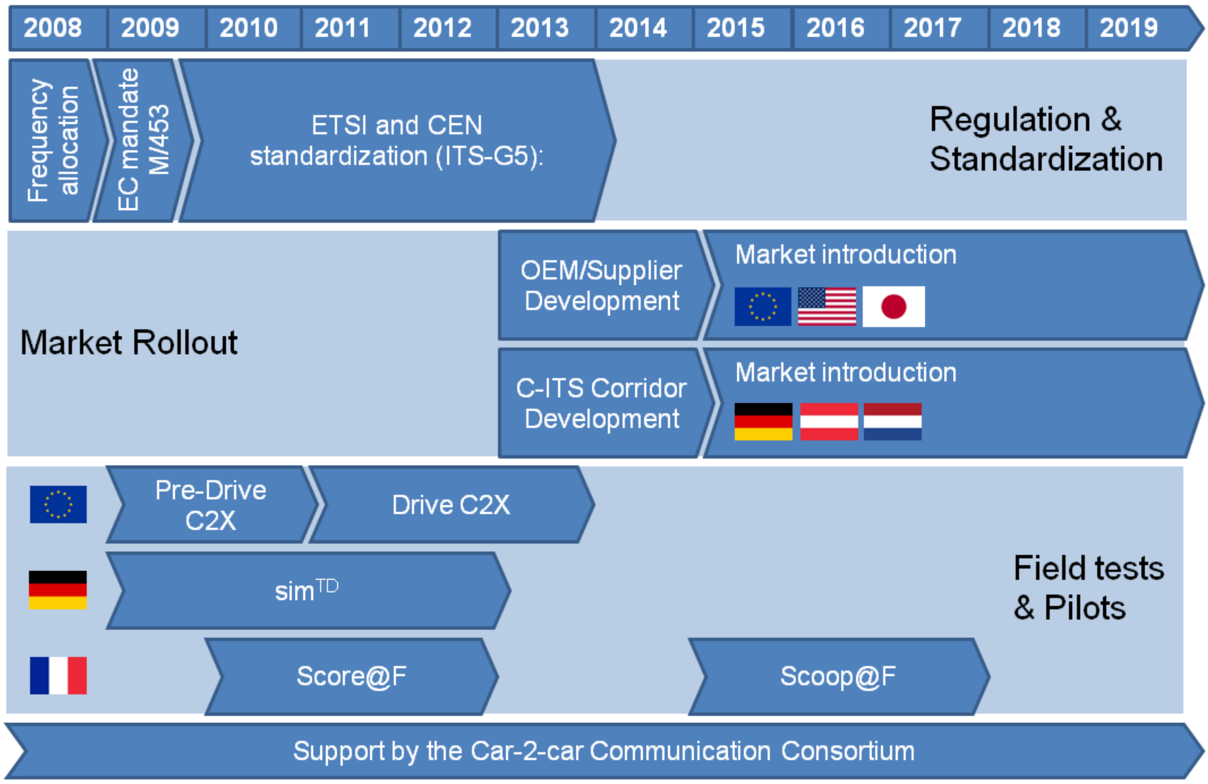

Figure 3: Past and ongoing activities until market introduction of ITS-G5 applications Source: Continental AG

3.8.2 Deployment Roadmap

European car manufacturers will launch C-ITS (ITS-G5) in 2015.[11]

- C-ITS will be the key technology for future systems including driver assistance systems and automated vehicles

- Day one use cases are:
  V2V day one use cases
  Hazardous location warning, Slow vehicle warning, Traffic Jam ahead warning, Stationary vehicle warning, Emergency Brake light, Emergency vehicle warning, Motorcycle approaching indication
  V2I day one use cases are
  Road works warning, In-vehicle signage, Signal phase and time, Probe Vehicle Data

Example for typical day one use cases are:

[11] MoU of V2V-CC, Car-2-Car Communication Consortium (Press Release of 10 October 2012): "European vehicle manufacturers working hand in hand on deployment of cooperative Intelligent Transport Systems and Services (C-ITS)", available at: http://www.car-2-car.org/index.php?id=231

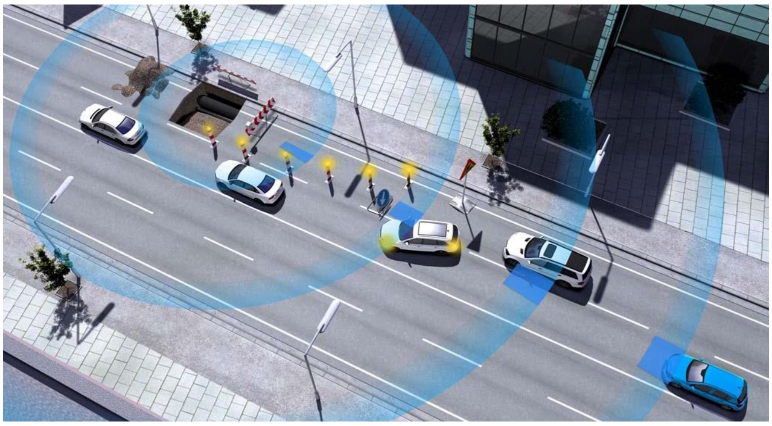

Figure 4: Hazardous Location Notification (Road works warning), Source: C2C-CC

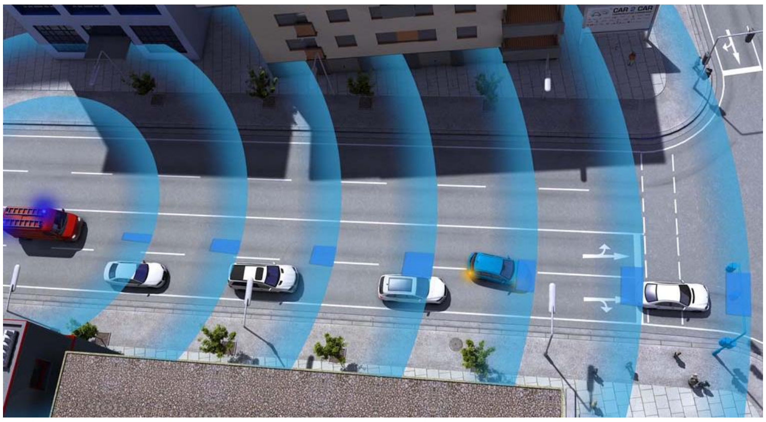

Figure 5: Emergency Vehicle Warning, Source: C2C-CC

Day one applications are non-complex use-cases like traffic warnings and alerts where user benefits are achieved even with limited penetration of ITS in vehicles and equipped road side units in hot spot areas. In the following phases more advanced and complex use cases like automatic crash avoidance (supported by vehicle sensors) are foreseen with increased penetration of vehicles with ITS equipment and increased infrastructure coverage.

Type	Application / Use case	Standard Message
V2V	Hazardous location warning	DENM
V2V	Slow vehicle warning	DENM
V2V	Stationary vehicle warning	DENM, CAM
V2V	Emergency Brake Light	DENM, CAM
V2V	Emergency vehicle warning	DENM, CAM
V2V	Motorcycle approaching indication	CAM
I2V	Road works warning	SAE J2735
I2V	In-vehicle signage/information	In Vehicle Information (IVI) DT8.3 in CEN/TC278/WG16 & ISO/TC204/WG18 CEN ISO TS 19321 (WG review Q2/2014) CEN ISO TS 17425 CEN ISO TS 17426
I2V	Signal phase and time of traffic lights	SPAT, MAP DT8.1 in CEN/TC278/WG16 & ISO/TC204/WG18 CEN ISO TS 19091
I2V	Probe vehicle data (Floating Car Data)	Probe Vehicle Data (PVD) Probe Data Management (PDM) DT8 2 in CEN/TC278/WG16 & ISO/TC204/WG18

Table 4: Mapping of day-1 applications to standards

3.8.3 Future applications

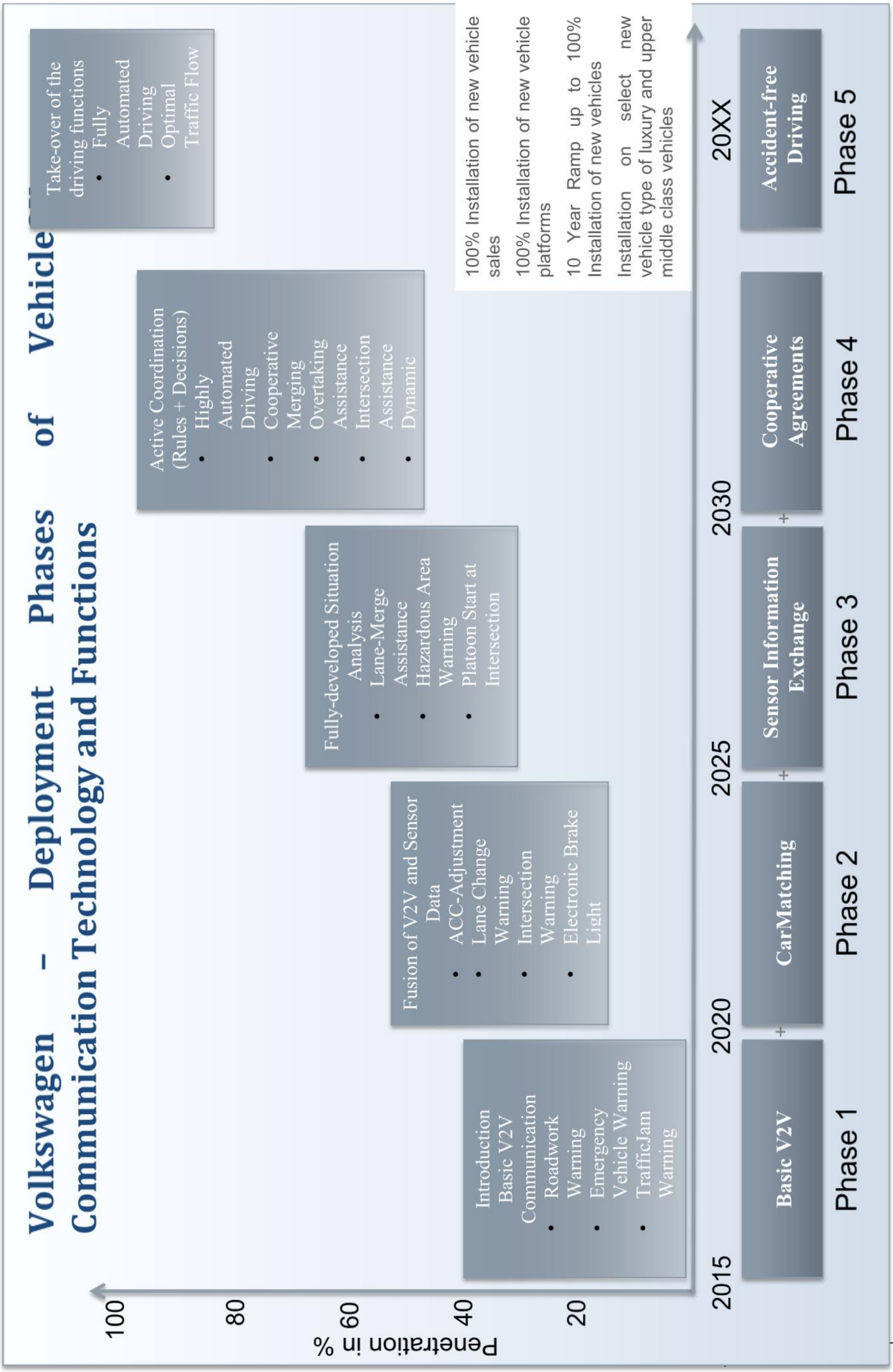
Volkswagen – Deployment Phases of Vehicle Communication Technology and Functions
Penetration in %
100
80
60
40
20
2015
2020
2025
2030
20XX
Basic V2V
Phase 1
CarMatching
Phase 2
Sensor Information Exchange
Phase 3
Cooperative Agreements
Phase 4
Accident-free Driving
Phase 5
Introduction Basic V2V Communication
• Roadwork Warning
• Emergency Vehicle Warning
• TrafficJam Warning
Fusion of V2V and Sensor Data
• ACC-Adjustment
• Lane Change Warning
• Intersection Warning
• Electronic Brake Light
Fully-developed Situation Analysis
• Lane-Merge Assistance
• Hazardous Area Warning
• Platoon Start at Intersection
Active Coordination (Rules + Decisions)
• Highly Automated Driving
• Cooperative Merging
• Overtaking Assistance
• Intersection Assistance
• Dynamic
Take-over of the driving functions
• Fully Automated Driving
• Optimal Traffic Flow
100% Installation of new vehicle sales
100% Installation of new vehicle platforms
10 Year Ramp up to 100% Installation of new vehicles
Installation on select new vehicle type of luxury and upper middle class vehicles

Figure 6: Deployment phases of V2X communication technology and functions based on ETSI ITS-G5 technology, source: Volkswagen AG, presentation held on VDE ITG 7.2 workshop on ITS

3.9 The European ITS corridor

To complement the introduction plans by the vehicle manufacturers Netherlands, Germany and Austria intend to have an ITS G5 corridor between Rotterdam and Wien ready by 2016. The two first applications are Roadwork Warning (RWW) and Probe Vehicle Data (PVD).

