Cooperative Vehicle-Infrastructure Systems

D.CVIS.3.1	Reference Architecture

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Abstract	This deliverable defines the CVIS system architecture in terms of entities, boxes, and relations and interactions between these. In addition, the reference architecture describes the core enabling services of the CVIS system.

Control sheet

Version history			
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Abbreviations and Definitions

2G	Second generation cellular phone technology, e.g. GSM.
3G	Third generation cellular phone technology, e.g. UMTS.
API	Application Programming Interface. A set of request/response protocols, typically in XML format.
APN	Access point name.
AT	Command set used for modems.
C2C-CC	Car-to-car communications consortium.
CAG	Core architecture group sub-project within CVIS.
CALM	Standard (group of standards) in ISO TC204 WG16: *Continuous communications Air interfaces for -Long and Medium Range*. (http://www.iso.org/iso/en/ISOOnline.frontpage, http://www.tc204wg16.de)
CD	Committee draft. Stage of standard at ISO.
CF&F	Cooperative freight & fleet applications sub-project within CVIS.
CINT	Cooperative intra-urban applications sub-project within CVIS.
CME	Calm management entity. System management component in the CVIS platforms responsible for the global station management.
CoA	Care of address.
COMM	CVIS communications service compliant with CALM.
COMO	Cooperative Monitoring applications sub-project within CVIS.
CTA	Cooperative Traveller Assistance.
CTG	CVIS CoreTech group.
CURB	Cooperative urban applications sub-project within CVIS.
CVIS	Cooperative vehicle infrastructure system integrated project.
DNS	Domain Name Server.
DSRC	Dedicated Short Range Communications – ISO/CEN/ETSI standards working at 5.8 GHz.
EDA	Enhanced driver awareness.
EGNOS	European geostationary navigation overlay service.
ERTICO	ERTICO – ITS Europe is a multi-sector, public/private partnership pursuing the development and deployment of Intelligent Transport Systems and Services (ITS). (http://www.ertico.com/)
WAVE	Wireless access in vehicular environments. Work title for series of IEEE standards P1609.x. Basis for CALM M5.
ETSI	European telecommunications standards institute (www.etsi.org)

FOAM	Framework for open application management sub-project within CVIS
GLONASS	Global orbiting navigation satellite system
GNSS	Global navigation satellite system
GNU	Recursive acronym for "GNU 's not UNIX". Name of an OS. (http://www.gnu.org)
GPL	General public license for GNU
GPRS	General packet radio service
GSM	Groupe spéciale mobile. 2G version of the cellular phone system.
Host Platform	A CVIS platform providing applications, services, middleware and the core functions JVM and OS.
HSDPA	High speed downlink packet access. Transmission protocol for UMTS.
HW	Hardware
I2C	Infrastructure to centre communications
I2I	Infrastructure to infrastructure communications
IEEE 802.11p	IEEE 802.11p task group was established for extension of IEEE 802.11 for automotive mobility WAVE.
IETF	Internet engineering task force (http://www.ietf.org), the open organization specifying protocols for communications in the internet, but not how they should be used and put together for specific use cases.
IME	Interface management entity. Management component responsible for the management of the OSI lower layers (media).
Infrastructure	In an ITS, the term infrastructure comprises all kinds of equipment related to travel- and transportation.
IPv4	Version 4 of the Internet Protocol. Note: this version currently is deployed.
IPv6	Version 6 of the internet protocol which provides embedded mobility support, security and multicasting, more flexibility by allowing for optional headers, auto-configuration of the networks without human intervention, and an increased address space.
ITS	Intelligent transport systems are information technology systems that support travel- and transportation applications and infrastructure.
JAVA	Name of a SW technology
JVM	JAVA virtual machine
Linux	Name of a platform-independent multi-user OS. Often referred to as GNU/Linux.
M5	CALM microwave medium at 5 GHz, based on IEEE 802.11p and the set of IEEE standards P1609.x for WAVE.
NEMO	IETF work title "Network mobility".

NME	Network Management Entity. Management component in the responsible for managing the CALM / CVIS OSI network layer.
OS	Operating system.
OSGi	Open services gateway initiative.
PDA	Personal digital assistant, i.e. a hand-help personal computer.
PIN	Personal identification number
Platform	A computer with a specific set of functionality (hardware and software), such as router, host, gateway.
POMA	Positioning and mapping sub-project within CVIS
PPP	Point to point protocol
PUK	Personal unblocking key-number.
Router Platform	The CVIS platform that includes at least all or some of the following air interfaces CALM M5, DSRC, CALM IR, Galileo/GPS and 2G/3G, together with the CALM management entities CME, NME and IME, and the CALM networking functionality.
SAFESPOT	Name of research project on safety related ITS applications.
SIM	Subscriber identity module. Here used in the context of cellular phone systems.
Subsystem	The term *subsystem* is used with respect to the *vehicle*, *roadside* and *central* part of the CVIS system
SW	Software
TCP	Transport control protocol
UDP	Universal datagram protocol
UMTS	Universal mobile telecommunications system. 3G version of the cellular phone system.
V2C	Vehicle to centre communications
V2I	Vehicle to infrastructure communications
V2V	Vehicle to vehicle communications

Executive Summary

This document describes the architecture of future cooperative systems in terms of entities/boxes that are expected to be the main building blocks in the cooperative systems world. Additionally, the document describes the relations and interactions between these entities and even specifies the core enabling CVIS services. Furthermore several technologies to be used in the development of the CVIS system are proposed in the document.

The Reference Architecture is largely a definition document for the bottom-up part of development undertaken in the CVIS. The document consequently does not relate to abstraction levels such as motivations or visions. In addition to this document High-Level Architecture deliverable will be describing the top-down development view on the CVIS architecture.

The Reference Architecture is the first deliverable dealing with the CVIS system architecture. The content of this deliverable will be validated and updated, if needed, throughout the project. It will form an important input to the Architecture and System Specifications work package and be one of the inputs to the D.CVIS.3.4 "Final Architecture" deliverable.

1. Introduction

1.1. Intended audience

This document is the first deliverable dealing with the CVIS system architecture. The intended audience for the document are the CVIS developers and external project partners.

The document aims on supporting

- the developers to harmonize the work in the sub-projects, and
- external partners to understand what entities the CVIS system consists of, and how these can be used.

1.2. Document structure

The main content of this document is split into four parts:

(i) Chapter 2 defines the CVIS High-Level System Architecture,

(ii) Chapter 3 presents the CVIS Subsystems,

(iii) Chapter 4 presents the Platform Components

(iv) Chapter 5 describes the Applications and Services.

1.3. Reference Architecture in the CVIS world

The development principle in the CVIS is a combination of top-down and bottom-up approaches. Top-down is the guiding principle for everything apart from the technical developments of the platforms. This Reference Architecture largely is a definition document for the bottom-up developments being undertaken in the CVIS Core Technology Group.

This document will consequently not relate to abstraction levels such as motivations, visions or technical implementation details. It will serve as an input to several processes in the further Architecture and Specification work. However, the main purpose is the Core Technology developments under Core Architecture Group (CAG).

How this document relates to other documents describing the CVIS system has been illustrated in *figure 1*. Together with System Concept Definition, the High-level Architecture and templates for Architecture and System specification it will be used as input to the sub-project work in WP3, Architecture and Specifications. Based on these inputs, the technology and application subprojects will elaborate their subproject specific Architecture and Specification documents, below exemplified with D.CURB.3.1 Arch/Spec, D.COMM.3.1 Arch/Spec and by D.FOAM.3.1 Arch/Spec.

As the next step, based on the specific inputs from the sub-project a common D.CVIS.3.3 Architecture and Specification document will be presented. This deliverable will present the overall CVIS architecture and specifications.

By the end of the CVIS project, the subprojects will produce their final architectures and specifications deliverables, here exemplified with D.CURB.3.2 Arch/Spec, D.COMM.3.2 Arch/Spec and by D.FOAM.3.2 Arch/Spec. These deliverables will be based on the D.SP.3.1 and D.CVIS.3.3 deliverables, which have been validated throughout the project. The final outcome of the project will be the D.CVIS.3.4 "Final Architecture and Specification" deliverable.

