Abstract

Most people in the developed world depend on transportation, both privately and in business. Overpopulated roads lead to problems like traffic inefficiency, e.g. congestion, and traffic accidents. Intelligent Transport Systems (ITS) deals with the integration of information technology into the transport system. Through this, applications for improving traffic efficiency, traffic safety and the driving experience are introduced. This report is going to look at ITS systems in general, explore an international standard under development for communication systems designed for these kinds of applications (CALM), look at a project aimed to use this standard to create a international system for ITS applications (CVIS), and explore some of the proposed applications for this system. A few applications have been thoroughly described and analysed through the use of use cases. This has resulted in a set of test cases from which the applications can be evaluated. Through the execution of these test cases it would be possible to draw conclusions on whether or not the applications proposed will be viable in a real world situation.

Preface

This is a master thesis written for and in co-operation with Q-Free. It performs a study within Intelligent Transport Systems, and describes an international standard under development, CALM. Applications for this new standard are described and analysed, and test cases for these are developed. It was written by Morten Berg, in the time period from 20th January to 23rd June.

Acknowledgements

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I also wish to thank Per Jarle Furnes and Knut Evensen at Q-Free for letting me write this report, and for their contribution to it. Per Jarle Furnes for directing and guiding me through this thesis, and Knut Evensen for teaching me the technological aspects within this field.

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Part 1: Introduction and Research method

This part contains the introduction which presents the report and the motivation behind it. A context chapter is also found here, to be able to relate this report to other reports and projects within this field of work. The report contains a lot of technical words and abbreviations, so a table to describe these is placed here for future reference. How the report is build up is presented in the last section of this part, along with questions to be answered and methods to use to accomplish this.

Chapter 1 Introduction

Most people in the developed world depend on transportation, both privately and in business. The transportation sector is an ever growing field, and cars are transporting more passengers around than any other means of transport. And the number of cars in the world is still growing. This ever growing number of vehicles on the roads causes the road networks to get congested and degrading traffic flow. Traffic accidents are another big problem with today's transport system, the number of fatalities and serious injuries are simply too high.

Intelligent Transport Systems (or ITS) deals with the integration of information technology into the transport system. Through this, applications for improving traffic efficiency, traffic safety and the driving experience are introduced. Throughout the world there are many different regional, small-scale systems deployed, systems like automatic fee-collection, automatic speed controls and GPS map and positioning service. The problem with some of these systems, e.g. automatic fee collection, is that they only work for users with that regional technology. There are no written standards for these systems yet, which makes development of systems larger than regional very difficult.

This report is going to look at ITS systems in general, explore a standard under development for communication systems designed for these kinds of applications (CALM), look at a project aimed to use this standard to create a international system for ITS applications (CVIS), and look at some of the proposed applications for this system. In the field of ITS systems, different ITS actors and visions will be presented, and ITS technology and standards will be discussed. Use cases and test cases have been developed for the applications evaluated. Through the execution of these test cases it will be possible to draw conclusions on whether or not the applications proposed will be viable in a real world situation.

The test cases were not executed during this report; this was considered out of scope. Further work should contain executing these test cases and draw proper conclusions from the theory presented in this report.

Chapter 2 Context

This assignment is performed for and in co-operation with Q-Free. Q-Free is *one of the world's leading total suppliers of intelligent transport systems and toll collection systems* [43]. They offer complete systems for tolling, traffic information, parking, ticketing, access control, and logistics systems for production to mention some. The first Electronic Toll Collection system in Trondheim was delivered by Q-Free back in 1988, and they've delivered systems all around the world.

Q-Free is also active within research and development of new systems, and it is through this activity that this assignment comes in. Q-Free are, in association with other big companies and organisations around the world, working on a new standard within ITS called CALM – Continuous Air-Interface over Long and Medium range. Many applications have been envisioned for this new standard, and it is these visions that this assignment is going to work with.

Chapter 3 Words and abbreviations

This report will explore different fields related to Intelligent Transport Systems, including organisations, standards and technologies. These fields are filled with abbreviations, which will be used throughout this report. Most of these abbreviations are gathered here for future reference. This will also make it easier for the reader to understand the report.

Word	**Description**
General	
ITS	Intelligent Transport Systems
IPR	Intellectual Property Rights
QoS	Quality of Service
OEM	Original Equipment Manufactor
OSI	Open Systems Interconnect
EFC	Electronic Fee Collection
DMB	Digital Mobile Broadcasting
DSRC	Dedicated Short Range Communication
GQM	Goal-Question-Metric
ETA	Estimated Time of Arrival
GPS	Global Positioning System
Organisations	
ERTICO	Road Transport Telematics Implementation Coordination
ITSA	ITS America
ITU-T	International Telecommunication Union – Telecommunication
ETSI	European Telecommunication Standards Institute
RTTT	Road Traffic and Transport Telematics
DOT	Department of Transport (UK) / Department of Transportation (US)
ISO	International Organisation for Standardisation
VII	Vehicle Infrastructure Initiative
VSCC	Vehicle Safety Communication Consortium
IETF	The Internet Engineering Task Force
ISO TC204 WG16	ISO working group formally authorized to write CALM standards.
CALM related	
CALM	Continuous Air Interface over Long and Medium Range
OBU	On-Board Unit
RSU	Road-Side Unit
NEMO	Network Mobility, part of IETF
WAVE	Wireless Access in Vehicular Environments
IVC	Inter Vehicle Communication
RVC	Roadside Vehicle Communication
CME	CALM Management Entity
NME	Network Management Entity
CVIS	Co-operative Vehicle-Infrastructure Systems

Chapter 4 Research questions and methods

To complete an assignment like this one, the assignment itself has to be analyzed and research questions have to be extracted. By the end of this project, these questions have been answered through the work done. But to reach those answers, a set of research methods have to be defined. These methods are going to be a guide through the project and hopefully give results which will answer the research questions defined.

This section is going to analyze the assignment given and extract research questions, before defining what research methods to use to answer those questions.

4.1 Research Questions

Evaluate ITS applications in a mobile environment with respect to different QoS-parameters, e.g. infrastructure, security, bandwidth and latency. The assignment requires the student to acquire knowledge of, and relate new technologies and standards against a specific set of ITS applications. The chosen applications are to be described by use cases, and test cases should be defined. The assignment will be related to a research project at Q-Free by creating test cases from hypotheses. Results from this would be included if available.

ITS stands for Intelligent Transport Systems, and is a collective term for a broad range of technologies including information processing, communications, control and electronics which combined will improve security, efficiency and user-friendliness throughout the transportation system. ITS applications are mostly service applications where mobile clients access public or commercial services offered from the road side or from other vehicles. This mobile environment forces developers to take special considerations when developing the applications. They are for example very dependent on the communication channel between the stationary server and the mobile client. This is a wireless communication channel and would perform differently depending on which carrier it is using, e.g. GSM, WLAN or InfraRed. The chosen carrier would greatly affect the Quality of Service parameters of the application, and these are the parameters that have to be measured in different scenarios to evaluate the quality and usefulness of each application [40][41].

Several ITS applications have been proposed for the next generation ITS system. These will be classified into groups of similar applications. A few applications would be evaluated further. The goal of this evaluation is to see if these applications are viable with current and near-future technology. These applications have to be analysed and requirements for each QoS parameter have to be found. The QoS parameters that would affect these applications are:

- Infrastructure
    - Communication type
    - Communication link
- Security
    - Authentication
    - Authorization
    - Integrity
    - Confidentiality
- Bandwidth
- Latency

Metrics for each QoS parameter would be defined so that it is possible to define test cases and get measurements. The evaluation of each application would rely on these measurements gathered from testing.

4.2 Methods

Research methods have to be defined in order to answer the research questions discussed in the previous chapter. This section will define and describe each method which is going to be used.

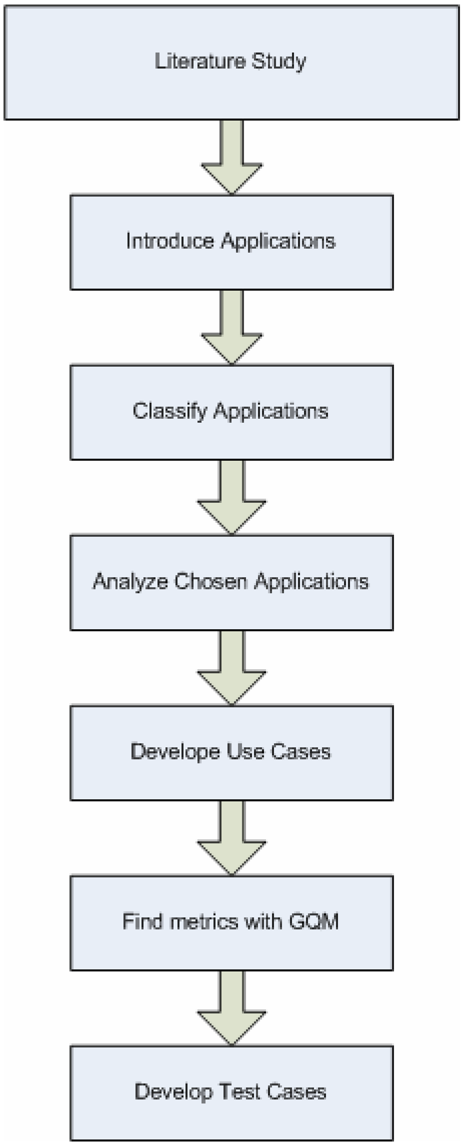

Figure 1 – Research Method Flow

This assignment can be split up into four main parts: Explore Field of Work, Introduce Applications, Classify Applications and Analyze Chosen Applications, as shown in *Figure 1 – Research Method Flow.* The first part, *explore field of work*, is performed to get a general overview of the different organisations, standards and technologies which are related to this assignment. To do this part, a Literature Study would be performed. The next two parts, *Introduce Applications* and *Classify Applications,* would be pretty straight forward after the literature study. The last part is the main part of this assignment, *Analyze Chosen Applications*. This will be done through the use of Use Cases, GQM and Test Case development. The different parts are described in the following sections.

4.2.1 Literature study

A literature study will be conducted to explore previous work, technologies, standards, organisations and other areas of interest which could contribute to this evaluation of ITS applications. The main source of information in this literature study is working drafts from Q-Free and their projects. In addition to that, a lot of public documents from other ITS organisations, books on computer science, web encyclopaedia [26], and papers from various conferences are used.

The first section of this literature study will explain why ITS is an interesting and important field, what parts of everyday life is affected by this and what the future could bring. There are many actors, international, national and local, working in this field, both competing and cooperating. Some of these actors and their relationships would be described in this section.

The ITS applications to be evaluated are all operating in a mobile environment. This literature study will analyse and define what a mobile environment is, what characterizes it and how such an environment will affect applications.

There are many new and upcoming technologies and standards in the field of ITS. These will be looked into and discussed, with focus on CALM, a standard being developed for continuous communication over long and medium ranges. CALM is using a wide array of different technologies. These will be described, and their influence on both the mobile environment and the applications.

To evaluate applications a set of parameters that would describe each applications service level have to be defined. These are usually called Quality of Service parameters, and will be discussed at the end of this literature study. These parameters are also used when defining and classifying the applications discussed.

After the literature study, a general introduction to different ITS applications proposed through different projects would be presented. There are several ways to classify these applications, and some classifications are presented next. A few of the applications presented would be further analyzed and discussed through the use of *Use Cases*, *GQM* and *Test Cases*.

4.2.2 Use Case

Use Cases would be used to methodically analyze and describe the applications under discussion. This will give a clear and easy understanding of who are involved in each application, what goals it has and how they are reached. UML Use Case Diagrams would also be used to illustrate relationships between different use cases and users (actors) [23][43].

This section will describe the different elements used in the Use Cases.

Scope: What is really the system under discussion?

In the scope element we want to identify what part(s) of the system we are discussing. We usually mark some areas as inside scope, which will be discussed further, and others as outside scope, which we will take for granted.

Stakeholders: Someone or something with a vested interest in the behaviour of the system under discussion (SuD).

The stakeholders are everybody which is involved in the system in any stage of the process. We usually identify them by asking four questions regarding the system:

Who wants it?
    E.g. authorities, service providers and end users.
Who makes it?
    E.g. technology/equipment manufactors.
Who uses it?
    E.g. end users.
Who rules it?
    E.g. authorities.

Level: How high- or low-level is the goal?

The level of the use case will decide how coarse or fine-grained the goals and interactions should be. A *summary-level* use case will have very coarse-grained goals and interactions; this would probably be the outer-most use cases describing business strategies or overall system functionality. This kind of use case could span several hours, days, months or even years. A *user-level* use case, on the other hand, will have more specific goals, with detailed interactions between the primary actor and the system. A use case on this level should be performed during a "sitting down", e.g. a user session, and should not take several days or months. The finest-grained type of use case is the *sub-function* use case. This use case will explain the detailed behaviour of the system during one interaction. This is usually not very useful until the system user interface is designed, but other methods might be more useful when describing these situations.

Actors: Anyone or anything with behaviour.

Actors can be both real life persons, interacting with the SuD, and it can be parts of the system itself, which other actors have to interact with.

Primary Actor: Who has the goal?

The PA of a use case is the stakeholder who uses one of the system's services. The PA is often the actor which triggers the use case, but not always.

Preconditions: What must be true before the use case runs?

To prevent the use case from being very long and detailed, certain conditions are ensured by the system to be true before the use case can start. These conditions will not be checked during the use case.

E.g. "User is logged on to the system".

Guarantees: What must be true after the use case runs?

What could an end user expect from the system when he calls on it to deliver a service? There should be minimum and maximum guarantees describing what the system would output in case of failure and success.

Trigger: What starts the use case?

The trigger is the event that starts the use case, and is usually the first step in the use case.

Main Success Scenario: A case in which nothing goes wrong.

The Main Success Scenario is a list of steps which explains the shortest way from start to end for the PA. In this scenario everything goes as planned, and the PA's goal is fulfilled. The steps are written in plain, simple English, but consequently in one grammatical form; an actor accomplishes a task or passes information to another actor through a simple action.

Extensions: What can happen differently during that scenario?

This section should take care of all the situations that differ from the Main Success Scenario. What happens if the user isn't authorized? What happens if information entered into the system isn't valid? Extensions trigger on invalid actions, and explain further interactions for the user. An extension can be remerged back to the Main Success Scenario, end in failure or trigger a new use case.

Variations: Specification of a general term in the Main Success Scenario.

Use case steps should be as clean and simple as possible, and might include general terms which need to be specified. This is done in the variations-list.

E.g.

7. Customer pays clerk.

Variations

7'. Payment done by cash, check, credit card or any other authorized payment method.

4.2.3 The QGM process

GQM is a measurement mechanism for feedback and evaluation, and it is one of the most effective and well-established methods for software measurements. This method will be used to define metrics for which the applications' goals could be evaluated. A *metric* is a unit which is measurable, and the goal of this method is to develop *metrics* for which an object could be measured. In software engineering such an object could be a product, process, project or resource. The resulting metrics can then be measured, and higher level goals can be measured by interpreting the different results. GQM is mainly used to define measurable software improvement goals, but will here be adapted and used to create measurable technology goals [21].

The method is developed at University of Maryland in co-operation with NASA Software Engineering Laboratory, and is being used by several large actors like Ericsson, Schlumberger and Nokia.

GQM is a simple process where metrics are being defined in a top-down fashion. Software developers and managers start by defining high level goals which the object under discussion should achieve. The goals would then be refined into a set of questions for which we need to develop metrics that can answer these questions. The measured results can be interpreted in a bottom-up way so that the high level goals could be evaluated. This way, both developers and managers know what is being measured, and for what purpose this is done. The Goal breakdown is illustrated in *Figure 2 – GQM [15]*.

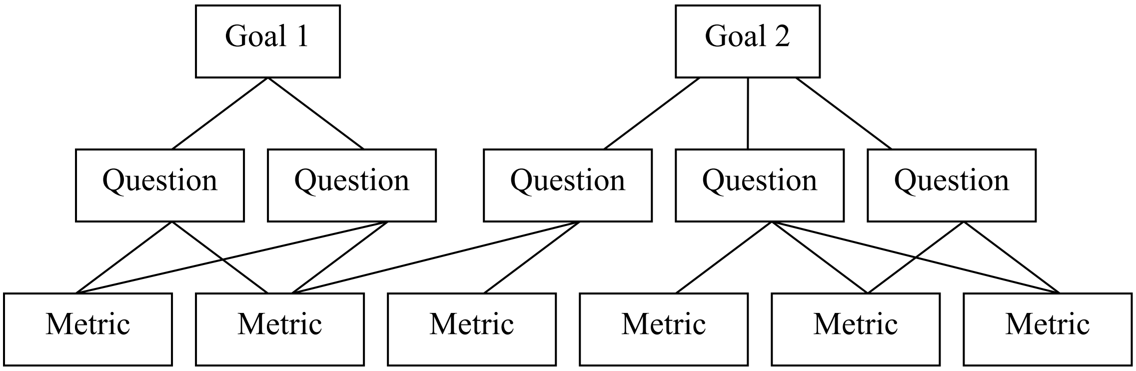

Figure 2 – GQM [15]

The metrics found can be classified as either objective or subjective. An objective metric would only depend on the object being measured and not by the viewpoint from which it is taken; e.g. number of hours spent on a task, size of a program. A subjective metric will in addition to the object itself be dependent on the viewpoint from which it is measured; e.g. level of user satisfaction.

In this report, the GQM method is applied to extract metrics from the applications under evaluation. Through the Use Cases discussed in the previous section, goals for each application would be defined. These goals would be used as input for the GQM method, and requirement questions for each goal are defined. The answers to these questions would be a set of metrics. The applications can now be evaluated by measuring these metrics, and drawing conclusions based on the goals they represent.

4.2.4 Test Case

Test cases would be developed to test the applications in regard to the metrics produced by the GQM method. They will be simple and straight forward, and aim to test the core technology in each application. This report will only present the test cases developed, but not perform them, as this is out of scope for this report. When performed, these test cases should produce results which can help the evaluation of the applications. The results should give an indication on the usability and quality of the service provided by the application under evaluation. They will also prove or disprove theory discussed in this report.

Part 2: Literature Study (State-of-the-art)

This part contains the literature study described in Part 1 Chapter 4 *Research questions and methods*. It is going to describe ITS, the Mobile Environment, ITS technologies and standards with focus on CALM, and Quality of Services parameters within ITS. The motivation behind this literature study is to build a foundation on which the application evaluation can be performed.

Chapter 5 describes what ITS is and the motivation behind it, which actors are working within ITS and their relations, and a project within ITS called Co-operative Vehicle-Infrastructure Systems. Chapter 6 gives a definition to mobile computing and mobile environment, and describes what characterises these fields and which challenges lies here. Technologies and standards for the ITS field is described in chapter 7 before parameters which will affect application performance, Quality of Service parameters, are summed up in chapter 8.

Chapter 5 Intelligent Transport Systems (ITS)

ITS is a collective term for a broad range of technologies including information processing, communications, control and electronics which combined will improve security, efficiency and user-friendliness throughout the transportation system. ITS will also provide a cleaner environment and decrease noise-pollution from transportation. The technology used is usually advanced applications of information and communications technology, and all types of transport are represented; rail, air, sea and road [40][41].

ITS might seem futuristic, and the future of ITS is promising, but many applications of ITS have been around for quite a while. Examples include:

- Electronic Fee Collection is quite common in Norway. Q-Free was the first provider of this kind of system in Trondheim [42], and has also started a project called AutoPass which standardises eTags in Norway [6]. This enables drivers to pass toll points without payment hindrance throughout Norway. This was introduced in February 2004, and the plan is to extend this to cover ferry-fees by the end of 2005.
- GPS roadmap service. This application has become a common technology in many vehicles.
- Ticket free travel. When ordering a railway or plane ticket, many companies offer you a ticket free travel. This way the ticket is registered on your Visa, MasterCard or any other accepted card which you could be identified by, and the regular paper ticket is not necessary.
- Electronic timetables for railways, busses and so forth. Here in Trondheim we have a system called BussTUC [36] which allows users to send natural language queries by Web or SMS, and receive timetables throughout Trondheim.

5.1 ITS Motivation

The transportation sector is an ever growing field. Information technology has globalised industries all over the world. But even though IT has made it possible to communicate with people globally without leaving your office, people are travelling more than ever before. Cars are still the most widely used mean of transportation, which amount to more than 10 times the passenger-kilometres of air or railway travel [1].

The ITS market is a huge market, and will only become bigger because of the constant growth in the transportation sector. For example, Hong Kong's road networks were one of the busiest networks in the world in 2001, with a daily average 7.7 million passengers trips using public transport [2]. But instead of building more and bigger highways, Hong Kong opted for a wide adoption of Intelligent Transport Systems. Hong Kong has been using ITS services over the last twenty years, but this has mostly been single purpose systems implemented over a small scale. One of the main reasons Hong Kong chose to adopt ITS is because of its lack of space to build new and bigger road networks. Many other big cities suffer under the same lack of space, and will have to rely on ITS to overcome problems in the transportation sector.