Figure 7: Cooperative ITS Corridor in Netherlands, Germany and Austria[12]

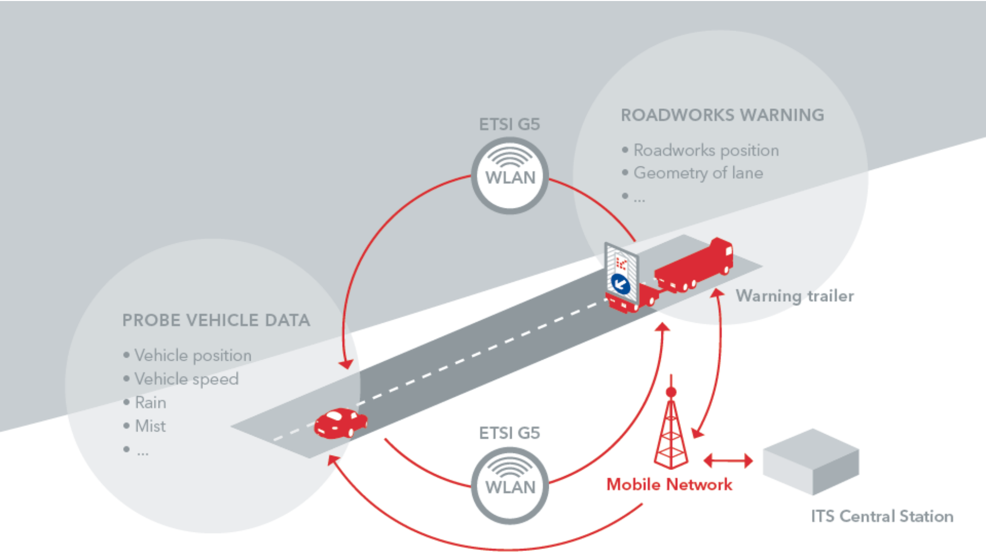

Figure 8: Day one use cases in Cooperative ITS Corridor in Netherlands, Germany and Austria

Further deployment activities planned and in preparation in line with the activities of the Amsterdam Group[13]

[12] MoU for the establishment of cooperation in a corridor between the BMVBS – Federal Ministry of Transport, Building and Urban Development (Germany), the Ministry of Infrastructure and the Environment, Directorate-General Rijkswaterstaat (The Netherlands) and BMVIT (Austrian MoT) was signed on 10 June 2013 alongside the Council of Transport Ministers in Luxemburg, source: http://www.bmvi.de/SharedDocs/DE/Pressemitteilungen/2013/110-ramsauer-rat.html

• C-ITS Corridor Austria – Germany – The Netherlands, from 2015

• French corridor pilot project Paris – Strasbourg, from 2015

• Corridor project in Sweden, estimated 2016-17

• Corridor project in Poland, estimated 2016-17

• Corridor project in Portugal, estimated 2016-17

• City projects in accordance with the EC supported COMPASS4D project

o Bordeaux, France

o Copenhagen, Denmark

o Eindhoven, Netherlands

o Newcastle, UK

o Thessaloniki, Greece

o Verona, Italy

o Vigo, Spain

• City projects under consideration within the POLIS organisation

It is expected that all European Deployment projects apply the same standards and system specifications in order to ensure interoperability.

Further deployment projects or pilots will contribute to a European wide C-ITS implementation and deployment.

[13] "Roadmap between automotive industry and infrastructure organizations on initial deployment of Cooperative ITS in Europe Version 1.0", Amsterdam Group, available at https://amsterdamgroup.mett.nl/default.aspx

4 Communication technologies

The classical vision of C-ITS use all possible means of telecommunication.

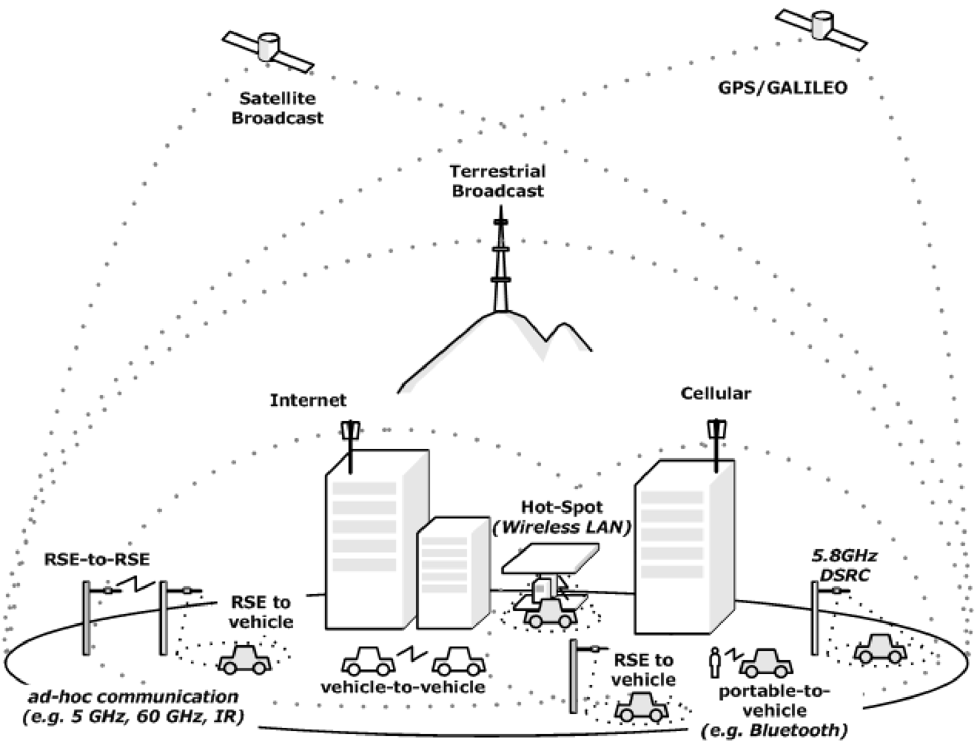

Figure 9

The vision promoted in this report for C-ITS is to enable the usage of complementary and appropriate communication technologies to serve scenarios as described in the main report and previous text.

There are plenty of access technologies that could be used for ITS applications and it is anticipated that new access technologies will appear on a regular basis (every two years or so given the recent trend).

Access technologies have different characteristics and serve different purposes according to their characteristics

- Type: Wired and wireless access technologies
- Range: short range, medium range, long range
- Directionality: unidirectional (e.g. satellite) or bi-directional
- Scope: broadcast or point-to-point

Communication scenario: vehicle-to-vehicle (V2V), vehicle-to-roadside (V2R), roadside-to-centre (R2C), vehicle-to-centre (V2C), etc. V2R and V2C are two examples of vehicle-to-infrastructure (V2I) communications where WiFi is generally used for the former and any technology for the later.

For ITS there are today four main radio access technologies that are deployed in various use cases: FM/DAB radio broadcast, mobile broadband (3G/4G/5G cellular networks), ad hoc broadcast V2X technology (ITS G5 short range WLAN), and satellite (L, S, C, X, Ka, Ku bands). This is in line with the ITS station reference architecture standard (ISO 21217) which is at the core of the set of Cooperative ITS standards.

We present in the following clauses these different communication technologies.

4.1 Broadcast radio

4.1.1 Overview

FM broadcast has been used for traffic information for a long time and almost all cars have a FM radio receiver. The area coverage is close to 100%. Many local radio stations send traffic reports during rush hours and many car radios interrupts ongoing program or music for the traffic alerts.

RDS-TMC

Traffic Message Channel is sent via Radio Data System embedded in FM broadcast. The system is based on geographical reference points (TMC locations) in combination with text and timestamps. Information about traffic accidents, road works and road weather is transmitted. To receive the messages the car radio, GPS-navigator or smartphone must support RDS-TMC. Many navigation systems can optimize the route planning based on RDS-TMC information. The messages are standardized and can be displayed in any language on the (vehicle) display. One limitation is that maximum 50 messages can be sent per minute over the broadcast area. This service is active in most EU member states, operated by the authorities and / or private service providers.

DAB-TPEG

The FM radio system is gradually being replaced by DAB-radio (Digital Audio Broadcast) and there are plans to decommission the FM system (to free up spectrum for other use) in some European countries. Expected timeframe is 2017 in the UK, 2017-19 in Norway, 2019 in Denmark and 2022 in Sweden but not firm decisions are taken yet. Via DAB radio, TMC can be transmitted as well, but more frequently used for traffic messages is the encoding according to the Transport Protocol Expert Group (TPEG)[14]. There are operational services already in many countries and tests in other countries. Due to the higher channel bandwidth in DAB, more messages can be distributed. Further, TPEG facilitates the use of on-the-fly location referencing methods, which are not limited to a pre-defined set of locations, but can reference any point on a digital map by using WGS84 coordinates together with characteristic map-matching features of that location. In addition, TPEG messages contain much more detail than TMC messages. A TMC message could for example convey the information “Traffic jam between A and C, starting 1km after point A”, whereas a TPEG message may contain information like “the average speed of vehicles travelling from A to B is 58 km/h and from B to C is 37 km/h” not only for the current conditions, but also shorter term predictions (up to 1-2 hours ahead). This more detailed information is used to enhance the route planning in navigation devices. Other TPEG applications target services for available parking places, fuel price information, electric charging locations, and weather information.

4.1.2 Key characteristics

RDS-TMC can provide 50 traffic alerts per region per minute and the transmission time is 3 to 5 minutes. DAB-TPEG can provide 500 traffic alerts per region per minute and the transmission time is 30 to 90 seconds.

Radio broadcast I2V

4.1.3 Technical characteristics

Technical characteristics RDS-TMC:

- *Coverage:* Nationwide, close to 100%
- *Capacity:* 50 traffic alerts per minute per geographic area (region of a country). Limited number of pre-defined messages (~1400), limited geographical resolution (mostly intersection-to-intersection, although a 100m resolution metric offset to indicate a start of an incident is feasible for selected incidents).

[14] http://www.tisa.org/technologies/tpeg/

- *Quality of Service:* Very high
- *Transmission time:* 3 - 5 minutes
- *Latency:* Not applicable
- *Bi directional*: No
- *Broadcast:* Yes

Technical characteristics DAB-TPEG:

- *Coverage:* Varying over the different EU Member States, but growing.
- *Capacity:* About 500 traffic alerts per minute per geographic area (region of a country) next to regularly updated Traffic Flow and Prediction information for all relevant major roads in the vicinity of the car when using TPEG as encoding protocol[15], digital broadcast may give many more and richer messages with better geographical resolution than in RDS-TMC.
- *Quality of Service:* Very high
- *Transmission time:* 30 – 90 seconds
- *Latency:* Not applicable
- *Bi directional:* No
- *Broadcast:* Yes

Technical characteristics TPEG-over Mobile-IP services:

- *Coverage:* Pan European services are offered by commercial service providers.
- *Capacity:* With TPEG-over-IP provided content is tailored to a vehicle's location and itinerary as communicated to the TPEG server. The vehicle is provided with Traffic Flow and Prediction information for all relevant major roads in the vicinity of the car and on potential routes to its destination, next to relevant Incidents. TPEG using especially on-the-fly location referencing provides many more and richer messages with better geographical resolution than in RDS-TMC.
- *Quality of Service:* Very high
- *Transmission time*: fast
- *Latency:* Not applicable
- *Bi directional:* Yes
- *Broadcast:* No

4.1.4 Deployment

RDS TMC has very good coverage over EU. DAB is under deployment and will probably reach very good coverage by 2020.

[15] Note that TMC services are also feasible via DAB.

4.1.5 Cost structure:

Virtually all cars already have a FM-radio and soon a DAB-radio. Basic RDS-TMC services are in some countries financed as public service by the authorities. In other countries, only commercial RDS-TMC services are available. Even in countries with government-financed public services there may be additional, premium services with individual payment structures (e.g. a one-off fee or monthly subscriptions).

4.2 Public Land Mobile Networks (Cellular Networks)

The 3GPP standard family of mobile phone systems has evolved from 2G-GSM over 3G-WCDMA to 4G-LTE (and LTE Advanced) and 5G is now under definition with a launch horizon of beyond 2020. The evolution has given higher peak data rate, lower latency (delay) and increased coverage of both population and area – in many counties up to 98% respectively 90%.