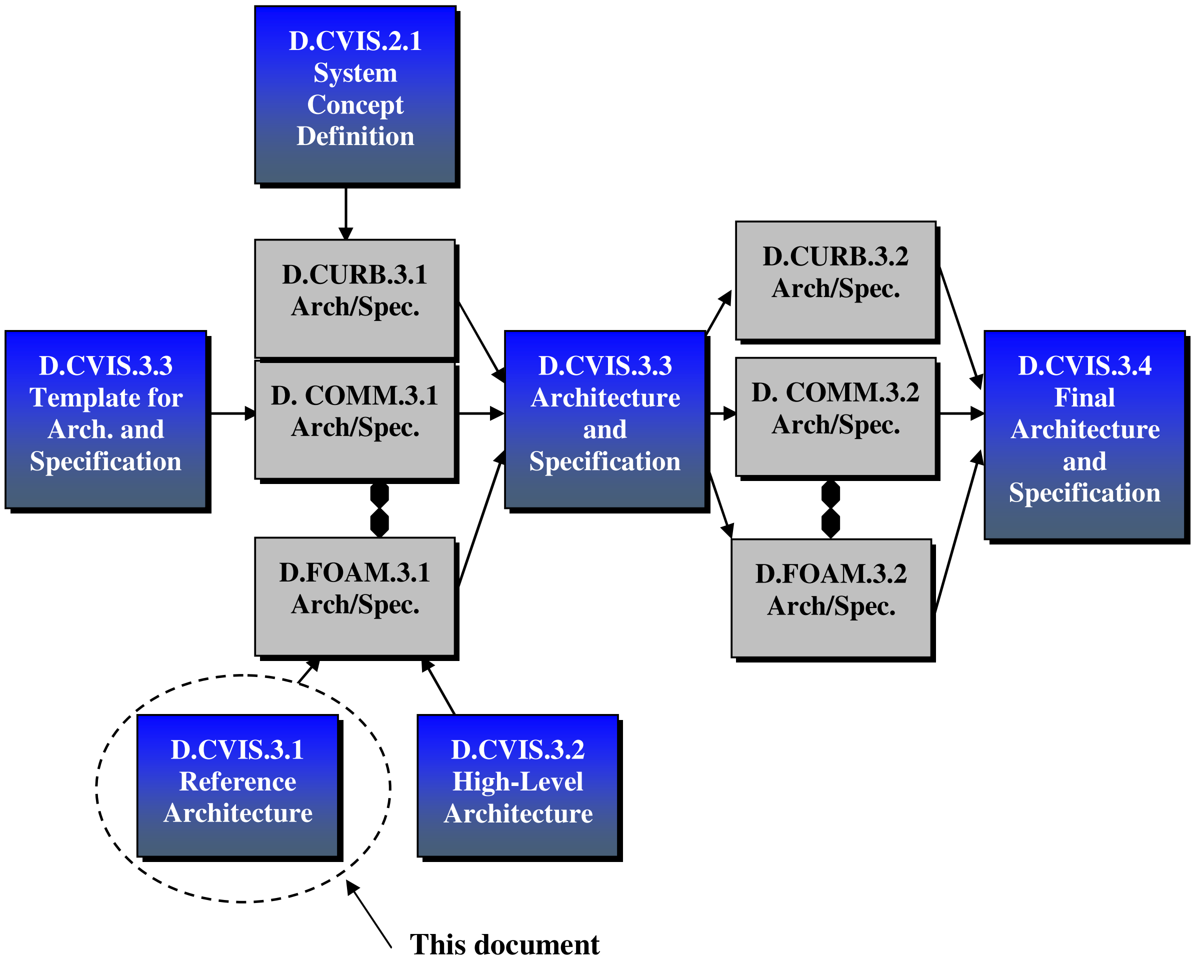

Figure 1. Relation between Reference architecture and other CVIS system documents

1.4. Development process in the CVIS technology sub-projects

From the technical perspective, the proposed development process is divided into three phases:

- Alpha
- Beta
- Gamma.

This process needs to be agreed on and will be described in more detail in a separate document. For the conceptual idea behind the process, please see Annex A.

2. CVIS High-Level System Architecture

From a high-level view, the CVIS system can be divided into three *subsystems; see figure* 2:

- The Vehicle subsystem
- The Roadside subsystem
- The Central subsystem

All three subsystems contain similar components.

Wireless or fixed-line communication routers can be found in all three subsystems. In the vehicle subsystem such a router is called a Mobile Router while in the roadside and in the central subsystems it is called a Border Router.

Host units are used for running CVIS applications and services. They are also part of all three subsystems.

Gateways also can be found in all three locations. Their main purpose it to enable safe and secure connectivity with already existing systems, e.g. in-vehicle components.

In order to validate the results of the specification phase, a number of CVIS platform prototypes will be developed. They will be based on open computers, which imply that vehicle, roadside and central systems will use PCs with open operating systems. All drivers and components will be fully documented, controllable and reproducible.

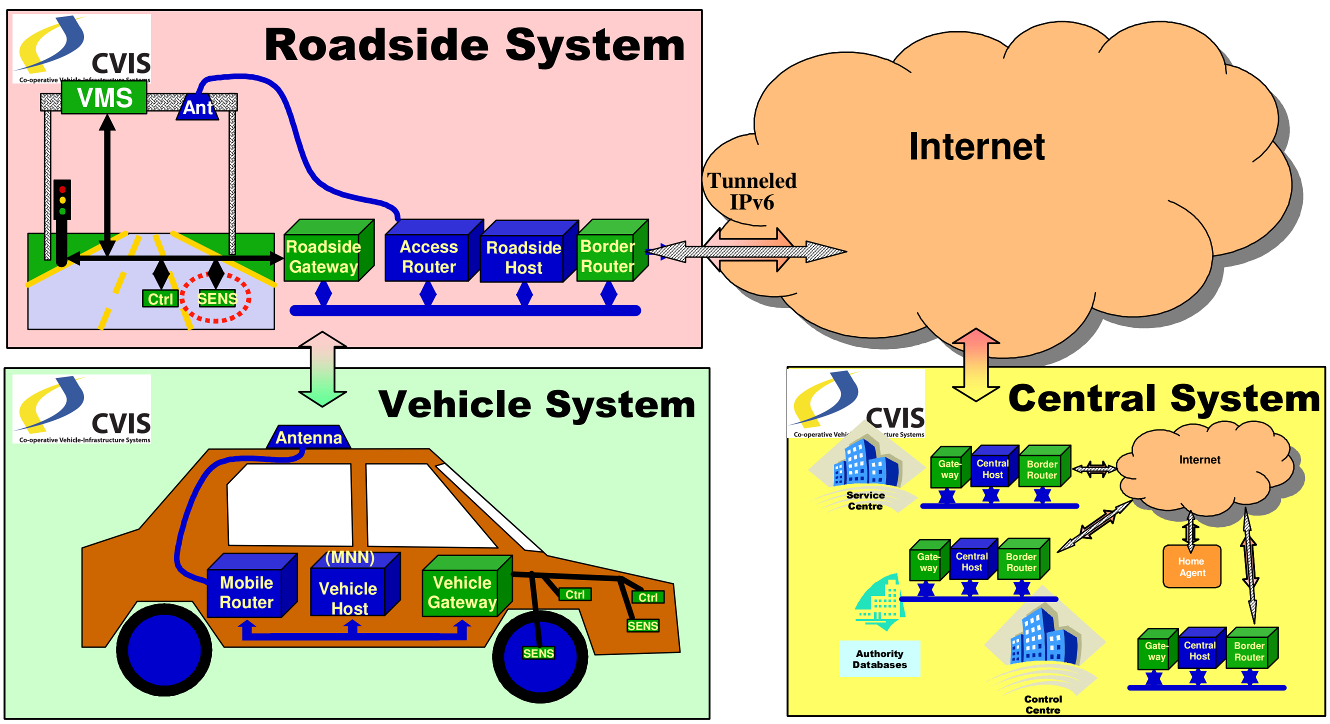

Figure 2. CVIS high-level system architecture

The high-level entity relationship is illustrated in the figure 3. Additionally, for the WP3 High-level Process Diagram, please see the Annex B.

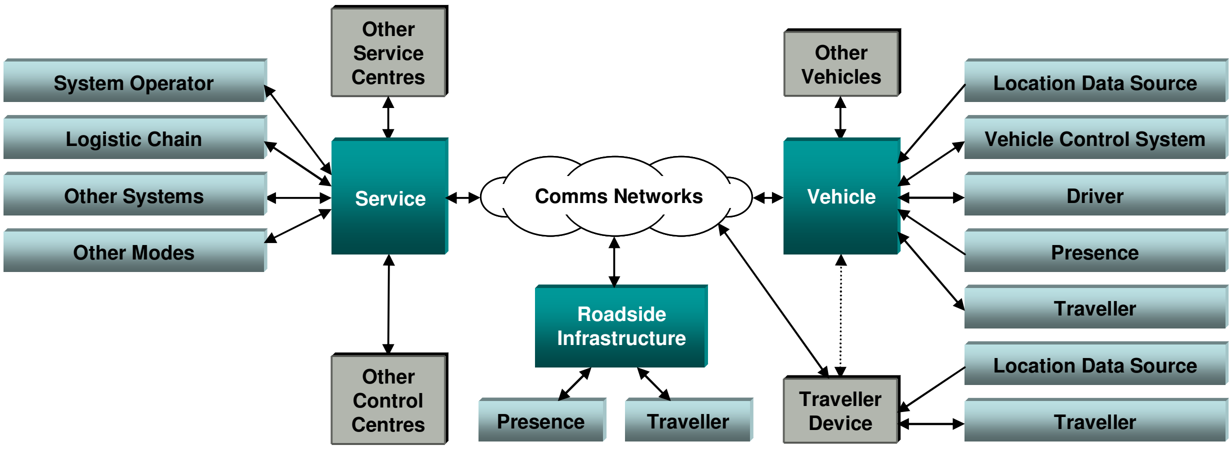

Figure 3. High-level entity relationship

After decomposing CVIS into entities according to their physical or logical location at vehicle-, road- or centre side, some additional concepts to be found in the CVIS architecture are described here. This shall support a common understanding of CVIS.

CVIS mobile units are entities which can move around in the network. In-vehicle units and nomadic units correspond with the CVIS mobile units, see figure 4. CVIS mobile units may have vehicle sensor access. Nomadic units, e.g. PDA, may be a specialization of CVIS mobile units, which shall also be able to connect to the CVIS wireless communication network. CVIS mobile units communicate among each other for direct information exchange, i.e. V2V, with road side units, i.e. V2I, or with Centres, i.e. V2C.

CVIS roadside units are entities which are not moving, e.g. are installed as road side equipment. These entities shall be able to access road side sensors and communicate among each other for direct information exchange, i.e. I2I, with mobile units, i.e. V2I, or with Centres, i.e. I2C.

In a CVIS cooperative system several "centres" appear:

- ***Service Centres*** support different End user Services. They communicate with Roadside or Mobile Units when delivering a service. They shall get the content, which is needed for a service, from Content Centres. They shall cooperate with Traffic Management Centres to align their services with the goals of traffic managers. Finally they shall cooperate with Application Management Centres to support remote download and configuration of service applications on Mobile- or Roadside Units
- ***Application Management Centres*** support the remote management (e.g. download, configure) of applications in Mobile- or Roadside Units.
- ***Traffic Management Centres*** are operated by institutions/authorities responsible for managing the traffic on a specific road network in a dedicated area.
- ***Content Centres*** fulfil the function to provide any (raw/pre-processed) transportation relevant content to other centres. Typically Service Centres process content from different content centres and create value added services. In CVIS also traffic Management Centres and Mobile Units shall be able to directly exploit information provided by a content centre.
- ***Communication Network Management Centres*** are needed for organising the mobile wireless CVIS IPv6 Network.

