Cooperative Mobility Systems and Services for Energy Efficiency

D230.22(D2.2)	**High Level Architecture**

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Abstract

The eCoMove project is targeting at reducing fuel consumption and CO_2-emissions with 20% by supporting drivers of both vehicles and trucks to drive more efficient, to plan their routes more efficient and traffic managers to manage traffic more efficiently.
Information from road side units, traffic management centre, ecoMaps and also from other vehicles are exchanged to determine the best route, the most efficient driving strategy and the optimal traffic management and control strategy and settings.

This document is the second deliverable of the Core technology & integration sub project (SP2) and describes the results of the work package 3 (WP3) activities on architecture & system specification. This deliverable describes an integrated view of how the application subprojects ecoSmartDriving (SP3), ecoFreight & Logistics (SP4) and ecoTraffic Management & Control (SP5) build on the facilities and services provided by the Core Technology and Integration subproject (SP2) to realise a cooperative eCoMove system.

As a starting point, the approach that used for the WP3 activities is described. In this approach, the incorporated documentation standard is explained, followed by a brief description of the ArchiMate modelling language used in this document and employed by the architecture work packages in all subprojects.

Based on the deliverables from the Use Cases & Requirements Workpackage, system wide design decisions are presented, which describes the products and services provided to external customers. It shows the capabilities and dependencies between all applications are defined by multiple organisational concepts, which need to be explained as they are referenced often throughout all eCoMove architecture documentation, i.e. subproject related operational environment cross-sections, the three phases have been defined: pre-, on- and post-trip, and the Time and Area Scales of Operation. Finally, it describes the decisions related to privacy, security and multi-platform compatibility.

The high-level system architectural design is described. The description subdivides the complete eCoMove system according to the standards, eCoMove work structure and views employed in the project, creating multiple cross-sections that clarify the terminology and logical divisions. System components are described per subproject, followed by the informational flows between applications and facilities within and between the different types of ITS stations. It also describes the overall strategy to address the inefficiencies identified in [D2.1].

The interfaces between components and applications have been identified and listed in tables showing exchanged data objects. In addition, two-way traceability between architecture components and requirements is provided, including references to documentation where applicable.

Finally, a justification is given of architecture & system integration work package activities and deliverables.

Control sheet

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Terms and Abbreviations

Term	Abbr.	Definition
component		see 'configuration item'
computer software configuration item	CSCI	a group of software treated as a single entity: operating systems, drivers, system software layers, databases, applications
configuration item	CI	a collective term used for referring to both CSCIs and HWCIs
data element		an atomic unit of data that has precise meaning or precise semantics
data element assemblies		a collection of data elements, treated as a single entity: records, messages, files, arrays, displays, reports, etc.
Database	DB	an organised collection of data for one or more uses
database management system	DBMS	a set of computer programs that controls the creation, maintenance, and the use of a database
developer		one who programs or designs the system to match the requirements of the project
eDRP	eDRP	eCoMove Development reference platform
eML	eML	eCoMove Modelling Language
hardware configuration item	HWCI	a set of hardware treated as a single entity: processors, storage devices, network cards, radio antennas, GPS receivers
identifier		a project unique code used for reference
inputs		changes which are inserted into a system, which activate/modify a process
interface		a point of interaction between two systems
outputs		changes which exit a system, which activate/modify a process
privacy		the ability of an individual or group to seclude information about themselves
security		a degree of protection against danger, damage, loss, and criminal activity
service		a set of related software functionalities, together with the policies that should control its usage
subproject	SP	An organisational structure in the eCoMove project with a defined set of work
system		a set of interacting or interdependent entities forming an integrated whole
system state		a unique configuration of information in a program or machine
system mode		see system state
user		a person who uses a service provided by a system

1. Introduction

This document describes the results of the second phase of the eCoMove research project. It describes the overall high-level architecture of the eCoMove system based on the input from the first phase of the project which produced use cases and requirements described in [D2.1].

1.1. System Overview

The eCoMove system is designed to tackle the problem of energy efficiency in road transport by applying the latest vehicle-to-infrastructure and vehicle-to-vehicle technologies to create an integrated solution comprising cooperative eco-driving support and eco-traffic management. The project focuses on reducing wasted energy with the aim to demonstrate that the combination of these new ICT measures can potentially deliver up to 20% overall fuel savings and CO_2 emission reductions.

1.1.1. eCoMove Vision

As taken from [DoW], Figure 1 shows the vision of the eCoMove project which aims at minimising avoidable energy use in the transport of people and goods by road through the application of advanced ICT. The idea is that, for a given trip in a particular vehicle, there is a theoretical minimum energy consumption that could be achieved by the "perfect eco-driver" travelling through the "perfectly eco-managed" road network. In current situation, both drivers and traffic management system fall short of the ideal, and much energy is wasted and CO_2 emitted unnecessarily. However, information and communication technologies (ICT) have the potential to target this avoidable energy consumption without impairing the quality of mobility of people and goods.

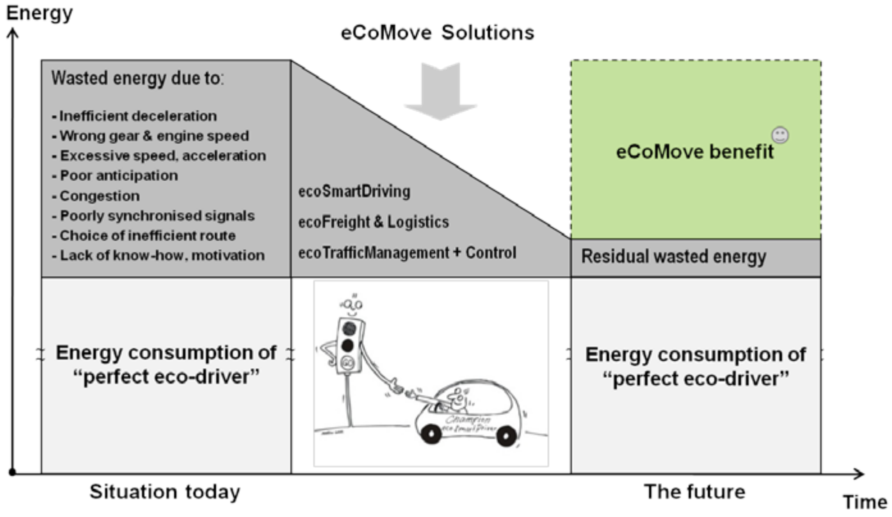

Figure 1 – eCoMove Vision

Note that the project approach assumes that demand for mobility and corresponding supply are unchanged – it is assumed that people make the same trips as before but use less energy for each trip. Thus any type of demand management measure is not included amongst the measures presented.

1.1.2. eCoMove Concept

Wasted energy due to driving behaviour can be addressed by eco driving systems including pre-trip planning, real-time eco-driving support and post-trip feedback. Waste due to inefficient traffic management can be addressed by eco-traffic management. In this context "eco" means a specific variant of an ITS measure that is specially configured for improved energy efficiency.