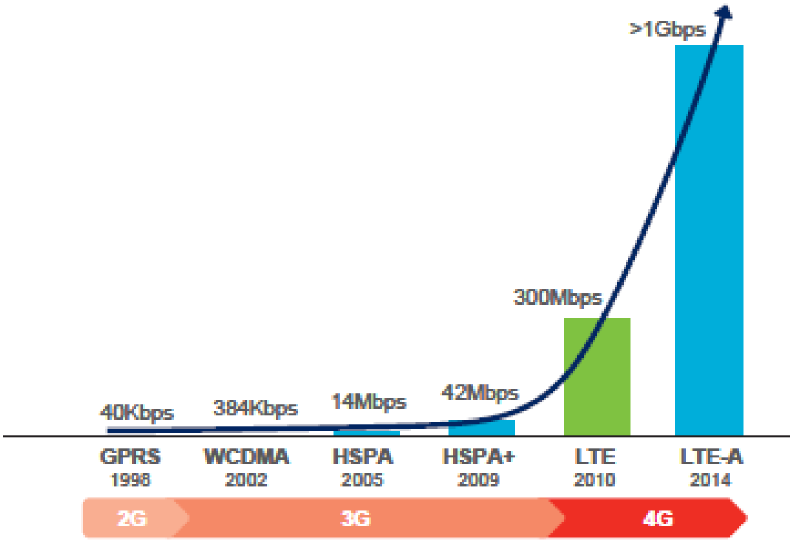

Figure 5: Peak rate

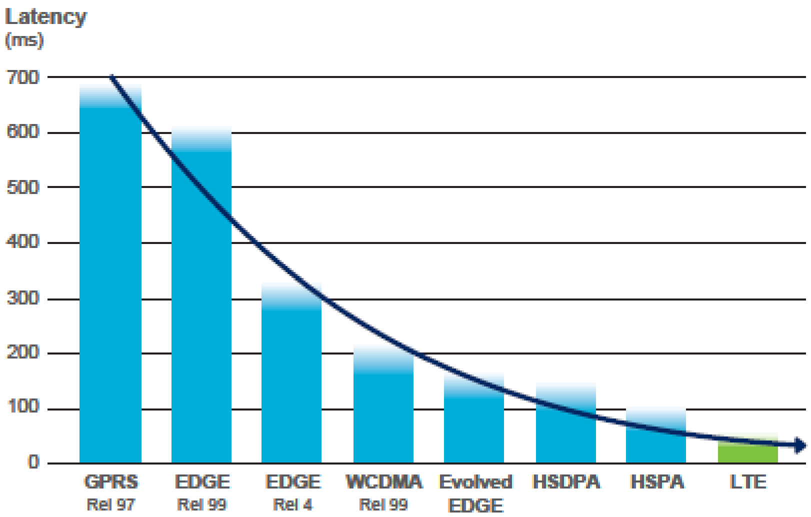

Figure 4: Latency evaluation in operational LTE networks [6]

Figure 10 Mobile broadband evolution

From an ITS perspective the improved latency of WCDMA and LTE is of particular interest. Research projects have shown that car to car messages and warnings can be transported via the mobile network in 350 – 500 ms using WCDMA and below 50-150 ms using LTE. The existing infrastructure can be reused, no changes in the networks are needed. The only additional requirement is some new application servers in the mobile network and / or on the Internet level to enable geographical addressing (geocasting) and to optimize message streams for the cellular distribution channel. Also the upcoming LTE broadcast system (eMBMS) can be used in the distribution and will be very efficient in areas with dense traffic and many users.

To generate a Road Hazard Warning, the phone or a built in modem must be connnected to the vehicles systems, but any phone or connected navigation device can receive the warnings, thus giving all drivers with a smartphone the option to use the service from day 1.

The different mobile access technologies are today using different licenced frequency bands (in Europe).

Technology	(LTE/WCDMA)	LTE/WCDMA	GSM	GSM	WCDMA	LTE
Frequency (MHz)	(700)	800	900	1800	2100	2600

Table 5 Mobile broadband spectrum allocation

The lower frequency bands are suited for large rural cells (radius 10 – 20 km or more) and the high frequency bands are suited for small urban (and indoor) high capacity cells. As frequency licences expire and are renewed, over the Member States, conditions are changed. Re-farming mean that guard bands between the different operators are removed and each operator get as much continuous spectrum as possible. This is to increase the spectrum efficiency to cope with the enormous growth in data traffic. The licenses are also becoming “technology neutral” – the operator is free to use any access technology in any frequency band to optimize the business. In LTE Advanced carrier aggregation, using several frequency bands to increase peak data rate, can be used.

The core part of the mobile networks is now being evolved from circuit switched to packet switched technology using Internet Protocol. This enables a whole range of new possibilities in multimedia communication, secure communication and encryption, setting Quality of Service and differentiated billing. We will have all-IP communication end to end.

Multimedia emergency calls from smartphones (in 3.5 G and 4G networks) have already been standardized in 3GPP. ETSI recently started to investigate the next generation multimedia eCall´s from vehicles – the same standards as in 3GPP should be used with only some minor differences in the high level data protocol.

However, it is not only base stations and antennas that make up a mobile network! There are many interacting layers that perform the services. In an ITS perspective an efficient multi-service platform is needed where all stakeholders, service providers and those needing information from the traffic system have access via simple interfaces that provides a common technology platform with economy of scale and efficiency. The networks have functions to handle the connectivity (“SIM cards”), the software in the mobile device, the services and information and the interfaces to more or less integrated services and providers. Correct handling of the rights to data (privacy) and media must be in place and a cost efficient payment and clearing systems are possible as well.

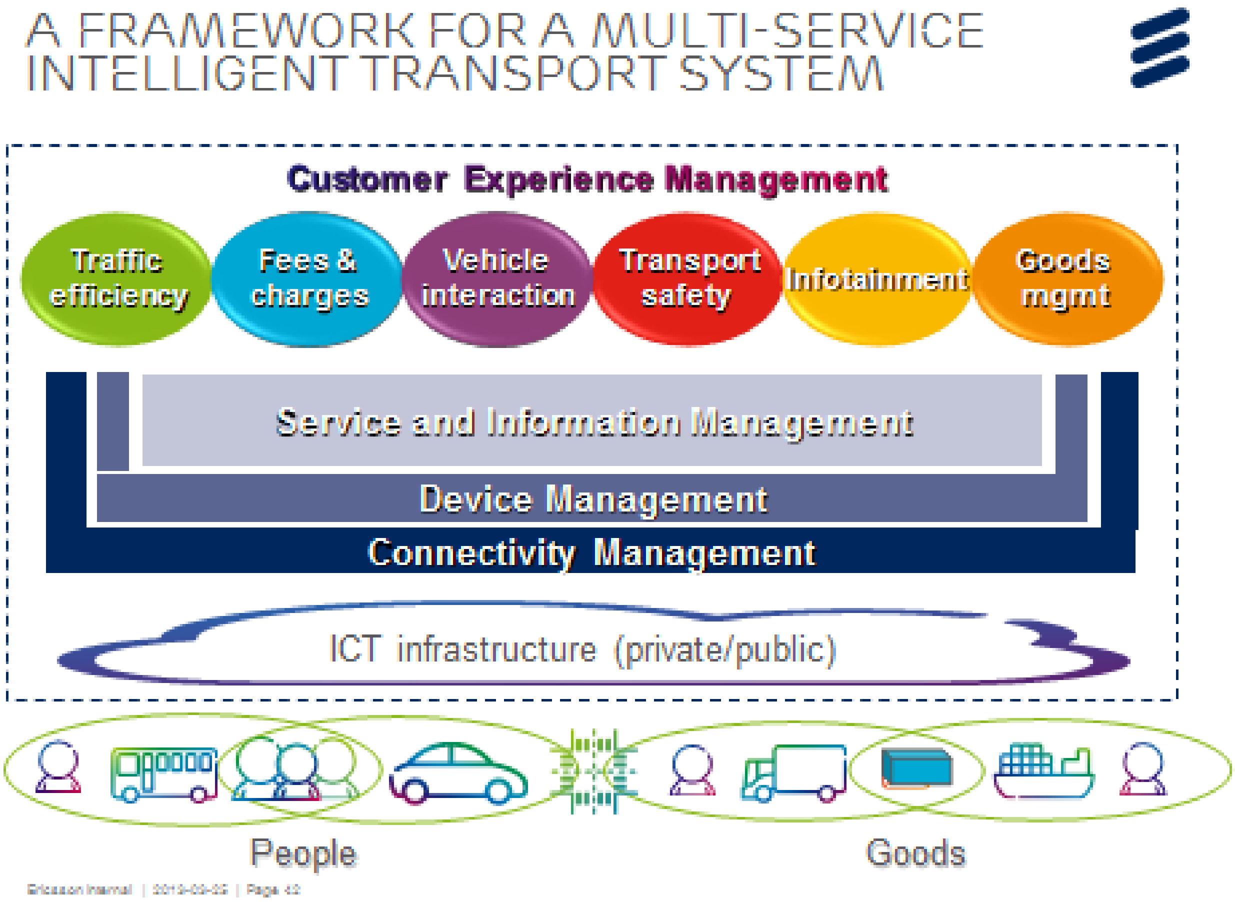

Figure 11 Horizontal service enablement platform

Cars and trucks are in increasing numbers getting connected via mobile networks for many different services including TPEG over IP for Europe-wide advanced Traffic Information Services; and some of them are C-ITS. TPEG as a bearer independent protocol has been deployed successfully throughout Europe (and also elsewhere) by means of mobile internet connectivity.

Almost everyone has got a smartphone today and from a C-ITS aftermarket perspective that means that many C-ITS use cases can be supported by smart apps (at least to receive messages and warnings). There is a great potential for C-ITS to use the infrastructure investments in mobile networks and the mass market of smartphones.

4.2.1 Future outlook - 5G

The foundation for the next generation mobile networks, 5G, is laid in the EU project METIS where European and Asian telecom stakeholders and even non-telco partners such as BMW are involved. The EU Commission has launched the 5G PPP (Public Private Partnership) within the H2020 program with an EU budget of 700 M€ + an industry commitment of 3500 M€ up to 2020. The purpose is that European research, telecom and industry shall create the advanced 5 G network for the Networked Society and future Internet. Up to the system launch around 2020 we will see tighter integration of 3G, 4G and carrier grade WiFi-WLAN. New technology will be added and spectrum between 300 MHz and 300 GHz will be exploited. Goals set for 5 G are: 10 Gbit/s from a node, 1000 times today's data volume, 50 to 500 billion connected devices, 10 to 100 times better user data rate, latency shortened with a factor of 5, 10 times today's battery time. Also options for direct communication between devices shall be explored. A vision of 5G is illustrated below.

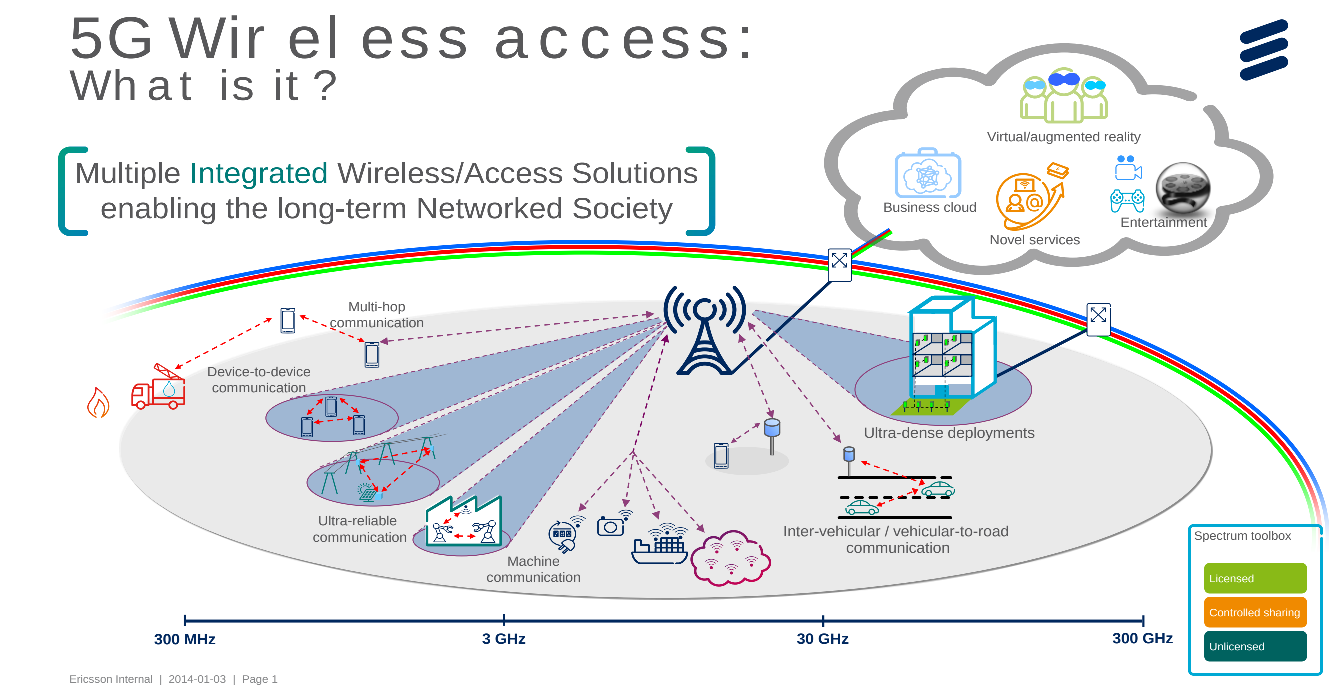

Figure 12 5G vision

Direct device to communication in LTE has been standardized for public safety first responder use and is to some extent network assisted and use reserved operator spectrum. “LTE Direct” is a kind of Ad Hoc advertisement service not very applicable to ITS. For LTE Advanced and 5G more demanding D2D use cases are under study.