Traffic accidents are very expensive, first and foremost because of the loss of lives, but also in terms of money. Congestions and traffic delays result in lost productivity and wasted energy. Traffic safety and efficiency are therefore two fields in which the public are more than willing to spend money on research and development [38].

The ITS market is also a very attractive market for commercial actors, because of its size and growth. But one of the main problems will be different systems in different places of the world if no-one is able to make an international standard. The Utopian dream is to have a standardised system for ITS throughout the world so that you can use the same applications wherever you might travel. This might be hard, considering that we're living in a world where we can't even decide which side on the road to drive on!

5.2 Actors in the ITS domain

Since ITS is such a big field, covering all actors within ITS would be too big to overcome. This section will try to give a broad description of the biggest actors, and show which parts of the world they work on. Until recently, the road, rail and sea transportation sector was largely the domain for construction companies and large automobile manufacturers. Common for most of the big actors is that they rely on funding from both public and private sectors. The previous section showed that transportation and ITS are areas in which both public and private actors need and want to invest in [40][41].

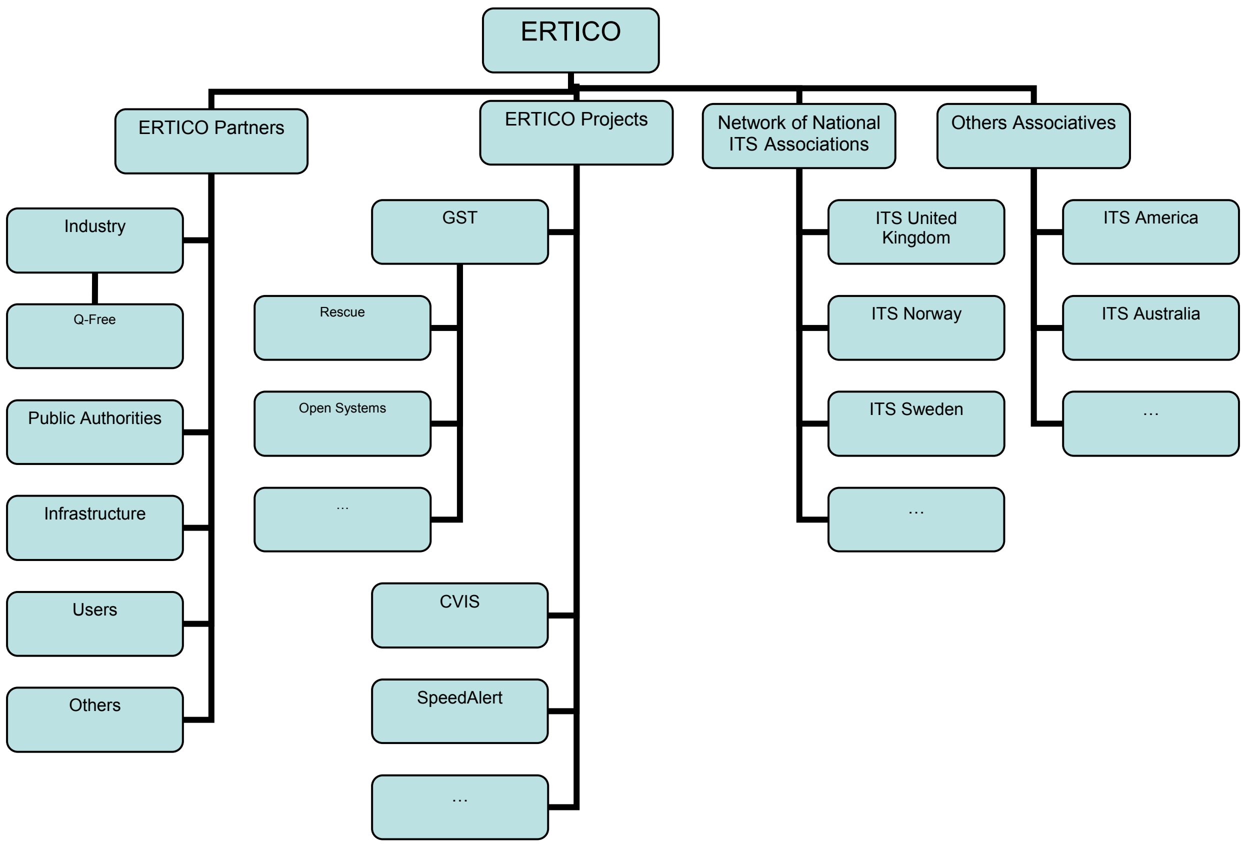

Figure 3 – ERTICO organisation with relations

5.2.1 Ertico – ITS Europe

ERTICO stands for European Road Transport Telematics Implementation Coordination and is a multi-sector partnership consisting of both public and private actors. The work done by the actors of this partnership consists of developing and deploying ITS applications. The goal is to have a pan-European ITS system which unifies interests throughout Europe. And a higher goal is to represent these European interests throughout the rest of the world [39].

ERTICO was born 13th November 1991 by a small team of four persons with 15 founding Partners and a single project. Already at this time, work was done within research and development of ATT (Advanced Transport Telematics).The initial vision of ERTICO was to have an organisation to support European interests in the implementation of this research and development. From the initial 15 partners in 1991, ERTICO has grown and has as of 15th May 2005 102 partners, and even more contacts through networks like "Network of National ITS Associations". ERTICO is still working with Research and Development (R&D), but has in the later years turned its focus onto implementations, business models, organisations and legal aspects.

ERTICO states that their current mission is *to promote and support the efficient research, development and implementation of Intelligent Transport Systems and Services in Europe, contributing to better sustainable mobility, environmental and societal aspects and user satisfaction, with acceptable economic returns for its Partners [39].*

As shown in *Figure 3 – ERTICO organisation with relations*, ERTICO has a set of direct partners, which are grouped into five sectors:

- **Industry**
  Here we find technology manufacturers like Q-Free, Nokia and IBM, car manufacturers like BMW Group, DaimlerChrysler and Volvo, and IT industry like Gapgemini, LogicaCMG among others. This is the biggest sector with 47 partners.
- **Public authorities**
  Different departments, mostly department for transport but departments like economy and informatics, are represented here. Countries which are represented include Norway, Germany, United Kingdom, Italy and Poland among others. Total number of partners in this sector is 33.
- **Infrastructure.**
  This is mostly telecom companies which provide infrastructure systems. Number of partners in this sector is 12.
- **Users**
  Clubs and tourist associations are the users represented as partners. A total of 3 partners in this sector.
- **Others.**
  All other companies and organisations that do not fit into the other sectors are placed here. 9 partners are located in this sector.

5.2.2 Network of ITS Associations

In addition to the direct partners, ERTICO has coordinated a *Network of National ITS Associations* in order to keep a network between the majority of ITS actors both on a local and national level [45]. This promotes ITS development from the ground up, and helps small and medium-sized companies to stay inside the ITS discussion. A National – or regional ITS Association is an organisation which aims to support the rapid deployment of ITS at a national or regional level. The main tasks consists of encouraging national consensus for ITS deployment, developing ITS national strategy which would be the foundation of future development of applications, distribute ITS information and ITS R&D results and building networks with other European and non-European organisations. The network currently consists of 17 members including ITS Norway, ITS Sweden, ITS United Kingdom and ITS Munich among others.

5.2.3 ITS Norway

ITS Norway is Norway's representative in *Network of National ITS Associations*. It was founded 15th June 2004 by 9 organisations, among them Q-Free ASA, Telenor and SINTEF. Number of members in 2004, including the founders, was 34. By 6th June 2005 this number had risen to 47 [4].

ITS Norway's main goal is to protect and represent their members' interests and to influence national and international decision-makers. ITS Norway shall help spread information amongst its members, evaluate the international ITS market, and establish and promote meetings, working groups and conferences. It should also work as a link between the different members, by always having updated information and links up on its homepage.

5.2.4 ITS America

ITS America stands for Intelligent Transportation Society of America, and it is one of ERTICO's contacts which neither is a partner nor a part of the Network of National ITS Associations. It is a non-profit organisation which works with coordination and deployment of ITS in the United States. It was founded in 1991, and has over 400 members registered so far [5].

ITS Americas vision states: *A future where people and goods are transported without delay, injury, or fatality, by integrated systems that are built and operated to be safe, cost-effective, efficient, and secure [5].*

ITS America refers to this as *Vision Zero*, a future with zero fatalities or delays within the transportation sector. ITS America wants to achieve this by identifying causes of fatalities and deaths, and encouraging other organisations to ally up with ITS America and work together towards this Vision Zero. They want to raise the public awareness and expand the scope of ITS, and to influence governments and other decision-makers.

5.3 Co-operative Vehicle-Infrastructure Systems

Co-operative Vehicle-Infrastructure Systems (CVIS) is an integrated project under the eSafety call, a consortium lead by *ERTICO*. It's funded by the European commission and got a time span of 4 years, starting in 2006. The project has a significant amount of partners, and Norway is represented by Q-Free and SINTEF, which will work on Core Technology / Architecture and developments of the wireless networking protocol IEEE 802.11p. About a quarter of the entire projects budget is to be used on CALM development and prototyping [3].

Other partners include car manufacturers which are involved in technology and organisations like EUCAR – European Council for Automotive R&D and CLEPA – European Association of Automotive Suppliers. Car manufacturers are a vital part of the project, since they have to agree on the interfaces which are going to link up CVIS technology like CALM with their own proprietary car technology.

The CVIS project has two high-level objectives which it seeks to achieve [3]:

- *to create a unified technical solution that will allow all vehicles and infrastructure elements and nodes to communicate with each other in a continuous and transparent way using a variety of media, with enhanced localisation, and that will enable a wide range of potential cooperative services to run on an open application framework in the vehicle and in roadside equipment*
- *to define and validate an architecture and system concept for a number of cooperative system applications, and develop common core components that can be used to support cooperation models in real-life applications and services that will bring advantages to drivers, operators, industry and other key stakeholders.*

Figure 4 – CVIS scenarios [3] shows different scenarios for the CVIS system.

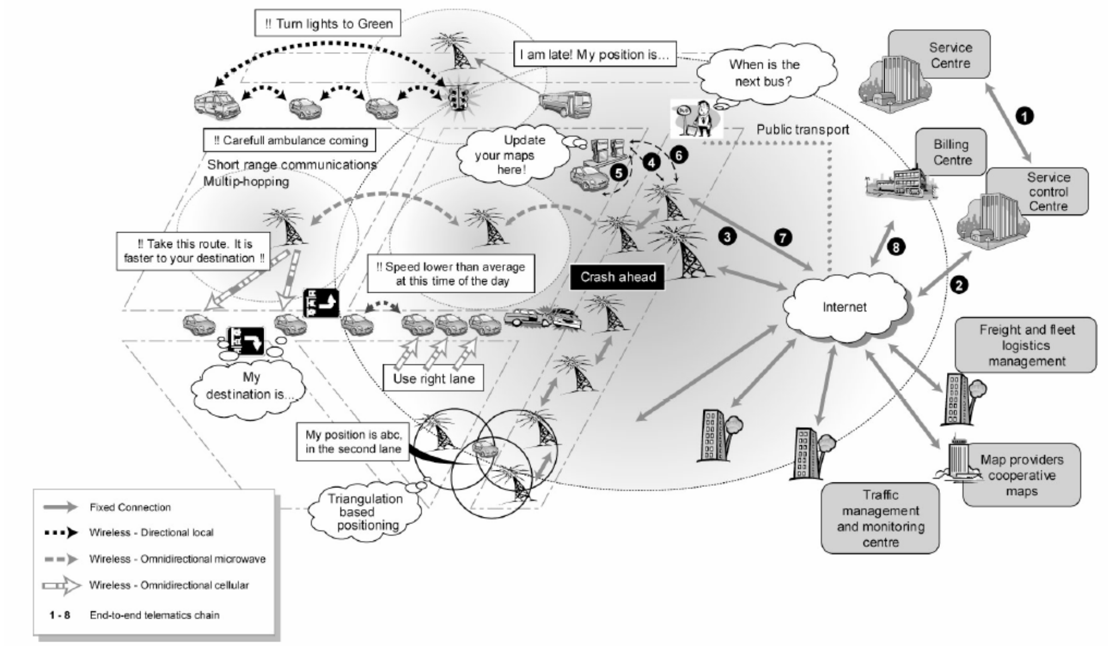

Figure 4 – CVIS scenarios [3]

As the project name implies, Cooperative Vehicle-Infrastructure Systems, the objective is to create a system which can support cooperation between vehicles and infrastructure. This kind of cooperation would need communication between the nodes, existing technology like GSM/GPRS and UMTS which covers most of the existing road networks are too expensive for this kind of system. However, the cost of wireless networking technology based on the IEEE802.11 a/b/g standards is plunging, and "WiFi hotspots" are emerging everywhere. The challenge here is to adapt this technology to support moving vehicles. This work is being done with CALM, which in addition will support quasi-continuous communication links. With communication links up and running between vehicles and infrastructure, the next goal is to develop a minimum toolkit which will enable other actors to create cooperative applications and services. The CVIS project will itself create a few reference applications to demonstrate how this new system could be used. GST, Global System for Telematics, is one of the organisations set to develop applications for this system.

Chapter 6 Mobile Environment

Mobile Computing is defined as *the use of a portable computer capable of wireless networking* [27]. It has been around for a long time, but the technological advances have been enormous, and it doesn't seem to stop. For example, the cellular technology has advanced from the analog, first generation wireless telephone technology to the third generation UMTS technology, allowing bit rates up to 2Mbps. Other technologies like WLAN, digital radio and satellites are also having great advances, and are delivering faster and more reliable communication links.

A Mobile Environment could be defined as an environment in which clients are using mobile computing to perform tasks and access available services. ITS is a great example of such an environment. Vehicles would act as clients and would access services offered by road side equipment through mobile computing, i.e. wireless communication. The clients could also co-operate through mobile computing to accomplish a task and reach a common goal.

The challenges of mobile computing remain the same, even though technology is advancing at such a pace. There are three main parameters that affect mobile computing [27]:

- **Communication**
  In mobile computing, the communication is based on wireless networks. Signals are sent by modulated radio waves or pulsing infrared lights, and an area covered by a signal is usually referred to as a cell. Cells could range from an infrared transmitter covering a room up to satellites covering hundreds of kilometres in diameter. Problems with the wireless communication is size of bandwidth, variations in bandwidth, error-rates, disconnects and security-flaws. New technology offers better bandwidth and more secure connections, but application demands are also rising.
- **Mobility**
  Clients are moving around in the mobile environment, and may move in and out of different coverage areas. This will change their point-of-attachment to the network, and would usually mean that their address in the network is changed. Address migration, that a client keeps its address when moving across networks, is needed to prevent this. And some applications are dependent of the clients' location, i.e. location aware applications.
- **Portability**
  Mobile clients usually have limited resources, e.g. power supply, and may need to degrade performance because of the resources. Because of this, power management is a vital factor in mobile devices. Another problem related to portability is the risk of data. As opposed to a big stationary computer, a small mobile client can easily be stolen or accessed, and the data within can reach unauthorized actors. Another issue is the user interface: Because of the size of mobile clients, user interfaces are usually very small, and the usability is affected by this.

Chapter 7 The CALM Technology and Standards

Continuous Air Interface over Long and Medium range (CALM) is a standard under development which determines a common architecture for wireless communications using Cellular 2nd Generation, Cellular 3rd Generation, 5GHz (WLAN), Millimetre and Infrared communications. The main purpose for CALM is to be used in the Intelligent Transport System sector, ITS, and therefore it should support broadcast, point-point, vehicle-point and vehicle-vehicle communications. Also because of the wide range of media available, quasi-continuous communication is a desired feature for CALM [8][9].

The CALM standard is being developed under the International Organisation for Standardization, ISO. A working group has been created under the name ISO TC204 WG16 which is formally authorized to write the CALM standards.

CALM aims to provide a standardized set of air interface protocols and parameters for medium and long range communication. Different carriers to be used include Cellular networks (GSM/GPRS – 2G and 3G), 5GHz Wireless LAN, Millimetre waves and Infrared. These are carriers with quite different features when it comes to range, coverage, bandwidth, response time, cost to deploy and cost to use. For example, a line switched carrier like GSM has other features than the packed switched carrier GPRS. WLAN has shorter range and coverage, but better bandwidth than for example the cellular networks. Because of their different features, these media will complement each other by always offering the best possible connection the surrounding environment can offer. CALM should be able to determine the communication needs of different applications and assign communication links to the applications based on these needs and user preferences.

CALM is a standard, not an implementation. It describes how different technologies can work together in an environment with multiple carriers and different communication needs from applications. When it is finished and published, it will be an international standard without Intellectual Property Rights (IPRs), which makes it easier for commercial users to start using this standard. Such an international standard would promote cooperation among companies throughout the world, encourage further development of new systems and discourage development of local, low scale applications on proprietary systems which would only benefit local users.

Whilst this standard could be used in any scenario where there are multiple carriers present, its main scenario is within ITS. In ITS, the clients, usually vehicles, can travel great distances at high speeds, going in and out of different carriers' coverage range. They can be within reach of many carriers at the same time, each with different characteristics, and applications usually have different requirements. Stationary receivers/transmitter along the road are referred to as Road Side Units, or RSU, whereas in-vehicle receivers/transmitters are referred to as On-Board Units, or OBU. *Figure 5 – CALM Scenarios [10]* shows different scenarios in which the CALM system could be used:

- **GPS, Satellite DMB and Terrestrial DMB**
  These transmitters have large coverage and are used for broadcasting services. CALM can access these services through adaptation interfaces, so called *convergence layers*.
- **Portable Internet**
  CALM should be able to access the internet through MAN/WAN technology, through convergence layers.

- **Cellular**
  These are carriers based on the 2G, 2.5G and 3G cellular networks. This technology has coverage in most of the western world because of the cellular phone. These are only partly native in CALM, and have to be accessed through special convergence layers.
- **Regional DSRC systems**
  Regional specific DSRC systems not directly implemented into CALM can be accessed through convergence layers.
- **Hot-Spot (WLAN)**
  Gas stations, shops or other actors can install short ranged WLAN transmitters to establish a service to by passers. Services can be electronic payment of gas or parking, internet access, tourist information points or video and music direct purchase.
- **CALM M5 (5GHz WLAN), CALM IR and CALM MM**
  These are all native interfaces of CALM. They have three different communications scenarios:
    - **Road-to-Road (or RSU-to-RSU)**
      This type of communication is usually through short-range carriers like 5.9GHz WLAN. This is a way to extend the infrastructure by making information hops available. Vehicles may communicate with other vehicles or services out of direct range by using RSUs as a communication channel. It might also be used to spread "Store&Forward" information out to the various RSUs.
    - **Road-to-Vehicle (or RSU-to-OBU)**
      This might be the most common scenario in ITS, where dedicated RSUs are the communication points between Traffic Control Centres and the vehicles on the road. Applications here might be *Store & Forward*, where information is stored at the RSU and sent out to all oncoming traffic, very much like a regular traffic sign. Other applications might require a communication link to be established so that the RSU gets some information or requests from the vehicle, and responds with the required information or suggested action.
    - **Vehicle-Vehicle (or OBU-to-OBU)**
      In these scenarios the vehicles are using their OBUs to communicate directly with each other. This can be used as with the RSU-RSU scenario, where the Units are used as infrastructure, sending information up or down the road. There are also many applications which would use this direct communication like for example platooning, where one vehicle controls 2 or more vehicles down a single lane. The first vehicle is driving, while the other vehicles are "hooked on to" the vehicle in front, driving on "autopilot".