The eCoMove concept is that by exchange of data describing their current state, both the vehicle (and the driver) and the traffic system can benefit from extra information that helps them to perform better and to reduce their energy consumption. As originally stated in [DoW] and further developed in [D2.1], the eCoMove operation environment, including high level entities involved in the eCoMove System plus an example of specific data objects and applications related to a selection of use case scenarios, is shown in Figure 2.

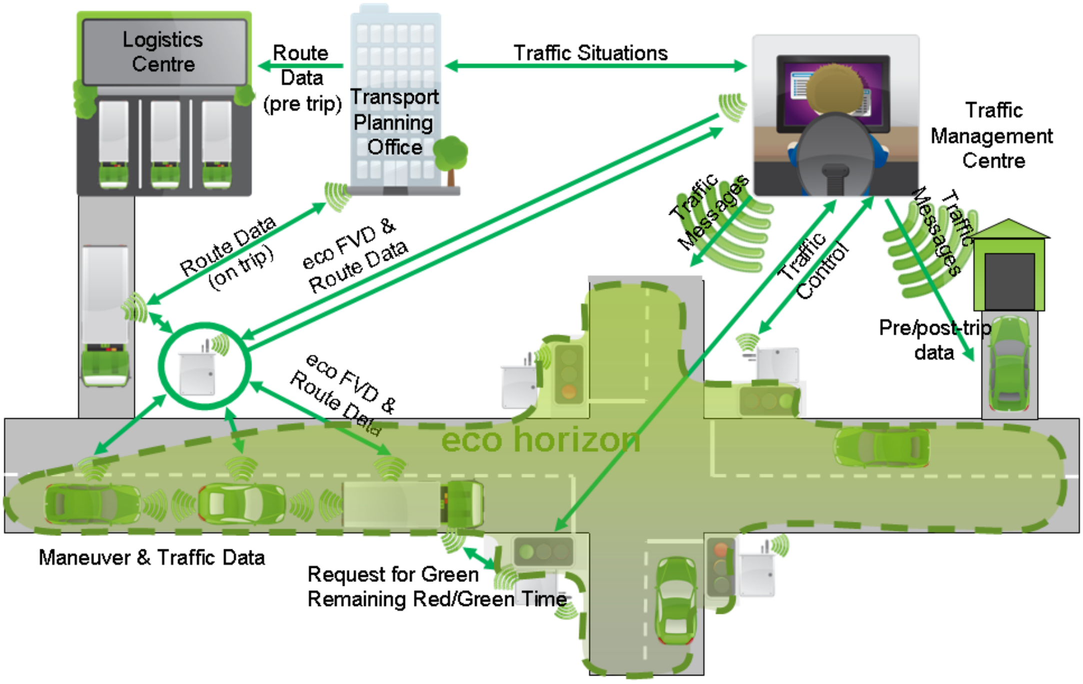

Figure 2 - Overall system concept

All entities displayed in Figure 2 are employed to realise the eCoMove subproject objectives, and are specified in [D2.1], [D3.1], [D4.1] and [D5.1].

1.1.3. eCoMove Objectives

The eCoMove project aims at reducing the fuel consumption by 20%. To achieve this overall target as average value in Europe, the eCoMove project has designed and will develop, test and evaluate ICT tools, systems and services to:

- Help a driver apply the appropriate actions and driving strategy to use the least possible fuel for a journey by finding the "greenest" route, the most economical use of vehicle controls, the best path through surrounding traffic and how to negotiate the next traffic signals with least chance of stopping;

- Improve truck/cargo energy efficiency by introducing a self-learning “driver coaching system” based on incentives for energy efficiency gains, and a cooperative planning/routing system that selects the most economical route for a truck while the traffic system optimises traffic lights to avoid unnecessary stops;
- Allow the traffic system and its manager to adapt traffic signal parameters and apply other traffic measures so that the ensemble of vehicles in the network consumes the least possible energy, while offering an advantage to specific types of vehicle that consume most fuel and to vehicles whose drivers adopt the most energy-efficient behaviour.

The eCoMove project aims not only to develop in-vehicle and traffic applications, but also to have these applications working within an eco-cooperative integrated solution to support individual drivers to drive most efficiently without giving up quality of mobility and to enable the maximum possible reduction of wasted fuel as defined in Figure 1.

As can be read in [D2.1], the majority of the system concept relates to urban environments. The justification for this is the fact that on-trip inter-urban operational environment contains a subset of components present in the urban environment. Inter-urban inefficiencies can be addressed with the same technology as urban ones.

Further description of this aim is described in Section 3.2, as this system-wide architecture decision has influenced all architecture activities.

1.1.4. eCoMove Organisational Structure

As described in the [DoW], the eCoMove project is split up into six numbered subprojects (called SP’s) and structured according to Figure 3. The systems and applications are developed in the subprojects ecoSmart Driving (SP3), ecoFreight & Logistics (SP4) and ecoTraffic Management & Control (SP5) and integrated in subproject Core Technology & Integration (SP2). Subproject Validation & Evaluation (SP6) focuses, as the name suggests, on the validation and evaluation of the eCoMove systems.

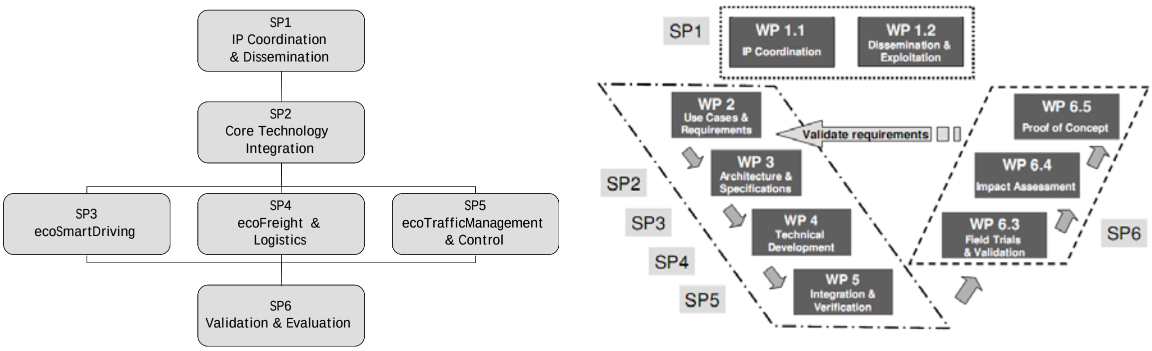

Figure 3 - eCoMove Subproject and V-Model Process Structure

The work in eCoMove is structured according to the V-Model, also depicted in Figure 3. The common goal of the architecture work package (referred to as WP3) activities has been to:

- define specific application and component architectures,
- define organisational entities,

- define relationships,
- define data flows,
- define and specify interfaces, and
- to define system specifications as blueprint for application and prototype development.