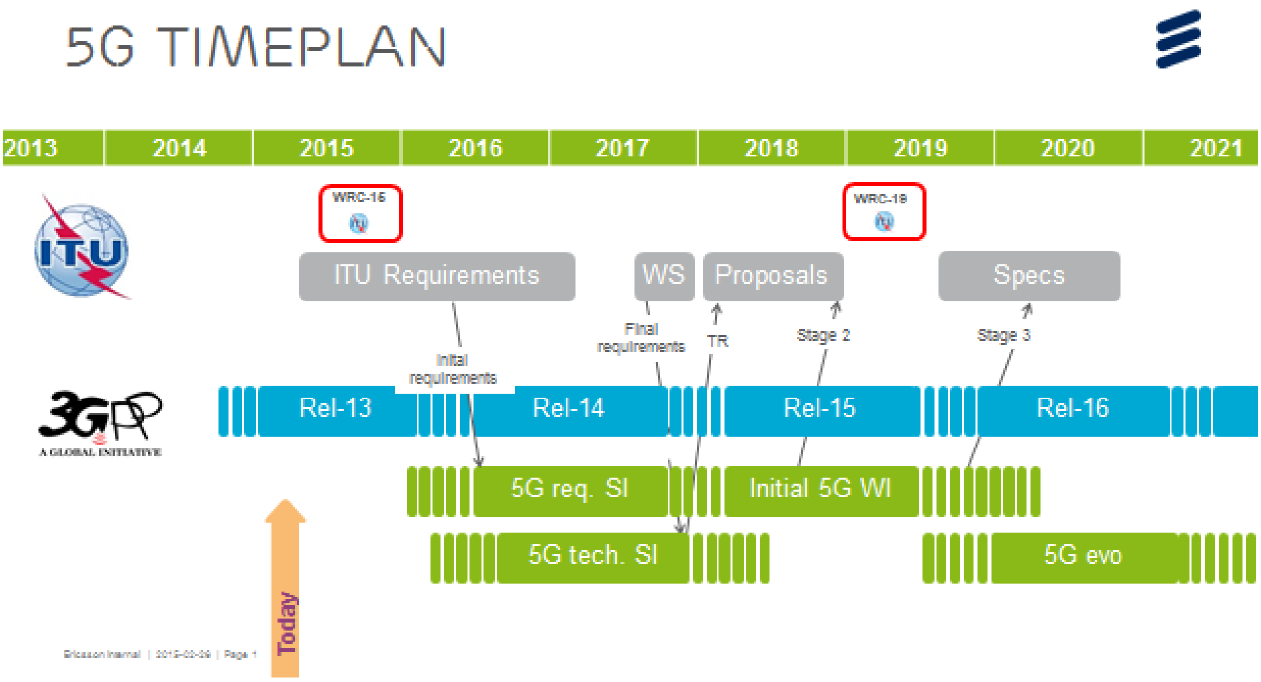

Figure 13 5G time plan

4.2.2 Key characteristics

The table 6 below presents a summary of the key characteristics for the different types of PLMN.

Table 6: key characteristic of PLMN technologies

Access technology	Population coverage in Europe[16]		Latency
	2013	2019	
2G GSM	90%	95%	2-5 sec
3G WCDMA (UMTS)	75%	90%	350 – 500 ms
4G LTE	25%	80%	50-100 ms
4G LTE Advanced	<2%	75%	Target 10 ms
5G		Experimental	Target 1 ms

The figures and forecast in the Ericsson Mobility report (June 2014[17]) measure the mobile network coverage of the population in Europe. This is of course not the same as area or road network coverage, but might be a good approximation from a road traffic volume perspective?

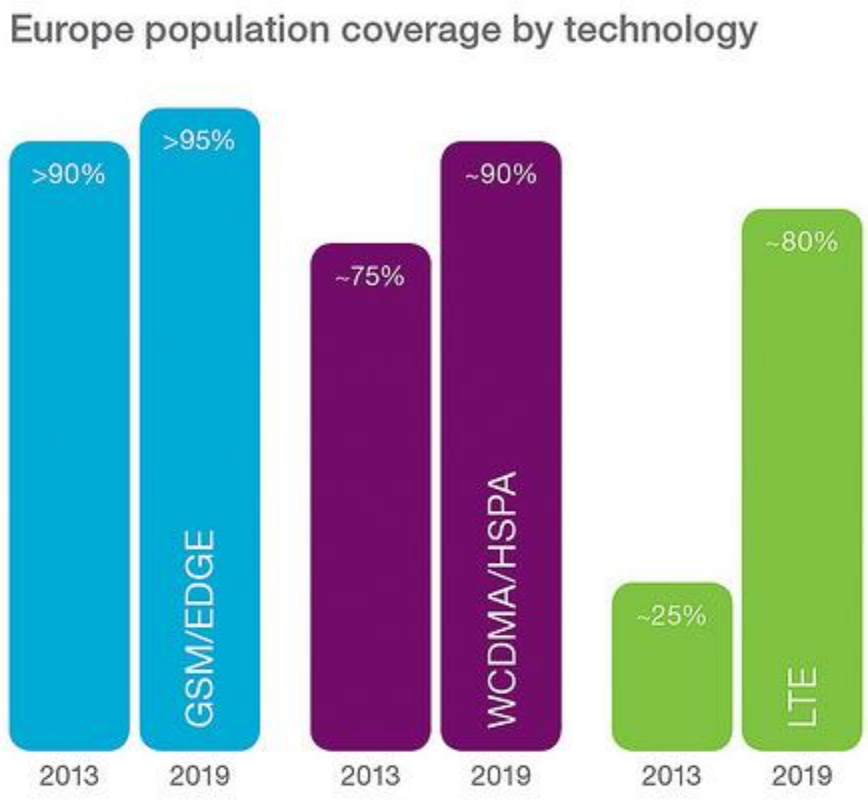

Figure 14 Coverage

Depending on choices of cellular operators, technology, country and region the coverage will vary. But a demanding application like eCall is roaming on all networks and this is considered sufficient for this “life critical” application.

[16] Source Ericsson Mobility Report http://www.ericsson.com/res/docs/2014/ericsson-mobility-report-june-2014.pdf
[17] http://www.ericsson.com/res/docs/2014/ericsson-mobility-report-june-2014.pdf

4.2.3 Technical characteristics

Technical characteristics GSM:

- *Coverage*: Very good – up to 90%
- *Capacity:* Voice and medium data rate
- *Quality of Service:* Best effort.
- *Transmission time:* Relatively long latency, but after that the data rate is "high" for the type of messages we are considering (EDGE/GPRS).
- *Latency:* 2-5 seconds
- *Bi directional:* Unlimited.
- *Broadcast:* No, a geo-messenger server is needed. (Public safety "Tsunami" warnings can be broadcasted via SMS.)

Technical characteristics 3G WCDMA (UMTS)

- *Coverage:* Good and improving – up to 75 to 90%
- *Capacity:* Very good broadband. 3G has excellent capacity for event driven ITS messages (DENM) but large automotive road traffic in big cells can cause overload in the signalling channels for "here I am" messages (CAM) so ITS G5 is best suited to carry the CAM traffic. The cost for transmitting CAM messages can be a commercial limitation (most CAM messages have a very low "value").
- *Quality of Service:* Best effort, with 3.5 G (packet switched IMS core network) QoS can be set (priority for urgent messages, lower probability for packet loss)
- *Transmission time:* Fast
- *Latency:* 350 to 500 ms
- *Bi directional:* Unlimited
- *Broadcast:* For 3 G not implemented everywhere, a geo-messenger server is needed.

Note: for 3.5 G broadcast functions can be implemented, and a geo-messaging server can be combined with it.

Technical characteristics 4G LTE

- *Coverage:* Networks are operational and there is good urban coverage in many countries, rural coverage is coming in a second wave on lower frequency bands. Licenses are not yet issued in some Member States.
- *Capacity:* Good, 4G LTE has even better capacity for event driven ITS messages (DENM) but large automotive road traffic in big cells can cause overload in the signalling channels for “here I am” messages (CAM) so ITS G5 is best suited to carry the CAM traffic. The cost for transmitting CAM messages can be a commercial limitation (most CAM messages have a very low “value”).
- *Quality of Service:* Best effort, QoS can be set (priority for urgent messages, lower probability for packet loss), but QoS is not implemented everywhere.
- *Transmission time:* Fast
- *Latency:* 50 -150 ms
- *Bi directional:* Unlimited

  Although direct communications between devices (device to device: D2D) is being developed the requirements are set for emergency first responders communication and some commercial advertisement use cases, so at present this is not suitable for ITS applications.
- *Broadcast:* Yes, eMBMS is supported but a geo-messaging server can also be used if the feature in not activated in a particular network.

Technical characteristics 4G LTE advanced

- *Coverage:* Partial network roll-out started
- *Capacity:* 5 to 10 times 4 G
- *Quality of Service:* Reliable communication for many critical applications (redundancy).
- *Transmission time:* 10 – 20 times faster than 4G LTE
- *Latency:* 10 to 20 ms
- *Bi directional:* Direct communications between devices (device to device: D2D) is foreseen (3GPP Rel. 12 March 2015).
- *Broadcast:* Yes, as well as device to device and multi hop.

Technical characteristics of 5G

Only rough ideas are available yet. A first set of stable definitions is expected by ITU-R in 2015:

- *Capacity:* 50 to 100 times 4G
- *Quality of Service:* Ultra reliable communication for many critical applications (redundancy).
- *Transmission time:* 50 – 100 times faster than 4G LTE (especially short burst machine to machine: M2M)
- *Latency:* 1 ms
- *Bi directional:* Direct communications between devices (device to device: D2D).
- *Broadcast:* Yes, as well as device to device and multi hop.

4.2.4 Deployment

Depending on choices of cellular operators, technology, country and region the coverage will vary. In almost every car there is a mobile phone today that can have navigation and ITS applications. There is no Road Hazard Warning back-end server system for ITS applications deployed yet but the rest of the infrastructure for

V2X in cellular networks is "in place". For mobile communication, a standardization of the cooperative functions is needed. Backend architecture via different backend provider, different traffic management centres, different OEM back-ends for safety (now started with CONVERGE[18]) is missing until now.

The market development of connected car services is likely to result in such attractive services for users and the stakeholders of the value chain, that the penetration rate of built-in cellular connectivity (or closely integrated smart phones) in new vehicles, will reach close to 100% in a few years. These vehicles can then support V2X services based on the DENM-messages over the cellular networks.

4.2.5 Cost structure

The cost for spectrum, investment in radio network HW/SW, operational cost and maintenance cost is paid by subscription fees and transaction based fees or flat fees for the general (smart phone) usage of the mobile systems. For new additional V2V, V2I and I2V applications there will be subscription costs and communication costs similar to smartphones to cover investment and operations. But note that many different business models are possible, enabled by the systems capabilities to flexibly bundle the communication cost into the complete safety or efficiency service. Data rates needed for V2X are relatively small compared to common applications used now on smartphones.

4.3 ITS G5 (vehicular WiFi)

ITS G5, also known as IEEE 802.11p and DSRC (in the US) is a short range WLAN standard developed for ad hoc broadcast communication between vehicles and to the road side infrastructure. The specification is derived from the well-known WiFi specification (IEEE802.11), specially adapted to the vehicular environment, supporting high driving speeds and low latency requirements. It operates in a dedicated spectrum on 5.9 GHz. There are many kinds of messages, best known is maybe: CAM – *here I am, going there* and DENM – event messages, like *roadwork warning, post-crash warning, icy road, emergency vehicle warning, electronic brake light* etc. Other messages relate to traffic signal states (SPAT/MAP), variable message signs, in-vehicle signage (IVI), and vehicle probe data (PVD). These messages are broadcasted, the range is 300 m to 1 km, and may be forwarded further via multi hops. Many research and pre-deployment projects have piloted this technology and it is on the edge of start of deployment.

- In 2008 the European Commission announced an action plan for the deployment of the Intelligent Transportation Systems (ITS).[19]
- And the frequency band 5875 - 5905 MHz was allocated for safety-related ITS. [20]

ITS-G5 is designed to support time critical road safety applications where fast and reliable information exchange is necessary. ITS-G5 communication is the kind of communication technology which fulfils real-time requirements in the best way, because of direct communication with very low latency in a highly dynamic ad hoc network. To warn and support the driver without time delay both V2V and V2I applications are necessary.

No roaming or translation between different providers is necessary. Additionally a physical "prioritization" is built into any direct communication, because the closer the communication partner the faster and smaller is

[18] http://www.converge-online.de/?id=000000&spid=en

[19] COM(2008) 886 "COMMUNICATION FROM THE COMMISSION, Action Plan for the Deployment of Intelligent Transport Systems in Europe"

[20] Commission Decision 2008/671/EC of 5 August 2008 on the harmonised use of radio spectrum in the 5 875-5 905 MHz frequency band for safety-related applications of Intelligent Transport Systems (ITS).

the probability of errors in the communication. This schema fits very well with the intended safety applications.

The short range ad-hoc network has no 'server' or similar that keeps track of the vehicles positions in order for the communication to be routed to the recipients in the vicinity in the V2V and V2I mode. But for traffic management centres to reach out a back end is needed and cross border and cross road operator coordination will be needed in many places.

Global harmonization enhances economies of scale in equipment manufacture and will result in a wider cross-border mobility. In the USA 75 MHz of spectrum within the band 5850-5925 MHz has been allocated to Dedicated Short Range Communications (DSRC, WAVE) providing ITS applications with specific channels for safety and with general access priority to safety applications in all bands. In Japan 80 MHz (5770-5850 MHz) is dedicated for DSRC and intended for ITS applications including V2V and V2I communication. Other countries worldwide are considering the 5.9 GHz band for road safety applications which may provide further global harmonization of the use of this particular frequency range for ITS.