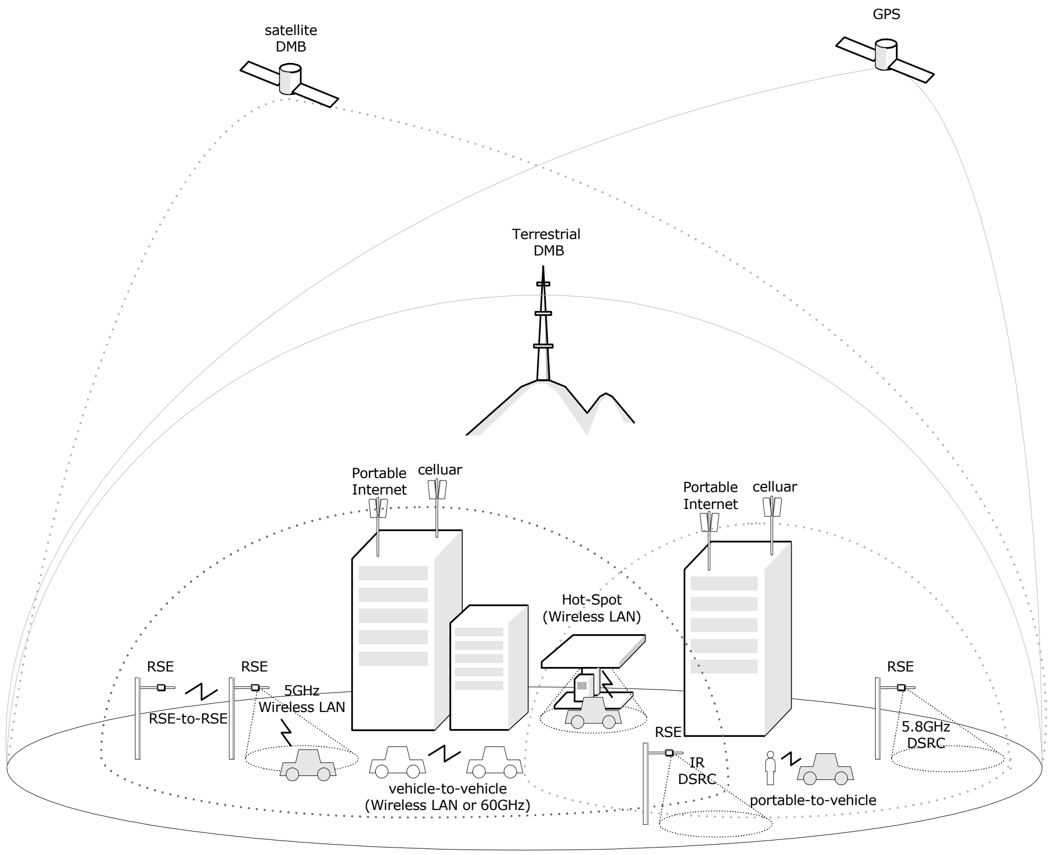

Figure 5 – CALM Scenarios [10]

Some applications require continuous communication, like for example internet access, and streaming video or audio. In addition, some of these applications, e.g. video streaming, might require a certain amount of bandwidth. But because of the rather short range of WLAN transmitters, the vehicles won't stay inside the range of one transmitter for a very long period of time, hence there need to be some kind of handoff-mechanism which keeps the communication-link up. This is where the quasi-continuous features of CALM come into play. CALM should be able to keep a connection up, while changing carriers, both between same technology carriers (homogeneous handover), and between different technology carriers (heterogeneous handover). This way, a vehicle could be driving along different roads and always have access to different services through different carriers. One of the challenges is when a high performance communication link is lost, and only lower performance links are available. Then CALM has to decide if the lower performance link is good enough for the running application. Different carriers also have different cost-models, which also has to be taken into account.

Before presenting the CALM architecture, the OSI model will be described in the next section. This is because the CALM architecture is based on this layered OSI model.

7.1 The OSI model

OSI stands for Open Systems Interconnect and was a networking effort initiated back in 1982 by ISO and ITU-T. Back then, inter-computer communications were vendor-developed and proprietary, and often not compatible with each other. ISO and ITU-T saw the need for a common networking protocol, and developed OSI [37]. But the OSI protocol stack that was specified turned out to be too complex and unimplementable. The OSI model however, turned out to be one of the most important advances in network concepts.

The OSI model shows the functionality of a networking protocol. It divides functionality into different layers, each layer with a set of functions which it must perform as well as possible. This is one of the challenges of creating a networking protocol: There will always be errors somewhere along the chain. Without errors, networking and computer communication wouldn't take up much place in literature.

The OSI model is divided up into seven layers, as shown in Figure 6 – OSI Modell [13]:

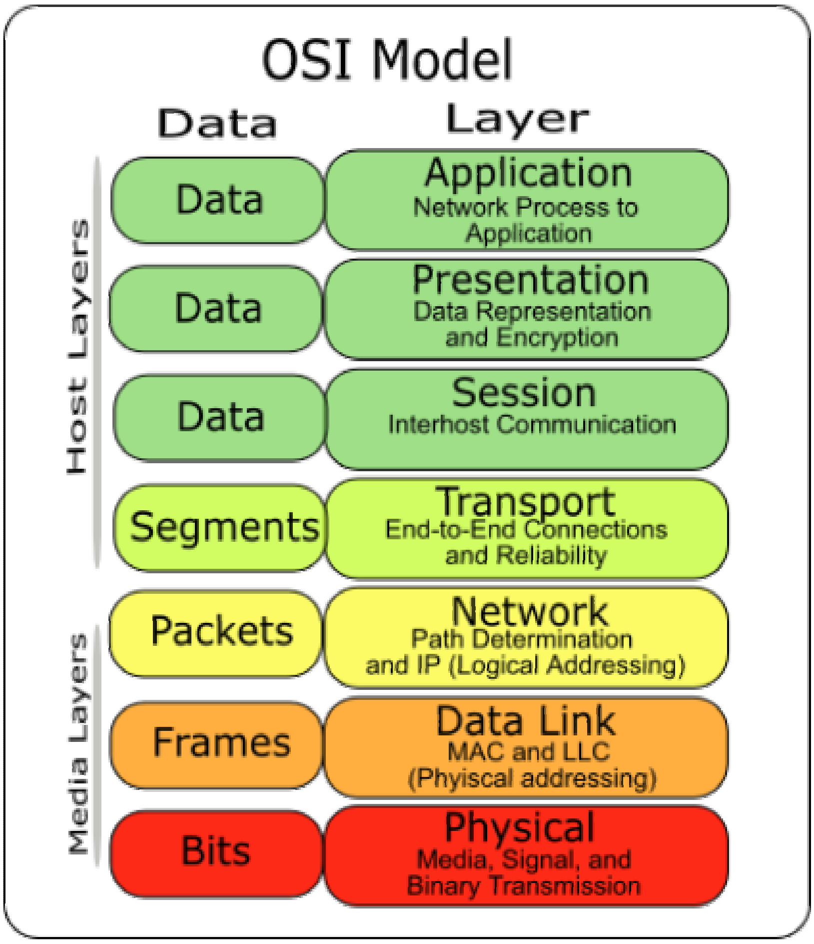

Figure 6 – OSI Modell [13]

- **Physical Layer**
  The physical layer is concerned with transferring the most fundamental unit of information, the bit. The physical layer does not concern itself with what each bit represents, only that the bit is successfully transferred over the physical communication link. This layer has direct contact with the hardware. Errors will always occur at this layer during transfers, no matter how sophisticated the protocol used is. However, it is not the job of the physical layer to check for these errors, this is the job of the next layer, the Data Link Layer [15].
- **Data Link Layer**
  The Data Link Layer receives bits from the physical layer, assembles them into frames, checks for errors and sends the error-checked data to the Network Layer. A

common method for error checking is CRC – Cyclic Redundancy Codes. The Data Link Layer works on bit level, with 0 and 1s. It is also responsible for flow control, a mechanism which prevents a high-speed sender to overwhelm a low-speed receiver [15].

- **Network Layer**
  The network layer is responsible for the flow of data through the network. Routing and switching are two important mechanisms here. Segments of data are converted into smaller datagrams and source and destination addresses are added before the datagrams are sent out on the network. The Physical Layer, Data Link Layer and Network Layer are sometimes called the communication sublayers of the OSI model. The layers above these three layers communicate on an end to end basis. Examples of protocols on this layer are IPv4 and IPv6 [15].
- **Transport Layer**
  This is the first end-to-end layer of the OSI model. This layer has many of the same functions as the three lower level layers, but at an end-to-end basis. Functions include reliable transfer of data through error control, flow control and error recovery. This layer is also responsible of segmenting files into smaller chunks which the network layer is able to handle. Examples of protocols on this layer are TCP and UDP [15].
- **Session Layer**
  This layer is responsible of managing application-to-application sessions. This is done on a logical level, by assigning and releasing connections to the applications. The session layer is also responsible of handling synchronization points in case there is a communication fault on the lower levels. This way the system can easier recover from communication faults, without losing too much data if a file transfer was in place [15].
- **Presentation Layer**
  This layer is responsible for presenting the data received from the lower layers in a correct way, as the correct data type. Functions like encryption and compression could be placed in this layer, so that only encrypted or compressed data is sent out onto the communication link. But this is optional, and depends on the implementation [15].
- **Application Layer**
  This layer provides the end-user programs with communication protocols. This could be protocols for electronic mail (SMTP), for web page access (HTTP), for file transfer (FTP) and so on [15].

7.2 CALM architecture

The CALM architecture is based on the layered OSI model. It consists of four main parts as shown in *Figure 7 – CALM Basic Architecture*.

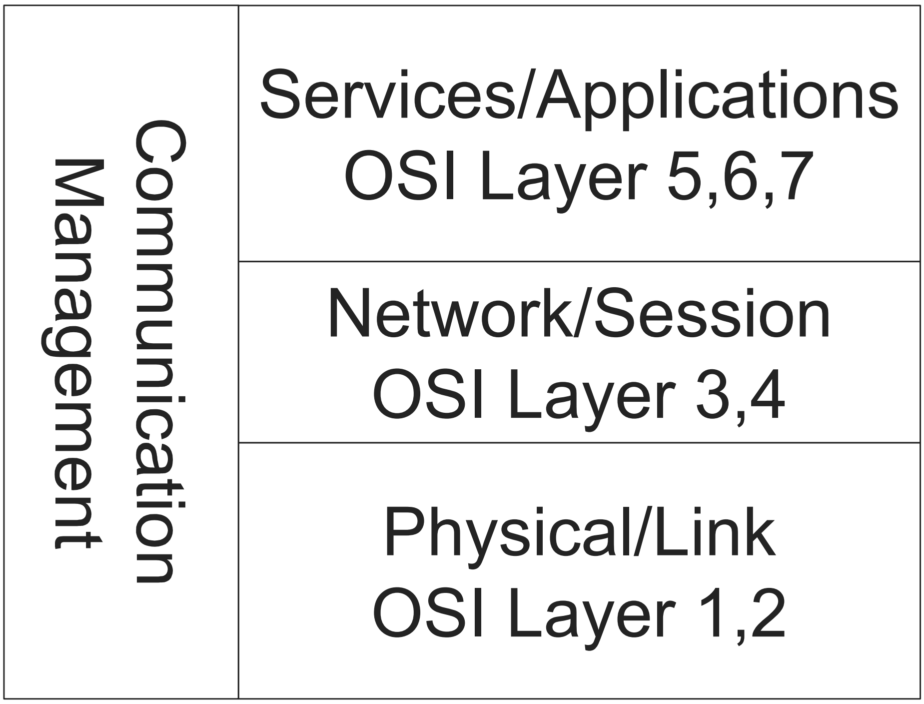

Figure 7 – CALM Basic Architecture [9]

A more detailed Figure is shown in Figure 8 – CALM Detailed Architecture [8]. The three blocks on the left hand side, Calm System Management Entity, Network Management Entity and Specturm Manager represent the Communication Management part of *Figure 7 – CALM Basic Architecture [9].* The lower blocks ISO21212 to ISO21216 represent the Physical/Link Layer, the middle block "Network Interface" and the convergence layers represent Network and Session Layer while the topmost blocks represent the Services/Application layer.

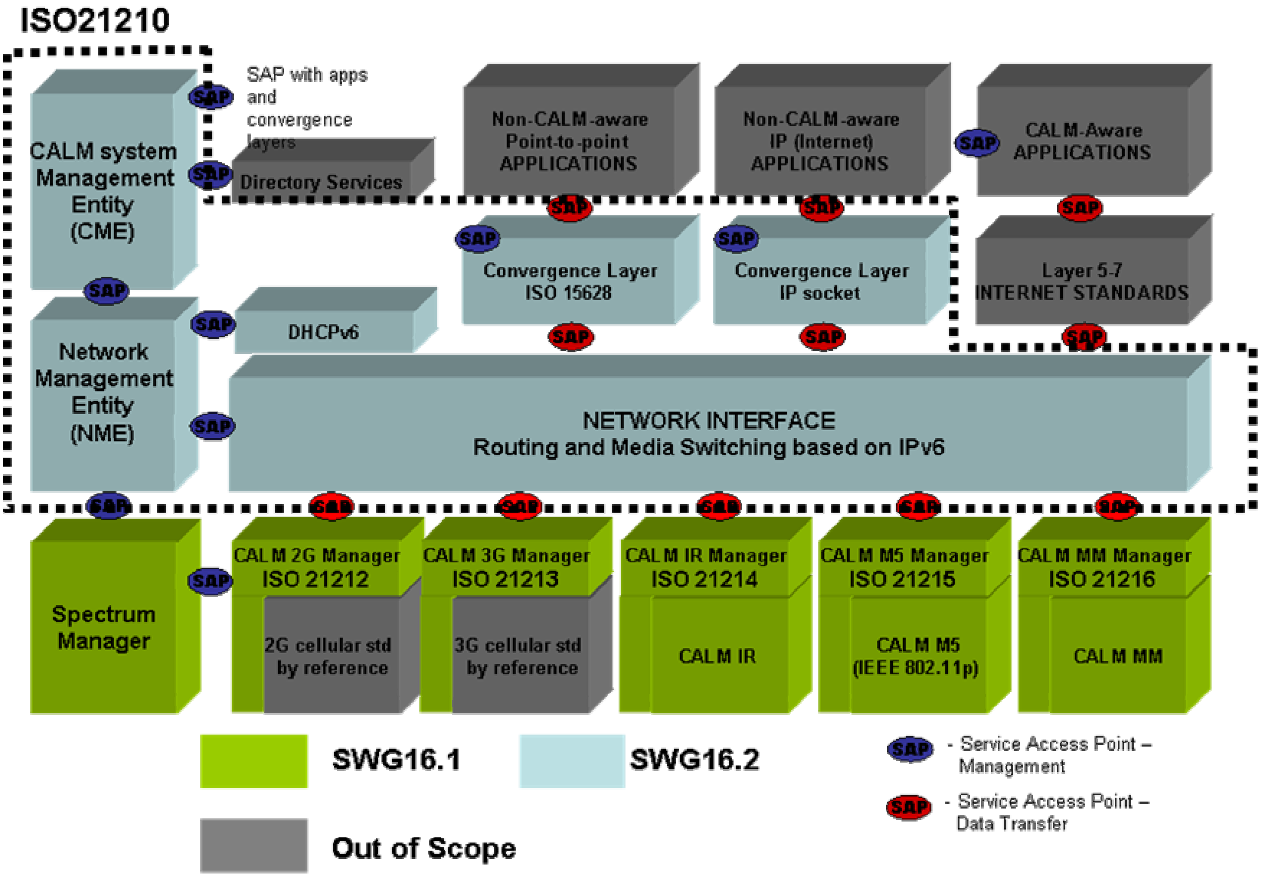

Figure 8 – CALM Detailed Architecture [8]

These architectural models do not imply anything about the implementation of a CALM system. The system could be implemented into one box, or could be spread over several physical devices, independent of these models. But a CALM compliant system must contain all four blocks from *Figure 7 – CALM Basic Architecture [9]*. These four blocks will be further discussed in the following chapters [9].

7.2.1 Communication Management

This part of the architecture resides outside the communication stack. It is responsible for management functions like setting up and releasing connections, and to assign connections to services/applications. The general concept of CALM is to select the optimal communication link for each application. Applications can have different requirements regarding bandwidth, cost and service levels, and it is up to the Communication Management to assign a communication link to the right application based on these requirements. The Communication Management part consists of 3 modules: The CALM Management Entity (CME), the Network Management Entity (NME) and the Spectrum Manager.

CME

The CALM Management Entity is the brain in the CALM system. This module is responsible to compare the capabilities of the currently available communication links with each application requesting a communication link. This is done by merging two lists, one list over available communication links and another list over application requirements. The communication links list is supplied by the Network Management Entity, and the application requirements list is supplied by the applications. In addition it is possible to set different

Medium Selection Policies affecting the selection strategy for the CME. These policies can be manufacturers' policies set by the manufacturer, regional policies set by local authorities and broadcasted from e.g. local roadside units or they can be user policies set by the user. They can for example be set such that for application "A" the data rate factor has a higher priority than the cost factor, making the CME to select the highest available bandwidth in spite of higher cost.

The two lists are merged together under the rules of the Medium Selection Policies set, and new routing tables are created between the applications and different media. This mechanism is illustrated in *Figure 9 – CME [9]*:

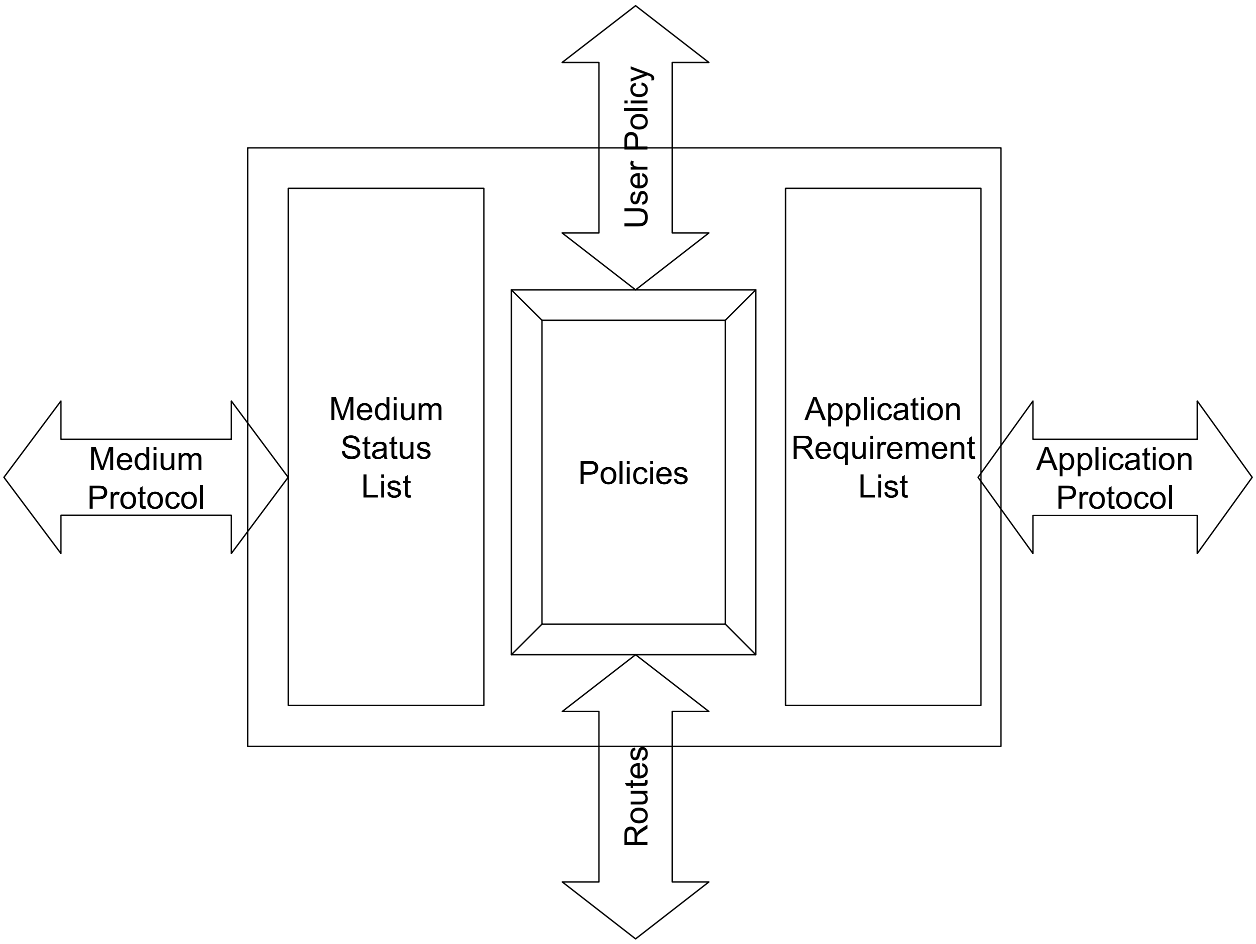

Figure 9 – CME [9]

NME

The Network Management Entity is responsible for keeping track of the different media, and to always notify the CME of any changes in media availability. It is also this entity that will update the different routing tables on command from the CME. It will constantly monitor the received signals of the communication media in order to identify which media are available and which are not. When the NME detects changes on a communication link, it will immediately notify the CME, which in turn will activate the Media selection mechanism again.

For example, if the CALM unit leaves a WLAN covered area, the NME must notify the CME that the WLAN link has been lost, which in turn will trigger the Media selection. Now the

CME has to allocate new communication links to the applications previously connected through the WLAN link. The newly setup routing tables will be deployed through the NME.

Spectrum Manager

CALM is designed to support many air interfaces at once. One problem that can arise with different receivers/transmitters located so closely physically is interference. A transmitter can block other interfaces from receiving if those interfaces are using the same frequency or nearby frequency bands. It is therefore very important to handle these situations, and to take the proper measures if interference occurs. Many of CALM's applications are related to safety, in which signal interference could be disastrous. The Spectrum Manager's function is to co-ordinate the different air-interfaces and through this minimise interference and prevent blocking of vital services.