Work and specification has been done according to the procedure and templates defined in the Core Technology & Integration (SP2) architecture work package, which are explained in the following section.

1.2. Document Overview

The reasons and motivation for drafting this deliverable are to achieve the following:

- to create a common understanding among creators of the eCoMove system (e.g. which aspect of the system is discussed at a certain description),
- to support interoperability between all parts of the eCoMove system,
- to ensure that the eCoMove system parts together deliver the desired reduction of CO_2 emissions.

As described in the description of work, the structure of architecture deliverable relations is depicted by the PERT chart in the [DoW], of which a subsample is shown in Figure 4. IPM2, IPM3 and IPM4 are numbered Integrating Project Milestones. The delivery of this deliverable D2.2 marks the 3rd milestone in the eCoMove project.

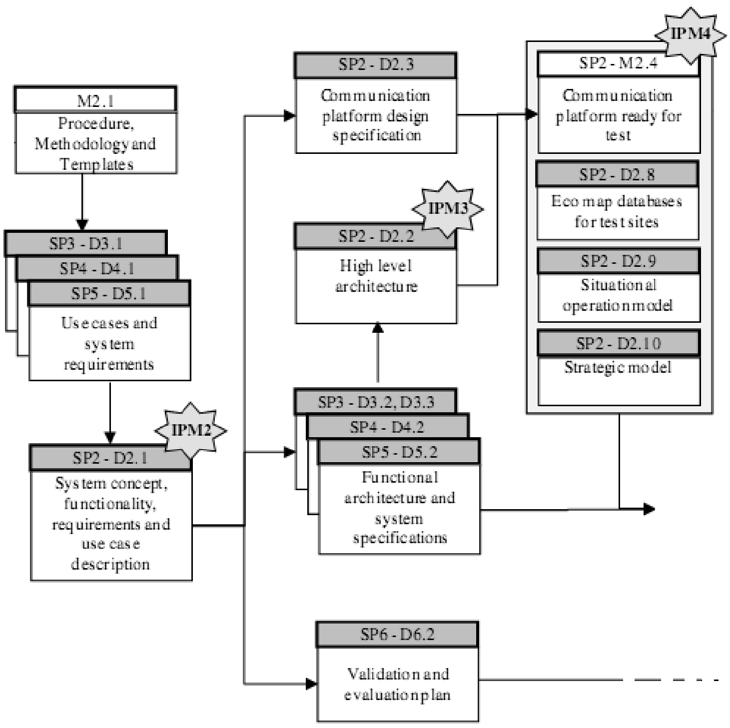

Figure 4 – Subsample PERT chart [DoW], page 42.

This document, as second deliverable of the SP2 Core Technology & Integration, brings together the results of the work in the architecture work package (WP3) of the applications subprojects ecoSmart Driving (SP3), ecoFreight & Logistics (SP4) and ecoTraffic Management & Control (SP5) that are described in the deliverables [D3.2], [D3.3], [D4.2] and [D5.2]. This document also describes the high level architecture of the core technologies supporting the eCoMove applications. The core technologies will be further designed and specified in [D2.3], [D2.4], [D2.5], [D2.6], [D2.9] and [D2.10] (not all of them are depicted in the PERT chart).

1.2.1. Intended Audience

The intended audience of this document are all stakeholders interested in the eCoMove project and in the Cooperative Systems. Four main audiences can be distinguished:

- System architects and developers in the eCoMove project who need to identify how parts developed in the subprojects (SP) are related to other project activities, to check consistencies / overlaps and to identify missing links,
- the European Commission who is supporting the eCoMove project,
- the correlated projects in the area of Cooperative ITS, and
- external stakeholders who would like to understand the eCoMove system architecture.

1.2.2. Document Structure

The eCoMove documentation in Use Cases & Requirements and Architecture work packages is structured according to templates based on the J-STD-016 standard, which is a documentation standard for software development processes. The standard establishes uniform specification for designing, developing, modifying, and documenting software, which has been specified in [JSTD].

A document overview is provided here:
Chapter 1 briefly states the purpose of the system to which this document applies. It shall describe the general nature of the system; summarise operation, user, developer, and support services; identify current and planned operating sites. It shall describe the intended audience and summarise the purpose and contents of this document.
Chapter 2 lists the number, title, revision, and date of all documents referenced in this document.
Chapter 3 is divided into paragraphs to present system-wide design decisions, that is, decisions about the system's behavioural design (i.e. how it will behave, from a user's point of view, in meeting its requirements, ignoring internal implementation) and other decisions affecting the selection and design of system components.
Chapter 4 describes the system high level architectural design. It both summarises architectural designs from the application subprojects as well as provides core technology architecture.
Chapter 5 is divided into sections to describe the interface characteristics of eCoMove systems.
Chapter 6 provides both traceability from each system component identified in the deliverable to the system requirements allocated to it as well as traceability from each system requirement to the system components to which it is allocated.
And finally, **Chapter 7** provides justification of architecture & system integration work package (WP3) activities and deliverables.

1.2.3. Modelling Language in eCoMove Architecture

The modelling language used in eCoMove is based on [ArchiMate], which supports the description, analysis and visualisation of architecture across the SP's in an unambiguous way. It consists of active structure elements, behavioural elements and passive structure elements. These three aspects – **active structure, behaviour and passive structure** – have been inspired by natural language, where a sentence has a subject (active structure), a verb (behaviour), and an object (passive structure). E.g. "The ecoNavigator calculates a route." All building blocks used in the modelling language relate to either one of these categories. By being aware of the type of the element, it makes it easier to understand the relations between elements.

Also, to be able to read eCoMove design diagrams, the reader must be aware that ArchiMate language defines three main layers, based on specialisations of the three types of basic elements described in the previous section:

- The **Business Layer** offers products and services to external customers, which are realised in the organisation by eCoMove processes performed by eCoMove actors.
- The **Application Layer** supports the business layer with application services which are realised by eCoMove applications.
- The **Technology Layer** offers infrastructure services (e.g., processing, storage, and communication services) needed to run applications, realised by computer and communication hardware and system software.

As the level of experience with Enterprise Architecture's ArchiMate differed greatly in the eCoMove consortium, a subset of the complete set of modelling concepts was selected by Core Technology & Integration (SP2) coordination, which resulted in the eCoMove Modelling Language, or eML. In eML, no new concepts have been introduced. This is done based on the rationale that any designs made in eML can be correlated and expanded to complete ArchiMate designs without modification. The eML specifications have been documented in [eML], which includes descriptions of

- Concepts (what do the different shapes of the objects mean?),
- Relations (what do the different shapes of the lines and arrows mean?), and
- Colours (what do the different colourings of the concepts mean?).

The [eML] document also contains simple examples which explain how to read/construct the diagrams.