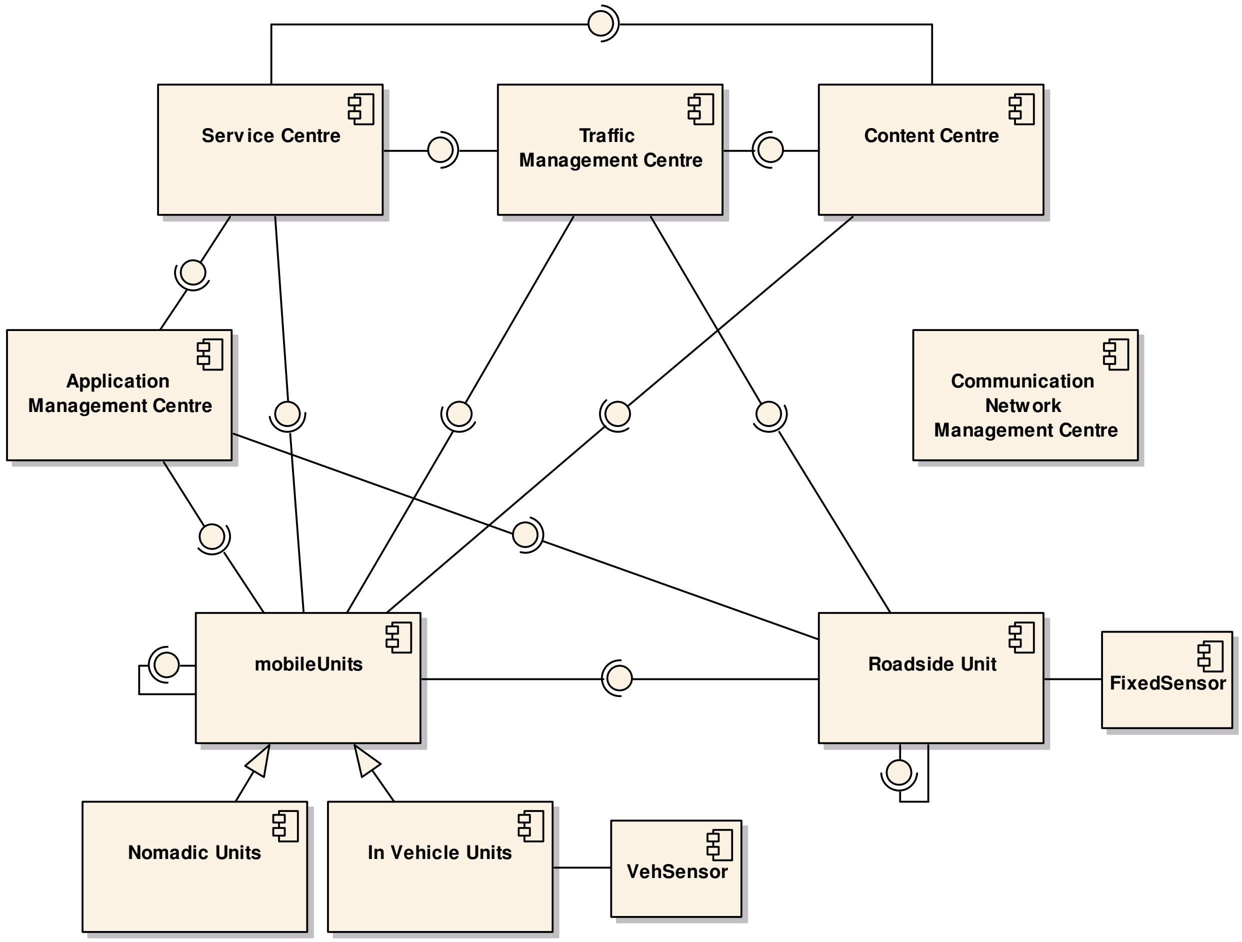

Figure 4. CVIS entities relations

3. The CVIS Subsystems

3.1. The Vehicle Subsystem

In CVIS vehicles are used as a fleet of probes in order to monitor the complete traffic condition on road networks over geographical areas. The concept is referred to as *cooperative monitoring*, COMO, one of the four enabling services defined in the CVIS.

The vehicle subsystem, see figure 5, consists of the following platform elements:

- The *Vehicle Host*: the platform for applications and services at the driver end of the system. Note that this entity is called a *Mobile Network Node* in the Internet terminology.
- The *Mobile Router*: connecting the vehicle subsystem to the communication system.
- A *proprietary network*: connecting embedded control systems in the vehicle.
- An *open local area network*: connecting the router, the host(s) and the proprietary network.
- A *Vehicle Gateway:* protocol converter and firewall between the open and the proprietary network, to protect the technical infrastructure in the vehicle.

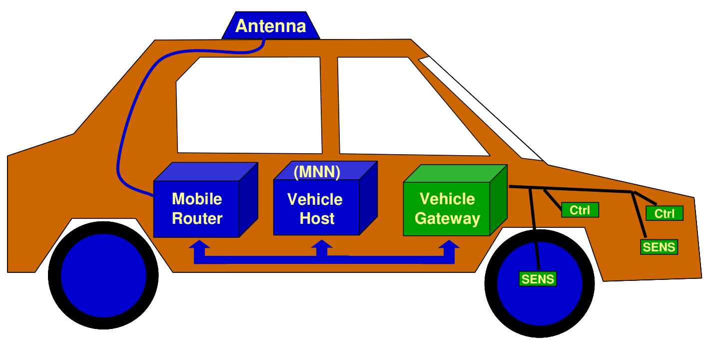

Figure 5. Vehicle subsystem

3.2. The Roadside Subsystem

The roadside equipment, see figure 6, comprises components such as traffic lights, cameras, Variable Message Signs (VMS), etc.. These components run on a platform with architecture similar to the one in the Vehicle Subsystem:

- A *Roadside Host*: for applications and services at the roadside.
- An *Access Router*: connecting the roadside subsystem to the communication system.
- A *Border Router*: connecting the CVIS roadside rack to the internet through IPv6 / (IPv4).
- A *closed network*: connecting the roadside equipment, network, etc.
- An *open local area network*: connecting the *router*, the Host(s) and the *access router*.
- A *Roadside Gateway*: between the open and the closed roadside network.

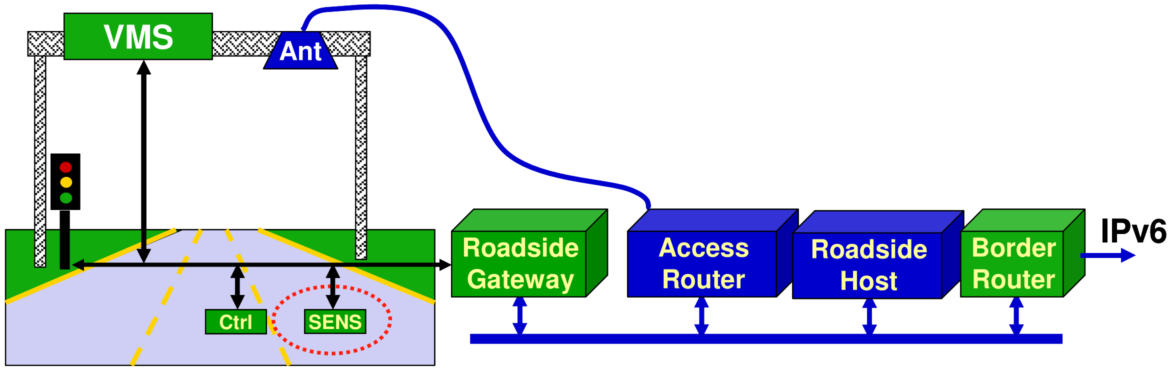

Figure 6. Roadside subsystem

3.3. The Central Subsystem

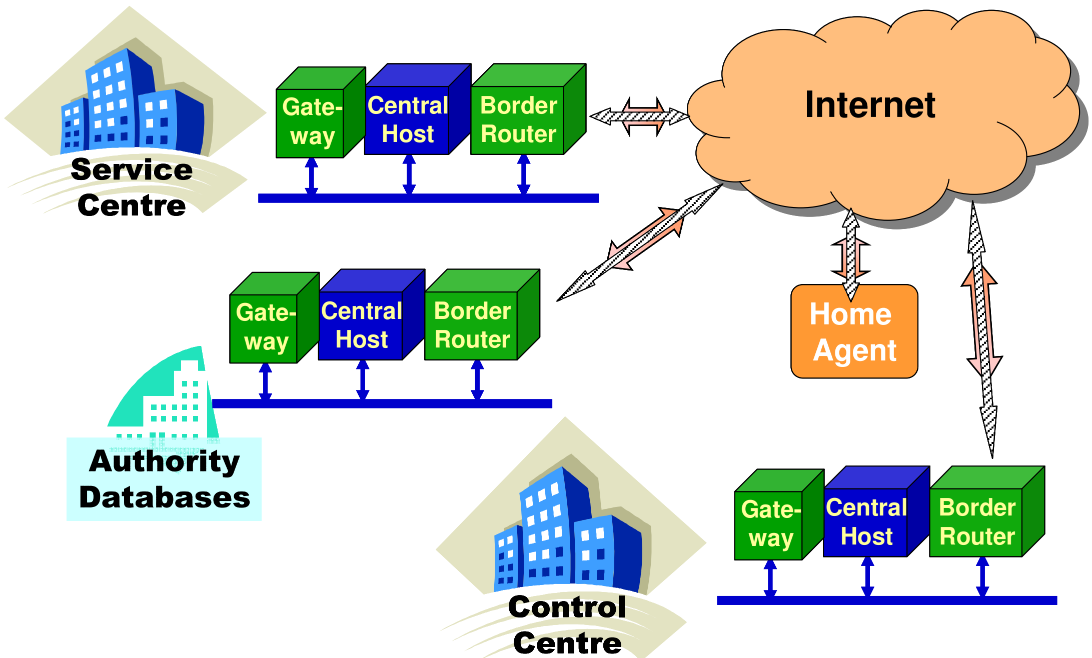

Figure 7. Central subsystem

3.3.1. Service Centre

The Service Centre, see figure 7, is the back-end infrastructure that a Service Provider constructs, deploys, and operates additionally to the Service Application. It frequently comprises remote servers and applications supporting and communicating with the Service Application on the Client System.

3.3.2. Control Centre

A Control Centre manages multiple Client Systems and End-Users. It is responsible for registration of Client Systems, authentication, service provisioning, subscription and the subsequent download of service applications, service updates, remote administration and all other needed management procedures on a Client System. A Control Centre is a component that is decomposable in different entities representing organizational units within an element between the Service Centre and the Client System.

3.3.3. Home Agent

The Home Agent will control various IPv6 mobility aspects in the CALM/CVIS network. Its main purpose is to act as a forwarding entity for messages to the mobile units

3.3.4. Authority Databases

Authority databases are existing entities that have two main areas of interest in CVIS:

- To act as a basic data and/or content provider for service and control centres,
- To receive updates from the CVIS system.