7.2.2 Physical/Link Layer – OSI Layer 1 and 2

This layer represents the lower blocks labelled ISO21212 to ISO 21216 *Figure 8 – CALM Detailed Architecture [8]*. These are the air interfaces connecting the vehicle to outside devices, also called the *egress interfaces*. The *ingress interface* is the interface towards the in-vehicle computer, most likely a wired Ethernet connection. The different media specified at the current stage are [9]:

- **ISO21212/ISO21213 2G/3G Cellular**
  These interfaces represent the cellular media used in CALM. They might be considered partly native since special convergence layers have to be used to integrate them into CALM. The different versions proposed include 2G (GSM), 2.5G (GPRS), 2.9G (EDGE) and 3G (UMTS). These media are protected by intellectual property rights (IPR), but access is provided through ITU protocols and ETSI standards.
- **ISO21214 IR**
  The Infrared interface is one of the fully native interfaces of CALM. It is developed in an open forum to prevent IPR issues. Infrared communication use pulsating light to communicate and is therefore limited to line of sight (LoS) when operating.
- **ISO21215 M5 (IEEE 802.11p)**
  This is also a native interface of CALM. IEEE is currently working on the 802.11p protocol which will be a part of the Wireless LAN 802.11 family. The project has been named WAVE, Wireless Access in a Vehicular Environment. This protocol should improve the range and speed of other 802.11 protocols, with ranges up to 1000 feet and bandwidth averaging at 6 Mbit/s. This solution is also developed in an open forum.
- **ISO21216 MM**
  Millimetre wave is also using radio waves for communication, but in the 60GHz band, as opposed to 5.9GHz for CALM M5. As with IR and M5, this solution is also developed in an open forum to prevent IPR issues.

This list of media is not yet complete, and other standards might be added at a later stage. But new media have to satisfy a minimum of protocol functions and performance to work seamlessly as a CALM medium. In addition to that, a common convergence layer is planned. This convergence layer should be able to support media such as existing DSRC protocols, broadcast protocols and positioning receivers.

This layer also has the functionality of MAC, Mac Extension and Logical Link layers. It should associate unique medium access control (MAC) to each physical interface, provide a smooth interface from this MAC to the upper layers and control the flow of data to and from the different protocols at the network layer.

7.2.3 Network/Session Layer – OSI layers 3 and 4

This part of the CALM architecture represents layers 3 and 4 of the OSI model, and is described in the specification ISO 21210. This describes CALM's network protocols for media management and transfer. This layer binds applications and services from the above layer down to the different media available from the Physical/Link layer. This way, it isolates the upper layers from the communication media. Network protocols such as PPP (Point-to-Point Protocol), IPv6, IPX, ROHC (Robust Header Compression) and others may be needed in this layer.

CALM will use IPv6 as its main protocol. IPv4 is currently the most used protocol, and is the fundamental protocol to send information over the internet. It's been around since the 1970's, and a few problems have emerged during the years. Some of the main problems are that the range of IP addresses is too small and that the protocol lacks security mechanisms. At the current rate, the 32bit address range would be filled up in the near future. IPv6 is a new standard aiming to solve these problems. It has a 128bit address range which in practice *provides 655,570,793,348,866,943,898,599 (6.5 x1023) addresses for every square meter of the Earth's surface*[17], something that should be more than enough for the nearest future, IPv6 also has a new layer called IPSec, which provides network security features in the network layer. This will make security functions transparent to the applications using this network interface [17].

Network-layer specific functionality will be implemented in this layer, among them:

- **Global multicast**
  Multicast is the mechanism of having a single source sending information to many receivers in a network. Examples of applications using these mechanisms are streaming audio/video services like Windows Media Player and online conferencing services like NetMeeting. Global multicast is an internet-wide multicast mechanism which uses regular multicasting along with membership control protocols [18].
- **RSVP (Resource Reservation Protocol)**
  RSVP is a part of the IETF framework called Integrated Services, IntServ. It is a mechanism which enables internet applications to obtain different Quality of Service (QoS) levels. It is not a routing protocol, but a network control protocol which works in conjunction with routing protocols to ensure the preferred quality of service. Thus, RSVP can be installed in an existing network without changing the routing protocol [19].
  RSVP has three levels of service for an application:
    - **Best-effort**
      Traditional IP traffic. Requires reliable data flow without time delay concerns.
    - **Rate-sensitive**
      Communication links that require a guaranteed transmission rate, such as videoconferencing.
    - **Delay-sensitive**
      Communication links that require timely delivery of data, but where the data

rate may vary. MPEG-II is a video format which has a varying bit rate, but the data has to arrive on time for the video to play correctly.

- **DiffServ (Differentiated Service)**
  While IntServ offers a rich end-to-end QoS solution through RSVP flow and reservation, DiffServ offers a much simpler and coarser method of supporting end-to-end QoS. Some of the problems of IntServ are that route reservation might be complex and requires maintenance to keep communication links up. Instead of reserving routes like RSVP, DiffServ marks each packet with a priority classe, and each class has a service level throughout the network. Any node along the packets path would know the relative priority of the packet, and would forward it accordingly. There are two main priority classes [20]:
  - **Premium Service**
    This service offers guaranteed maximum bandwidth.
  - **Assured Service**
    This service can be further categorized into three smaller classes, ranging from best to worst:
    - Gold
    - Silver
    - Bronze

  Since the complexity at each network element is drastically reduced, this method is far more scalable than the richer IntServ/RSVP approach.
- **Mobile IP**
  Mobile IP is a mechanism which allows end nodes to change point of attachment to a network, without losing the connection. Through this, mobile clients can travel across different subnets while staying connected.
- **NEMO**
  NEMO is usually referred to as NEtwork MObility or "a NEtwork that is MObile". This is a mechanism that allows a network to change its point of attachment to a larger network, e.g. the internet. An example could be a router on a bus which is connected to the internet through WLAN A. There are clients connected to this router, and the router is providing internet access to them. But through mobility, this router comes out of range from WLAN A, and into range of WLAN B, and has to change its point of attachment, just as a client would change its point of attachment with Mobile IP. But through NEMO, the router can change this attachment without disrupting the connection of its clients, and the network as a whole is made mobile, as illustrated in *Figure 10 – NEMO keeping clients connected*. In this figure the router is using NEMO to remain connected while the point of attachment is changed [44].

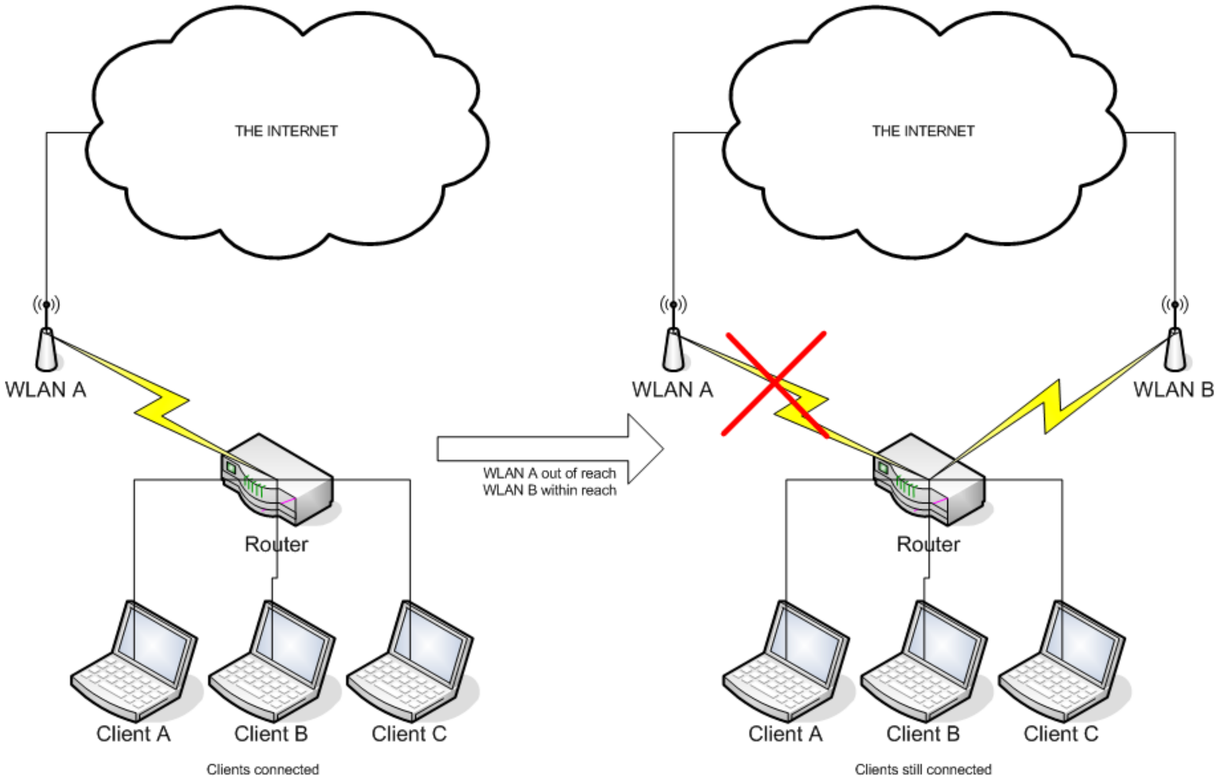

Figure 10 – NEMO keeping clients connected

- **IPSec**

  IP Security (IPSec) is a mandatory part of the IPv6 protocol suite. It has also been adapted for IPv4, but with certain limitations since it is an optional part of IPv4. This means that while IPSec in IPv6 offers complete end-to-end security, it will in IPv4 typically only offer security between border routers of separate networks. IPSec provides security on the network layer which means that applications running over an IPv6 network automatically would benefit from this security, since the application data is encapsulated within the IPv6 packet [7][17].

  IPSec has two mechanisms to provide network security:

  - Authentication Header
  - Encapsulating Security Payload

  These two mechanisms can be used separately or in combination to provide different types and levels of security. A fundamental concept in IPSec is that of *Security Associations* (SA). A Security Association is a relationship between sender and receiver which describes the type of security services for a connection. The SA is uniquely identified by the destination IP address, the security protocol used (AH or ESP) and a field in the AH/ESP header called Security Parameters Index. It describes which encryption or authentication algorithm to use, and usually contains the key for this algorithm. To establish a new SA, processes like Internet Key Exchange are used to negotiate parameters like secret key and algorithms to be used.

  The two protocols AH and ESP can support different security mechanisms, as listed in Table 1- Security features in IPSec [7]:

Authentication Header	Encapsulation Security Payload
• Data Authentication • Data Integrity • Anti-Replay Protection	• Data Authentication • Data Integrity • Anti-Replay Protection • Data Confidentiality

Table 1- Security features in IPSec [7]

IPSec may support different authentication algorithms. RFC2402 has proposed Hash Message Authentication Code (HMAC) with Message Digest No. 5 (MD5) and HMAC with Secure Hash Algorithm No.1 (SHA-1) as authentication algorithms for global interoperability [17]. Encryption algorithms include DES, triple DES and AES, but only DES is defined for globally interpretability, the other two algorithms are too strong for US export regulations.

- **IP Firewall**
  Packet filtering should be supported, and *IP Firewall* is just a generic name for packet filters. A packet filter works like this: When a packet is received at the router, it checks for filter rules if the packet is allowed, and forwards it if the packet passes the rules. If it doesn't pass the rules, it is discarded [8].
- **Static Routing**
  All destination addresses (routes) are established on initialization of the router, and there is no mechanism to change these without re-initializing the router.
- **Dynamic Routing Protocol**
  Routes can in this protocol be changed dynamically, without re-initializing the router. If a router goes down in a network with static routing, destinations can become unavailable. With dynamic routing, the routes can change on the fly, allowing data to reach it's destination in other ways than the initial route.
- **NDP (Neighbourhood Discovery Protocol)**
  This functionality allows new clients to determine the preferences of a network they've come across. Routers and hosts with NDP installed will periodically advertise their presence to other clients through neighbourhood and route advertisement. Clients will also determine what the requirements for this network are through this protocol [24].
- **DHCP (Dynamic Host Configuration Protocol)**
  When end-nodes are connecting to a network, they need to get a unique address specified for that network. If DHCP is used the DHCP server will automatically assign an address to new clients. This is commonly referred to as a state-full approach, since the server is aware of all clients connected to the network [8].
- **SLAAC (Stateless Address Auto-Configuration)**
  This is also a mechanism for connecting end-nodes to a network. But in this mechanism, the router/server is sending out router advertisements, which are caught by connecting end-nodes and the end-nodes are creating their own address. This is a stateless configuration, since the router would not know the address of all clients connected [8].

7.2.4 Services/Application Layer – OSI layers 5, 6 and 7

This layer contains the applications and services of CALM, and provides Application Programming Interfaces (APIs) from the lower layers in the stack. Protocols for communication initialization and establishment of data transfer could be found here for some stacks.

Applications using CALM to communicate can be split up into two groups:

- **Calm-aware applications**
  These applications are able to respond to the CALM management entity to automatically register the application in the CME. These applications can use lower level actions supplied by the CALM environment, like power settings, channel settings, beam pointing and so.
- **Non-calm-aware applications**
  These applications are not able to respond to the CALM management entity, and are not able to automatically register with the CME. The user has to manually enter registration information. The application would treat the connection as a regular UDP or TCP connection, without caring about how the connection is set up. For example, the switch of carrier is not important as long as a connection is present.

7.3 Handoff mechanisms: Horizontal vs. vertical

Handing off connections are one of the main functions of CALM. Carriers would lose and gain coverage as the vehicle changes location, and it's up to CALM to always stay connected through properly handing off connections between carriers. There are different types of handoffs:

- **Soft Handoff**
  A soft handoff is when there are overlapping coverage areas, and the mobile device is able to connect to several points at one time. This way the mobile device is already connected at the new connection point when it leaves the previous connection point, hereby reducing the handoff delay.
- **Hard Handoff**
  In a hard handoff, the mobile device is only able to connect to one point at a time. When leaving a coverage area, the device has to disconnect from the previous connection point, and then establish a connection to the new connection point. This could cause a handoff delay. Hard handoffs are widely used in the current GSM and GPRS systems; whereas newly CDMA based cellular systems such as WCDMA (UMTS) and 1xRTT (CDMA2000) use soft handoffs.
- **Homogeneous Handoff (Horizontal Handoff)**
  Homogeneous handoff is a handoff between two carriers of the same type, for example WLAN ⇔ WLAN handoff. This could happen when a car is leaving the coverage area of WLAN Access Point A, and driving into the coverage of WLAN Access Point B.
- **Heterogeneous Handoff (Vertical Handoff)**
  Heterogeneous handoff is a handoff between two carriers of different type, for example WLAN ⇔ GPRS. An example here is a car driving out of a WLAN coverage area, but not into a new WLAN coverage area. Then CALM has to transfer the connection over to another carrier with coverage, in this case the cellular carrier GPRS.

Several propositions have been made to improve handover mechanisms:

- **A new architecture for seamless handoff between heterogeneous wireless networks [31]**
  In this proposition, the authors imagine an integrated UMTS-WLAN architecture where both carriers belong to the same administrative domain. This requires the two carriers to be operated by the same operator, but the authors believe that this is

something that will happen in the future. Through this architecture, vertical handovers will be much easier and cause less link disruption.

- **Predictive Handover [32]**
  This proposition introduces so-called Ghost-Agents which are deployed in probable future networks for a moving client. Through this, the Ghost-Agent will have already set up the Agent used in Mobile IP before the client arrives at that network, improving connection handoff.
- **OmniCon: A Mobile IP-Based Vertical Handoff System for Wireless LAN and GPRS Links [33]**
  OmniCon aims to improve GPRS ⇔ WLAN handoff by introducing a simple extension to the existing Mobile IP implementation. This is done through a so-called GPRS-foreign-agent which acts as a gateway to the GPRS network. This way Mobile IP functions can be applied to the GPRS-connection.
- **A Seamless Handoff for Dual-interfaced Mobile Devices in Hybrid Wireless Access Networks [34]**
  This paper shows that devices with several wireless interfaces can exploit this to connect to a network through several interfaces simultaneously, greatly improving handoff times. A threshold-system is introduced for interface-selection.

Chapter 8 QoS Parameters

Quality of Service parameters are parameters that will affect application performance. Examples of these could be bandwidth and latency: Some applications will run at all or at degraded performance if the bandwidth is too low, e.g. video-streaming; some other application will be unusable or at degraded performance if the latency is too high, e.g. live voice communication.

8.1 Infrastructure

The infrastructure defines the setting in which the communication is performed. For example, in the field of ITS communication can occur between stationary equipment like Road Side Units and the vehicles, or between the vehicles themselves.

8.1.1 Communication types

In the communication model used by CALM, there are three major types of communication between the different nodes.

- **RSU→OBU**
  Typically for safety and transport efficiency applications there is the unidirectional communication from the Road Side Unit out to the On Board Units in the vehicles. This kind of communication would probably use a *Store & Forward* mechanism, where information is sent out from a control room out to the RSUs, which store the information and forward it to all OBU nodes in its vicinity. This could be information such as speed limits, road conditions, traffic load, accident warnings and so on. It will almost be like electronically traffic signs, giving the information directly to the vehicle, which in turn can give it to the driver through the driving computer. The main feature of such applications is that the vehicle (OBU) doesn't have to reply to the incoming signals.
- **RSU⇔OBU**
  Another type of communication is the bidirectional communication between RSU and OBU. Here the RSU might advertise for an application, the OBU will request information or a service, and the RSU will respond to that request. Typical for this kind of communication is that we have a continuously link between the server application, projected through the RSU, and the client application in the vehicle (OBU). This means that mobility is of concern, and network mobility (NEMO) or mobile IP plays a major role. Applications would typically include entertainment applications like requested tour guides, music and video and information applications. Internet access would also be achieved through continuously, bidirectional communication.
- **OBU⇔OBU**
  The last of the major communication types is the inter-vehicle communication. Here the vehicles (OBUs) would communicate directly with each other through ad-hoc networking.

8.1.2 Communication link

Most CALM applications will probably not need a continuous connection to a service, just short bursts of data communication sending warnings or information updates. But some applications need to communicate with a service over a longer period of time. Data streaming, for example video or music streaming, would require a continuous connection to the service.

In a mobile scenario such as the ones CALM is dealing with, this is not a trivial matter. Communication links such as WLAN does have a rather short range, and several transmitters along the road are needed. Handover mechanisms between the different transmitters must be incorporated, so that the connection would seem continuously. In this case we would have homogeneous handover, since the medium before and after the handover mechanism is the same. But because of the short range of high bandwidth media, there would often be cases when you're leaving a WLAN connection, and have to switch to other types of media. This could be cellular media, such as GSM or GPRS, with a much higher coverage. In this case we would have a heterogeneous handover, switching between different media. The challenge would be to make this handover transparent to the user. But some applications which require high bandwidth would not be able to run at a desired level after a switch to a low bandwidth media.

Types:

- Continuously
- Non-continuously

8.2 Bandwidth

The term bandwidth says how much data a carrier is able to transfer per second. This can vary very much between the different carriers, from a few kilobits per second, up to several megabits per second. Some applications need a bandwidth higher than a specific value, and are not able to perform with less bandwidth, e.g. video streaming. With too low bandwidth, the video wouldn't be able to show the frames fast enough. Some of the carriers proposed for CALM and their theoretical bandwidths are listed below:

- GSM – 9.6 Kbps
- Tetra – 28.8Kbps
- GPRS – 40 Kbps
- EDGE – up to 384 Kbps [26]
- UMTS – up to 2.048 Mbpts, depending on size of cell [25]
- IR – up to 128Mbps
- MM – up to 432Mbps
- WLAN – 6-54Mbps

8.3 Latency

Setup time is how long time elapses from a media discovers a signal to when it is able to send data back and forth over that media.

This might be one of the most critical parts of the communication between different nodes in CALM. Mobile nodes such as cars can travel at high speeds, which make it important that messages are received in time. The requirements sketched for WLAN transmitters in CALM assume a range of up to 1000 meters. If a car travels straight through the cell of a transmitter, it would be within its range for 2000 meters. Travelling at 80 km/h equals 22.22 metres per second, meaning that it will be within range of that transmitter for approximately 90 seconds. If we think of an application where a warning signal is sent out from a stationary transmitter such as a warning sign, the receiving vehicle will be 22.22 metres closer for each second used in setting up the connection.

Latency is affected by different parameters such as carrier type, security features used, environmental obstacles and so on. Typical numbers for latency could be:

- High – >1000 ms
- Medium – 500 ms
- Low – <50 ms

8.4 Security

Computer security is an important topic, especially now that the internet is a part of everyday life and eCommerce is getting more widespread than ever before. Security and privacy are two areas which are getting harder to maintain since information is so easily available.

Systems can have *vulnerabilities*, weaknesses that might be exploited to cause loss or harm to the system itself or users of the system. When a vulnerability is deliberately exploited, we say that the system is *attacked*. *Threats* are circumstances that can potentially cause harm or loss to the system; this includes deliberate attacks, natural disasters, human errors and internal hardware and software flaws. To make a system less vulnerable to threats, certain *controls* can be installed as protective measures [22].