4.3.1 EU Regulations applicable to ITS-G5

The conditions of use of ITS in the band 5855-5925 MHz have been split into three sub-bands in which different regulations and status apply:

- 5875-5905 MHz: this band is designated through EC decision for ITS safety-related applications.[21]
- 5905-5925 MHz: this band is identified as potential extension band for ITS.[22]
- 5855-5875 MHz: the band is recommended to be made available for ITS applications.[23]

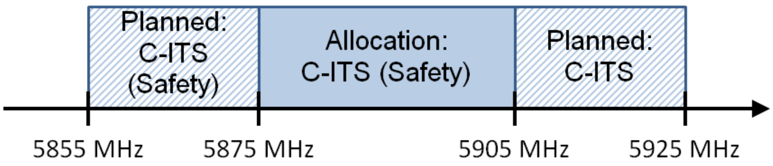

Figure 15: Spectrum Allocation for C-ITS in the 5.9 GHz band, Source: C2C-CC

4.3.2 ITS-G5 technical description

Radio communication systems in the 5 GHz range can today offer communications with a high data rate, ranges typically 300 – 500 meter and up to 1 000 meter, low weather-dependence, and global compatibility and interoperability for ITS communication.

The connectivity required by the applications can be summarized as:

1. Inter-Vehicles Communications (V2V) (this includes multi-hop routing involving several vehicles):
   a. Linear (e.g. for convoys of vehicles);
   b. Vehicle cluster covering several lanes (e.g. for lane management, overtaking assist).
2. Vehicle to Roadside (uplink) V2I and Roadside to Vehicle I2V (downlink), V2I and I2V are summarized as V2I:
   a. One vehicle to beacon;

[21] EC Decision 2008/671 and ECC/DEC/(08)01: “ECC Decision of 14 March 2008 on the harmonised use of the 5875-5925 MHz frequency band for Intelligent Transport Systems (ITS)”.
[22] in ECC Decision(08)01
[23] through ECC/REC/(08)01: “ECC Recommendation (08)01 on the use of the band 5855-5875 MHz for Intelligent Transport Systems (ITS)”.

    b. Beacon to one vehicle;
    c. Beacon to many vehicles (broadcast, short range and long range);
    d. Beacon to selected vehicles.

3. Cluster of vehicles communication, including to roadside beacon.

4.4 Technical characteristics

Technical characteristics ITS G5 for V2V

- *Coverage:* Ranges are typically 300 - 500 m and up to 1 km around the vehicle. The multi-hop communication extents the range of ITS-G5 communication up to several kilometres.
- *Capacity:* Enough for CAM and DENM and I2V messages to support safety and efficiency applications. An additional congestion control is required in certain scenarios to ensure availability of safety functions at all times.
- *Quality of Service:* Very high with other equipped vehicles within range and "Best effort".
- *Vehicle intervention:* Day 1 applications - Only by the driver. For future application automatic intervention is in development in connection with other in-vehicle systems.
- *Transmission time:* Defined by triggering conditions/use cases, depends on the availability of In-Vehicle data. On network level <5ms including security
- *Latency:* the End2End Latency shall be <100ms including security operations, on network level latency times <15ms have been demonstrated in the simTD FOT.
- *Bi directional:* ITS-G5 can be used bidirectional with service announcements. For Day1 application only Broadcast and Multi-hop Broadcast are used.
- *Broadcast:* Ad Hoc networking

Technical characteristics ITS G5 for V2I

- *Coverage:* Limited on a global scale, but good for use cases as road work warning or green light optimal speed advisory, local traffic control/management services and in particularly for time critical and safety related use cases.
- *Capacity:* Enough for CAM, DENM, SPAT, MAP and PVD messages. An additional congestion control is required in certain scenarios.
- *Quality of Service:* Very high for equipped cars passing by.
- *Vehicle intervention:* Day 1 applications - Only by the driver.
- *Transmission time:* Same as V2V.
- *Latency:* Same as V2V.
- *Bi directional:* Same as V2V.
- *Broadcast:* Same as V2V.

4.4.1 Deployment

Deployment ITS G5 for V2V

Starting 2015 and increasing over the next 15-20 years until approaching 100 % penetration in motor vehicles.

Deployment ITS G5 for V2I

Pilots are starting in 2015, during which roadside ITS station (R-ITS-S) and road work warning trailers will be deployed.

4.4.2 Cost structure

Costs ITS G5 for V2V

Up-front costs are foreseen for the vehicle buyer to provide ITS G5 on-board equipment, but no costs for data transfer or spectrum. Small life time costs in the context of vehicle software / data provisioning and update and periodic technical inspection.

Costs ITS G5 for V2I

Investment in roadside ITS stations (HW+SW) are necessary, the integration into existing infrastructure systems is possible and reduces the investments into civil works, electrical power, internet connection, back end servers as well as operation and maintenance cost. It is assumed that the road operators will make the investment. The number of R-ITS-S depends heavily on the use case. For Road works warning only the warning trailers need R-ITS-S equipment, power is available and mobile networks is used for back haul communication with traffic management centres. It is expected that existing traffic centers can handle the incoming data so no new backend infrastructure is needed. Classical traffic center tasks are supported by the probe vehicle data, so with rising equipment rate the need for classical traffic flow detectors will go down, so that a counter funding is possible if the equipment rate reaches >30%.

Overall fixed costs are foreseen per road side unit for Wifi capacity as well as annual maintenance costs. The average lifetime of the roadside units is expected to be around 10 years.

Important notes:

- From a cost point of view it will be financially challenging to cover the whole European road network with a short range communication technology. Cost/benefit analysis will guide the deployment to areas with dense enough traffic or high risks for accidents. This is another justification for the need of a hybrid communication technologies approach.
- To reduce costs in the context of deployment, existing infrastructure should be used/adapted wherever possible e.g. the emergency call stations at the motorways.

4.5 Satellite Communications

Satellite Communications technologies have achieved remarkable breakthrough in efficiencies and increases in performance in nearly a half century. These developments, however, have occurred in parallel with large gains in performance by other IT and telecommunications systems. Thus, these dramatic gains are not as apparent to the general populace as might have been the case if this explosion in performance had happened in isolation.

In many ways today's satellites are digital processors in the sky and specialized software defines how they perform and defines their communications capabilities. In fact, the innovations in satellite communications as well as the progression in all forms of telecommunications and computer processes have followed similar courses. In short, Moore's law that predicted a doubling of performance every 18 months has generally held true for all fields involving digital processing whether it be computing, communications. What had been past is thus likely to be prologue. It is reasonable to anticipate continuing gains in terms of overall processing power, digital communications, and "intelligent" space communication systems.

In short, there are remarkable new technologies still to be developed in terms of space-based satellite communications systems, more powerful processors, new encoding capabilities, and new user terminal capabilities that can make user systems more mobile, more versatile, more personally responsive, more powerful in terms of performance, and yet lower in cost.

There are typically four types of communications satellite systems. They are categorized according to the type of orbit they follow.

A low-earth-orbit **(LEO)** satellite system circular orbit at a constant altitude of a few hundred miles. Each revolution takes approximately 90 minutes to a few hours. A constellation is arranged in such a way that, from any point on the earth surface at any time, at least one satellite is visible

A medium earth orbit (MEO) satellite is one with an orbit within the range from a few hundred miles to a few thousand miles above the earth's surface. Satellites of this type orbit higher than low earth orbit (LEO) satellites, but lower than geostationary satellites. The orbital periods of MEO satellites range from about two to 12 hours. Some MEO satellites orbit in near perfect circles, and therefore have constant altitude and travel at a constant speed.

A geostationary satellite **(GEO)** orbits the earth directly over the equator, approximately 22,000 miles up. At this altitude, one complete trip around the earth (relative to the sun) takes 24 hours. Thus, the satellite remains over the same spot on the earth's surface.

Highly Elliptical Orbit (HEO) or also known as Molniya orbit, these satellites are designed so that the satellite spends the greatest majority of its time over the far northern latitudes, during which its ground footprint moves only slightly. Its period is one half day, so that the satellite is available for operation over the targeted region for eight hours every second revolution. In this way a constellation of two Molniya satellites can provide uninterrupted coverage in the northern latitudes.

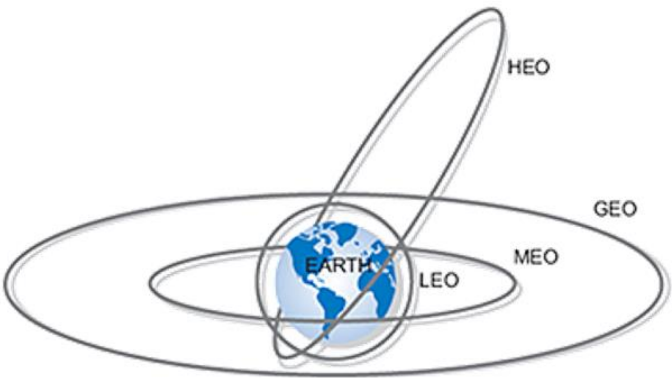

Figure 16

Orbital Type	Orbial Distance	Access time
LEO - Low Earth Orbit	100 to 500 Kilometres above the earth	typically in 90 to 120 minutes
MEO - Medium Earth orbit	5,000 to 10,000 Kilometres above the earth	typically in 2 to 8 hours
GEO - Geostationary Orbit	36,000 Kilometres above the earth	Maintains a set orbital position over required area of the earth surface
HEO - Highly Elliptical Orbit	Low-altitude about 1,000 kilometres a high-altitude over 35,786 kilometres	Elongated orbits have the advantage of long dwell times at a point in the sky

Table 7

Footprint & coverage

Satellites offer ubiquitous and large scale coverage in support of numerous applications. A single GEO satellite can cover almost 1/3 of Earth's surface, offering a reach far more extensive than any terrestrial network. Its coverage or 'footprint' varies dependant on the design of the antenna and satellite payload /mission, it is also dependant on its distance from earth.

Today's satellites provide coverage on either a large global footprint , regional footprint or multiple spot beams cover typical 100km distances on the surface of the earth.

Splitting the satellite frequency into small coverage areas called spot beams (similar to mobile phone cells) enables frequency and spectrum to be reused many times increasing total satellite capacity. To avoid interference, adjacent beams use alternating signal frequencies and polarization

Figure 17

Spectrum & Frequencies

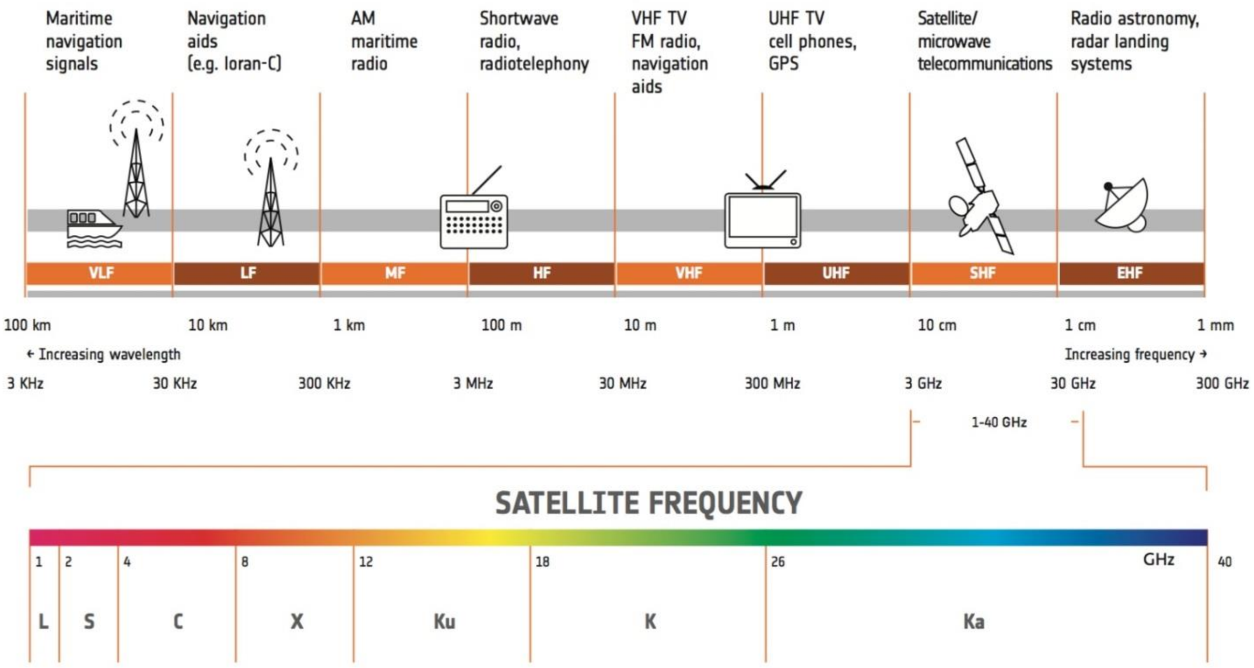

Figure 18 Satellite spectrum and frequencies

With the variety of satellite frequency bands that can be used, designations have been developed so that they can be referred to easily. The higher frequency bands typically give access to wider bandwidths, but are also more susceptible to signal degradation due to 'rain fade' (the absorption of radio signals by atmospheric rain, snow or ice).

Because of satellites increased deployment over the past decade frequency congestion has become a serious issue in the lower frequency bands (C, L and Ku Bands). The higher frequency band technologies are being deployed in the form of high throughput satellites (HTS) these operate in the Ku , Ka Band with the potential in the coming decade to operate in the Q and V Band , however this technology is very immature and costly.

4.5.1 Key characteristics

Fixed vs Mobile

Satellite communications can be utilised in 2 configurations – fixed and mobile satellite services. Within the C-ITS context, fixed satellite connectivity can be used to connect assets in location where terrestrial communication infrastructure is either immature, unavailable or costly to deploy. Tolling stations in remote locations and variable message signs (VMS) for instance can use such connectivity.