2. Referenced Documents

This chapter provides a listing of all documents referenced by this deliverable, including details known at the time of writing.

2.1. eCoMove Deliverables

This section contains deliverables (to be) produced within the eCoMove project. All public deliverables will be available for download on the eCoMove project website http://www.ecomove-project.eu/publications/deliverables/.

2.1.1. Finalised eCoMove Deliverables

Ref	Doc	Version, Date
[D2.1]	101110-DEL-D2.1-System-concept-requirements-and-use-case-description-v06-LR.pdf	V0.6, 2010-11

Table 1 – Finalised eCoMove Deliverables

2.1.2. Future eCoMove Deliverables

Ref	Title	Expected Date
[D2.3]	D2.3: eCoMove Communication platform design specification	2011-03
[D2.4]	D2.4: eCoMove cooperative communication protocols specification	2011-03
[D2.5]	D2.5: Preliminary definition of Eco Message	2011-03
[D2.6]	D2.6: ecoMap specification	2011-04
[D2.9]	D2.9: ecoSituational model (eSiM)	2011-09
[D2.10]	D2.10: ecoStrategic model (eStraM)	2011-09
[D3.2]	D3.2: Functional architecture and specifications for ecoSmartDriving & ecoTripPlanning	2011-03
[D3.3]	D3.3: Functional architecture and specifications for ecoPostTrip & ecoMonitoring	2011-03
[D4.2]	D4.2: Functional architecture and system specifications	2011-03
[D5.2]	D5.2: Functional architecture and System Specifications	2011-03

Table 2 – Future eCoMove Deliverables

2.2. eCoMove Reference Documents

This section contains internal documents (to be) produced within the eCoMove project. All documents are or will be available for download on the eCoMove project collaboration portal on ProjectPlace: https://secure.projectplace.com/en/Log-in. All partners in the consortium have access to the portal, account management is owned by ERTICO.

Ref	Doc	Version, Date
[DoW]	DoW-PartB_eCoMove_v1.2 final-NEF.pdf	V1.2, 2010-06
[eML]	DOC-SP2-WP3-eML_Specification_Doc_TS.pdf	V0.4, 2010-11
[eDH]	110118_eCoMove-Dev-Handbook.doc	V0.21, 2011-02

Table 3 – eCoMove reference documents

2.3. External Documents & Standards

This section contains external documents and standards referenced by this document.

Ref	Doc	Version, Date
[ETSI]	ETSI EN 302 665	V1.1.1, 2010-09
[ArchiMate]	Enterprise Architecture at Work: Modelling, Communication, and Analysis	9783540243717 ISBN, 2005
[OSI model]	ISO/IEC 7498-1: "Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model".	90.93, 2000-06

Table 4 – External Documents and Standards

2.4. Web Links to Referenced Projects

This section contains external links to projects referenced by this and other architecture documents.

Project	Link
AIDE	http://www.aide-eu.org/
AKTIV	http://www.aktiv-online.org/
COMeSafetey	http://www.comesafety.org/
COOPERS	http://www.coopers-ip.eu/
CVIS	http://www.cvisproject.org/
Pre-Drive C2X	http://www.pre-drive-c2x.eu
SAFESPOT	http://www.safespot-eu.org/
simTD	http://www.simtd.de/
SPITS	https://spits-project.com/

Table 5 – Web Links to Referenced Projects

3. System-wide design decisions

As stated in [D2.1], the eCoMove concept is that through the exchange of state description data between a vehicle and the traffic system, both the vehicle (and the driver) and traffic system can benefit from the extra information that helps them to perform better and to reduce their energy consumption.

The eCoMove project develops an eco-cooperative system built around information exchange via advanced V2V (vehicle-to-vehicle) and V2I (vehicle-to-infrastructure and vice versa) communication. Each eCoMove application uses cooperative data exchange in some way, as either originator or recipient. In the system, an individual vehicle equipped with an on-board eco-driving system and communication platform can exchange data with infrastructure and other equipped vehicles. Likewise, an eCoMove roadside traffic management unit is equipped with a fully compatible communication platform able to exchange data with equipped cars, trucks, etc.

Given the combination of these new ICT measures described above, users and stakeholders have the means to cooperate on different timescales and area levels. Policy makers have the means to modify the parameters on a macroscopic level which has an effect throughout the network, while drivers have the opportunity to directly react on information provided to them. Cooperation aims to show up to 20% overall fuel savings and CO_2-emission reductions without impairing the quality of mobility of people and goods.

3.1. Process Viewpoint

This section describes the products and services provided to external customers, which are realised in the organisation by eCoMove processes and performed by eCoMove actors.

3.1.1. Products and Services

The eCoMove project provides services which tackles three main causes of avoidable energy use by road vehicles without impairing the quality of mobility of people and goods:

- Inefficient trip planning & route choice;
- Inefficient driving performance;
- Inefficient traffic management & control.

A thorough analysis on Fuel efficiency improvement is provided in [D2.1], section 2.3. In this deliverable, the inefficiencies have been categorised according to the trip phasing described in subsection 3.1.2.2 below, and the tables have been cross-checked with all application developing subprojects to ensure that all relevant inefficiencies that can be targeted by the eCoMove system are indeed included.
One of the highly informative overviews from the analysis is shown in Figure 6, where different types of inefficient behaviours are mapped to the environmental causes that initiated them. This is an example which provides an indication of the research on inefficiencies addressed by eCoMove products and services: for the complete analysis and a clear view and explanation of Figure 6 (colouring and content of the boxes), please read contents of [D2.1], chapter 2.