Typical examples of authority databases are road databases and vehicle (owner) databases.

4. The CVIS Platform Components

Cooperative systems, e.g. CVIS, are systems that can interact in real-time, and can organize behaviour at decentralized levels. One of the key enablers for cooperative services is therefore a system that allows communication at every location, at any time and also to everybody (ubiquitous communications).

4.1. The CVIS Router Platform

4.1.1. ISO TC204 WG16 CALM

The communication subsystem in the CVIS follows the ISO TC204 WG16 series of draft standards under the acronym CALM *(Continuous communications Air interface for Long and Medium range).* One of the goals of CVIS is to validate, improve and qualify these CALM standards for European use.

CALM describes a *hybrid mobile network* based on various communication channels such as GPRS, UMTS, M5, MM, and IR. The CALM technology applies policy-based rules to select the optimal communications channel at any time and any place, for *always-on* connection.

The communication subsystem consists of:

- Air media channels, as mentioned above.
- IPv6 and non-IP protocols for very fast communications, e.g. as needed for safety related applications.
- Adaptation layers enabling existing communication technologies to join the CALM environment.
- Management entities.

The connection is transparent to the applications.

4.1.2. Router Platform Elements

The three types of communication in CVIS are:

1. Localized Directed Communication.
   This includes communications between e.g. adjacent roadside installations, between a roadside installation and approaching vehicles, and between adjacent vehicles.
2. Localized Omni-directional Communication.
   This includes communications between e.g. vehicles in a single cluster, or vehicles of adjacent clusters.
3. Wide-area Communication.
   This includes communications based on cellular networks and using satellites.

The following figure 8 illustrates the platform elements in the CVIS Router.

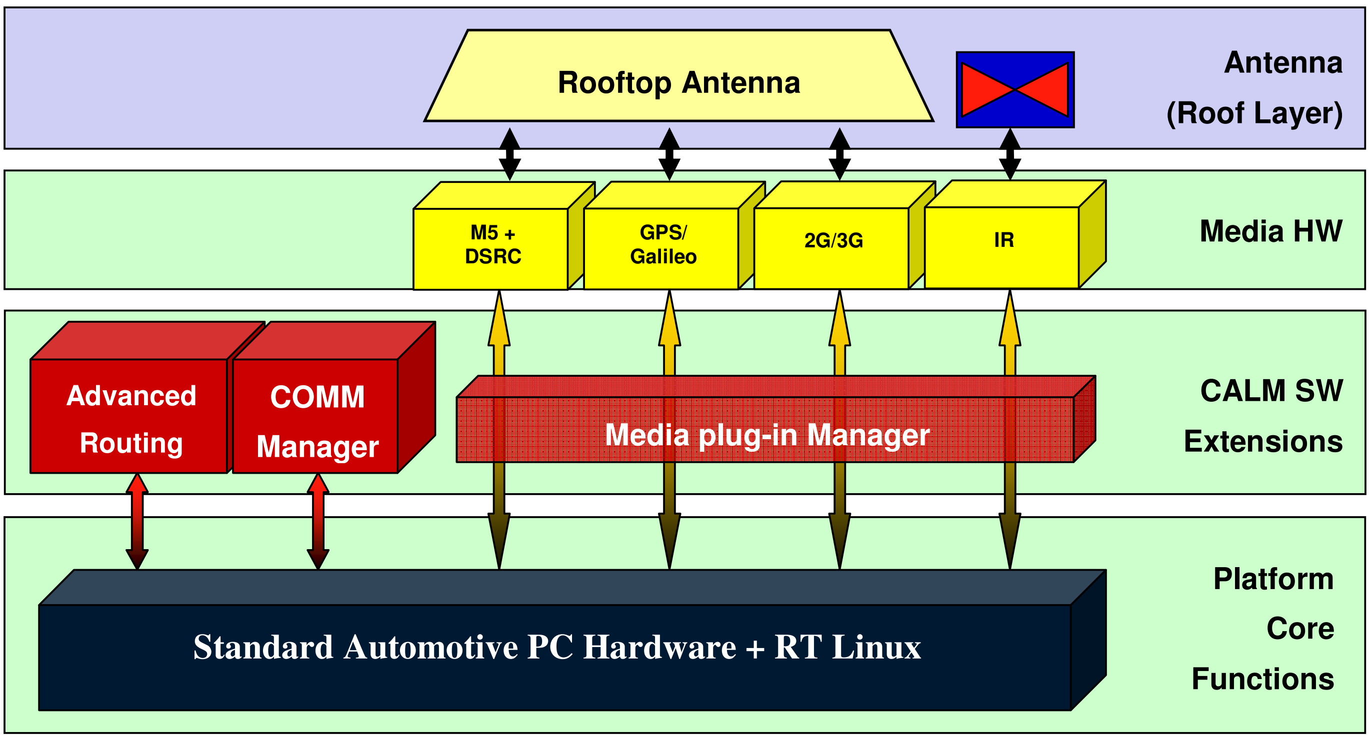

Figure 8. CVIS Router

Referring to the figure 8, the CVIS Router comprises the platform elements as follows:

1. *Rooftop Antenna.*
   - The Rooftop Antenna is a pod with the antennas for the respective air interfaces in CVIS, see below.
2. *Media Hardware.*
   - Media Hardware are the physical devices that implement the air interfaces in CVIS. The air interfaces comprises M5, IR, 2G/3G, and DSRC for communication, and GNSS - *Global Navigation Satellite System* – for positioning.
3. *CALM SW Extensions*
   - Advanced routing
   - COMM Manager (CALM management)
   - Media plug-in Manager

4. *Platform Core Functions* –
    - PC Hardware and operating system. The platform core functions are implemented as software running on a standard automotive PC hardware with real-time Linux operating system.

A CVIS router can be configured to operate in

1) *mobile router mode* in a vehicle, or in
2) *access router mode* at the roadside.

There can be one or more CVIS routers per vehicle or per roadside station.

The communication media in CVIS are:
- Microwaves CALM M5. [ISO TC204 WG16, CD 21215, IEEE 802.11p, IEEE P1609.x].
- Millimeter waves CALM MM. [ISO TC204 WG16, CD 21216]. Note: basically considered, but not implemented.
- Infrared light CALM IR. [ISO TC204 WG16, CD 21214].
- Cellular technology CALM 2G/3G. [ISO TC204 WG16, CD 21212 / CD 21213]. This technology especially supports wide-area communication.
- Microwaves CEN DSRC. [CEN EN 12253, EN 12795, EN12834, EN13372, ISO 15628].

The protocol functionalities in CVIS are:
- Mobile IPv6 routing functionality will be fully implemented. This functionality allows access to a mobile client based on a home agent.
- Geographically mapped IPv6 addressing is enabled. This functionality performs proper IP address mapping based on the geographical location.
- Fast location addressing will be fully implemented. This functionality uses the geographical location as addresses for communication.
- Real-time data exchange is enabled. This functionality allows for extremely fast communications of mostly very short messages by reducing protocol overhead.
- CALM management CME / NME will be fully implemented. This is responsible for managing bindings between various applications and various communications media based on the requirements of applications and the capabilities / cost / availability of media.
- CALM interface management IME will be fully implemented. This functionality allows real-time control of communications media parameters, such as frequency, power, directivity, data rate, … etc, in order to comply with applicative needs and regional regulatory requirements, e.g. spectrum management.

4.1.3. Microwaves CALM M5

[ISO TC204 WG16 document CD 21215, and IEEE 802.11p and P1609.x]. M5 supports directional and omni-directional communication and localized broadcast communication between moving objects, and between moving objects and roadside installations, with a minimum data rate of 6 Mbps, and covering a communication distance of several hundred meters. It is particularly useful for low-directive vehicle-to-vehicle and vehicle-roadside communication. This technology is considered by the European car industry in e.g. C2C-CC with a preliminary focus on safety related applications, but not restricted to such applications. Types of applications may be separated by means of different frequency channels allocated in Europe. Regional regulatory requirements are considered and managed by the IME.

4.1.4. Millimeter waves CALM MM

[ISO TC204 WG16 document CD 21216]. This technology especially supports localized directed communication. Different physical propagation properties as compared with CALM IR makes CALM MM complementing CALM IR for safety related applications, where different simultaneous communication paths are required. MM allows for much higher data rates (in the order of hundreds of Mbps) in the range of several hundred meters. Directional communication is useful since the communication range can be confined to a specific object of set of mobile objects. Millimetre wave will not be implemented or tested as part of CVIS.

4.1.5. Microwaves CEN DSRC

[ISO 15628]. This technology was developed in Europe through several R&D projects and CEN standardisation. It is arguably the most successful ITS technology today with wide spread usage all over the world. It is imperative that the CVIS systems will coexist and migrate seamless with existing DSRC systems since they represent heavy investments. The main current use is for payment systems and access control.

4.1.6. The GSM/GPRS/UMTS/HSDPA Subsystem

High Speed Downlink Packet Access transmission protocol (HSDPA) supports transmission speed of 1.8 Mbps, while UMTS supports 384 kbps on 3G UMTS networks. If no UMTS is available the system will fall back to GPRS with lower data rates.

On the hardware side a UMTS card shall be physically connected via CardBus or MiniPCI. The card shall have an external antenna connector. A virtual serial interface allows accessing the card via the operating system. The card is then configured with AT commands; some of them are standard, some might be vendor or network provider specific.

The Interface Management Entity (IME) provides generic management features for all kinds of interfaces. The IME shall be responsible for

- Profile management for selected mobile net provider. A database shall be provided with profile data for different mobile net providers. The profile shall comprise parameters like APN and userid. A mobile network provider shall be selected based on availability and roaming agreements.
- Data transmission preferences. Based on requested/available transmission data rate, GSM/GPRS/UMTS/HSDPA is selected as preference. The network will automatically fallback to a lower rate. This is monitored by the IME and reported to the NME.
- PIN/PUK manager. The PIN and PUK as supplied by the mobile network provider must be provisioned and managed. This is important as the SIM card is locked in case the PIN is wrong and hence the communication will fail subsequently.
- Traffic manager (data volume and time). As the cost is a criteria in selecting an interface, any changes must be monitored and reported. This can occur when changing from an off-peek to a peek tariff or when a certain data volume has been reached.
- Performance monitoring. Dynamic values such as average/maximum data rates shall be monitored
- Card management. Insertion and removal of the card shall be monitored
- Card firmware upgrade. Since UMTS cards often contain firmware, that can be upgraded, the IME shall support the flashing of firmware images.