Mobile satellite services embrace an architecture similar to cellular networks – thereby able to provide connectivity to vehicles (land, sea and air).

Antenna

There is a diverse range of antenna when it comes to satellite communications due to the wide range of frequencies (1 to 40 GHz). The form factor can range from a small hamburger size or shark fin antenna for L-/S-bands to large parabolic antenna for the Ka/Ku bands. Vehicular antenna can be omnidirectional (typically low-data rate) or tracking/directional antenna (which automatically tracks the satellite to maintain line of sight).

The type of service also determines the form factor of the antenna. If it is a receive-only antenna, such as receiving satellite broadcast for in-vehicle entertainment, then a small low-power antenna is sufficient. However, if transmission is required, then based on the throughput required and the type of satellite used (constellation and communication band), the antenna required can grow significantly in size and be power hungry.

Figure 19 ***LDR vs Broadband/HDR Terminals***

Based on the several factors including the type of vehicular antenna, orbit of satellite constellation, coding/modulation scheme and the frequency band used, peak achievable data rates vary from a few bytes to a few MB. A Low Data Rate (LDR) vehicular terminal would be sufficient to support typical M2M applications for e.g. for fleet management or sending an MSD within eCall. The use of satellite communication for fleet management can be found around the globe. For instance, in Brazil, VOLKSNET is an Iridium-based telematics solutions that is used for Long-Haul truck tracking, automation and control. Broadband/HDR terminals can support high speed connectivity to the vehicle supporting voice calls and rich data transfer.

4.5.2 Deployment

Satellite communications systems offer the immense benefit of wide coverage. Several operators have hence developed services that offers voice and data services on regional or global basis , the following represent the type of satellite constellation (GEO, MEO, LEO) with over 100+ operators offer broadcast, broadband & mobile services and application.

INMARSAT – GEO telecommunications satellite

Inmarsat operates twelve geosynchronous satellites and provides voice and data satellite communication worldwide using dedicated terminals. The Inmarsat terminals provide satellite communication to a ground station through one of their twelve GEO satellites. The network provides reliable satellite communications to aviation, maritime, governments, emergency services, news media, and businesses that need communication in areas with no reliable landline or cellular services

The I-4 constellation is made up of three large and powerful geostationary satellites that are placed in high earth orbit 22,240 statute miles above the Earth. They are part of a global constillation of satellites owned and operated by Inmarsat. The Inmarsat-2s, where the first generation design for a 10 year operating lifespan they were Inmarsat's first wholly owned satellites. The Inmarsat 3s launched later that decade were the first generation to use spot beam technology. The Inmarsat I-4s are the most powerful satellites so far launched by Inmarsat. The I-4s are 60 times more powerful than their Inmarsat 3s. The I-4s satellites are expected to continue commercial service until 2020.

I-4 satellites deliver a global voice and data services know as Broadband Global Area Network (BGAN) designed to support simultaneous voice and high speed data to very small, highly portable mobile terminals with target data rates up to 492kbps Support the full range of applications running on a network architecture based on a terrestrial 3G network adaptation. Inmarsat i-4 fleet operate in the L Band frequency spectrum offers high susceptibility to rain fade experience by other frequency bands (Ku , Ka)

In Mid 2014 Inmarsat launch its first satellite in a new constellation I-5 Global Express (GX) the satellites will operate in the Ka Band spectrum and will deliver high bandwidth IP services on a global basis. EuropaSat planned for launch in 2017 will provide high speed internet service operating in S band spectrum for the aviation industry, this service will be complemented with a complementary LTE ground segment limited to European coverage.

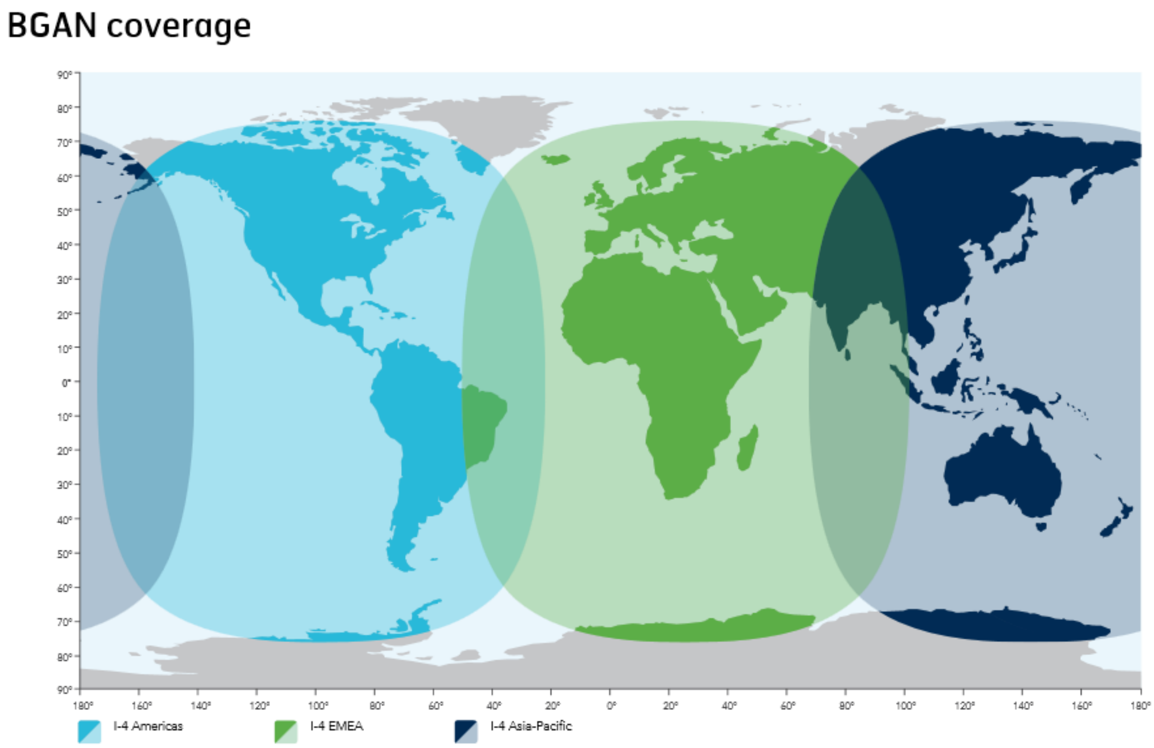

Figure 20 BGAN coverage

IRIDIUM - LEO telecommunications satellite

Iridium constellation consists of 66 LEO satellites flying in six orbital planes with 11 satellites equally spaced apart from each other in each orbital plane. The satellites have polar orbits at an altitude of 485 miles

Each satellite completely orbits the earth in 100 minutes traveling at 16,832 miles per hour. From horizon to horizon it takes 10 minutes. As satellites move out of view from the satellite user the call is handed over to the next satellite coming into view ensuring continuity of service.

One of the reasons Iridium works so well is their system has more satellites than any other satellite provider, giving coverage to every part of the planet. With minimal service gaps, Iridium users can place and receive calls from virtually every part of the planet as long as they have line-of-site to one of the satellites.

Voice and data messages (2.4Kbbs to 10Kbs) can be routed anywhere in the world by the Iridium network. Calls are relayed from the satellite phone or data unit on the ground to one of the Iridium satellites. It is then relayed from one satellite to another then down to an appropriate ground station. The call is then transferred to the public voice network or Internet when it reaches the recipient. The satellites communicate with each other using Ka-band inter satellite links. Each satellite has four inter satellite links, two to the fore and aft satellites in the same orbital plane and two to the satellites in orbital plane to either side. These inter satellite links allow calls to be routed among the Iridium satellites before being transferred to a ground station.

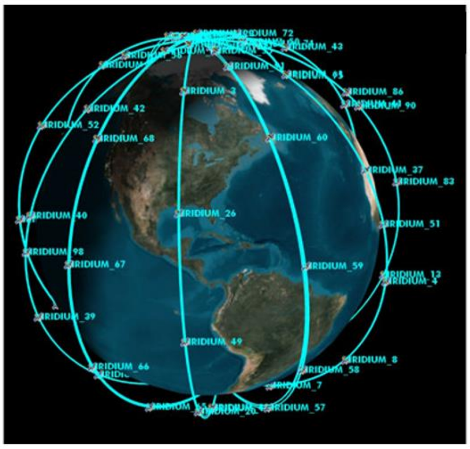

Figure 21 Iridium

O3b - MEO telecommunications satellite

O3b Networks is constellation of eight high capacity medium Earth orbit satellite in a circular orbit along the equator at an altitude of 8063 km. The network will combine the ubiquitous reach of satellite with the speed of fibre to deliver satellite Internet services and terrestrial mobile backhaul . Each satellite is equipped with twelve fully steerable Ka band antennas (two beams for gateways, ten beams for remotes) that use 4.3 GHz of spectrum (2 × 216 MHz per beam) with a proposed throughput of 1.2 Gbit/s per beam (600 MBit/s per direction), resulting in a total capacity of 12 GBit/s per satellite. The constellation offers IP communication, and an end-to-end round-trip latency of 238ms for data services. The maximum throughput per TCP connection is 2.1 Mbit/s. The initial deployment provides coverage as depicted in the picture below.

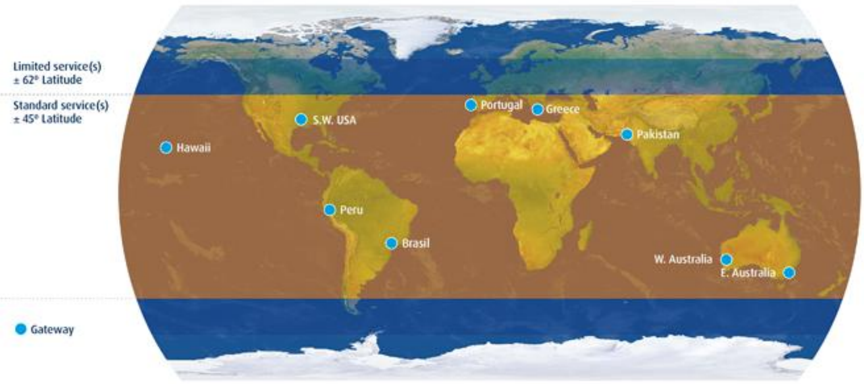

Figure 22 O3b –coverage

List of typical operator services, service description and data rates and associated latency

Service	Description	Service description	Datarate MAX	Latency
ORBCOM	a constellation of 46 LEO satellites utilising the 137-150 MHz frequency band	Message based Machine 2 Machine service	Message based	Variable 1 to 4 minutes message based delivery delay
SES	47 Geo Broadcast & broadband fixed services satellites	VSAT fixed broadband services	IP data rates Ku VSAT 1-2Mbs Ka VSAT 10-20Mbs	520mS RTD
EUTELSAT	47 Geo Broadcast & broadband fixed services satellites	VSAT fixed broadband services	IP data rates Ku VSAT 1-2Mbs Ka VSAT 10-20Mbs	520mS RTD
AVANTI	3 GEO satellites offer broadband services for Europe, africa	Ka Band fixed broadband service	IP data rates Ka VSAT 10-20Mbs	520mS RTD

Isat-M2M	"Two-way burst messaging service" Coverage across the globe except poles valid for both fixed and mobile assets.	Fixed or mobile M2M device of small size, designed for low data rate and volume usage (typically <10kB per month).	Tx Messages of 10.5 or 25.5 bytes (flex option to go up to 192 bytes) Rx Messages of 100 bytes.	30 to 60 seconds
Isat-datapro	"Two-way short messaging service" Coverage across the globe except poles valid for both fixed and mobile assets.	Advanced version of Isat-M2M service, targetting higher data rates (typically <1 Mbps per month).	Tx 6400 bytes Rx 10 000 bytes (unclear)	15 to 60 seconds
BGAN M2M	"Two-way IP data service" Coverage across globe except poles valid for fixed assets only	BGAN M2M declined version (possible to buy up to 25 000 SIM cards at a time) relies on Inmarsat's broadband BGAN service, and can offer higher quality of service.	Up to 448 kbps	From 800 ms
Globalstar dual service	Data service mapped over voice service Uses Globalstar Constellation (see assiocated coverage)	Dual service refers to duplex communications (other offers for single side communications are also available)	9600 bps ***(source : Globalstar website)***	Not indicated (probably lower than other offers)
Iridium SBD service	Data service of Iridium "real" worldwide coverage	"Low Cost" Data service of Iridium constellation	Size is between 30 and 340 bytes	Order of magnitude : 10 seconds
Thuraya IP Land	Data service of Thuraya ; worldwide coverage.	Thuraya broadband offer (not especially M2M) for fixed or mobile terminals.	Up to 444 kbps.	~1 second.

Table 8 Technical data on satellite transmission

4.5.3 Cost Structure

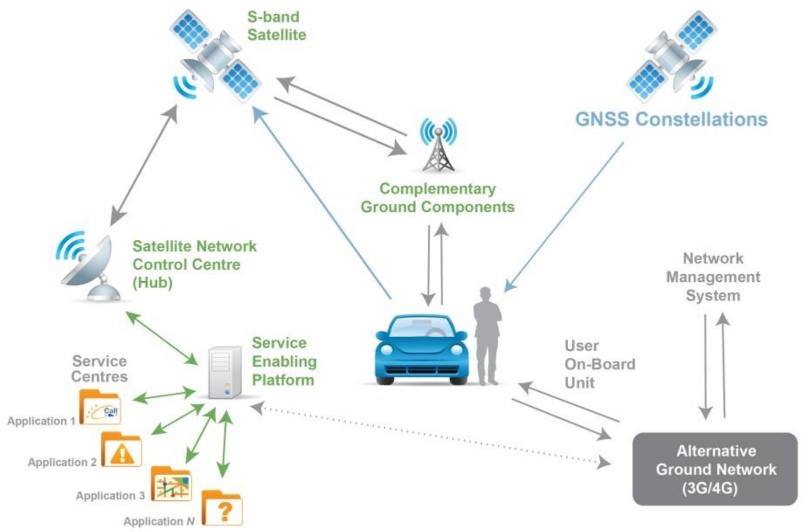

Figure 23 ***Emergency Services Application***

Satellite communication can be used to increase the availability and reach of the pan-european eCall service.