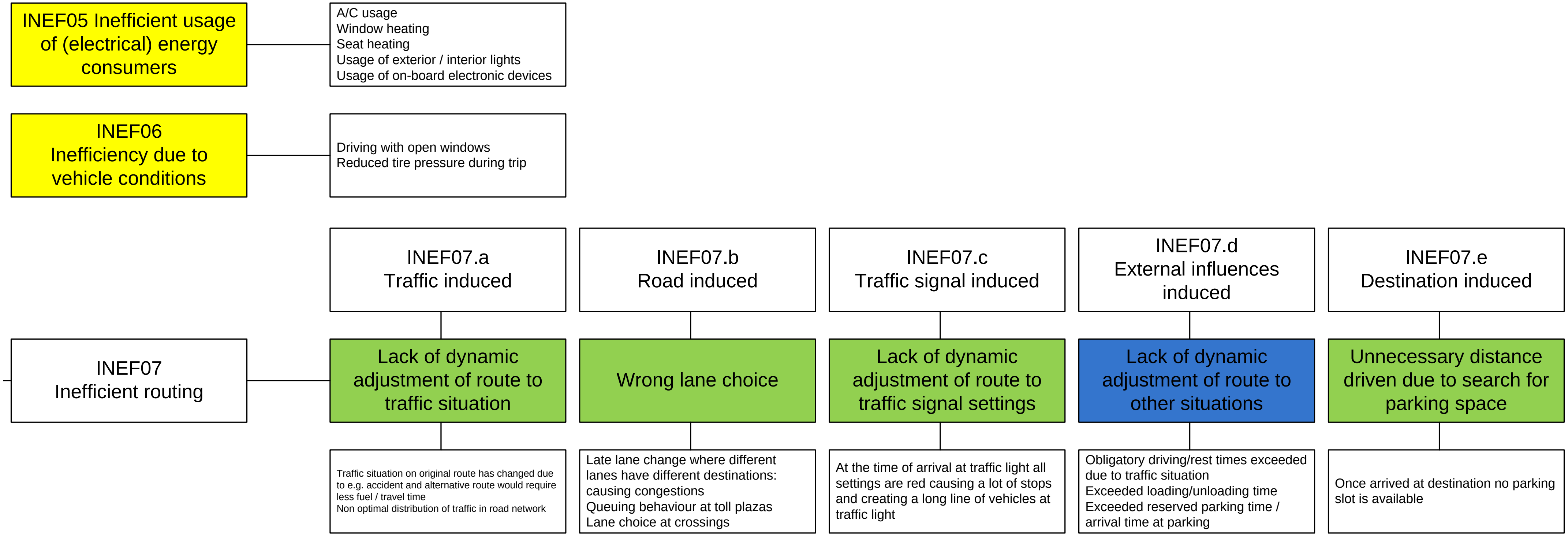

Figure 5 – On-Trip fuel consumption inefficiencies identified in eCoMove (part 1)

INEF08 Inefficient acceleration	Heavy acceleration in dense traffic Heavy acceleration in stop-and-go traffic Inefficient merging Overtaking other vehicle	Approaching higher speed limit (e.g. leaving urban area, entering highway) Returning to speed limit after left or right turn Driving up/downhill	xxx	Driving aggressively: Inappropriate acceleration Overtaking other vehicle Fast closing of gaps in stop-and-go traffic	Leaving red traffic light Leaving after closed bridge / railway crossing Entering highway with ramp metering	ACC system acceleration when approaching lower speed limit / vehicle is changing (entering) lane in front
INEF09 Inefficient deceleration	Vehicle in front suddenly slowing down Unexpected lane change of other vehicles Bad visibility due to vehicles in front Approaching congestion / road works Approaching accident Driving past accident on opposite lane	Approaching left or right turn / roundabout Approaching (sharp) curve Approaching lower speed limit Approaching road bumps or other traffic slowing measures Approaching stop sign Approaching merging point	Slippery surface (ice, snow, water, leaves, etc.) Blinded by sunlight Bad view due to much water on road	Driving aggressively: Heavy / late braking Keeping insufficient distance to vehicle in front	Approaching traffic light Approaching closed bridge / railway crossing Approaching ramp meter Approaching toll gate	ACC system decelerating while vehicle in front is changing (leaving) lane
INEF10 Inefficient (unnecessary) Idling	Vehicle in front standing still (e.g. before turn right or left)l Traffic jam / congestion Need to give way to other vehicles	xxx	Leaving the engine on for cooling / heating during wait period	Not turning the engine off Starting the engine and not drive away directly	Leaving the engine on during red light / closed bridge / closed railway crossing	xxx
INEF11 Inefficient speed	Speed of traffic not most efficient speed for specific vehicle Traffic does not enable constant speed / unstable traffic flows (e.g. stop-and-go traffic)	Driving up/downhill Varying speed due to speed bumps or other traffic slowing measures	Weather could influence (non) awareness of speed: Slippery surface (ice, snow, water, leaves, etc.) Blinded by sunlight Bad view due to much water on road	Driving too fast Driving too slow Driving non-constant speed (saw-tooth)	Speed for Green wave	ACC system not keeping correct speed for Green wave
INEF12 Inefficient gear / rpm	Dense traffic could influence (non) awareness of gear choice	Driving up/downhill	Weather could influence (non) awareness of gear choice	Using inefficient gear for selected speed Selecting lower gear for increased power Not using 'N" in automatic vehicles	xxx	ACC system not choosing right gear for driving situation (e.g. slope)
INEF13 Unnecessary stops	Stop-and-go traffic	xxx	xxx	Fast closing of gaps in stop-and-go traffic	Lack of traffic light synchronisation Lack of traffic light flexibility	xxx

Figure 6 – On-Trip fuel consumption inefficiencies identified in eCoMove (part 2)

This approach resulted in the following eCoMove system wide design decisions, which are given an identifier in the format **eSWDD#**, for future reference.

eSWDD1. For the eCoMove applications in passenger cars it is assumed that the trip destination and the selected mode of transport are both a given: the applications that are designed for passenger cars will focus on how a given trip in a given vehicle can be executed in the least fuel consuming way. If the destination of a trip is changed once underway, then this is treated as if a new trip is started. This means that applications are designed to help a driver to plan a trip better (e.g. providing a route and a time to travel, resulting in optimal fuel consumption), to support a driver to drive as fuel efficient as possible, and to provide a driver with feedback on his or her actions. Also, next to optimising primary driving tasks, applications help a driver to optimise vehicle condition (e.g. tire pressure, unnecessary loading and to manage the use of on-board energy consumers). The designs for services provided to drivers of passenger cars are described in subsection 4.1.1, and have been documented in [D3.2], [D3.3].

eSWDD2. For freight / logistics the eCoMove applications aim to optimise the way transport is organised in the planning phase, as well as to optimise driver behaviour with respect to fuel consumption on the road, while accepting the transport of goods as a given. Given the transport assignment, a different trailer-truck combination, different loading or an alternative route can be proposed, in combination with the provision of on-trip driver coaching to reduce fuel once the route has been determined. The designs for services provided to fleet management and operations are described in subsection 4.1.2, and have been documented in [D4.2].

eSWDD3. The ecoTraffic Management and Control measures developed within eCoMove are based on the assumption of fixed traffic demand, including the time of travel. This assumption holds if the expected traffic demand changes slower than the action time scale by the traffic management. Exceptions are e.g. sudden traffic demand generating events, like unexpected ends of football matches, or stadium concerts. Two approaches have been identified in this sub-project to create an eco-intelligent network:

- Improvement of the operation of traffic systems like traffic lights and ramp metering installations in a way that is more fuel efficient
- providing vehicles and drivers with roadside information and tailored advices that enable drivers to improve driving behaviour, and to then provide feedback to show how effective that measure was in that particular situation

The designs for services provided to traffic management and policy control are described in subsection 4.1.3, and have been documented in [D5.2].

eSWDD4. All these services combined aim to approach the theoretical minimum fuel consumption for vehicles, drivers and their journeys as originally stated in [DoW], from which Figure 7 is directly taken.