Software security has three desirable security goals: *Confidentiality*, *Integrity* and *Availability*. These goals can sometimes overlap or can be mutually exclusive. Fulfilling just one of them is trivial; the problem is to preferably fulfil all three at once, to different degrees depending on the application under discussion.

8.4.1 Confidentiality

Confidentiality is about only letting authorized users access protected data, and hiding it from unauthorized users. The authorized users shall be able to read, view or print the data, while unauthorized users might not even know that the data exists.

8.4.2 Integrity

Integrity can have many different meanings:

- precise
- accurate
- unmodified
- modified only in acceptable ways
- modified only be authorized people
- modified only be authorized processes
- consistent
- internally consistent
- meaningful and correct results

For example, integrity should ensure that data sent over a channel arrives unmodified to the receiver. If something has changed the data in unauthorized ways, this would be found and the users would be notified.

8.4.3 Availability

Availability might be the biggest challenge of computer security. It is easy to ensure confidentiality and integrity if data and services are kept unavailable. Assets should be made available to authorized parties, and the assets should be presented timely and in an usable form. The opposite of available is sometimes called denial of service. Availability should ensure goals like usability, timely response, fair allocation, fault tolerance and controlled concurrency.

To support these three main security goals, lower level goals and mechanisms are employed. *Authentication* and *authorization* are two mechanisms used to ensure confidentiality, integrity and availability. The goal of authentication is to identify a user, and verify that the user is who he claims to be. Usual means of authentication might be username and password, public/private key system, digital signatures or digital certificates. When a user is authenticated, the system needs to decide what he is allowed to do. Authorization is the process of deciding which resources and services an identified user is allowed to access. So the problems of authentication and authorization are in most cases very similar.

Part 3: Own Contribution

This part contains the actual work of describing and analysing the applications. Chapter 9 describes a few of the envisioned applications from the CVIS project. The applications here are presented as either Road-to-Vehicle or Vehicle-to-Vehicle applications. This classification and a few others are described in Chapter 10. Chapter 11 presents a summary use case of the CVIS system, to show the relationship between the system, its actors and stakeholders. The applications *Road Condition Warning* and *Emergency Vehicle Approaching* are described and analysed in Chapter 12, and test cases are developed.

Chapter 9 General list of applications proposed

This is a list of applications proposed for the CVIS project. They are grouped in two groups: *Road-to-Vehicle and Vehicle-to-Vehicle.* These are just visions, and are not well documented. A larger list of applications is found in Appendix A.

9.1 Road-to-Vehicle

Table 2 – Examples of Road-to-Vehicle applications describes a few applications which are envisioned for the CVIS project.

Application name		Brief description
Cooperative Vehicle-Highway Automation System (Platooning)	:	One vehicle controls 2 or more vehicles down a single lane. The first vehicle is driving, while the other vehicles are "hooked on to" the vehicle in front, and following at the same speed and same direction.
Curve Speed Warning – Rollover Warning	:	Road Side monitors speeds of incoming vehicles, and warns vehicles of rollover if they are driving to fast in the curve.
Enhanced Route Guidance and Navigation	:	Routes are selected dynamically based on congestion and other factors affecting travel time.
Intersection Collision – Infrastructure-Based Warning	:	Intersections are equipped with sensors and transmitters. If a hazardous situation is detected, warning signals are sent out to incoming vehicles.
Low Bridge Warning	:	Road Side transmits warning signals to incoming traffic. This works like an electronic sign. Warnings are displayed at drivers display.
Map Downloads and Updates	:	Road Side offers maps and updates to vehicles in range. Vehicles download the information directly.
Road Condition Warning	:	Road Side transmits warning signals to incoming traffic. This works like an electronic sign. Warnings are displayed at drivers display.
Work Zone Warning	:	Temporary road side equipment is set up and transmits warning signals to incoming traffic about road work in progress.

Table 2 – Examples of Road-to-Vehicle applications

9.2 Vehicle-to-Vehicle

Table 3 - Examples of Vehicle-to-Vehicle applications describes a few applications which are envisioned for the CVIS project.

Application	:	Brief description
Approaching Emergency Vehicle Warning	:	Emergency vehicles transmit warning signals telling other road users their location, direction route and speed. This way the road users can be warned early enough to let the emergency vehicle travel uninterrupted.
Cooperative Collision Warning	:	Vehicles send out information about their position, direction and speed regularly. If two vehicles notice that they're on a collision course, warnings will be sent to the drivers.
Electronic Brake Lights	:	Vehicles transmit information when it is breaking, warning other drivers behind the vehicles, and further back in a possible queue.
Instant Messaging	:	Communicate directly with other road users through instant messaging.
Lane Change Assistant	:	Electronically warn other road users when a vehicle is performing a change of lanes.

Table 3 - Examples of Vehicle-to-Vehicle applications

Chapter 10 Application Classifications

There are several ways of classifying applications. Applications in this report can all be classified with respect to the different QoS parameters presented, such as communication types, bandwidth and security requirements. This section will present three classification schemes. The first one is a scheme proposed by the CALM MM group which classifies applications with respect to their communication type. The next scheme is proposed by the CVIS project, and classifies applications with respect to their different application areas, e.g. Urban vs InterUrban applications. The last classification scheme is also based on application area, but classified in a different way than the previous scheme, e.g. safety applications versus transport efficiency applications.

10.1 Classified by type of communication type

CALM MM group has proposed a classification scheme classifying applications with respect to communication types. They propose a classification scheme for CVIS applications as shown i*n Figure 11 – Classification by communication type*:

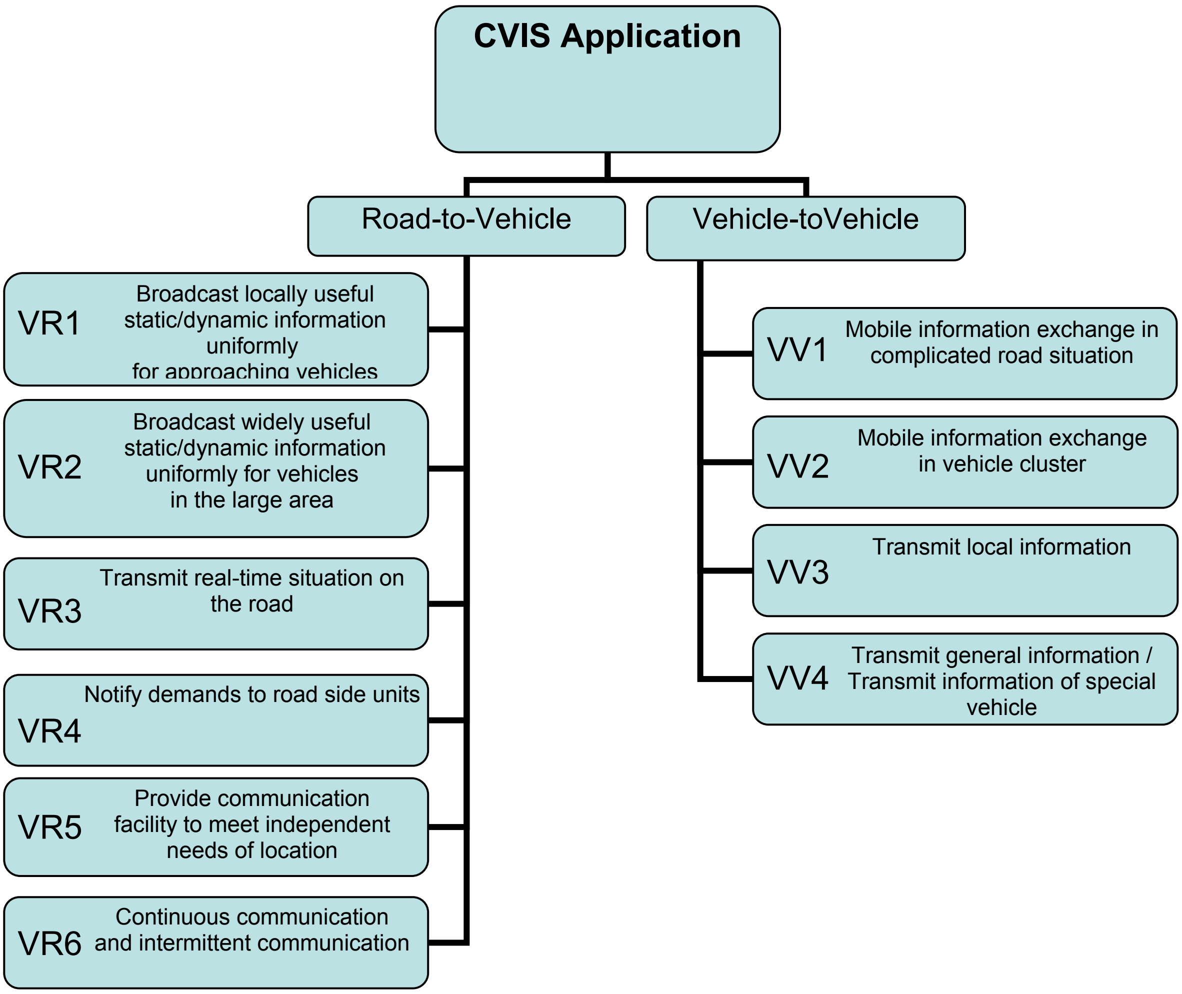

Figure 11 – Classification by communication type

First off, applications are divided into Road-to-Vehicle (R2V) and Vehicle-to-Vehicle (V2V) applications. One can argue that there should be a Vehicle-to-Road scenario as well, where the vehicle requests something from the Road Side Unit (RSU), e.g. Road Condition Warning, where the Vehicle notifies the RSU about the current road conditions. But in any scenario regarding communication between infrastructure and vehicles, the infrastructure have to broadcast their services or availabilities so that vehicles are aware of it. This way we can say that any communication is initiated by the infrastructure, hence Road-to-Vehicle.

10.2 Classified by application area

Another way to classify applications can be on their application area. That is, who uses the application, for what purpose do they use it and where is it used? The "where"-part is very important for applications in a mobile environment, as application needs can vary with respect to location.

The CVIS project proposal [3] introduces a classification scheme with respect to application area, as shown in *Figure 12 – Classification by application area*. The main areas are Cooperative Urban Applications (CURB), Cooperative Interurban applications (CINT), Cooperative Fleet and Freight Applications (CF&F), Cooperative Public Transport Applications (CPUB) and Cooperative Monitoring (COMO). These areas are basically based on the questions "who uses it" and "where is it used". The CVIS project has individual subprojects for each area, and these projects are presented next:

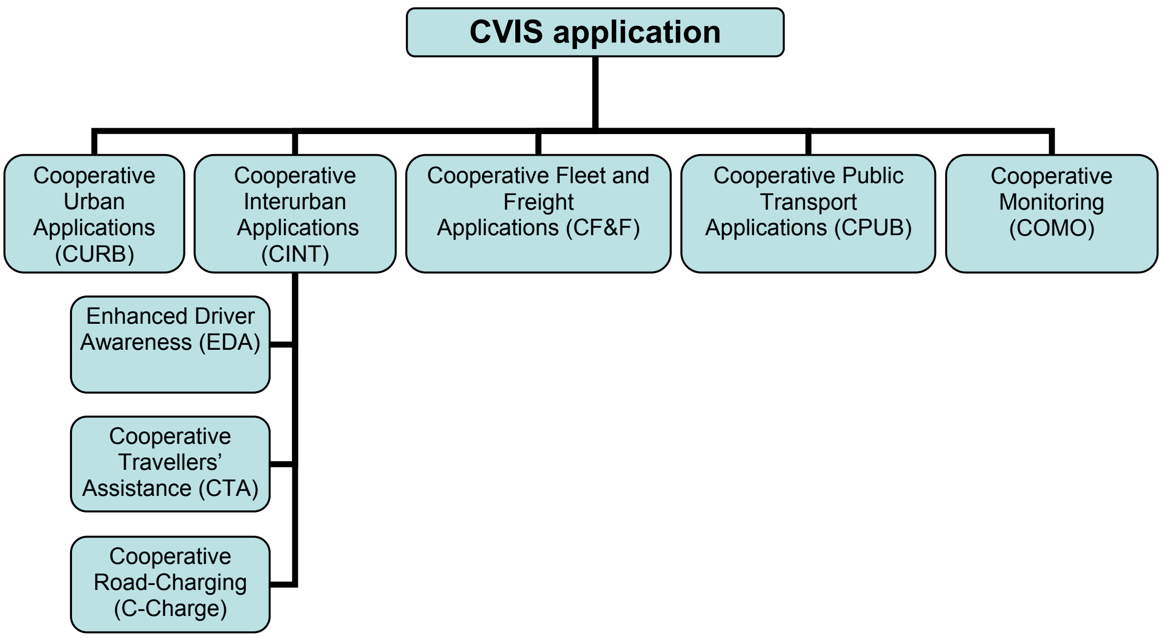

Figure 12 – Classification by application area

10.2.1 Cooperative Urban Applications (CURB)

The CURB project aims to improve traffic efficiency, safety and road side environment in the urban road network and to improve individual mobility. This should be done through intensive real time data exchange between vehicle and road side infrastructure. It should provide tools for maximizing traffic float through the network and at the same time cope with traffic fluctuations, disturbances and priority vehicle requests. Examples of applications include [3]:

- Cooperative Network Management
- Cooperative Area Routing
- Cooperative Local Traffic Control

10.2.2 Cooperative Interurban Applications (CINT)

The CINT project is very much like the CURB project, as it aims to improve efficiency and safety, but to the inter-urban road network instead of the urban network. In addition it aims to improve environmental friendliness of traffic and to offer a comfortable journey to drivers and passengers, as these goals are more aimed at inter-urban travel. Examples of applications here include [3]:

- Enhanced Driver Awareness (EDA)
- Cooperative Travellers' Assistance (CTA)
- Cooperative Road-Charging (C-Charge)

10.2.3 Cooperative Fleet and Freight Applications (CF&F)

The aim of the CF&F project is to increase efficiency, safety, security and environmental friendliness of cargo movement by implementing cooperative systems into commercial vehicles where information about position, cargo and destination is transmitted to regional public authorities. The main goals would be [3]:

- Increase the safety of dangerous goods transports
- Optimize delivery logistics for transport companies
- Reduce, within sensitive areas, vehicle breakdowns

10.2.4 Cooperative Public Transport Applications (CPUB)

The aim of the CPUB project is to improve quality of Public Transport services, and through this relieve the rest of the road network from a huge amount of private cars causing traffic congestions and environmental damages. Two main applications are proposed:

Park & Ride facility – Major cities are being swamped by private cars, causing heavy traffic and congested road networks. Many of these cities have big parking lots outside the inner city, which are serviced by public transport. Many drivers are not aware of this, but through better information directly to the user, more drivers will use this service, relieving the inner city from heavy traffic

Flexible Bus-Lanes – A bi-directional bus lane which changes direction with respect to the traffic situation would greatly improve the public transport. Semi-static bi-directional lanes already exists, which changes direction twice each day, but with this Flexible Bus-Lane, the traffic situation will decide the direction, giving an overall better performance.

10.2.5 Cooperative Monitoring (COMO)

COMO is not a set of stand alone applications like CURB, CINT, CF&F and CPUB, but rather a set of underlying support applications. COMO should provide a communication interface between cooperative applications, like the ones just described, and the monitoring infrastructure of probe vehicles and infrastructure sensors. It should also provide a standardised interface providing raw or nearly raw data of the vehicle as well the local sensor infrastructure.

10.3 Classification by application area II

The main focus of CALM is to be a communication link for safety and transport efficiency applications. Safety applications can include road condition warnings which for example will warn drivers if the road is slippery, if there are unusual driving patterns or other dangers in the road. We also have environment warnings like low bridge warnings and blind merge warnings. If there has been an accident, warnings could be sent out to slow down incoming traffic. And emergency vehicle sends out warnings so that everybody becomes aware of them. Transport efficiency applications will include applications such as automatic fee collection which will minimize fee collection queues, alternate route suggestion which will maximize traffic float and reduce traffic jams and cooperative vehicle-highway automation system, platooning. But apart from the main areas of safety and transport efficiency, CALM will be the communication platform for numerous other applications targeting the big market within the transportation system. This is where the commercial actors come into play, offering a vast majority of services to our road users. This can be information applications such as GPS corrections, tour guides and advertisements or it can be entertainment applications such as video streaming or purchasing music on the fly.

A classification scheme to divide applications into these three main sectors is presented in *Figure 13 - Classification by application area II*:

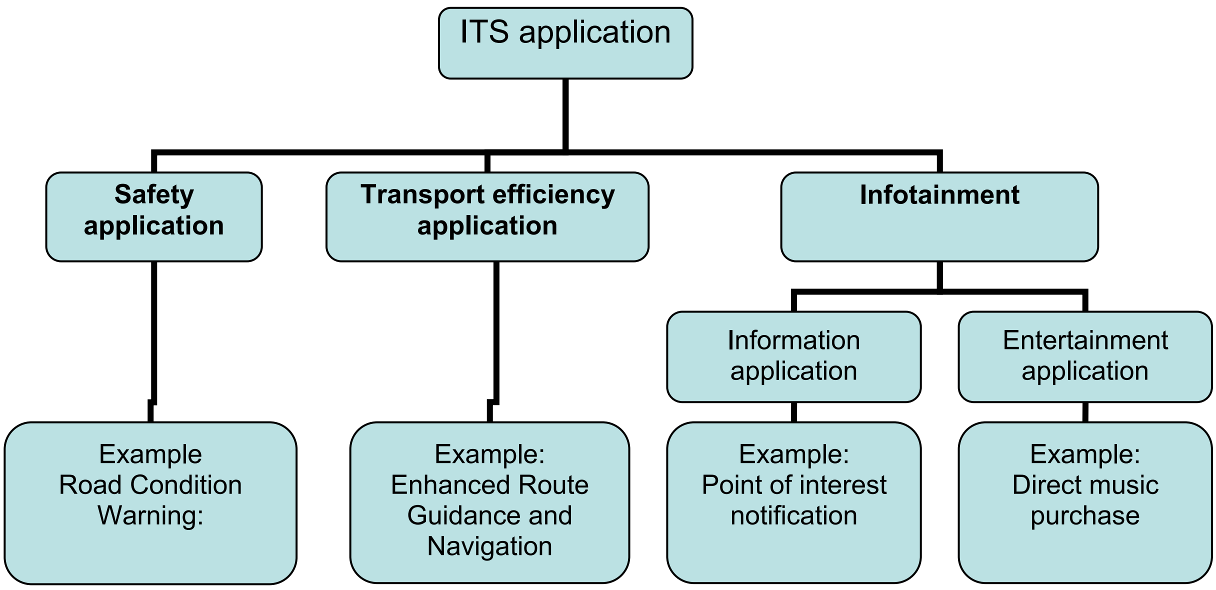

Figure 13 - Classification by application area II

Chapter 11 Summary use case

The application presented later on will be described with use cases. But first off, a summary use case for the CVIS system will be presented in the next section. This is an outermost use case showing the system and businesses involved as a whole. The motivation behind this use case is to show how the different actors and stakeholders who are involved in making and using this system are interacting with each other and with the system itself. And to make the system work, all of the involved actors have to agree on standards and rules for the system.

11.1 Use Case: CVIS system

Figure 14 – CVIS Use Case Diagram shows a graphical representation of the CVIS system discussed in this section.