- The IP connectivity shall be established using the PPP protocol and the PPP daemon (with IPv6 support). The IP address shall then be obtained via the medium specific method. In this case, the PPP protocol is used to obtain an IP address and other network specific parameter. A very important, but open issue, at this time, is that the UMTS providers do not support IPv6, but only IPv4.

4.1.7. The IR Subsystem

In accordance with the strong capabilities to "beam" information in dedicated directions, the IR-Subsystem is focusing on directed communication service. Within CALM, IR has predefined beam-directions, so-called "shortcut-directions". The CALM-IR implementation within CVIS will not support all shortcut-directions but a selection of it as required by the applications.

The CVIS CALM-IR car-transceiver will appear in the alpha-stage as a functional model with one IR-channel and in the beta-stage as an integrated solution with four IR-channels. Each channel will provide a full independent 2 Mbit/s transfer-rate with a range up to 100 m. Antenna and transceiver are joint together in a rooftop housing and connected with a firewire to the CVIS-router.

The CVIS CALM-IR roadside-transceiver will also appear in the alpha-stage as "breadboard design" and in the beta-stage as integrated solution but always with one IR-channel only. Each channel will provide a full independent 2 Mbit/s transfer-rate with a range up to 50 m. Antenna and transceiver are joint together and connected with a firewire to the CVIS-router.

4.1.8. GNSS

GNSS (Global Navigation Satellite System) is a satellite system that is used to pinpoint the geographic location of a user's receiver anywhere in the world. Two GNSS systems are currently in operation: the United States' Global Positioning System (GPS) and the Russian Federation's Global Orbiting Navigation Satellite System (GLONASS). A third, Europe's Galileo is aiming at reaching full operational capacity in 2010. Each of the GNSS systems employs a constellation of orbiting satellites working in conjunction with a network of ground stations.

GNSS, and in particular GPS, is a key component of the POMA positioning devise. It provides the basic information from which the vehicle position can be calculated. This information can be augmented with car sensor information (gyroscope, odometer, radar, map) as well as with other external sources of information (assisted GPS data, RF signals, etc.). It also provides a universal timing reference.

Using GNSS is today common practice and the market offer for GNSS products is very large. The challenge for POMA is to best integrate such product with other sensing solutions to meet the CVIS application positioning requirements.

4.1.9. Antenna Pod

The Antenna Roof Layer consists of the Rooftop Antenna unit as described in this section. The IR roof unit is a separate unit not described here. The Rooftop Antenna Unit contains four antennas/ systems as specified in the following table.

Antenna no.	Application	Frequency
1	GPS	1.575 GHz
2	CALM 2G/3G (GSM/UMTS)	900/1800/1900/2100 MHz
3+4	CALM M5 (IEEE 802.11abg + .11p WLAN)	Two elements, each supporting operation on 2.4 and 5.9 GHz
5	DSRC	5.8 GHz

The Rooftop Antenna Unit will have a weather protection shield (random), and will be fitted with a magnet base for easy mounting to a vehicle for the extensive testing at the CVIS test sites. The Rooftop Antenna Unit will be given an aerodynamic shape, and the size will be approximately 25x5x12 cm (LxWxH). Three coaxial cables will connect to the corresponding radio modules through the CVIS router. Similarly, signalling and power cables to the DSRC tag is connected to the DSRC module through the CVIS router. All cables will be bundled together for easy handling during installation.

4.1.10. Advanced Routing and Communication management

This component includes all the necessary networking protocols (from the IPv6 family as specified by the IETF [Internet Engineering Task Force http://www.ietf.org]) to achieve a permanent IPv6 connectivity between the vehicle and the roadside. In particular, this component performs the following functions:

- maintains IPv6 connectivity between the CVIS Mobile Router in the vehicle and the CVIS Access Router on the roadside (NEMO Basic Support) [RFC 3963]
- provides permanent IPv6 addressing to CVIS hosts so that these can configure an IPv6 address and transmit/receive IPv6 frames.
- performs routing over the proper communication medium between CVIS hosts and the CVIS Access Router on the roadside according to the communication medium availabilities and the packet transmission requirements.

4.1.11. Router Platform Core Functions

The platform called "Router" relates to the realization of CVIS system functions which are subject to data delivery and the allocation of available communication media by using the CALM methodology, for connecting the vehicle subsystem to the global communication system including the RSUs and other vehicles and *vice versa*. It optionally contains one or more of the following air interfaces: CALM M5, DSRC, CALM IR, Galileo/GPS and 2G/3G. A basic design principle of the Router is that new air interfaces can easily be integrated into the platform at any time in the future. The software structure of the Router is based on the CALM architecture, following the proposition of the CALM (draft)standard and implementing the CALM management stack within CVIS Reference Execution Platform environment. In short terms, Router functionality is concerned with managing the mobility of the entire dynamically changing mobile network in parallel to the objectives of the NEMO initiative.

Conceptually there is a single generalized Router in a CVIS installation. However the architecture supports the possibility to include two or more Router implementations in a particular subsystem (vehicle or RSU), if it is necessary. Both the Router and the Host share the same building blocks in the generalized SW architecture by providing specific functionality by means of scaling, customization and dynamic configuration. The Router can further be personalized to operate either as a mobile router in a vehicle, or an access router in the roadside.

An x86 based automotive PC with standard peripherals and add-on devices produced by CVIS COMM partners serves for the basis of the Router platform implementation. Its main features are:

- Intel Pentium M processor
- High performance with full feature I/O
- Supports PCI-X (64 bit) interface
- Supports four USB (2.0) ports and three COM ports
- Supports one Mini PCI interface
- Supports PCI-104 interface
- Supports CompactFlash
- One 2.5" HDD drive bay
- Watchdog Timer
- ATX 100W 24VDC-in power supply.

The Operating System (OS) is an essential SW component of the Router platform. The choice of the operating system influences portability, stability and extendibility not only of the Router but of the whole CVIS system. The OS provides standard APIs as well as a decent development environment. According to the general project requirement towards the creation of an open system architecture, the OS should be freely available. It also helps reducing costs of the development. As an additional requirement, the source code of the OS should be available under a license relaxed enough to be able to build commercial systems later upon it.

GNU/Linux is a choice for the OS, as far as the above requirements are concerned, which is accepted by CoreTech. GNU/Linux is freely available and has rather good quality industry-standard development tools. Moreover its license permits to use its source code as far as all components linked to its kernel are also licensed under the same license agreement, i.e., the GNU GPL. Also, GNU/Linux is a well-known system with accepted APIs and communication mechanisms. It is a well referenced system which is successfully used for research and development worldwide. It is proven that GNU/Linux also is suitable for embedded environments, especially for the prototype development stage of the project. So it will likely be accepted as a base of a later commercial product.

There are many GNU/Linux distributions. Note: The Debian GNU/Linux "Sarge" 3.1 is a well positioned distribution worth to further consideration.

Since CVIS CoreTech group has also to adopt third party project results, the kernel version is to be chosen such that this integration process is well supported by the OS itself. For this purpose the kernel 2.6.15 is proposed.

Real time requirements will obviously necessitate fine-tuning of the operating system for better performance. Ramsys, on the analogy of the microkernel applications OSEK VDX (e.g. NUCLEUS), which is widely accepted and used in recent car manufacturing industry, put forward a proposition for the application of a real-time Linux microkernel (namely L4 or Fiasco) in order to be able to guarantee real-time scheduling at the lowest OS level. In contrast with OSEK VDX, which is a proprietary solution, L4 provides an open platform alternative for CVIS. This L4 microkernel would render an additional abstraction layer between the hardware and the operating system.

4.2. *The CVIS Host Platform*

The platform called "Host" relates to the realization of CVIS system functions which are subject to the service and attendance of the CVIS applications. The host includes a set of middleware and other communication services that offer a fast JAVA virtual machine (JVM) with a very rich Application Programming Interface (API) including positioning, sensor data, Human Machine Interaction (HMI), applets, communications Quality of Service (QoS), remote management of applications and so on. Host is also responsible for certain application specific CALM functionality. In sense of NEMO terminology the host plays the role of the "Mobile Network Node" in the architecture.

Conceptually, there is a single generalized host structure not excluding the possibility, however, to include two or more hosts in a particular subsystems (vehicle or RSU) if it is necessary. Both the host and the router share the same basic building blocks in the generalized SW architecture by providing specific functionality by means of scaling, customization and dynamic configuration. The host can further be personalized to operate either as a vehicle platform, or a host in the roadside.

4.2.1. Host Platform Layers

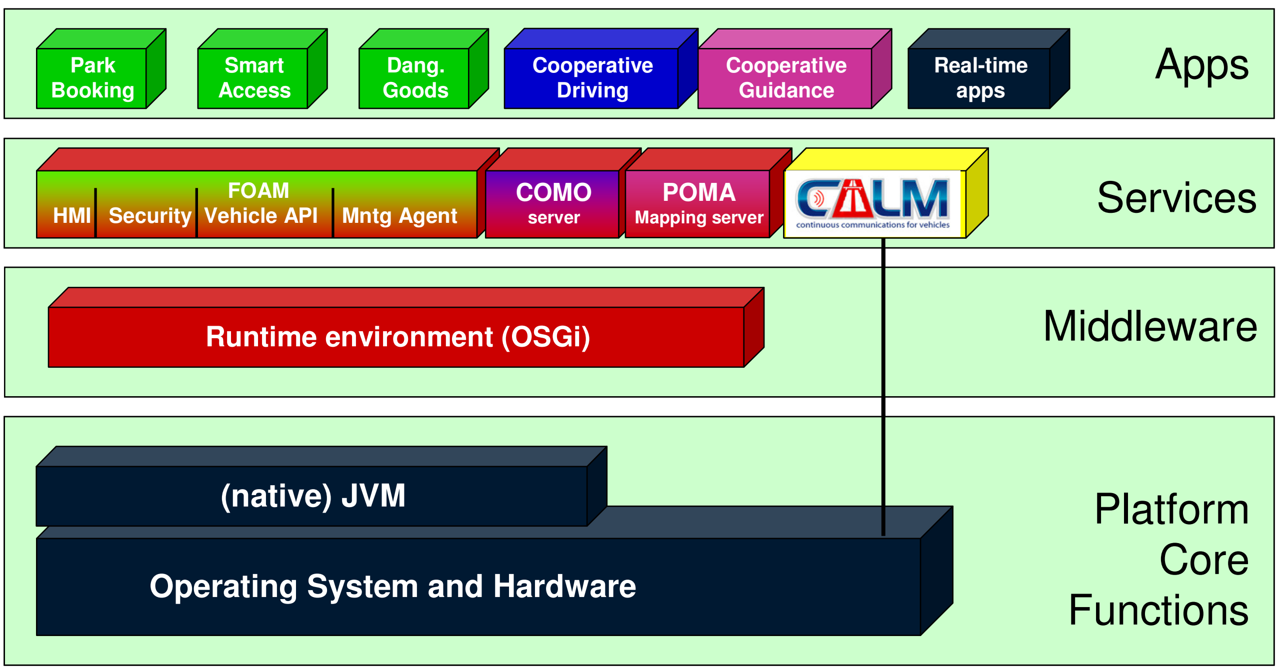

Figure 9. CVIS Host

The CVIS Host Platform

Referring to the figure 9, the CVIS Host comprises the platform elements as follows:

1. *Applications.*
   - Requiring specific security means, e.g. for payment, dangerous goods
2. *Services.*
   - Being available to the applications
3. *Middleware.*
   - Providing the OSGi runtime environment

4. *Platform Core Functions.*
    - Providing the OS and a native JVM.