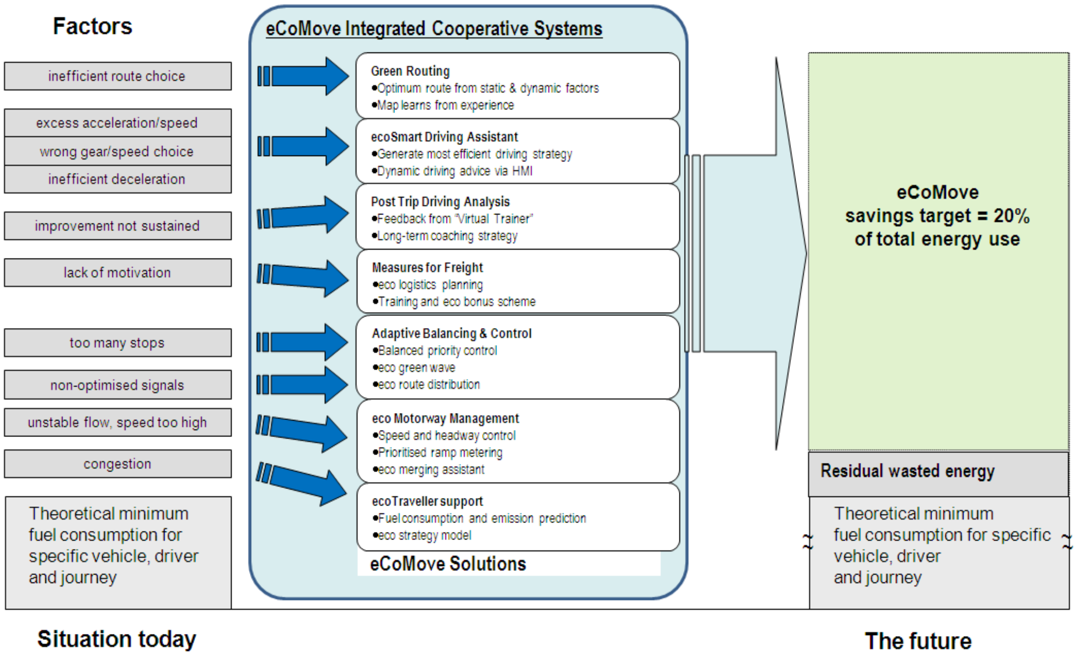

Figure 7 - eCoMove services aimed to reduce inefficient fuel consumption

These eCoMove system wide design decisions are reflected by the eCoMove architecture, as documented in the architecture specifications.

3.1.2. Concept

The capabilities and dependencies between all applications are defined by multiple organisational concepts, which need to be explained as they are referenced often throughout all eCoMove architecture documentation.

3.1.2.1. Subproject Related Operational Environment Cross-Sections

The first organisational cross-section is based on eCoMove sub-projects structure, which has already been introduced in previous chapters. The consequences of this separation between sub-projects is described in relation to the operational environment is depicted in Figure 8, where the complete integrated cooperative ITS environment on overall project level is separated per application subproject into subsets.

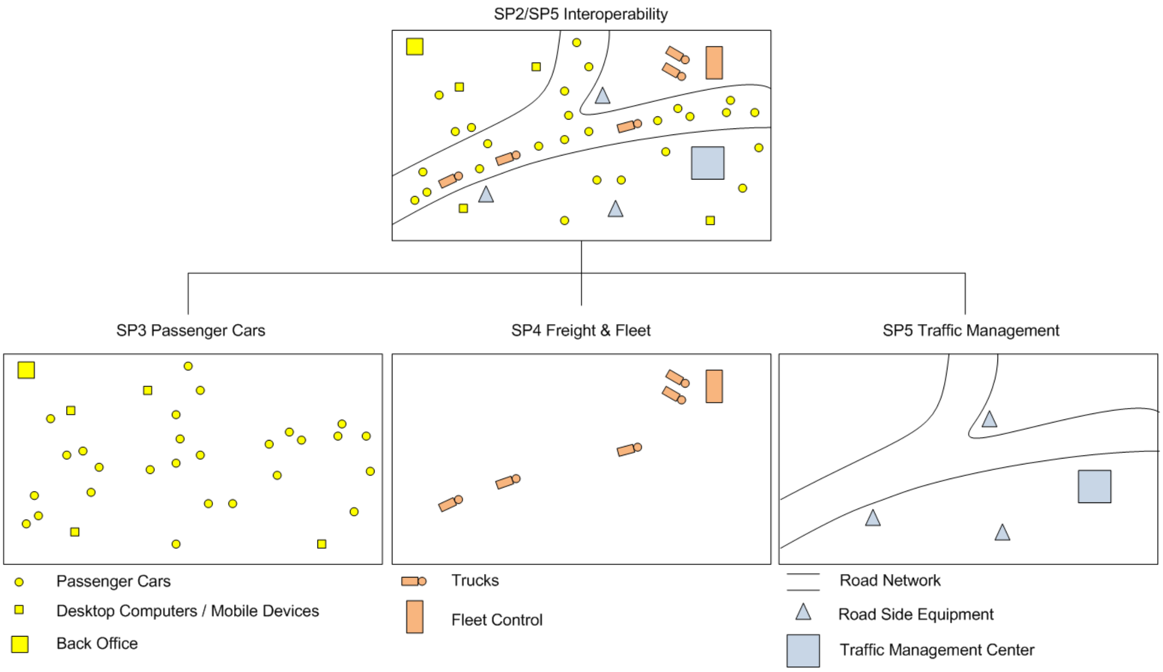

Figure 8 – Project Structure Related Operational Environment Cross-Sections

Key concepts of the three application subproject environments are:

- SP3: Passenger Cars cooperating with mobile devices, used by private drivers using the eCoMove system in their private and professional lives.
- SP4 Freight & Fleet: Trucks driven by professional drivers, managed by their Fleet Company management offices, integration of the eCoMove system in highly advanced fleet management business protocols and strict government regulations.
- SP5 Traffic Management: Vast road networks equipped with road-side sensors and communication devices, regional traffic management centres operating on a macroscopic scale, setting out traffic policies and regulations for the present and the future.

Understanding this three-way separation is crucial to understanding the challenges and solutions which are considered within the application subprojects, as well as the challenges and solutions which are considered in the Core Technology & Integration (SP2) and ecoTraffic Management & Control (SP5) subprojects which assess the integration between the application subprojects on the overall project level.

3.1.2.2. Pre-Trip, On-Trip and Post-Trip

As described in [D2.1], three phases have been defined: pre-, on- and post-trip. The definitions are based on the driver behavioural state, as driver behaviour is central to the eCoMove objective. Based on the driver intention, the driver behavioural state can be subdivided into the three states depicted in Figure 9.

Even though the descriptions for these states have already been provided in [D2.1], they are given here again with slightly modified descriptions tailored to support architectural descriptions instead of use cases (e.g. more formal descriptions of phase transitions, etc.).