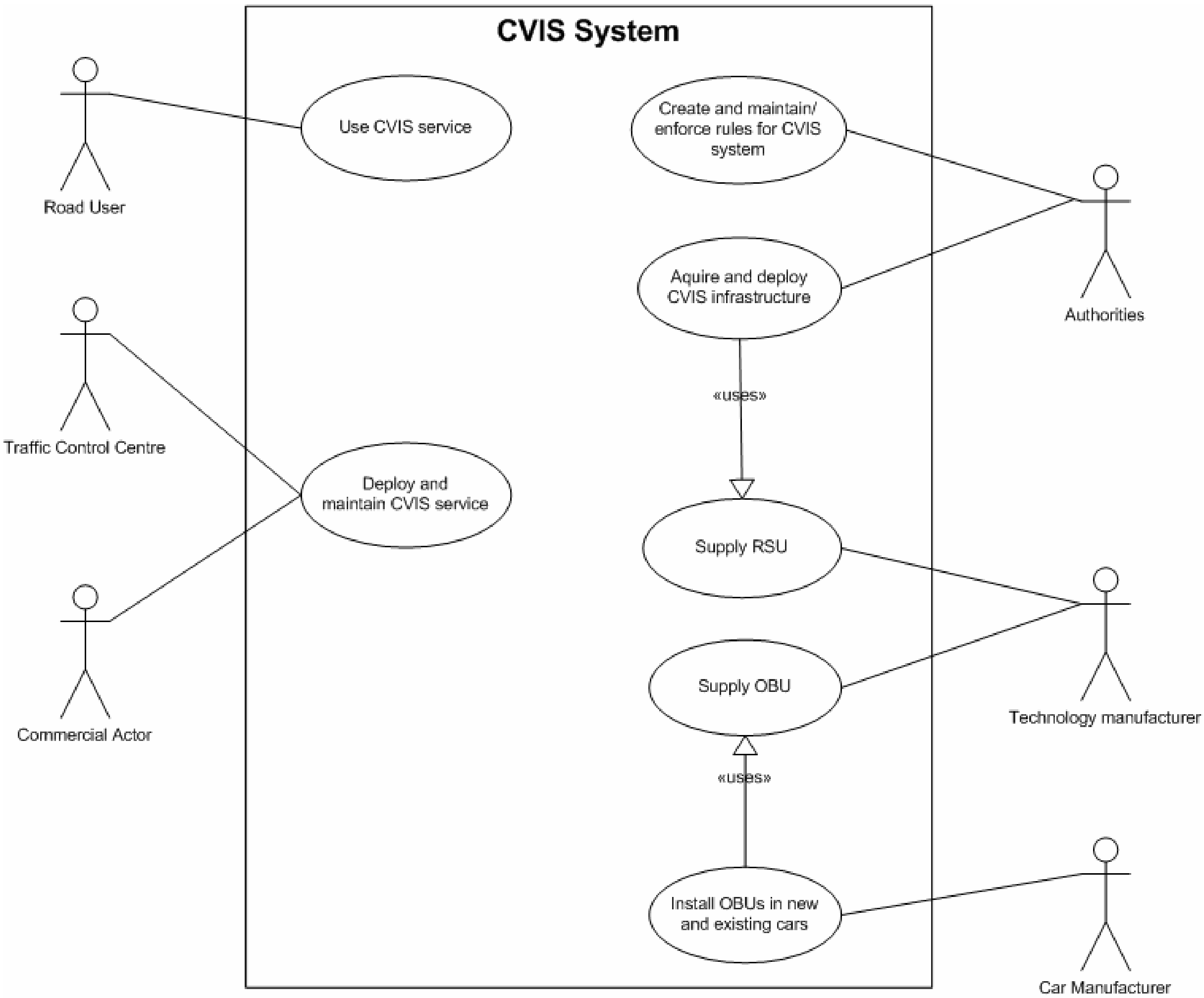

Figure 14 – CVIS Use Case Diagram

Scope:

- Outermost, the big picture of CVIS.

Stakeholders:

- Who wants it?
  Authorities - want it to improve road safety and traffic efficiency.
  Commercial actors - want it to supply services directly to road users.

- Who makes it?
  Technology manufacturers - supply technology equipment.
  Car manufacturers - integrate technology into cars.
- Who uses it?
  Traffic Control Centres - provide official road services.
  Commercial actors - provide various services.
  Road Users - access both official and commercial services.
- Who rules it?
  Local, national and international authorities.

Level:

- Summary

Actors:

- Road User
- Local Authorities
- Technology Manufacturer
- Car Manufacturer
- Traffic Control Centre
- Commercial Actor

Actor	**Goal**	**Brief**
Road User	Be able to access ITS applications made available through authorities and commercial actors.	The Road User wants to increase his own traffic safety and efficiency, and at the same time enhance his driving experience.
Local Authorities	Deploy traffic safety and efficiency applications to prevent accidents and to lighten the burden of an existing road network.	The authorities want to increase traffic safety and efficiency. This could be done by building bigger and better roads, but this is a costly approach, and in some cities there is no option of building bigger roads because of lack of space. ITS applications would here benefit an existing road network in both safety and efficiency.
Technology Manufacturer	Produce and sell technology to the ITS market.	The ITS market is a big market which is still growing worldwide. Being the provider of new technology to this market is an appealing position which many technology manufacturers long for.
Car Manufacturer	Improve traffic safety, efficiency and enhance the driving experience of the Road User.	Car safety is an important factor for cars. Car manufacturers want to provide safety and traffic efficiency along with a good driving experience, which both will be enhanced through the use of ITS services.
Commercial Actor	Deploy commercial applications to enhance the driving experience of the Road User.	Because of the size of the ITS market, commercial actors want to use this market to sell their products and services.
Traffic Control	Ease the way traffic is regulated through the use of new ITS	ITS applications would automatically ease traffic control by guiding road users to less

Centre	applications.	congested roads. In addition there will be several applications which could be controlled from the Traffic Control Centre to help traffic flow, e.g. dynamic road signs.

Table 4 – CVIS Use Case Actors and Goals

Primary Actor:
- Road User

Preconditions:
- Local Authorities have decided to implement CVIS infrastructure.

Main Success Scenario:

Step	Textual description
1.	Authorities acquire and deploy CVIS infrastructure.
2.	Technology manufacturer supplies RSU to authorities.
3.	Technology manufacturer supplies OBU to Car Manufacturer.
4.	Traffic Control Centre deploys and offers public CVIS services.
5.	Commercial Actor deploys and offers private CVIS service(s).
6.	Road User buys car with OBU integrated from Car Manufacturer.
7.	Road User gets services through RSU infrastructure.

Variations

Step	Textual description
4’.	Either integrated into new cars, or manually built into older cars.
5’.	For example Road Condition Warning or Emergency Vehicle Approaching

Chapter 12 Applications analysis

This section presents two applications related to the CVIS project discussed earlier: Road Condition Warning and Approaching Emergency Vehicle. At the current stage, these are envisioned applications, and the analysis of them is based on those visions in addition to own interpretation and thoughts. This analysis first gives a short description of the application, before presenting a thorough Use Case for it, applying the GQM method and developing Test Cases. The final result of this analysis is the development of the test cases, which is discussed in the last part of this report.

The following applications are further discussed:

- Road Condition Warning (Road-to-Vehicle)
- Approaching Emergency Vehicle (Vehicle-to-Vehicle)

12.1 Application: Road Condition Warning

This is a typical Roadside to Vehicle application, with a *Store & Forward* mechanism. It is an electronic sign with dynamic content, sending information directly to the Road User. The Traffic Control Centre is responsible for maintaining information stored at each RSU, which in turn is sent out to every driver approaching that RSU. As an electronic sign, this application is treated as public, and every user able to receive and interpret the signal is allowed to do so.

This application is responsible for informing approaching drivers of any hazardous road conditions like icy or wet road or some kind of debris on the road [28].

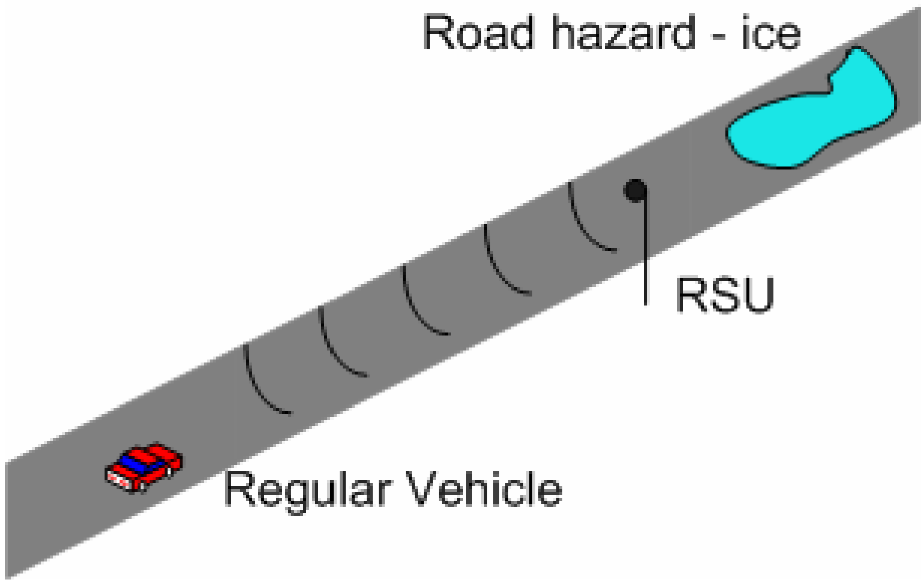

Figure 15 – Road Condition Warning

When placing regular warning signs, they have to be placed in a proper distance from the hazard so that the driver should have enough time to see the sign, identify its meaning, decide what action to take, and to perform that action. This is usually referred to as PIEV [28]:

- Perceive
- Identification / understanding
- Emotion / decision making
- Volition / execution of decision

This PIEV time can vary from 3 seconds to 10 seconds depending on the grade of judgement required from the driver and the time needed to break or manoeuvre [29].

12.1.1 Application Summary

Table 5 – Road Condition Warning Application Summary shows a technical summary of the application under discussion.

<table>
<tr><td colspan="3">Application name
Road Condition Warning</td></tr>
<tr><td colspan="2">Application Type
Safety application
(Cooperative Interurban Application – CINT)</td><td>Communication link
Non-continuously</td></tr>
<tr><td colspan="2">Bandwidth
Low</td><td>Setup time
Low</td></tr>
<tr><td colspan="3">Communication type
Unidirectional RSU → OBU
(VR3 from the CALM MM classification scheme – Transmitting real time situation on the road)</td></tr>
<tr><td colspan="3">Security</td></tr>
<tr><td>Authenticity</td><td>:</td><td>Of RSU: High – The user has to be sure that the RSU transmitting Road Condition Warnings is a valid RSU. This is to prevent random actors sending out false Road Condition Warnings, which could lead to hazardous situations, or degraded traffic float.
Of OBU: N/A – The RSU does not check whether or not the receiving OBU is a valid OBU, or if it is authenticated.</td></tr>
<tr><td>Authorization</td><td>:</td><td>Low – Any OBU able to pick up and interpret the signal is allowed to do so.</td></tr>
<tr><td>Integrity</td><td>:</td><td>High – The user has to be sure that the information received is exactly what the authenticated RSU actually sent out</td></tr>
<tr><td>Confidentiality</td><td>:</td><td>Low – Road Condition Warnings sent out are regarded as public information, and is not to be treated as secrets.</td></tr>
<tr><td colspan="3">Comments
An extra feature could be feedback from OBU. Vehicles report road conditions on the roads they are driving on. For example if the ABS triggers on a vehicle, it will send that information to the local RSU. In case of many ABS triggers in one area, the RSU will warn other vehicles of the road conditions.</td></tr>
</table>

Table 5 – Road Condition Warning Application Summary

12.1.2 Use Case: Obtain road condition information

This is a system function use case for the application "Road Condition Warning". OBU and RSU provision, setup and validation is not within the scope of this use case. Neither is infrastructure setup. It handles the scenarios which arise when the Road User (our Primary Actor) drive on roads which offer RCW services. For example, a Road User enters an RCW covered area, and the road up ahead is covered with ice. The RSU sends out warning signals saying that the road is icy, and advises a safe speed limit, e.g. 50 km/h. The Road User's vehicle receives the signal through its OBU which interprets the message and displays the warning. The Road User notices the warning on his drivers display, and slows down to avoid danger.

Figure 16 – RCW Use Case Diagram shows a graphical representation of the use case described in this section. Only the Obtain Road Condition Information-use case will be described in detail.

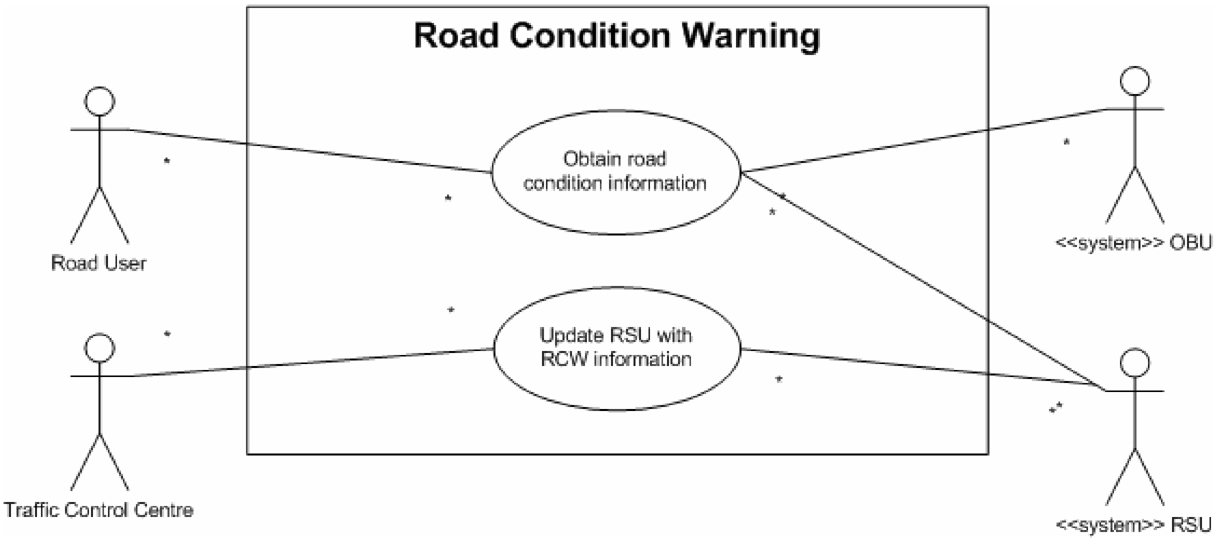

Figure 16 – RCW Use Case Diagram

Scope:

- Communication technology, CALM, is inside scope. Road-to-Vehicle communication.
- Integration of CALM into vehicles, CVIS, is inside scope.
- OBU and RSU provision, setup and validation is out of scope.
- The setup of RSU infrastructure and Traffic Control Centres is out of scope.

Topic	In	Out
Communication technology, CALM	In	
CVIS	In	
OBU provision, setup and validation		Out
RSU provision, setup and validation		Out
Infrastructure setup		Out
Traffic Control Centre setup		Out

Table 6 – RCW Use Case Scope

Stakeholders:

- Who wants it?
  Authorities – want it to improve road safety and traffic efficiency.
  Road Users – want to increase their traffic safety.
- Who makes it?
  Technology manufacturers – providing OBUs and RSUs.
  Car manufacturers – integrate OBUs into cars.
- Who uses it?
  Traffic Control Centres – provide official road services.
  Road Users – access both official and commercial services.
- Who rules it?
  Local, national and international authorities.

Level:

- User Goal level

Actor:

- Road User
- On Board Unit, OBU
- Road Side Unit, RSU
- Traffic Control Centre

Actor	**Goal**	**Brief**
Road User	Acquire road condition information before hazardous road conditions appear.	Road User has installed an OBU in his car. Road User travels along an RCW-serviced road. If a hazardous road condition is to appear, the Road User would be warned.
OBU	Catch incoming service signals from RSUs, and take actions on behalf of them.	The OBU listens for incoming signals. When a signal is found, it checks it for signal type and validity. If valid, the OBU displays the message on the driver's display.
RSU	Send out messages regarding road conditions.	Continuously send out messages telling what condition the road is in.
Traffic Control Centre	Update RSUs when hazardous road conditions are reported.	When new information regarding road conditions appears, the TCC will update RSUs in that area.

Table 7 – RCW Use Case Actors and Goals

Primary Actor:

- Road User – End user of the system.

Preconditions:

- Road User has an OBU.
- Road User has authorized himself to the OBU.
- RCW service has updated road condition information.
- RSU sends service signals (loop).

Success guarantees:

- If there are hazardous road conditions, the Road User would be notified x% of the time, where x is a threshold value for this application. Not 100% since a Road User could arrive at a road hazard which hasn't been reported.

Minimal guarantees:

- None.

Trigger:

- Road User enters area covered by an RSU providing RCW service.

Main Success Scenario:

Step	Textual description
1.	Road User enters area covered by an RSU.
2.	OBU receives signal from RSU.
3.	OBU validates signal.
4.	OBU classifies signal as an RCW signal.
5.	OBU interprets the RCW signal.
6.	OBU shows message containing current Road Conditions on the Road User's display.
7.	Road User reads Road Conditions, and takes proper action.
x.	At any time the TCC can run "Update RSU with RCW information"

Extensions

Step	Textual description
3a.	Signal received is an invalid signal, e.g. from an invalid RSU, not known by the OBU.
4a.	Signal received is classified as another signal, not an RCW signal.

Variations

Step	Textual description
5'.	Other actions can be taken.
6'.	Messages can vary in priority: (1 being lowest priority – 5 being highest) 1. Excellent road conditions, nothing special to report. 2. Good road conditions, road may be wet or have some debris. 3. Medium, road may be uneven, a bit slippery or quite a lot of debris. 4. Bad road conditions, road may be covered with ice, heavy water and so. 5. Road blocked

12.1.3 Finding metrics

To be able to define metrics for this application, the discussed Goal-Question-Metric approach would be applied.

High level goal:	**Evaluate if current and near-future technology will be able to support the Road Condition Warning application**

Goal 1:	**The application must establish contact with the roadside at least x seconds before the vehicle reaches the point. (PIEV)**
Question 1:	*What is the range of road side transmissions?*
Metric:	• Metres (maximum range, minimum range)
Question 2:	*What is the speed for the car to receive the transmission?*
Metric:	• Meters per second / Kilometres per hour
Question 3:	*What is the latency of receiving, validating, interpreting and displaying the message?*
Metric:	• Milliseconds • Type of protocol used/protocol settings • Carrier • Security features
Question 4:	*What is the required bandwidth?*
Metric:	• Carrier • bps

Goal 2:	**Must satisfy security requirements**
Goal 2.1:	**The RSU must be authenticated to ensure that the information received is valid.**
Question 1:	*Which authentication mechanism is used?*
Metric:	• MD5 • SHA-1
Question 2:	*How long time is used for security mechanisms?*
Metric:	• Milliseconds

Goal 2.2:	**The OBU must ensure the integrity of the data received.**
Question 1:	*What mechanism is used?*
Metric:	• CRC, Hash, Cryptographic hash
Question 2:	*What is the key length of encryption key?*
Metric:	• Key length
Question 3:	*How much time is used for checking integrity?*
Metric:	• Milliseconds

List of metrics found:

- Metres (range)
- Kilometres per hour (speed)
- Bits per second (bandwidth)
  Depends on
    - Carrier
- Milliseconds (latency)
  Depends on
    - Carrier
    - Authentication mechanism
    - Integrity mechanism
    - Key length

This application is thought of as a road side application, with road side transmitters sending out information to nearby road users. Because of this, the available carriers would be limited to cost effective, short ranged technology like WLAN. The main goal of this application is to warn approaching drivers early enough when they approach a place covered by an RCW application. This will be decided by the range of the transmission and the speed of the approaching vehicle, so these two factors would make a test case.

The latency metric is built up from the lesser parts of receiving, validating, interpreting and displaying. The latency of receiving and validating the signal is very dependent on which carrier is used and which security mechanisms are implemented. The performance of the security mechanisms are dependent on what level of security is chosen, for example the key length of an encryption key.

From these metrics test cases developed and measurements gathered. These measurements would hopefully be able to satisfy the goals set and contribute to the higher level goal of evaluating the application.

12.1.4 Developing test cases

From the metrics just discussed we have established the foundation for three test cases. First we test the bandwidth of the different carriers and decide which carrier(s) we could use in this application:

- Test case 1: Carrier and Bandwidth

Then we test how the communication set up and link performance is depending on which security mechanisms we are using. This will give us a measurement for how much time is required from the signal reaches the vehicle until the driver is notified:

- Test case 2: Security mechanisms and latency

Finally we test how range and speed affects the application. This way we can decide what ranges must be used at which speeds for the driver to get the message in time. The moving vehicle might also affect the bandwidth and latency, something we have to consider when we're testing.

- Test case 3: Range of transmission and speed of vehicle

Test case 1: Carrier and Bandwidth

Brief:
The bandwidth requirement for this application is very small. This test case would test the real bandwidth of the different carriers in a mobile environment, and see how they might differ from the theoretical specifications.

Input:

- Carrier

Use Case step(s) tested: N/A

Carrier	Expected bandwidth	Reported bandwidth
InfraRed	Depends on initial settings	
Millimetre 60GHz	Depends on initial settings	
WLAN 5.9GHz	6-54 Mbps	

Table 8 – Test Case 1: Carrier and Bandwidth

Test case 2: Security mechanisms and latency

Brief:
This application has requirements for authentication and integrity to ensure that road users get valid information through this application. Invalid information could cause hazardous situations and endanger human lives.

Input:

- Authentication on/off
- Integrity on/off

Use Case step(s) tested: 2, 3 and 4.

Authentication	Integrity	Time taken
Off	Off	
On	Off	
Off	On	
On	On	

Table 9 – Test Case 2: Security mechanisms and latency

Test case 3: Range of transmission and speed of vehicle

Brief:
One of the main inputs to this application, and all applications of this type, is the speed of the vehicle. Possible questions would be: How does the speed of the vehicle affect performance of electronic road signs? How would driving too slow or too fast affect the system?

This test case would check the range of the signal with vehicle speed as the variable input, *Table 10 – Test Case 3: Range of Transmission and Speed of Vehicle*. The first parameter to record is how far away the signal is detected. Then the system would validate and interpret the signal before presenting the information. This is the point where the Road User has to perform PIEV, and the estimated time of arrival in seconds would be recorded.