5 Service versus technology mapping

As indicated in our scenario at the beginning of the main report an event in the traffic system generates information that can be communicated using different channels addressing different stakeholders for different purposes, often simultaneously.

Table 9 below shows a mapping between service and communication technology. The first part of the table collects views about the mapping between ITS service features and features relating to communication.

The second part of the table is a mapping between communication technologies and the communication features from the above table.

The combination of the two mapping tables provides an estimation of the most appropriate communication technology according to the ITS service features.

Important note: the table 9 below is comparing the features of the different kinds of connectivity, from the communication network point of view. However, the latency of the whole value chain for instance will be higher, because it will also depend on the performance and of the service provider networks and servers.

Therefore, the latency, mentioned in the table 9 below, takes into account only the communication network performances, and thus the client to client latency.

Table 9: service versus technology mapping

From	To	Service	Information	Range 1m/10m/100m/1km/10km/100+km	Directionality Unidirectional/Bidirectional	Connection Broadcast/Point-to-point	Latency ms/sec/min/hr	Safety critical level (reliability)Low/Med/High	Investment cost (e.g. equipment)€/€€/€€€	Variable cost (e.g. data transmission) €/€€/€€€	Security level Low/Med/High	Privacy level Low/Med/High	Service performance requirements
Crash vehicle	PSAP	eCall	MSD	100 km	uni	P2p	sec	high	€€	€	med	high	
Crash vehicle	Vehicles	Post-crash warning	DENM	1 km	uni	bc	ms	high	€	-	high	high	
Crash vehicle	Vehicles	Pre-crash warning	DENM	1 km	uni	bc	Ms	high	€	-	high	high	
Crash vehicle	Roadside station	Pre-crash warning	DENM	1 km	uni	bc	ms	high	€	-	high	high	
Crash vehicle	Central station		DENM	100km	bi	P2p	sec	high	€€	€	high	high	
Infra loops	Roadside station		Flow	10m	uni	P2p	sec	low	€€€	€	low	na	

Roadside station	Central station		Flow	10km	bi	P2p	sec	med	€€	€	med	low	
Infra camera's	Central station		Crash	100km	uni	P2p	min	med	€€	€€	low	na	
Vehicles	Central station		FCD	100km	uni	P2p	min	low	€€	€€	low	high	
Central station	Travellers		TMC TPEG-TEC TPEG-TFP	100km	uni	bc	min	low	€	€	high	na	
Central station	Roadside station		Speeds	100km	uni	P2P	Min	med	€€	€	med	na	
Roadside station	Vehicles		Speeds	1km	bi	bc	Sec	med	€	-	med	na	
Central station	Roadside station		Routes	100km	uni	P2P	Min	med	€€	€	med	na	
Roadside station	Vehicles		Routes	1km	bi	bc	Min	med	€	-	med	na	
Central station	Vehicles		Speeds TPEG-SPI	100km	uni	bc	Min	med	€	€	med	na	
Central station	Vehicles		Routes TPEG-RMR	100km	uni	bc	Min	med	€	€	med	na	

Communication technology	Range 1m/10m/100m/1km/10km/100+km	Directionality Unidirectional/Bidirectional	Connection Broadcast/Point-to-point	Latency ms/sec/min/hr	Safety critical level (reliability)Low/Med/High	Investment cost (e.g. equipment)€/€€/€€€	Variable cost (e.g. data transmission) €/€€/€€€	Security level Low/Med/High	Privacy level Low/Med/High	Service performance requirements
RDS-TMC	100km	Uni	br	min	low	€	€	low	na	
DAB-TPEG	100km	Uni	br	min	low	€	€	low	na	
3G	10km	Bi	P2p	400 ms	med	€	€€	high	high	
LTE	10km	Bi	P2p	100 ms	med	€	€€	high	high	
LTE advanced	10km	Bi	P2p	10 ms	med	€	€€	high	high	
5G	10km	Bi	P2p	1 ms	med	€	€€	high	high	
ITS-G5	1km	Bi	P2p+br	100 ms	high	€	€	high[24]	high[25]	
Satellite	100km	Bi	P2p+br	300 ms	high	€€	€€	high	high	

[24] Certificates warrantees a high level of security
[25] Pseudonyms warrantees a high level of privacy

6 The Vehicle fleet and its evolution

The vehicle fleet in Europe is getting connected, driven by different service needs in different segments but it will take many years to reach high levels of penetration. So far, all the use cases described below are defined as non-interoperable silos, based on independent sets of standards specifying their own communication stacks (access technologies, protocols, message formats). All of them would heavily benefit from and contribute to C-ITS once independent sets of standards are harmonized and interfaces are defined.

6.1 Heavy Vehicles

Buses and long haul trucks are often equipped with cellular communications and satellite positioning equipment for fleet management, eco-driving support and remote diagnostics. Many of the major brands have line fitted telematics as a standard and C-ITS can benefit from this. New needs of communication with other vehicles and the infrastructure will appear with the introduction of extra heavy or long transports and even more important for platoons of trucks.

6.2 Cars and light commercial vehicles

6.2.1 eCall

Mandatory eCall in all newly type approved cars and light commercial vehicles in EU from 2018 means that an increasing number of vehicles will be equipped with GSM (and probably 3G WCDMA) communication devices. But in order to protect privacy (tracking of vehicles) the In Vehicle System will stay in dormant mode until an eCall is activated. The vehicle owner can of course sign up for a connected car subscription package from a service provider and also choose third party eCall.

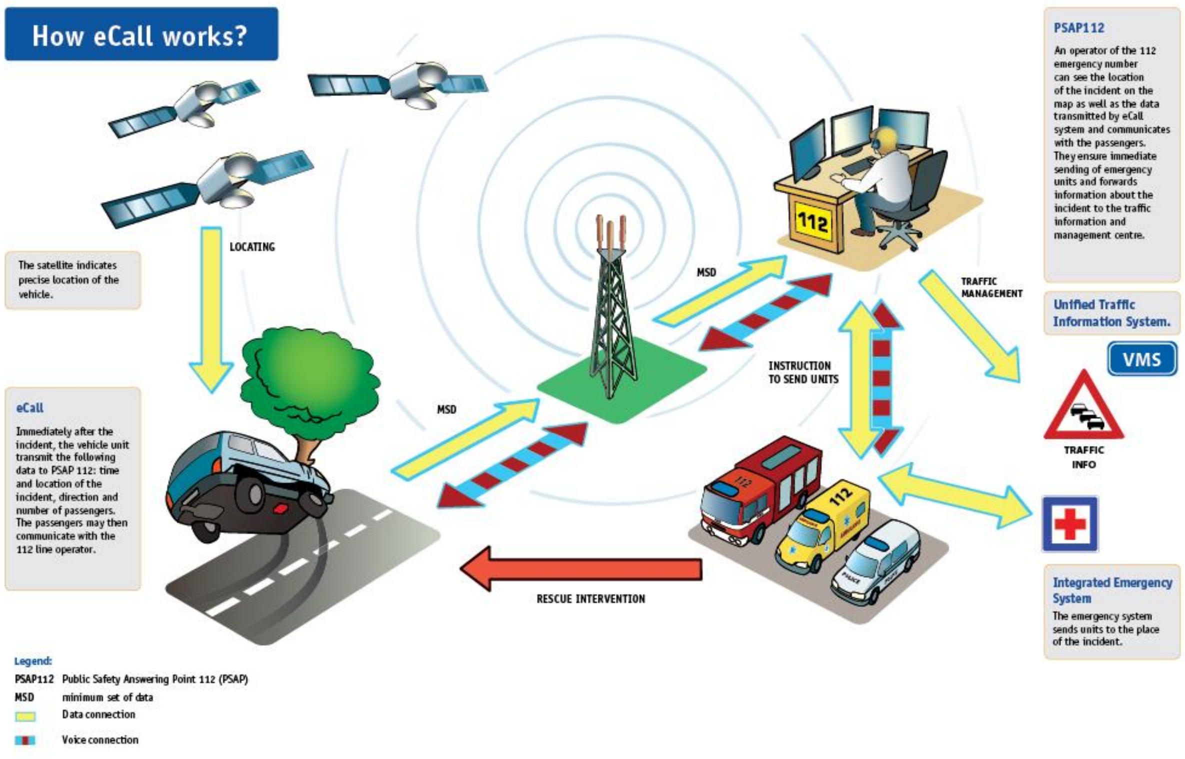

Figure 24 Pan EU eCall

6.2.2 Increasing Connectivity in Vehicles

Cars (starting in the premium segment) are getting connected in increasing numbers for a multitude of services. The drivers' smartphone can be used to provide the connectivity and subscription (tethered or integrated) and there can be an embedded device in the vehicle (like the eCall unit). Market analysts have different views of how fast this uptake will be.

When there are regulatory requirements on communication equipment in new vehicles or new type approved vehicles calculations has been made. Two examples are presented here:

Table 10 *eCall in Sweden* if eCall is mandatory from 2017:

Year	Penetration (%)	Elapsed time (years)
2017	1	0
2019	5	2
2024	27	7
2029	52	12
2034	74	17
2040	98	23

simTD project, the largest field operational text for V2X communication in Europe, has analyzed the predicted deployment of V2X in Europe from 2015 until 2035. According to the Figure 25 50% equipment rate with V2X (ITS-G5) can be achieved in 10 years and approximately 100% equipment rate of all passenger vehicles in 20 years.

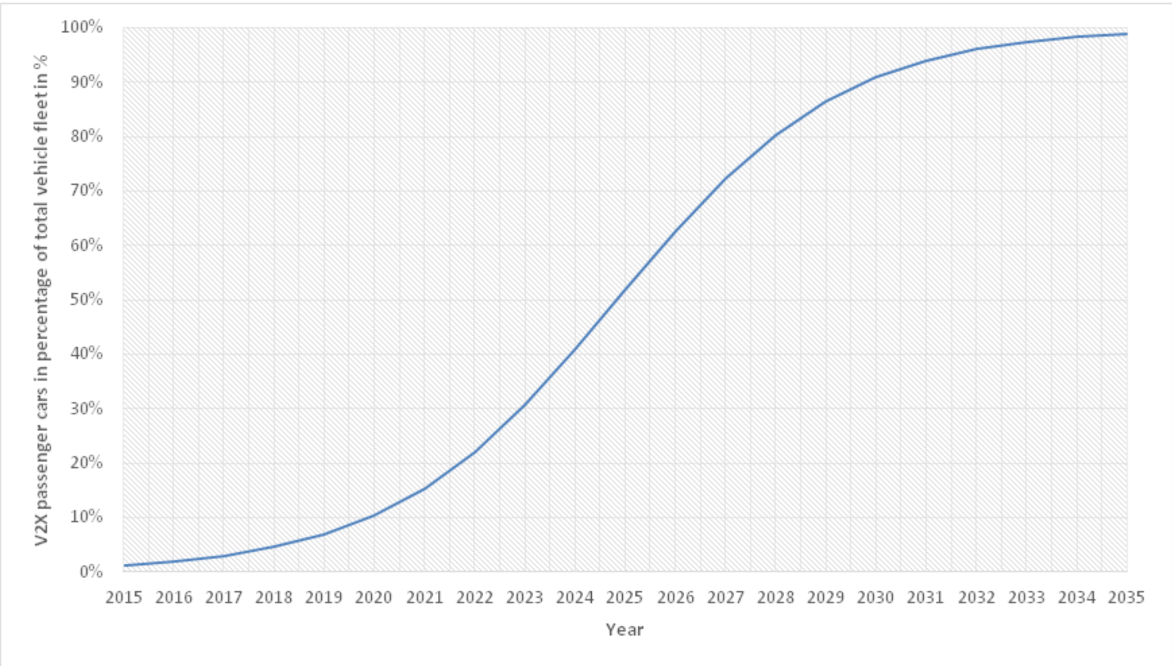

Figure 25: V2X (ITS-G5) equipment rate for passenger cars in % of the vehicle fleet in Europe 2015 – 2035 , source: sim^{TD} deliverable D5.5[26]

6.3 Public transport

Vehicles in public transport are connected via cellular networks and or private radio systems (TETRA). At the same time, public transport priorities form a very mature use case. Public transport would heavily benefit from and contribute to C-ITS once standards are harmonized and interfaces are defined

6.4 Transport as a Service

Emerging car sharing /carpooling as well as electrical vehicles are connected via the cellular networks to enable ease of use.

6.5 Connected travellers

Most travellers are connected today and live with a smartphone always in the pocket. The smartphone is the ITS tool in the hands of the multi modal traveller! New apps for the traveller are launched “every day”. To name one example, crowd sourcing feeds WAZE with instant information on the traffic situation for improved navigation and prediction. Many public transport companies provide travel planners and payment systems using smartphones and users you can in some cases see where their bus is in real time. This is of course only the beginning…..