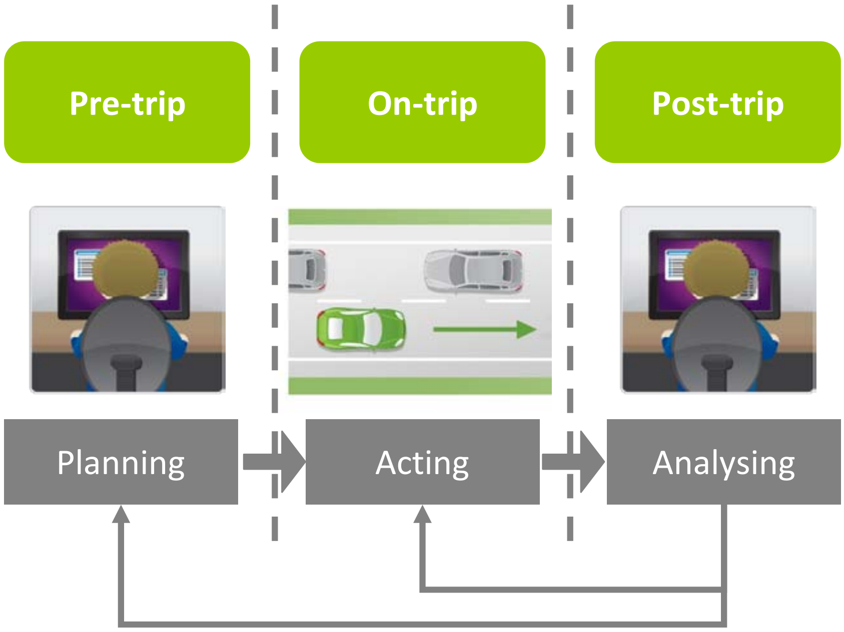

Figure 9 – Trip Phasing

- ***Pre-trip phase - Planning***: in this phase the driver or fleet planner creates travel plans. In the eCoMove project it is acknowledged that the decisions made in this phase have a direct influence the actual execution of the trip and hence on emission levels. The pre-trip phase commences when the driver or fleet planner plans the trip and checks vehicle or cargo condition/state. It finishes by definition with the driver starting his / her vehicle to drive to the planned destination as at that point the driver's immediate actions directly influence emission levels and the On-Trip phase has commenced. However, it must also be pointed out that some processes to be described as a pre-trip planning actions can be performed while the on-trip phase has started as technically a driver is continuously planning the part of the trip ahead.

- ***On-trip phase - Acting:*** in this phase the driver drives the vehicle within a network that is controlled by the traffic management centre. Here the driver's choices and actions directly influence energy consumption (such as driving behaviour, destination changes, etc). This phase commences with the moment the driver starts he vehicle to drive to the planned destination. The phase finishes when the trip-destination has been reached and the driver switching the engine and ignition off. Note that just one of the two occurrences does not denote the end of this phase.

- ***Post-trip phase - Analysing:*** in this phase the driver receives feedback and learns how his / her driving behaviour and route choices have impacted the fuel consumption and what possibilities he / she has to improve this in the future. Even though the driver might not immediately analyse behaviour after a trip, the phase does commence in by definition as soon as the on-trip phase ends.

These phases are a direct reference to the Deming Cycle (or PDCA cycle), which identifies the four problem-solving steps Plan, Do, Check and Act. Note that these phase descriptions have been created to support application designs where they apply. Given the scope and operational levels within subproject ecoTraffic Management & Control (SP5), trip-phases are not used much to describe applications as most application operations do not transit between them.

3.1.2.3. Time and Area Scales of Operation

Given the fact that eCoMove intends to operate on both micro- and macroscopic scales, a more formal assessment on the operational level of eCoMove actions and interactions with actors was formed. From SP5 point of view, terminology for assessing the operational levels was introduced early in the project. Early assessments of an energy map contained a threeway separation of scales in time and space, which proved to be useful for supporting design throughout the whole project. They have been assigned the project terms ‘Strategic’, ‘Tactical’ and ‘Operational'. A diagram depicting the rough correlation of these three operational levels has been provided in Figure 10.

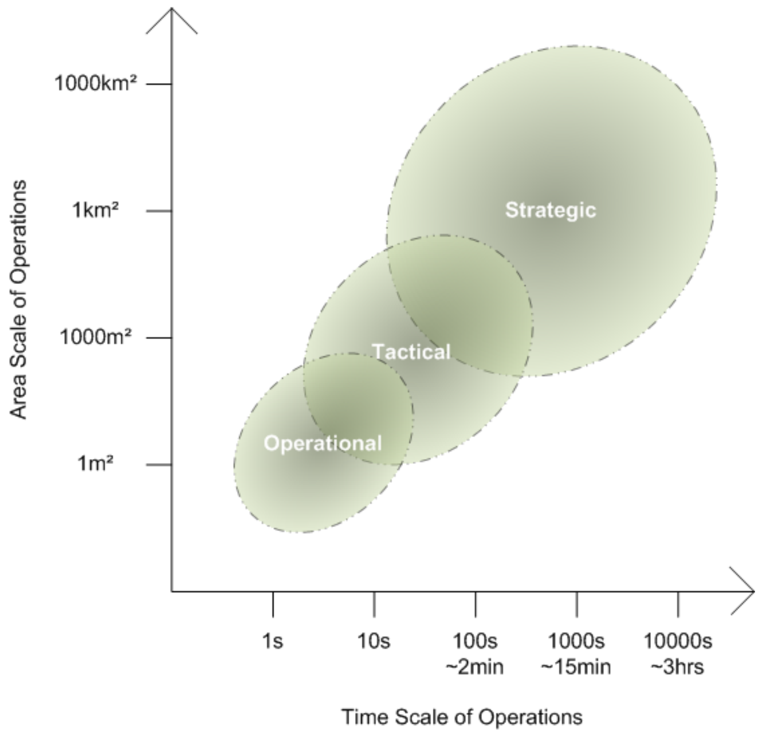

Figure 10 – Time and Area Scales of Operation

- ***Strategic:*** city or highway-wide. Update frequencies and data life spans from minutes to hours. Operational aggregated data assessment of 10K vehicles or more.
- ***Tactical:*** street, ramp or intersection-wide. Update frequencies and data life spans from seconds to minutes. Operational aggregated data assessment of between 10 to100 vehicles.
- ***Operational:*** vehicle-wide including direct surroundings. Update frequencies and data life spans in seconds. Operational assessment of up to 10 vehicles, with the ego-vehicle as central focus point.

Note that these identifications in time and space are not strict and that there is overlap: the levels indicate a generalised grouping of temporal and spatial properties of data and processes, which is useful to describe the general characteristics of the domain in which they operate. It must also be noted that, even though the diagram only indicates positive time values, the concepts apply to the temporal scale of operations in both the future and the past.