Input:

- Speed of car

Use Case step(s) tested: 1 and 2

Input	Recorded output							
Speed of car (km/h)	Signal detection		Signal validated		Signal interpreted		Message displayed	
	Range	ETA	Range	ETA	Range	ETA	Range	ETA
20								
30								
50								
80								
100								
120								
140								

Table 10 – Test Case 3: Range of Transmission and Speed of Vehicle

12.2 Application: Emergency Vehicle Approaching

When emergency situations happen, time is one of the most important aspects. The more time that elapses between when the incident occurs to when the emergency personnel arrives, the higher is the risk of for example losing lives. That is why there are uniformed emergency vehicles equipped with lights and sirens so that other road users should give way when emergencies occur. But for a regular driver, it might be hard to both hear and see the emergency vehicle in time, because of the distance to the emergency vehicle, geographic obstacles, weather conditions and so on. Slow-reacting drivers would severely slow down emergency vehicles. Another concern is emergency vehicles travelling at high speeds encountering unaware drivers either on the road or in intersections. This could get severe consequences in addition to the already existing situation.

The Emergency Vehicle Approaching application is a proposed application which would decrease travelling time for emergency vehicles and increase safety for both emergency vehicles and other road users. The main idea of this application is to send out electronic warnings to all other road users, and show it directly on their drivers display. This warning signal will have a longer reach, and since the signal is interpreted and displayed on the driver's display, it would catch the driver's attention much easier. The message on the driver's display would also show recommended actions for the driver.

The Emergency Vehicle Approaching application would also have an Emergency Vehicle to Road Side function, so that the traffic can be regulated to let the Emergency Vehicle pass. The Road Side units could for example let all the traffic lights in the Emergency Vehicles path turn green to speed up travel and avoid crossing traffic [31].

In short, this application would increase driver awareness of emergency vehicles, decrease emergency vehicle travel time and increase emergency vehicle safety.

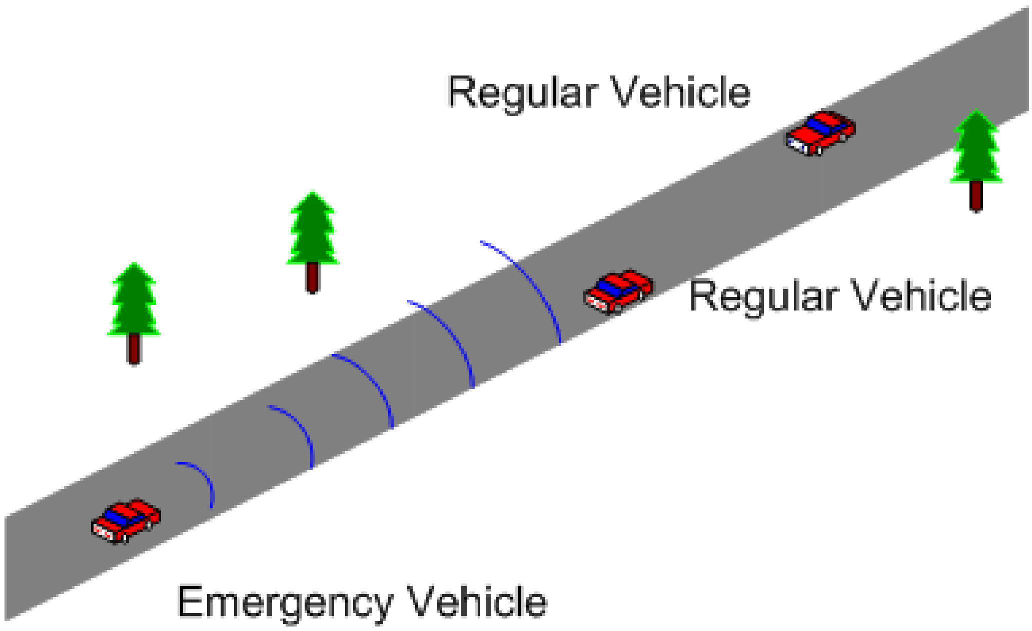

Figure 17 – Emergency Vehicle Approaching

The GST Rescue sub-project has an equivalent application referred to as *Blue Wave*. This is one of many applications in this sub-project, for which there already are done analysis and created use cases. The Blue Wave Use Case would be used as a reference, it would be further analysed and an extended Use Case would be created [31]).

One of the main parts of their analysis is the user needs in these applications. These are both system general and application specific user needs, and the ones that are interesting for the Emergency Vehicle Approaching application are summed up in Table 11 – Extraction from GST Rescue User Needs [31].

User Need ID	Description
UN RSQ 0074	The user shall require that the Blue Wave/Virtual Cones receiving device shall be fitted to all new vehicles from a given date.
UN RSQ 0075	The user shall require that the Blue Wave/Virtual Cones transmission device shall be fitted to all emergency service vehicles.
UN RSQ 0076	The user shall require that the Blue Wave/Virtual Cones transmission device shall identify what type of emergency service vehicle it is fitted to.
UN RSQ 0077	The user shall require that the Blue Wave/Virtual Cones transmission device shall only be fitted to authorised vehicles.
UN RSQ 0078	The user shall require that the Blue Wave/Virtual Cones transmission device shall only function when activated by the emergency service personnel.
UN RSQ 0079	The user shall require that on activation the Blue Wave/Virtual Cones transmission device shall send out a message to warn of the approach or presence of an emergency vehicle.
UN RSQ 0080	The user shall require that the Blue Wave/Virtual Cones transmission device shall offer a range of messages to the emergency service personnel.
UN RSQ 0081	The user shall require that the range/coverage of the Blue Wave/Virtual Cones transmission should be automatically adjustable by speed and location of the emergency service vehicle.
UN RSQ 0082	The user shall require that only people that are on the road ahead and on connecting roads ahead and to the side of the emergency service vehicle, on its route and within a prescribed distance should receive the warning from the Blue Wave transmission.
UN RSQ 0083	The user shall require that the Blue Wave/Virtual Cones transmission device shall be capable of being activated on a one touch approach or in combination with other warning instruments.
UN RSQ 0084	The user shall require that the activation of the Blue Wave/Virtual Cones transmission device shall be customisable to the requirements of the emergency service personnel as individuals and with preset functions.
UN RSQ 0085	The user shall require that the Blue Wave/Virtual Cones transmission device shall not interfere with any other components of the emergency service vehicle.
UN RSQ 0086	The user shall require that the Blue Wave/Virtual Cones transmission and receiving device shall be designed to be cognisant of HMI.
UN RSQ 0087	The user shall require that the Blue Wave/Virtual Cones device shall be designed to be capable of on transmitting, being received by any vehicle or other authorised device, equiped with a receiving device, no matter from where the vehicle or authorised device is from (roaming).
UN RSQ 0088	The user shall require that when activated the Blue Wave/Virtual Cones or other GST Rescue Emergency Service Device shall warn the emergency service vehicle occupants that it has been activated in a way that is

	cognisant of HMI
UN RSQ 0089	The user shall require that the Blue Wave/Virtual Cones or other GST Rescue Service transmitting/receiving device shall inform the occupants of the emergency service vehicle if it is not working (defective), whether it is activated or not.
UN RSQ 0090	The user shall require that the Blue Wave/Virtual Cones transmission/receiving device shall work in all weather and conditions that are applicable in its area of operation.
UN RSQ 0091	The user shall require that the Blue Wave/Virtual Cones transmitting/receiving device shall be designed so that it is robust and reliable.
UN RSQ 0092	The user shall require that the Blue Wave/Virtual Cones receiving device shall receive and interpret such a message and where appropriate provide the warning to the vehicle occupants or to the person in cases of other authorised devices in a language independent form.
UN RSQ 0093	The user shall require that the Blue Wave warning shall inform the person or vehicle occupants the type of emergency service vehicles approaching or present in a way that is cognisant of HMI.
UN RSQ 0094	The user shall require that the Blue Wave/Virtual Cones device shall warn the person or vehicle occupants from which direction the emergency vehicle is approaching in a way that is cognisant of HMI.
UN RSQ 0095	The user shall require that the Blue Wave device shall warn the person or vehicle occupants the number of emergency service vehicles that are approaching.
UN RSQ 0096	The user shall require that the Blue Wave/Virtual Cones device should provide advice as to what action they should take.
UN RSQ 0097	The user shall require that the Blue Wave/Virtual Cones device shall when it no longer receives a warning, reset and give a thank you message to the person or driver.
UN RSQ 0098	The user shall require that where a Blue Wave/Virtual Cones receiving device is fitted to an emergency service vehicle, it shall warn the emergency vehicle occupants of other emergency vehicles approaching and the direction in a way that is cognisant of HMI for vehicles used in emergency service driving.
UN RSQ 0099	The user shall require that the fitting and working of a Blue Wave/Virtual Cones receiving device shall be a legal requirement.
UN RSQ 0100	The user shall require that if a Blue Wave/Virtual Cones receiving device is not working (defective), it shall notify the person or vehicle occupants.

Table 11 – Extraction from GST Rescue User Needs [31]

12.2.1 Application Summary

Table 12 – Emergency Vehicle Approaching Application Summary shows a technical summary of the application under discussion.

<table>
<tr><td colspan="3">Application name
Emergency Vehicle Approaching</td></tr>
<tr><td colspan="2">Application Type
Safety application
(CVIS CURB)
(GST RESCUE – UC RSQ 006 – Blue Wave)</td><td>Communication link
Non-continuously</td></tr>
<tr><td colspan="2">Bandwidth
Low</td><td>Setup time
Low</td></tr>
<tr><td colspan="3">Communication type(s)
OBU → OBU
OBU → RSU

(VV4 – from the CALM MM classification scheme – Transmit information of special vehicle)</td></tr>
<tr><td colspan="3">Security</td></tr>
<tr><td>Authenticity</td><td>:</td><td>Of transmitting OBU: High – The receiving Road User has to be sure that the transmitting OBU is a valid OBU. This is to prevent random actors sending out false Emergency Vehicle Approaching messages.
Of receiving OBU: Low – Data sent is public information, and the transmitting OBU doesn't care about the authenticity of the receiving OBU.</td></tr>
<tr><td>Authorization</td><td>:</td><td>Low, data sent is public information and every device able to receive it should be allowed to.</td></tr>
<tr><td>Integrity</td><td>:</td><td>High – The user has to be sure that the information received is exactly what the authenticated transmitting OBU actually sent out.</td></tr>
<tr><td>Confidentiality</td><td>:</td><td>Low, data sent is public information and doesn't need to be hidden through encryption or similar mechanisms.</td></tr>
<tr><td colspan="3">Comments</td></tr>
</table>

Table 12 – Emergency Vehicle Approaching Application Summary

12.2.2 Use Case: Inform Road User of Emergency Vehicle approaching

Since this application is a Vehicle-to-Vehicle application, we have to differ between the vehicles communicating. Here we have the Emergency Vehicle (EV) which is supplying the service, i.e. sending out the signal, and the Regular Vehicle (RV) which is using the service, i.e. receiving the signal.

Figure 18 – EVA Use Case Diagram shows a graphical representation of the use case discussed in this section.

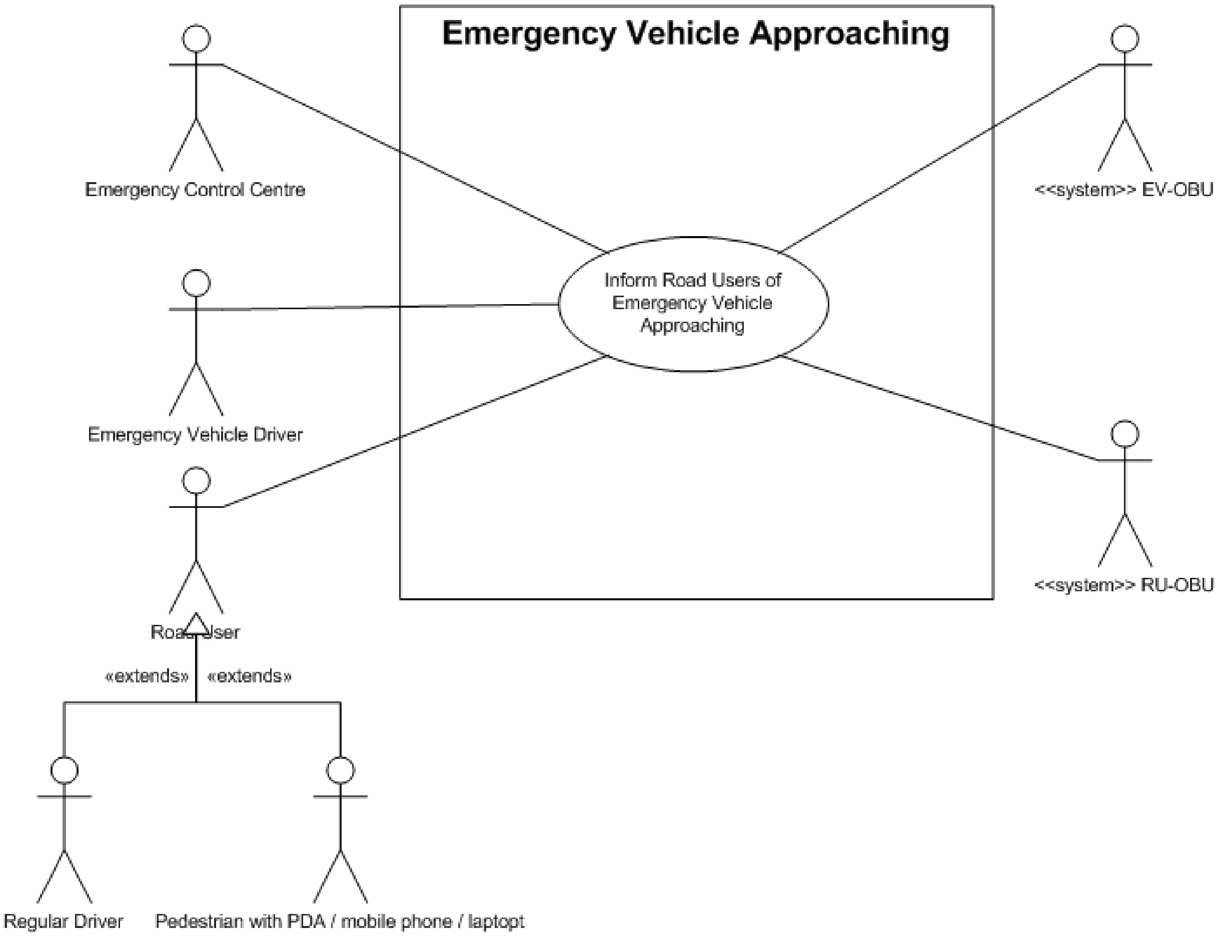

Figure 18 – EVA Use Case Diagram

Scope:

- Communication technology, CALM, is inside scope. Road-to-Vehicle communication.
- Integration of CALM into vehicles, CVIS, is inside scope.
- OBU setup is out of scope.

Topic	In	Out
Communication technology, CALM	In	
CVIS	In	
OBU provision, setup and validation		Out
Infrastructure setup		Out
Emergency Control Centre setup		Out

Table 13 – EVA Use Case Scope

Stakeholders:

- Who wants it?
  Authorities – want it to improve road safety and traffic efficiency.
  Road Users – want to increase their traffic safety.
- Who makes it?
  Technology manufacturers – providing OBUs and RSUs.
  Car manufacturers – integrate OBUs into cars.
- Who uses it?
  Traffic Control Centres – provide official road services.

Road Users – access both official and commercial services.

- Who rules it?
  Local, national and international authorities.

Level:

- User level

Actors:

- Emergency Vehicle Driver
- Road User
- Emergency Vehicle's OBU (EV-OBU)
- Road Users's OBU (RU-OBU)
- Emergency Control Centre

Actor	Goal	Brief
Emergency Vehicle Driver	Warn other Road Users of this emergency vehicle.	Emergency Vehicle has a transmitting device installed. When the Emergency Vehicle is responding to a situation, it will transmit an electronic warning, reaching other Road Users as early as possible so that the road could be cleared, both to avoid accidents and to shorten the travel time of this emergency vehicle.
Road User	Acquire emergency vehicle warnings from incoming emergency vehicles.	Road User has installed an authorized receiving device. When an emergency vehicle is heading this way, the receiving device would warn the Road User of this incoming emergency vehicle. The earlier this warning comes, the better it is since the Road User can take proper actions in a calm and controlled way.
EV-OBU	Send out warning signals regarding this emergency vehicle.	When the Emergency Vehicle Driver turns on the Emergency Vehicle Approaching application, the EV-OBU would start transmitting a warning signal. This signal would contain the emergency vehicle's location, direction, speed, route and type.
RU-OBU	Catch incoming service signals from EV-OBU, and take actions on behalf of them.	The OBU listens for incoming signals. When a signal is found, it checks it for signal type and validity. If valid, the OBU displays a message to the Driver showing what emergency vehicle is approaching, from where, estimated time of arrival and advice of which actions to take.
Emergency Control Centre	Dispatch Emergency Vehicle.	When an incident is reported, the ECC dispatches emergency vehicles to that location.

Table 14 – EVA Use Case Actors and Goals

Primary Actor:

- Emergency Vehicle Driver

Preconditions:

- A valid OBU is installed in both vehicles.

Success guarantees:

- Regular Vehicle driver is informed of approaching Emergency Vehicle, and from which direction it is approaching.

Minimal guarantees:

- None.

Trigger:

- Incident occurs and is reported.

Main Success Scenario:

Step	Textual description	User need(s) covered
1.	Incident occurs and is reported.	
2.	Emergency Control Centre dispatches Emergency Vehicle.	
3.	EV Driver turns on sirens and lights.	
4.	EV Driver decides to turn on EVA system.	78, 80, 83, 84, 88
5.	EV-OBU gets positional data from GPS unit.	
6.	EV-OBU transmits warning message to people in Emergency Vehicle's vicinity based on type, speed, direction and destination of Emergency Vehicle.	76, 79, 81, 85
7.	RU-OBU receives and interprets incoming signal from the Emergency Vehicle as an EVA warning signal.	82, 100
8.	RU-OBU interprets message in EVA signal as a valid message for this device.	92
9.	RU-OBU shows warning message and advice on action to take on driver's display in a language independent form.	93, 94, 95, 96
10.	RU Driver reads warning message from display saying where the EV is coming from and takes advised actions.	
11.	RU-OBU resets warning display and shows a Thank You message to RU when EV has passed.	97
12.	EVA system turned off by EV Driver when trip is finished.	

Extensions

Step	Textual description	User need(s) covered
4a.	EV-OBU reports malfunction	89
4a1.	EV Driver turns of EVA system, is aware of malfunction and regulates driving pattern.	100
5a.	EV-OBU is unable to acquire positional data from GPS unit	
5a1.	EV-OBU formats message with position and direction as unknown entities.	
7a.	RV-OBU receives and interprets incoming signal as an invalid signal.	
7a1.	RV-OBU notifies driver of invalid signal or ignores it, depending on the driver's configuration	

7b.	RV-OBU receives and interprets incoming signal as a signal for another application.	
7b1.	RV-OBU sends signal to the right application or ignores it, depending on the driver's configuration.	

Variations

Step	Textual description	User need(s) covered
7'.	RV-OBU could also be other authorized devices such as mobile phones, laptops, etc.	87

12.2.3 Finding metrics

To be able to define metrics for this application, the discussed Goal-Question-Metric approach would be applied. For easier identification of goals, the numbering of them will continue from the previous application. Goals 1 to 3 were defined for the RCW-application, and this section will define goals 4-6 for this application.

High level goal:	**Evaluate if current and near-future technology will be able to support the Emergency Vehicle Approaching application.**

Goal 4:	**The Emergency Vehicle application must establish contact with other regular vehicles at least x seconds before they meet each other.**
Question 4.1:	*What is the range of the Emergency Vehicle transmissions?*
Metric:	• Metres (maximum range, minimum range)
Question 4.2:	*What are the relative speeds of the communicating vehicles?*
Metric:	• Meters per second / Kilometres per hour (depending on direction)
Question 4.3:	*What is the latency of receiving, validating, interpreting and displaying the message?*
Metric:	• Milliseconds • Type of protocol used/protocol settings • Security features
Question 4.4:	*Which carriers are available?*
Metric:	• Carrier

Goal 5:	**The Emergency Vehicle Approaching application must send correct positional information, and receivers must correctly calculate estimated time of arrival.**
Question 5.1:	*What is the precision of the positioning data sent?*
Metric:	• Metres
Question 5.2:	*What is the precision of the time calculated by the receiving OBU?*
Metric:	• Seconds

Goal 6:	**Must satisfy security requirements**
Goal 6.1:	**The receiving OBU must authenticate to ensure that the information received is valid.**
Question 6.1.1:	*Which authentication mechanism is used?*
Metric:	• MD5

		• SHA-1
Question 6.1.2:	*How long time is used for security mechanisms?*	
Metric:	• Milliseconds	

Goal 6.2	**The OBU must ensure the integrity of the data received.**
Question 6.2.1:	*What mechanism is used?*
Metric:	CRC, Hash, Cryptographic hash
Question 6.2.2:	*What is the key length of encryption key?*
Metric:	Key length
Question 6.2.3:	*How much time is used for checking integrity?*
Metric:	Milliseconds

List of metrics found:

- Metres, range of transmission
- Kilometres per hour (speed, relative)
- Metres, GPS precision
- Seconds, ETA calculation precision
- Bits per second (bandwidth)
  Depends on
    - Carrier
- Milliseconds (latency)
  Depends on
    - Carrier
    - Authentication mechanism
    - Integrity mechanism
    - Key length

This is an event-driven application, where the emergency service personnel activate the event by turning on the Emergency Vehicle Approaching application, sending out electronic warnings to other road users. Because of this, the emergency vehicles need to have a transmitting device installed. This narrows down the list of carriers available for this application, and the most likely carrier would be short ranged carriers like WLAN. As with the Road Condition Warning application, the main goal of this application is to warn other road users of the approaching emergency vehicle early enough so they can take correct actions. This will be decided by the range of the transmission, and the speed of both the emergency vehicle and the receiving vehicle, so range and speed will make a test case for this application as well. But the scenario would be a bit different since this application is dealing with two moving objects and not a stationary transmitter such as the RSU in the Road Condition Warning application.