In a single CVIS host communication is offered as an integral service in the runtime environment for portable (JAVA) applications, or at a lower level offered as a real-time (TCP/UDP) socket for native in-vehicle or infrastructure CVIS applications.

The host application stack is connected to a local area network that also attaches to existing OEM gateways for accessing proprietary sensors and actuators in vehicles or roadside. Communications are then passed via the CVIS router to the various air interfaces. FOAM, COMM, POMA and COMO components will be embedded in the OSGi middleware to provide the rich services that may be needed by a CVIS application.

4.2.2. Host Applications

Host applications will run on the common software development platform (OSGI platform) or in special cases directly on the native vehicle system, a roadside system or a centre system.

Host applications comprise functions such as CF&F Park Booking, Smart Access, Dangerous Goods, CURB/CINT Cooperative Driving, Cooperative Guidance, Real-time applications in roadside controllers.

4.2.3. Host Services

This chapter introduces some core services as planned from COMM, COMO, FOAM, and POMA. More details see the deliverables D2.1 and D3.1 from these sub projects

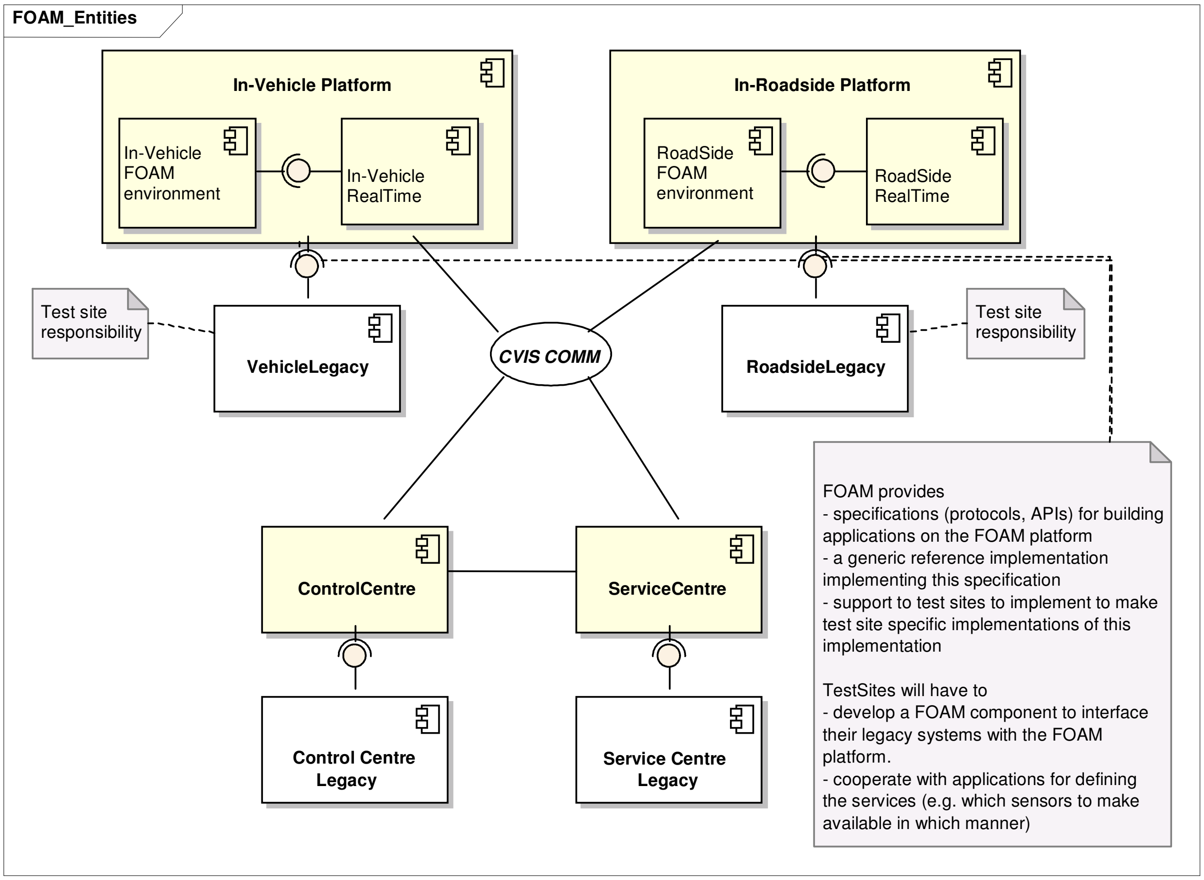

Figure 10 : FOAM entities

FOAM Security

The FOAM Security services will provide authentication, authorization and secure communication to Applications.

FOAM Remote Management

The FOAM Remote Management comprises remote installation, updates and configuration of software.

FOAM Vehicle API

The FOAM Vehicle API will provide standardized access to vehicle sensors for Applications. HMI connectors can are also be integrated, but are not in the main focus of FOAM developments

FOAM Roadside API

The FOAM Vehicle API will provide standardized access to roadside sensors and actuators for Applications.

COMM Services

Functionality from the CVIS Router platform is made available in terms of services. The services will be integrated in the Host Platform and can be used by other Host applications. An application can require a minimum link performance or set policies for how the communication session shall happen.

COMO Services

COMO Services will provide information on traffic status to other CVIS applications. Based on measurement data (roadside and vehicle) a cooperative, shared evaluation and fusion of this data will be done. Finally information products (e.g. dynamic travel time or speed limits on links, incident messages) are published to other applications.

COMO services shall run on the FOAM environment. Also native/real time implementations are within the scope of COMO.

POMA Mapping Server

The key HW and SW components to be delivered by POMA include:

- An in-vehicle positioning box providing the position of the vehicle, the computation being done at the vehicle level with the possibility to use information provided by the road side unit. Elements of the solution may be located in the CALM router while others may be implemented at the host level (e.g. high level of data fusion)
- An infrastructure positioning box providing the position of the vehicle, the computation being done at the infrastructure level.
- A map update server providing access to static map content
- A geospatial platform providing access to geo-referenced content through API. Such content includes maps, addresses, maps + traffic information, etc.
- A map matching module
- A location referencing coding/decoding solution

4.2.4. Host Middleware

OSGi

The OSGi Alliance platform (www.osgi.org) is a middleware standard that provides a framework for dynamic Java software components. The standard is designed with remote management scenarios in mind and it does not prescribe any single remote management protocol, rather it exposes functionality for use by Management Agents that can implement any remote management protocol. The framework is divided into a number of layers:

- L0 - Execution Environment
- L1 - Modules
- L2 - Life Cycle Management
- L3 - Service Registry

Java Virtual Machine – JVM

The Java Virtual Machine provides the execution environment for the OSGi framework. It will provide a great degree of hardware and operating system independence.

4.2.5. Host Platform Core functions

An x86 based automotive PC with standard peripherals and add-on devices produced by CVIS CoreTech partners serves for the basis of the Host platform implementation. Its main features are the following:

- Intel Pentium M processor
- High performance with full feature I/O
- Supports PCI-X (64 bit) interface
- Supports four USB (2.0) ports and three COM ports
- Supports one Mini PCI interface
- Supports PCI-104 interface
- Supports CompactFlash
- One 2.5" HDD drive bay
- Watchdog Timer
- ATX 100W 24VDC-in power supply.

The Operating System (OS) is the key SW component of the host/router platform. The choice of the operating system influences portability, stability and extendibility of the whole CVIS system. The OS provides standard APIs, as well as, a decent development environment. According to the general project requirement towards the creation of an open system architecture the OS should be freely available. It also helps reducing costs of the development. As an additional requirement, the source code of the OS should be available under a license relaxed enough to be able to build commercial systems later upon it.

GNU/Linux is a CTG accepted choice for the OS selection, as far as the above requirements are concerned. GNU/Linux is freely available, it has rather good quality industry-standard development tools, moreover, its license permit to use its source code as far as all components linked to its kernel are also licensed under the same license, i.e., the GNU GPL. Also, GNU/Linux is a well-known system with accepted APIs and communication mechanisms; it is a well referenced system which is successfully used for research and development worldwide, so it will likely be accepted as a base of a later commercial product from this point of view. It is proven that GNU/Linux is suitable for embedded environments as well, especially for prototype development stage of the project.

There are many GNU/Linux distributions. The Debian GNU/Linux "Sarge" 3.1 is a well positioned distribution worth to further consideration.

Since CVIS CoreTech has to adopt third party project results as well, the kernel version is to be chosen such that this integration process is well supported by the OS itself. For this purpose the kernel 2.6.15 is proposed.

Real time requirements will obviously necessitate fine-tuning of the operating system for better performance. Ramsys, on the analogy of the microkernel applications OSEK VDX (e.g. NUCLEUS), which is widely accepted and used in recent car manufacturing industry, put forward a proposition for the application of a real-time Linux microkernel (namely L4 or Fiasco) in order to be able to guarantee real-time scheduling at the lowest OS level. In contrast with OSEK VDX, which is a proprietary solution, L4 provides an open platform alternative for CVIS. This L4 microkernel would render an additional abstraction layer between the hardware and the operating system.