[26] sim^{TD} Deliverable D5.5 – Teil B2Volkswirtschaftliche Bewertung:Wirkungen von simTD auf die Verkehrssicherheit und die Verkehrseffizienz

7 Current ITS deployment activities

7.1 Introduction

The deployment of C-ITS is driven by different forces and interests. The automotive industry sees usefulness for V2V communication to complement the (autonomous) active safety systems and offer their customers connectivity for services. The driving forces are here "business to consumer" added with a touch of "business to business" as the different brands need to be interoperable, actions by the Car2Car consortium like the MoU[27] and prototype root CA being proof points.

With the present renewal rate of the vehicle fleet the deployment will stretch out for more than a decade.

From a policy point of view C-ITS is regarded as a tool to increase traffic safety, efficiency and reduce environmental impact of the traffic system. The traffic authorities and road operators will be based on cost/benefit analysis decide on the best investment and carry out public procurements on road infrastructure and back end systems. One example is the US AASHTO deployment investigation[28] on V2X communication (using vehicular WiFi, in US called "DSRC" while in Europe called V2X using ITS-G5) for intersections. The deployment will be gradual and stretch out for many years. Two more examples are the European Corridor and Compass4D discussed below.

The deployment of C-ITS is closely linked with the need for applications, bringing added value services to the road users.

In this perspective, some deployment activities are presented as example, in the context of C-ITS roll out.

The first example is about the Compass4D CIP pilot action, which concerns urban mobility and addresses needs for safety, as well as emission and congestion reduction in cities.

The second example presents the "C-ITS Corridor Austria – Germany – The Netherlands" cross border initiative for improving mobility on highways.

The third example is the ERTICO deployment platform TM2.0 aiming at developing the vehicle interaction with traffic management.

7.2 Compass4D – a urban mobility use case

Compass4D is an EC CIP (Competitiveness and Innovation framework Programme) pilot action to deploy cooperative ITS services in 7 European cities in order. This pilot action aims at improving road safety, increasing energy efficiency and reducing congestion for road transport.

In order to address these challenges, 7 cities (Bordeaux, Copenhagen, Helmond, Newcastle, Thessaloniki, Verona, Vigo), users and industrial Partners jointly implement three cooperative ITS services:

- Red Light Violation Warning (RLVW)
- Road Hazard Warning (RHW)
- Energy Efficiency Intersection (EEI)

These services will be piloted over one year of real life driving using more than 500 vehicles of different types (Busses, Heavy Good Vehicles, Emergency Vehicles, Taxis, electric vehicles, private cars).

[27] https://www.car-2-car.org/index.php?id=231
[28] http://ntl.bts.gov/lib/52000/52600/52602/FHWA-JPO-14-125_v2.pdf

The project works with public authorities, road operators, vehicle fleets and all road transport stakeholders to navigate their way to the sustainable deployment of cooperative services. Compass4D supports the work on global harmonisation of services.

7.3 C-ITS regional deployment initiatives

7.3.1 The A/DE/NL cooperative ITS corridor – a Highway mobility use case

Within ASECAP – CEDR - POLIS and the Car 2 Car Communication Consortium it is generally agreed to follow a phased deployment approach with an initial deployment of simple – non-complex use-cases where user benefits are achieved even with limited penetration of ITS in vehicles and equipped road side units in hot spot areas. In the following phases the complexity of use cases will increase including crash avoidance and hard safety with increased penetration of vehicles with ITS equipment and increased infrastructure coverage.

To complement the introduction plans by the vehicle manufacturers, Austria, Germany and The Netherlands governments have an MOU to establish an ITS G5 corridor (see figure 26 below) between Rotterdam and Vienna to be ready by 2016[29]. The two first applications are Roadwork Warning (RWW) and Probe Vehicle Data (PVD).

Figure 26: Cooperative ITS Corridor in Netherlands, Germany and Austria

7.3.2 SCOOP@F – the French cooperative ITS deployment pilot

The French ministry for Ecology, sustainable development and Energy is coordinating the French Cooperative-ITS deployment project started in 2014. The national cooperative ITS deployment in SCOOP@F will start with a large scale trial in 2016, through 2000 km of roads with different configurations, involving 3000 vehicles.

The project is involving a private-public partnership, including local authorities, road operators, vehicle manufacturers, suppliers and research institutes.

5 national pilot sites are considered:

1. Paris Region with speedways
2. The Britany region,

[29] MoU for the establishment of cooperation in a corridor between Austria, Germany and The Netherlands, source: http://www.bmvi.de/SharedDocs/DE/Pressemitteilungen/2013/110-ramsauer-rat.html

3. The Paris-Strasbourg highway,
4. Bordeaux and its ring
5. Regional roads in the Isere region

The project will use both the 802.11p network V2V and V2I communications, as well as the cellular networks. Several services to enhance user safety and traffic efficiency will be tested:

- Road work warning
- Contextual speed advisory
- Road hazard warning (traffic, jams …)
- Ghost drivers,
- Point of interest notifications

Cooperative ITS is expected to provide more accurate and real-time traffic information and thus to better manage and react on incidents. These services are also expected to replace the expensive variable message signage and other road sensors.

The deployment of Cooperative ITS through the SCOOP@F project allow the automobile industry to prepare for the next generation vehicles.

The table below shows the SCOOP@F roadmap.

Table 11: SCOOP@F roadmap

Year	Activity
2014	Technical specifications and development
2015	Equipment and test of roads and vehicles
2016	Large scale trial
2017	National deployment

7.3.3 BaSIC – the Czech cooperative ITS deployment pilot

The Czech Ministry of Transport launched 2-years national real demonstration C-ITS project focusing on co-operative systems V-2-I and V-2-V which was completed on 31 December 2013. For the real demonstration 2 following applications were selected (and because of real traffic operational environment this demonstration approved by Traffic Police) on Prague Road Ring in the section between motorways D1 (Prague-Brno-Ostrava), D5 (Prague-Pilsen) and D8 (Prague-Dresden):

1. to show (transfer) VMS symbol as displayed at VMS portal to the screen installed in the cockpit (at this moment without voice symbol and placed not in compliance with ESoP because of prototype):
   a. the speed reduction (from 130) to 120 km/h
   b. road works and slowly going maintenance vehicle ahead
2. to inform driver about the approaching of blue light forces vehicle (so called integrated rescue system - IZS) on mission.

For V2V and V2I communications the project used the 802.11p and 802.11g networks and standardised protocols DENM, CAM and FSAP.

The deployment of Cooperative ITS through the BaSIC project allowed the road operators to prepare for the new technologies and related installations on road side.

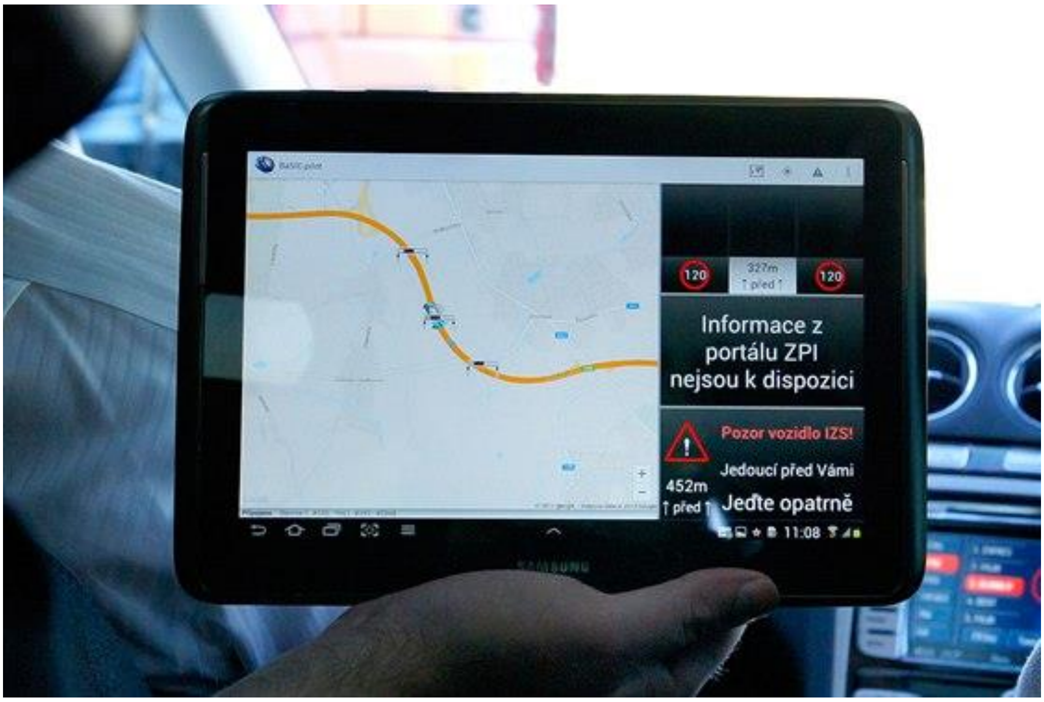

Figure 27: V2V communication through the BaSIC real C-ITS demonstration pilot in the Czech Republic

7.3.4 Other cooperative ITS pilots

Cooperative ITS deployment pilots are also foreseen in many other EU countries, as for instance:

• Nordic Way: Corridor project between Finland, Sweden, Norway and Denmark (2015-2017)

• Corridor project in Poland Estimated 2016-17

• Corridor project in Portugal Estimated 2016-17

7.4 The ERTICO platform TM2.0

7.4.1 Introduction

Traffic Management 2.0, in short *"TM2.0"* stands for a new proven collaborative concept for Traffic Management and Controls, in which the travellers and goods, through the use of new technologies and sensors, become entirely part of the data supply chain. It offers great new opportunities for Traffic Management and Control making it, on one side, cheaper and more efficient for the road operators, and, on the other side, more friendly and acceptable for the users.

"TM2.0 Platform" is an open group of significant public and private actors from the global traffic management and mobility service market who joined forces driven by the common vision and belief to "Enable vehicle interaction with traffic management".

7.4.2 Motivations

Current navigation systems in the vehicles use traffic information to provide singular route advices to the drivers, missing however the information related to traffic circulation strategies, traffic regulations or prioritized routes put in place by the Traffic Management Centers. This is especially the case when notable events are foreseen (planned or unplanned), such as important sport or cultural events, demonstrations, constructions or public transport strikes, but also when specific plans need to be enforced, e.g. in cases of degraded air quality warnings, evacuation alerts, or low-emission zones.

The future of traffic management is to combine intelligently the individual driver objectives (individual users' optimization) together with network wide management strategies (system optimization and equilibrium) in a win-win scenario. The figure 28 below show the different elements that need to be taken into account along the value chain of the TM2.0 concept.

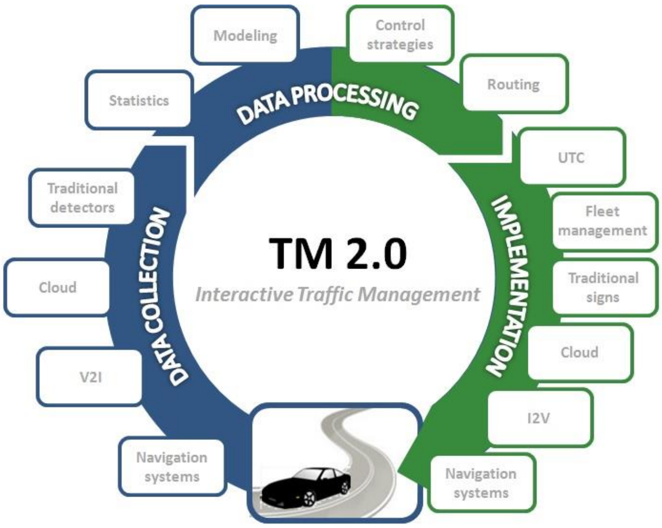

Figure 28: Element at work along the value chain of the TM2.0 concept

The scope of TM2.0 includes business models, deployment steps, public-private cooperation concepts, organisational architecture, and data exchange principles related to the interaction of the following services:

- Mobility services (Individual routing, Individual information and advice, High quality real time and reliable services, Interface to other modes of transport)
- Road traffic management (Traffic management and control strategies, Collective routing, Adaptive and dynamic Traffic control, Traffic Management Procedures, Interface to other modes of transport)
- Data collection (Privacy, Security and data collection, Journalistic, static and dynamic data, Probing, Dynamic Location Referencing, Update of the Local Dynamic Map)
- Legacy and evolution of current systems (Integration of traditional and probe data)

Abbreviations

Abbreviation	Definition
3G/4G/5G	3rd/4th /5th generation of mobile telecommunication technology
802.11p	DSRC standard to support ITS applications
CAM	Cooperative Awareness Message
DATEX II	Data Exchange II
DENM	Decentralised Environmental Notification Message
DSRC	Dedicated Short Range Communication
EEIS	Energy Efficient Intersection Service
GLOSA	Green Light Optimal Speed Advisory
GPS	Global Positioning System
ICT	Information and Communication Technology
ITS	Intelligent Transportation Systems
OSI	Open System Interconnection – see ISO/IEC 7498
RHW	Road Hazard Warning
RLVW	Red Light Violation Warning
RSU	Roadside Unit
SPaT	Signal Phase and Timing
TMC	Traffic Management Centre
TTI	Traffic and Travel Information
V2I/ V2V	Vehicle-to-Infrastructure communication / Vehicle-to-Vehicle communication