The next metrics found are the precision metrics for location and estimated time. Both the Emergency Vehicle and the receiving device need to have a GPS service installed in order to calculate position and estimated time. The Emergency Vehicle sends information regarding its position, direction and speed, and the receiving vehicle would calculates the estimated time of arrival based on this information plus its own location. Hence, the estimated time of arrival calculation is directly dependent on the location information sent from the Emergency Vehicle. This part of the application would decide the quality of this service. A general warning is good, but a warning that says where the vehicle is coming from and how far away it is, is much better.

12.2.4 Developing test cases

The carrier in this application would probably be a WLAN carrier. We still need to run a test case on the communication set up to see how security mechanisms affect the latency in this Vehicle-to-Vehicle scenario. This might be a bit different than the Road-to-Vehicle scenario in the previous application.

- Test case 1: Security mechanisms and latency in a Vehicle-to-Vehicle scenario

The next metric discussed is the GPS and Estimated Time of Arrival precision of this application. Issues here are route tracing and deciding, if applicable, when the vehicles will meet each other. The quality of this service is reduced dramatically if the information received turns out to be completely wrong.

- Test case 2: GPS and ETA precision

Range, speed and direction might affect the performance of this application. Two moving objects, moving at different speeds and maybe in different directions might have an impact on transmission range, latency and GPS/ETA precision

- Test case 3: Range of transmission, relative speed and direction of vehicles in a Vehicle to Vehicle scenario

Test Case 1: Security mechanisms and latency in a Vehicle-to-Vehicle scenario

Brief:
This test case is going to test the communication set up between two OBUs, based on which authentication and integrity mechanisms are being used. Stricter mechanisms would in most cases mean longer setup time. And the mobile environment might affect setup time of the different mechanisms differently than in a wired environment.

Inputs:
- Authentication on/off
- Integrity on/off

Use Case step(s) tested: 7 and 8.

Authentication	**Integrity**	**Time taken**
Off	Off	
On	Off	
Off	On	
On	On	

Table 15 – Test Case 1: Security Mechanisms and Latency in a Vehicle-to-Vehicle Scenario

Test Case 2: GPS and Estimated Time of Arrival precision

Brief:

This test case would test the precision of the live calculation of location and estimated time of arrival. The application should be able to decide if a particular vehicle should display the received warning message based on position, speed, direction and selected route of the emergency vehicle. If the message is displayed, the application should display where the emergency vehicle is, and be able to calculate when it reaches the current vehicles location.

Inputs:

- Relative speed
- Direction
- Position

Use Case step(s) tested: 6 and 9.

Inputs						Expected output		Recorded output	
Direction	EV Speed (km/h)	Regular Vehicle speed (km/h)	Relative speed (km/h)	Relative speed (m/s)	Range (metres)	Displayed direction	Calculated ETA (seconds)	Displayed direction	Calculated ETA (seconds)
Behind	50	30	20	5,56	1000	Behind	180,00		
Behind	50	30	20	5,56	500	Behind	90,00		
Behind	50	30	20	5,56	100	Behind	18,00		
Behind	80	50	30	8,33	1000	Behind	120,00		
Behind	80	50	30	8,33	500	Behind	60,00		
Behind	80	50	30	8,33	100	Behind	12,00		
Behind	120	80	40	11,11	1000	Behind	90,00		
Behind	120	80	40	11,11	500	Behind	45,00		
Behind	120	80	40	11,11	100	Behind	9,00		
Behind	80	30	50	13,89	1000	Behind	72,00		
Behind	80	30	50	13,89	500	Behind	36,00		
Behind	80	30	50	13,89	100	Behind	7,20		
Front	50	30	80	22,22	1000	Front	45,00		
Front	50	30	80	22,22	500	Front	22,50		
Front	50	30	80	22,22	100	Front	4,50		
Front	80	50	130	36,11	1000	Front	27,69		
Front	80	50	130	36,11	500	Front	13,85		
Front	80	50	130	36,11	100	Front	2,77		
Front	120	80	200	55,56	1000	Front	18,00		
Front	120	80	200	55,56	500	Front	9,00		
Front	120	80	200	55,56	100	Front	1,80		
Front	80	30	110	30,56	1000	Front	32,73		
Front	80	30	110	30,56	500	Front	16,36		
Front	80	30	110	30,56	100	Front	3,27		

Table 16 – Test Case 2: GPS and Estimated Time of Arrival precision

Test Case 3: Range of transmission, relative speed and direction of vehicles in a Vehicle-to-Vehicle scenario

Brief:

This test case is going to test the range of the transmission. Factors like relative speed and direction of the vehicles would probably affect the transmission range.

Inputs:

- Relative speed
- Direction

Use Case step(s) tested: 5 and 6.

Input				Recorded output							
Direction	Emergency Vehicle Speed (km/h)	Regular Vehicle speed (km/h)	Relative speed (m/s)	Signal detection		Signal validated		Signal interpreted		Message displayed	
				Range	ETA	Range	ETA	Range	ETA	Range	ETA
Behind	50	30	5,56								
Behind	80	50	8,33								
Behind	120	80	11,11								
Behind	80	30	13,89								
Front	50	30	22,22								
Front	80	50	36,11								
Front	120	80	55,56								
Front	80	30	30,56								

Table 17 – Test Case 3: Range of Transmission, Relative Speed and Direction of Vehicles in a Vehicle-to-Vehicle Scenario

Part 4: Conclusion and Further work

This section looks back on what has been done so far in this report, and sums up the achievements made. Results from each method executed are presented and discussed. Chapter 14 gives a short conclusion to this report, while Chapter 15 presents what assignments lay ahead for future work.

Chapter 13 Discussion

There were three main methods applied to perform the evaluation of each application: Use Cases, GQM and Test Cases.

The use case is a thorough method which can be used to show everything from big picture of an organisation down to a detailed description of a function in an application. In this report, the use case was used both to describe the overall setup of the system, down to the applications themselves. The CVIS use case illustrated how the system was built up and which actors would interact with the system at different stages. This use case was a summary use case made to show the big picture of the system. It showed that to make this system work, actors like the authorities, technology manufacturers, car manufacturers and traffic control centres all have to co-operate and contribute. This shows that the work of standardisation and co-operation done by ERTICO and other ITS associations is important. And last but not least, it showed that the road user has to realize the need of this system as well.

The other two use cases, Road Condition Warning and Emergency Vehicle Approaching, were user level use cases. They showed directly how the application would work from a user's point of view. They also showed which other actors that are directly involved in a user scenario, and what their goals might be. This is important on the user level use cases as well, because the application will not be achievable if one or more of the actors are not interested in participating.

In addition to relating actors to the system and its applications and showing their respective goals, the use case indicated technical needs and requirements which would lay the foundation for the next method, Goal-Question-Metric.

The GQM method took the step from goals defined in the use case to measurable factors, metrics, which would define the success or failure of the goals proposed. The metrics found through this method were:

- **Range of transmission**
  Coverage of a medium was one of the issues in mobile computing, as discussed in Chapter 6 Mobile Environment. This was the issue of communication, where the size of a cell, i.e. range of a transmitter, was one of the obstacles which had to be dealt with. Different media have different coverage, but settings of a medium could affect its coverage.
- **Speed of client**
  This metric would deal both with the communication and mobility issues of mobile computing. Communication features such as range, setup time and bandwidth would probably be affected by the speed of the vehicle. Mobility features such as address-handover would also be affected by the speed of the vehicle. Proposed mechanisms like *Predictive Mobile IP for rapid movement [32]* and *A Seamless Handoff for Dual-interfaced Mobile Devices in Hybrid Wireless Access Networks [34]* might be applicable here.
- **GPS and ETA precision**
  These metrics might be considered out of scope in this report since GPS precision depends on out-of-scope technology, delivered from an external actor and ETA precision is only dependent of correct data from the GPS and correct implementation of the software. But as with other technology in ITS, this could be affected by factors

like client movement speed and environmental interferences, and it will be interesting to see how this will perform in practice.

- **Bandwidth of transmission**
  Even though the applications evaluated in this report had very low requirements regarding bandwidth, this metric is an important one when it comes to ITS applications in general. This is also a part of the communication issue in mobile computing, where size of bandwidth along with variations in bandwidth are usual problems. Variations in bandwidth makes the communication link unpredictable, and functions like video/audio-streaming would be unable to work as intended. This metric might be more useful for other applications proposed, but not evaluated in this report, e.g. video/audio-streaming, continuous internet access and file upload/download.
- **Latency of setup**
  Both of the applications evaluated are time-dependent, with setup-time as one of the most critical requirements. The applications need to get the data as fast as possible, since the more time the receiver has, the more time can be put into making good decisions and manoeuvres. This was described as PIEV time in Chapter 12 Road Condition Warning. This metric is probably very dependent on which mechanisms that are turned on, e.g. security mechanisms.
  In applications like video/audio-streaming, continuous internet access and file upload/download, the latency of setup would probably not have such a big influence since they're not as time-critical. But in those applications the latency of handover, and the setup of a new media, would be more important.

From the metrics listed, none of them directly deals with the issue of portability, presented in Chapter 6 Mobile Environment. This issue was concerned about limited resources in portable devices, e.g. low power supply. In the ITS scenario, the clients, usually vehicles, have more resources than a regular portable device, and would in that sense differ from the main issues of mobile computing. Another part of this issue was that of small user interface, and this might in fact be an issue in ITS applications since in-car computers usually have smaller user interfaces than regular computers. And these applications might need other means of user input since the driver cannot use a keyboard or mouse while driving; a touch-screen is probably the most intuitive user interface.

These metrics were the foundation for the next method used in this evaluation: Test Cases.

The Test Cases were the final result of the application evaluation. They were created to test how different inputs of the system would affect the metrics identified by the GQM method. For the first application, Road Condition Warning, three test cases were created:

- **Test case 1: Carrier and Bandwidth**
  In this Road-To-Vehicle scenario, the available carriers were InfraRed, MM and WLAN. This test case was a simple test case to see if the practical bandwidth matches with the theoretical numbers given. The results from this test case might not help the evaluation of the current application, since this is a Store & Forward application, without a prolonged uplink between the two nodes. But the results would be useful for applications requiring prolonged communication, which will establish a link for sending information back and forth between the nodes.
- **Test case 2: Security mechanisms and latency**
  Authentication and integrity were two important parameters for this application, but at the same time, the parameter setup latency was just as important. It would be no good

getting valid information if it is outdated, and vice versa; no use getting information in time if it turns out to be false. This test case was developed to see how the security mechanisms in IPv6 were affecting the setup latency of the carrier chosen. This use case could also have been extended to test different other mechanisms than the ones in IPv6, or even try out different configurations of the IPv6 mechanisms. This way it would be possible to draw some relations between security level and time used to set it up.

- **Test case 3: Range of transmission and speed of vehicle**
  This test case was created to ensure that the application conforms to the PIEV principle. This principle stated that a Road User needs a certain amount of time to be able to Perveive – Identify – Emotion (decide) – Volition (manoeuvre). The test case recorded parameters like distance of signal and processing time to be able to calculate PIEV time. Through this, the test case would also give an indication on the setup time of this application, the metric which was thoroughly tested in the previous test case. This test case would show if the speed of the vehicle would have any effect on the setup time.

For the other application, Emergency Vehicle Approaching, the following three test cases were developed:

- **Test case 1: Security mechanisms and latency in a Vehicle-to-Vehicle scenario**
  This test case is the same as Test Case 2 of RCW, the only difference is that here the setup and communication is between two vehicles (OBU-to-OBU) which both are moving. Latency might differ from the RSU-to-OBU scenario, something which is important to know when designing these kinds of applications.
- **Test case 2: GPS and ETA precision**
  The ability to pinpoint its own and other vehicles' location is an important feature in ITS applications, and the Emergency Vehicle Approaching application was a perfect example of this. Without the positional information, this application would be an early warning system, just like the sirens and lights, just with electronic signals. Better than just the sirens and lights, but not as good as it could be with positional information and estimated time of arrival. This test case would also record how the GPS would work in this mobile scenario and if the transmission and signal processing latency would affect precision.
- **Test case 3: Range of transmission, relative speed and direction of vehicles in a Vehicle to Vehicle scenario**
  This was fairly similar to the *Range of transmission* test case from Road Condition Warning application, in the way that it also records how far the transmission reached and how long time the signal processing took. The main difference was that in this test case, the communication was between two moving vehicles, coming at each other either from behind or from ahead. Any differences between these two communication scenarios would be discovered here.

The test cases presented in this report were pretty straight forward and simple. They were developed to test the core functionality of the applications under evaluation, and would hopefully give a good indication on how they would work in a real situation when the system is deployed. They would act in a *proof-of-concept* manner, to see if the technological visions are viable in practice.

A combination of more test cases could have been more informative. For example, in what way would the bandwidth of a carrier be affected by different speeds of the vehicle and by security mechanisms? How about setup latency or handover latency? And would more media connected to different services at once affect each other? These test cases would be far more complex than the one presented in this report, as they would involve many different inputs into a few test cases. But they would also test more aspects of the CALM technology discussed in the theory. For example, to test the management block of CALM, different media should be connected at the same time. The Spectrum Manager should then prevent interference blocking signals, the Network Management Entity should detect new media and media disconnects and CALM Management Entity should designate connections to applications. As said, these test cases are too complex for this report, since the test cases here are simple proof-of-concept test cases, but they should be developed in a future step of application evaluation.

The two applications evaluated, Road Condition Warning and Emergency Vehicle Approaching, were pretty similar when it came to QoS parameters. Both were sending out public information intended to warn other Road Users of situations on the road. This was identified by low bandwidth, low setup latency and only authorisation and integrity mechanisms for security. But the main difference was the infrastructure; the Road Condition Warning had a Road-to-Vehicle communication link, while the Emergency Vehicle Approaching used a Vehicle-to-Vehicle communication link. This made the test cases fairly similar, but the results would probably differ quite some because of the different communication links.

Other applications would have produced different QoS parameters, and different test cases would have been developed. A commercial application would probably have needed more strict security mechanisms like confidentiality, e.g. data encryption, and authorisation. And handover mechanisms might have played a more vital role if prolonged connection was feasible, e.g. a video-streaming application.

The methods used, literature study, use cases, GQM and test cases, are all very theoretical methods. Actually executing the test cases developed would be a practical assignment, but as stated earlier, this was defined as out of scope. Thus, there are not many practical results in this report, only the theoretical ones from the methods mentioned. A more practical approach to the exploration and evaluation of the applications could have been taken, for example developing small prototypes to test some of the features of ITS applications. This would have been more time consuming, and in-depth analysis like use cases and the GQM methods would probably have been out of scope. But practical results would have been found. This report will therefore work as a foundation for further practical work like execution of test cases, and evaluation of results with respect to the theory presented here.

Chapter 14 Conclusion

This report has presented a thorough introduction to ITS and all its sides. It has shown that creating a standardised system for ITS isn't just based on having the right technology, you also need support from the different actors within ITS. A short introduction to different actors, their roles and connections were presented from ERTICO's viewpoint, one of the main ITS organisations in Europe. Apart from the organisational challenges, there are technological challenges. This report presented the CALM standard which still is under development. The goal of this standard was to have technology which could work with many different media over different distances, keeping vehicles *connected* all the time.

A set of applications was chosen for closer evaluation with respect to current and near-future technology like CALM. The applications chosen were *Road Condition Warning* and *Emergency Vehicle Approaching.* They were both safety applications which aim to improve safety on the roads. Use cases and test cases were developed through analysis and a method called Goal-Question-Metric. The test cases were not executed in this report because that was considered out of scope. When executed they will output results which can be used to draw proper conclusions based on the theory in this report. The conclusions from this execution and evaluation should contain whether or not the applications will be useful and provide quality in a real life scenario. This should be possible based on the test cases developed and the theory and use cases presented in this report.

I started on this assignment with no or little knowledge of ITS, its scope, its actors and the technology within ITS. This is a huge field, and through this assignment I've just touched a little piece of this. Through this study I've seen the importance of co-operation, not only locally, but also across borders and continents. For such a system envisioned here to become a world wide standard, organisations across the world have to co-operate and contribute. There are many new and interesting technologies and ideas emerging within this field, and this report has described some of the visions currently under development.

Chapter 15 Further work

In this report, the applications under discussion were analysed theoretically. The result of this evaluation was the development of a few test cases for each application. These were straight forward and simple test cases which should be used for proof-of-concept. Through these test cases it should be possible to draw some conclusions regarding the usability of the applications in a real life scenario. The next step will therefore be to actually perform the test cases, and gather results which will contribute to the evaluation of these applications.

Further work will also include analysing and developing test cases for applications with other requirements than the applications evaluated in this report. Examples of this were discussed in the previous sections, e.g. video-streaming. This will test other aspects of the CALM technology, like multi-carrier connections, with connection handovers and interference prevention, including parts of CALM like the CME, the NME and the Spectrum Manager. Special network layer functionality like DiffServ/IntServ, NEMO and Mobile IP along with different handoff mechanisms are also parts which might need to be tested in a mobile environment scenario.

During the writing of this report, documents on the standards under development were updated steadily. These changes would keep on coming until the standards are officially released. Technology would also keep on evolving, new and better communication media might emerge. Being updated on these areas is also an important exercise as future work in this field.

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Appendix A List of applications

This is a list of applications proposed for the CVIS project. They are grouped by the communication link type, in three groups: *Road-to-Vehicle, Vehicle-to-Road and Vehicle-to-Vehicle.*

Road-to-Vehicle

- Adaptive Drivetrain Management
- Adaptive Headlight Aiming
- Blind Merge Warning
- Cooperative Adaptive Cruise Control
- Cooperative Vehicle-Highway Automation System (Platooning)
- Curve Speed Warning – Rollover Warning
- Enhanced Route Guidance and Navigation
- GPS Correction
- Highway Merge Assistant
- Highway/Rail Collision Warning
- Intersection Collision – Infrastructure-Based Warning
- Intersection Collision – Vehicle-Based Warning
- In-Vehicle Signage
- Just-In-Time Repair Notification
- Left Turn Assistant
- Low Bridge Warning
- Low Parking Structure Warning
- Map Downloads and Updates
- Adaptive Drivetrain Management
- Non-Stop Tolling
- Pedestrian Crossing Information at Designated Intersections
- Point of Interest Notification
- Road Condition Warning
- Safety Recall Notice
- Safety Recall Notice
- Stop Sign Movement Assistance
- Stop Sign Violation Warning
- Traffic Signal Violation Warning
- Work Zone Warning

Vehicle-to-Road

- Just-In-Time Repair Notification
- Left Turn Assistant
- Low Bridge Warning
- Low Parking Structure Warning
- Map Downloads and Updates
- Non-Stop Tolling
- Pedestrian Crossing Information at Designated Intersections
- Point of Interest Notification
- Road Condition Warning

- Safety Recall Notice
- Safety Recall Notice
- Stop Sign Movement Assistance
- Stop Sign Violation Warning
- Traffic Signal Violation Warning
- Work Zone Warning
- Intersection Collision – Vehicle-Based Warning
- Just-In-Time Repair Notification
- Non-Stop Tolling
- Post-Crash Warning
- SOS Services
- Stop Sign Movement Assistance

Vehicle-to-Vehicle

- Approaching Emergency Vehicle Warning
- Blind Merge Warning
- Blind Spot Warning
- Cooperative Adaptive Cruise Control
- Cooperative Collision Warning
- Cooperative Glare Reduction
- Cooperative Vehicle-Highway Automation System (Platooning)
- Electronic Brake Lights
- Highway Merge Assistant
- Instant Messaging
- Intersection Collision – Vehicle-Based Warning
- Lane Change Assistant
- Left Turn Assistant
- Post-Crash Warning
- Pre-Crash Sensing
- SOS Services
- Stop Sign Movement Assistance
- Vehicle-Based Road Condition Warning
- Vehicle-to-Vehicle Road Feature Notification
- Visibility Enhancer
- Wrong-Way Driver Warning