4.3. *Local Networks*

4.3.1. The CVIS Vehicle Gateway / Firewall

The OEM gateway / Firewall is the protocol converter between the open network from the CVIS router and the OEM proprietary network in the vehicle.

The gateway will also handle firewall functions so that non-authorised access from the open networks into the closed, proprietary side is prevented.

The internal structure and the interfaces to the proprietary side may be defined per OEM or Roadside supplier, but it would be preferred to see co-operation for common devices and software since there are a lot of commonalities.

The interfaces and protocols on open network side shall be defined jointly between OEM/Roadside supplier and Core Technology group.

4.3.2. CALM IPv6 Network Layer

This component includes all the necessary networking protocols from the IPv6 family as specified by the IETF [Internet Engineering Task Force http://www.ietf.org] to configure an IPv6 address and to manage reception and transmission of IPv6 frames compliant with the set of CALM standards.

4.3.3. CALM FAST Network Layer

This component includes all the necessary networking protocols that do not make use of the Internet Protocol family, but enables the CALM FAST / WAVE communications.

The C2C-CC fast switching procedure is assumed to be covered by CALM FAST / WAVE. Details so far not standardized at ISO TC204 WG16 will be defined by CVIS based on requirements from Safespot.

5. Applications & Services

5.1. The CVIS service applications

A concept where any CVIS service application can be seen as software implementations in a CVIS host is illustrated in figure 11. The application is either Java OSGi Bundle or, in special cases, native implementations running directly on the host system.

All applications can offer service interfaces that can be used by other applications.

The Host platform itself is connected to the CVIS Router via an API. Also existing (Legacy) systems are connected via APIs. Through the APIs all service applications get access to the connected systems as the API shall implement service interfaces which transport the capabilities of the API connected systems in a standardised way to other service applications.

CVIS Sub projects will develop "reference implementations" of these APIs and their service interfaces. Test Sites will have to adapt the APIs to their specific context.

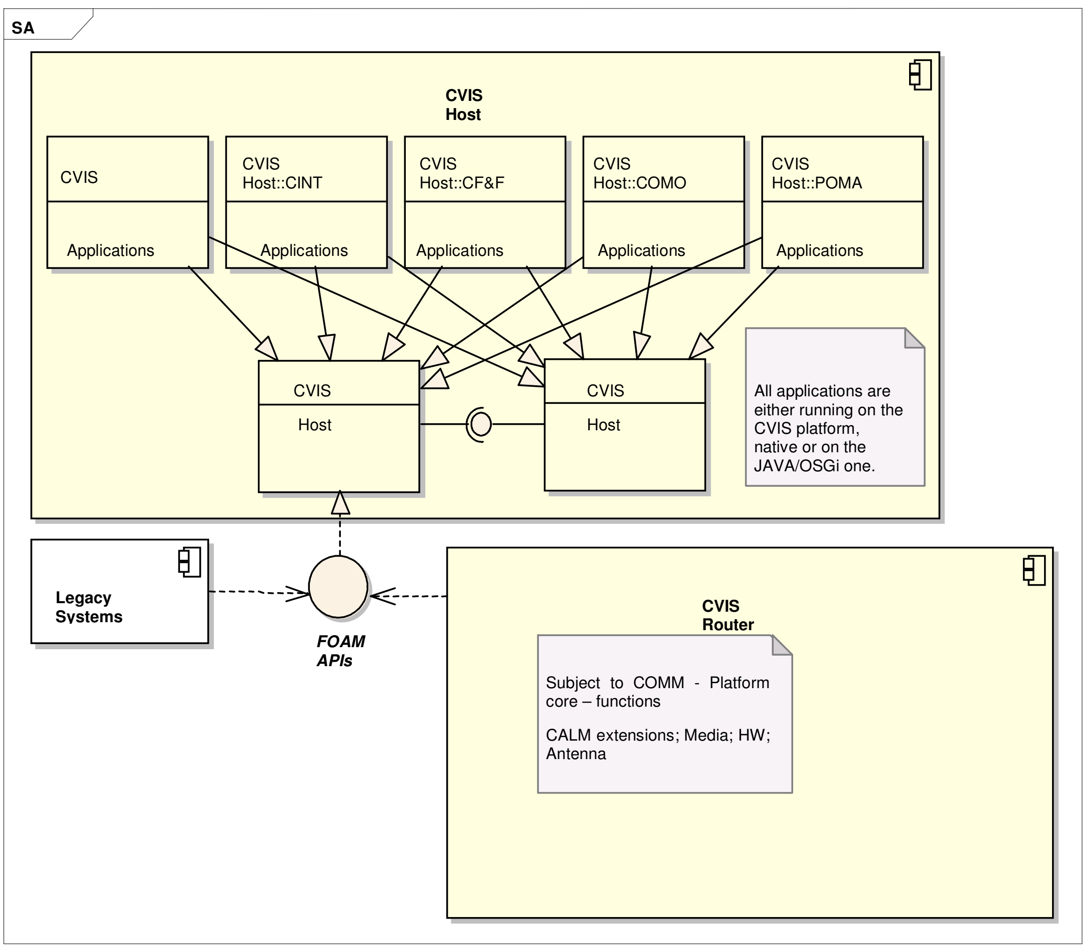

Figure11. CVIS service applications

- **COMM:**
  GPRS, UMTS, M5 / mobile Wi-Fi, IR, Ipv6, CALM FAST, Media Channel Policy.
- **FOAM:**
  Life cycle management of services, Remote Manageability of software / configurations; End-to-end security, Access to Legacy services (data, functions)
- **POMA:**
  Mapping information collection, Road Infrastructure information collection, Collaborative Positioning, Sensor data fusion solutions, GPS/EGNOS/Galileo**.** Road geometry description
- **CURB:**
  Cooperative Network Management, Cooperative Area Routing, Cooperative Local Traffic Control, Dynamic Bus Lanes
- **CINT:**
  EDA - Enhanced Driver Awareness, CTA - Cooperative Traveller Assistance
- **CF&F:**
  Hazardous goods management, Priority booking, Vehicle Coordination and monitoring
- **COMO:**
  Cooperative Vehicle/infrastructure traffic Monitor Data Interface, Distributed Data Fusion Algorithms

5.2. Service Sources

Services implement functions that can be used, e.g. chained together in different ways, in order to realize applications. An application is a composite process that fulfils some needs of the end user. Sample Applications are e.g. Park Booking and Dangerous Goods Handling.

Services are developed by some enterprise, agency by using software and hardware tools. Then they are installed in physical equipment in appropriate systems (roadside, vehicle and central system).

A service often exists in different versions: this can refer to a stage in development/revision or it can be tailored to serve some specific brand of equipment or customer. In the latter case we can distinguish between different profiles. Development and installation services in the CVIS project will be based on the principles given by the OSGi Alliance, the "framework" for handling the services.

5.3. Addressing

In order to make the cooperation possible, the CVIS must implement fast ways of addressing services, data and applications. The system approach describes as distributed approach whereby, area sub-centres, road-side clients and in-vehicle clients communicate "directly" (see e.g. Fig. 33 Co-operative management approach in CVIS Contract Annex 1). In order to facilitate this there might be a need for local or geographical based addressing scheme.

- In IPv6 we have the notion of a Care of Address (CoA). The CoA could correspond to a domain name based on a geographical area,

The namespace should be standardized, on a Pan-European Level. This will make it easy for equipment installed in moving vehicles to access the proper applications and information in new places.

By use of a local registry/DNS server, addresses can be mapped to the right processes on the given equipment.

5.4. System Initialization and Life Cycle Management

The total system described in CVIS involves several components, and initialization of the overall system entails multiple steps. Initialisation is one part of the life cycle management of the overall system, and the CVIS overall system is designed to be maintainable at least over the lifetime of a vehicle (15 years plus).

The following paragraph will just sketch some of the components and steps involved, while deliverable D.CVIS.3.3 "CVIS Architecture and Specification" will give a more comprehensive specification.

The main elements in the architecture are:

- Vehicle
- Roadside
- Centre

The life cycle management concept means that all elements and components need to have a clear specification and management for each of the following steps:

- Acquisition/planning
- Installation/Initialisation
- Operation/maintenance
- Decommission/recycling

Each step need to define and manage aspects such as data definitions, data flows, applications, firmware/hardware versions, identifiers, security key/certificates, protocols, etc.

The initialisation sequence in Vehicle involves steps such as installing hardware and approved firmware, installing trusted device, initialising hardware device and so on.

REFERENCES

[1] ***Annex I*** **- CVIS Cooperative Vehicle-Infrastructure Systems**

[2] D.CVIS.2.1. System Concept Definition Draft v5.0

ANNEX A – DEVELOPMENT STAGING

The following picture outlines the different development stages for the bottom-up process in CVIS:

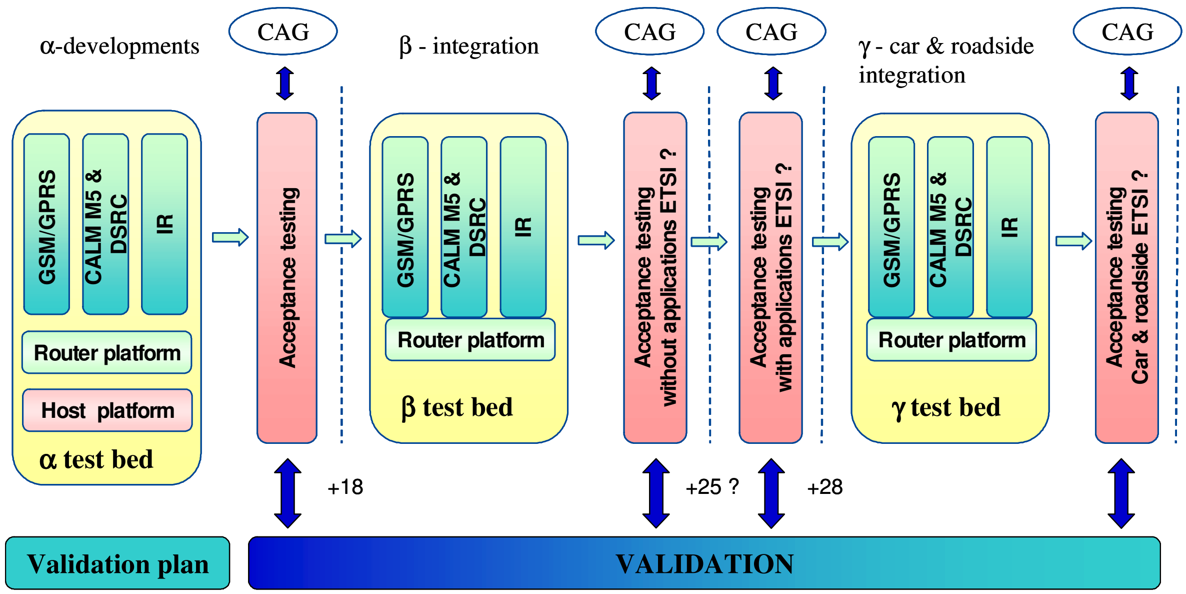

Figure 12. CVIS development stages

NOTE: The month numbers refers to when the testing shall be finished for all parties/all subprojects, starting from 1. February 2006.

NOTE: Please check in each SP for deadlines.

Alpha stage is defined as the development phase where one sub-technology is specified and developed/created to the point where it can be integrate into a beta platform. Alpha sub-technologies consist of SW and/or HW developments.

Beta stage is the phase where the different alpha sub-technologies are merged into workable platforms. There are two such platforms: the Router and the Host. Platforms are inherently generic at this stage, i.e. not personalized for vehicle, roadside or central usage.

Gamma stage is when the "personalization" of the platforms is done. For roadside this means packing router and host platforms into a portable roadside unit, adding local test-site specific services/applications, and qualifying gateways into existing roadside sensor networks. For vehicles this means integrating the beta units into the test vehicles, connecting to vehicle gateways, and adding specific software. Central system hosts will need to be adapted to the local requirements.

NOTE: Roadside suppliers and OEMs may want to implement and test the service element functions plus applications on their own proprietary hardware in addition to CVIS Host Platform. The Core Technology group will lend (porting) support to these activities as far as possible

The alpha and beta stage together form the Core Technology development, and will be developed in a generic way, but of course with help and influence from the six test sites.

The following **alpha sites** are defined (t.b.c.):

- Austria/Graz will develop IR with EFKON in the lead
- Germany/Stuttgart will develop 2G/3G with MM-lab in the lead
- Norway/Trondheim will develop M5/DSRC with Q-Free in the lead
- Germany/Berlin will develop the Galileo/GPS front-end with DLR in lead

NOTE: Tachograph will be supplied by OEM gateway, all other sensors like inertial sensors will be included in the Mobile Router platform.

NOTE: POMO may need to split this activity from the map/positioning services development, perhaps with two different alpha sites and different leaders ->

The router SW will be developed as a more spread out task with Budapest / Ramsys as the center, but with heavy inputs from INRIA and other alpha managers.

On the services part, then COMO, POMA and FOAM should each define an alpha site and the leader of that development activity.

The host SW (middleware and service management element) will partly based on GST results, and be an alpha site under FOAM control, suggested Gatespace/ Gothenburg?

The (test) applications will be based on the service element, and the intention is that these services should be very light-weight to implement. The platforms experts will need to be deeply involved in the first applications.

Another aspect is the back-office operations and databases/servers/control centres in the central system which will need significant resources to be operational. A good deal of the co-operative aspect of CVIS is based on joining databases, and re-using and fusing information from various sources. This will require heavy influence from each of the test sites and their existing infrastructure.

ANNEX B – WP3 High Level Process Diagram

CVIS will produce another deliverable called ***D.CVIS.3.2 – High Level Architecture***. The following diagram shows the assumptions and relations that are assumed when developing this Reference Architecture. Please note that the High-Level Architecture deliverable will replace this annex.

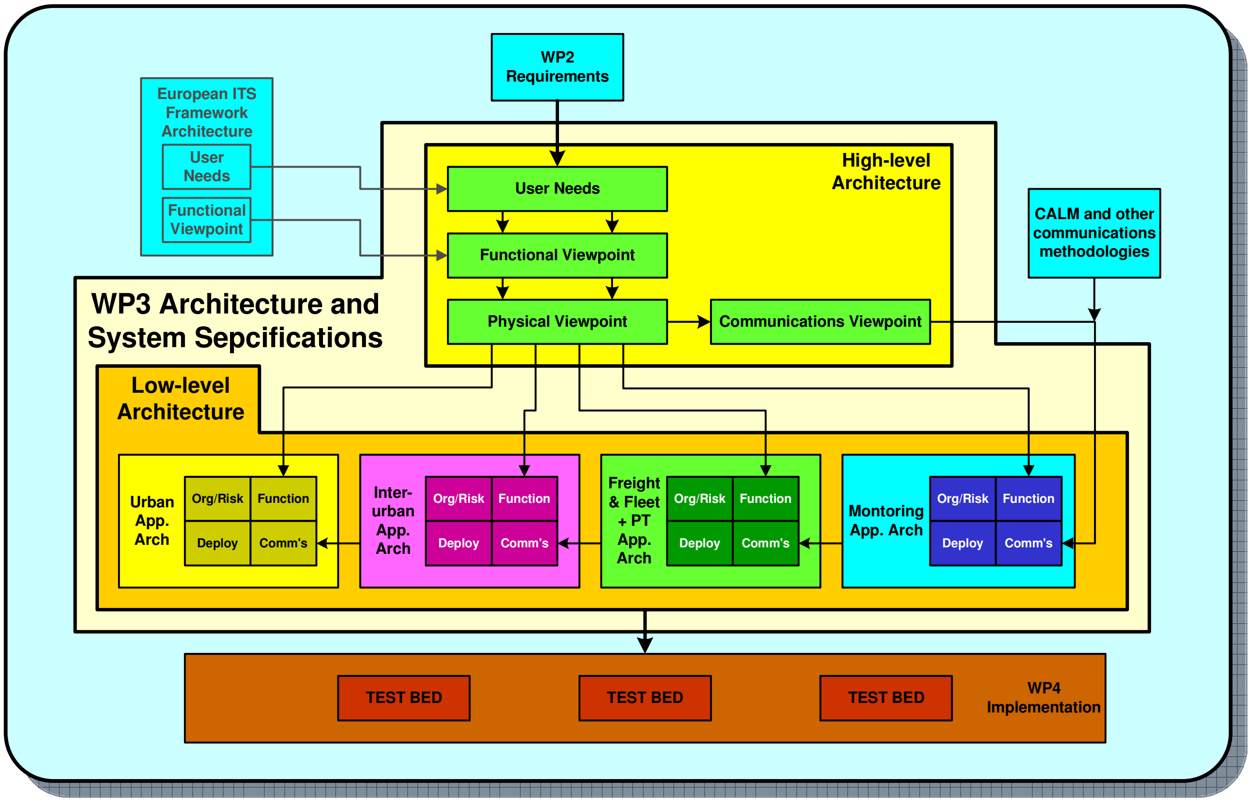

Figure 13. WP3 high level process

ANNEX C – COMM Design and Development Flow process

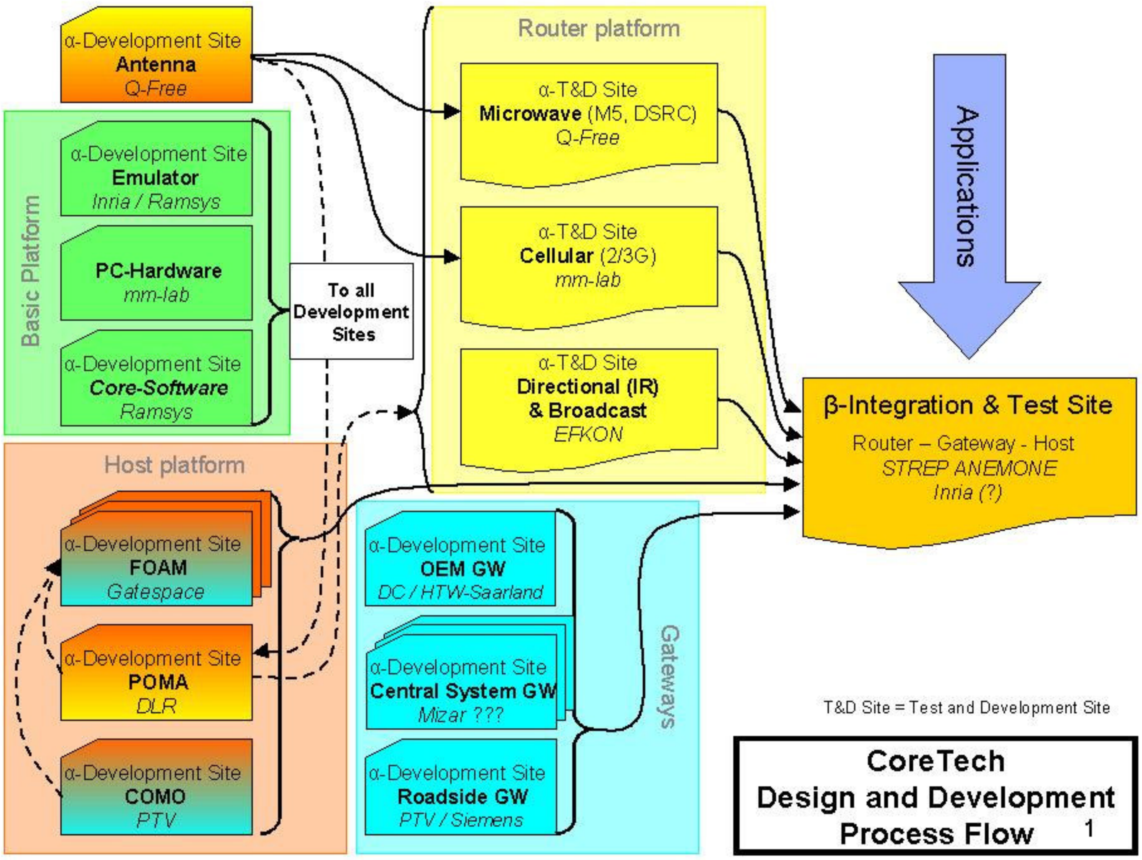

Figure 14. COMM design and development flow process