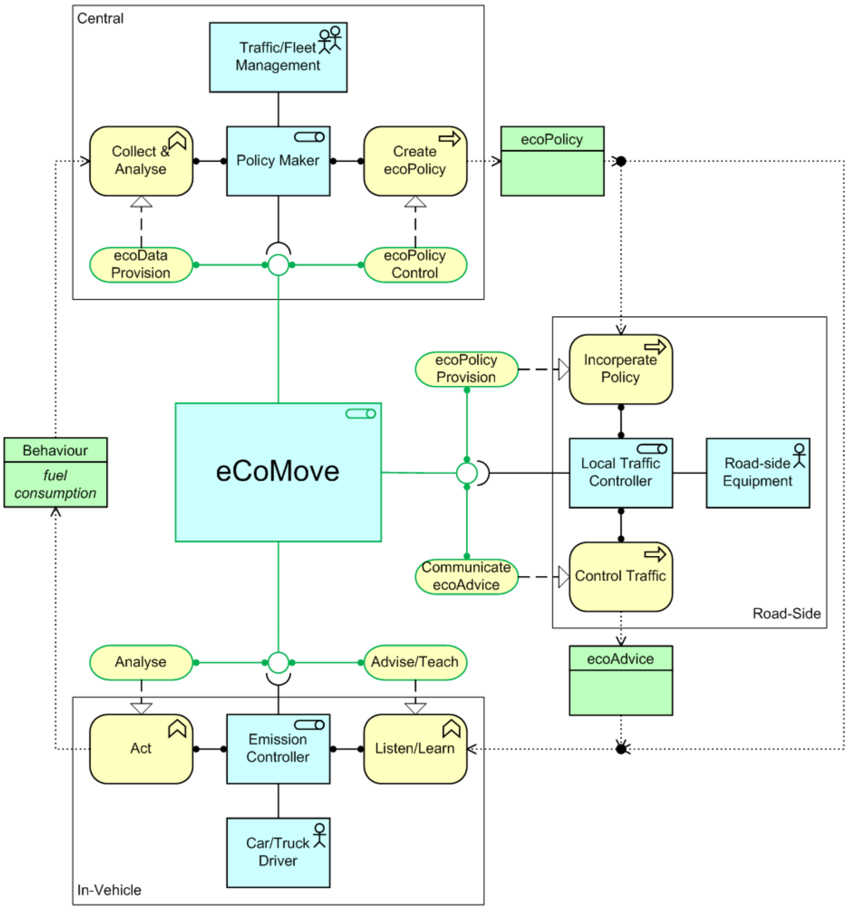

Figure 11 – High Level eCoMove System Business Model

3.1.2.4. eCoMove System High Level Business Layer Diagram

The eML Business Level diagram in Figure 11 is a high level depiction of the eCoMove system, which focuses on the aggregated interactions between actors (i.e. users, stakeholders and 3rd party systems) and the eCoMove system over collected interfaces. The actors, as identified in [D2.1] have been grouped according to ETSI standard ITS sub-system categorisation: Central, Road-Side and In-Vehicle [ETSI]. There is also a direct relation to the levels of operations described in the previous section, where Central, Road-Side and In-Vehicle sub-systems operate mostly on a Strategic, Tactical and Operational level respectively.

3.1.3. Privacy

As described in [D2.1] section 2.7.3, there are examples for specific cases of which it is known that private data is exchanged between vehicles and infrastructure. However, with the emergence of ITS systems this is expected to increase in the future. Hence, the set of eCoMove requirements contained the following requirements to ensure eCoMove adheres to current European and National laws concerning data security, user anonymity and the protection of individual privacy: ECOM-RQ-IP-0034, ECOM-RQ-IP-0078.

Privacy on the application level has been described in [D3.2], [D3.3], [D4.2], [D5.2], which describes how applications ensure user anonymity and the protection of individual privacy. On the core technology level, security of the system is ensured to provide applications with a means to exchange data securely, which is discussed in the next subsection.

3.1.4. Security

The term computer system security means the collective processes and mechanisms by which sensitive and valuable information and services are protected from publication, tampering or collapse by unauthorised activities or untrustworthy individuals and unplanned events respectively. The saying "a chain is as strong as its weakest link" is very illustrative for the implementation of security measures. Having a number of secure components does not help the overall security of the system if one of the components is non-secure: security is a system-wide aspect.

The deliverable [D2.1], section 8.3.13, contains a complete set of requirements which apply to the security of the complete eCoMove system: ECOM-RQ-IP-0066 to ECOM-RQ-IP-0078. These requirements have been taken into account in the design of the eCoMove architecture, as can be verified in Chapter 0 of this document.

3.2. Application Driven Multi-Platform Compatibility

As described in the [DoW], the project uses V2V and V2I communication to enable new kinds of interaction between vehicles, and between vehicles and infrastructure. eCoMove support systems will calculate the most efficient route and driving strategy, then assist drivers by providing that route in-vehicle and providing them real-time advice in terms of the most economic driving style.

This V2V /V2I platform consists of both hardware and software and is based on related projects developments such as simTD, CVIS, SAFESPOT, PRE-DRIVE C2X and others. Available V2V / V2I hardware and software is and will be evaluated and the most appropriate ones are, and will be in the future where necessary, selected based on technical requirements from the application SPs. The selected hardware and software will be improved during development to fulfil the requirements and remains to be compliant with the latest standards developed by ETSI TC ITS, [ETSI].

The application subprojects, given ETSI standard and previous project specifications, designed applications, which resulted in requirements for the core technologies subproject (SP2). These specifications resulted in an initial selection of suitable, available and to be made compatible candidate platforms: simTD and CVIS.

Given this selection of multiple platforms, two major issues appear which have been addressed in Architecture:

- Communications between the two platforms is to be made compatible.
- An approach is needed to have single implementations of eCoMove applications to be able to be hosted cross-platform without (too much) modification.

The issues were addressed in the Communication Platform work package, the ecoMessage work package and in Software Execution Platform environment Task Force activities. The High Level results are documented here in the next chapter, Subsection 4.1.4.

4. System architectural design

This chapter describes the high level system architectural design. It subdivides the complete eCoMove system according to the standards, work structure and views employed in the project, creating multiple cross-sections that clarify the terminology and logical divisions.

As described in Section 3.2 of this document, one important aim in the eCoMove project is to employ a V2V / V2I platform consisting of both hardware and software, which is based on related projects developments. In architecture progress, available V2V / V2I hardware and software have been evaluated and the most appropriate ones have been selected as candidates based on technical requirements from the application SPs. The approach described in Section 3.2 is reflected in the structure of the first section of this chapter. The second section describes a cross-SP concept of execution based on the identified components.

4.1. System Components

The perfect ecoDriver in the perfect eco-managed network: cooperation via communication between multiple platforms & standards. The ETSI standard as described in [ETSI], identifies ITS subsystems depicted in Figure 12.

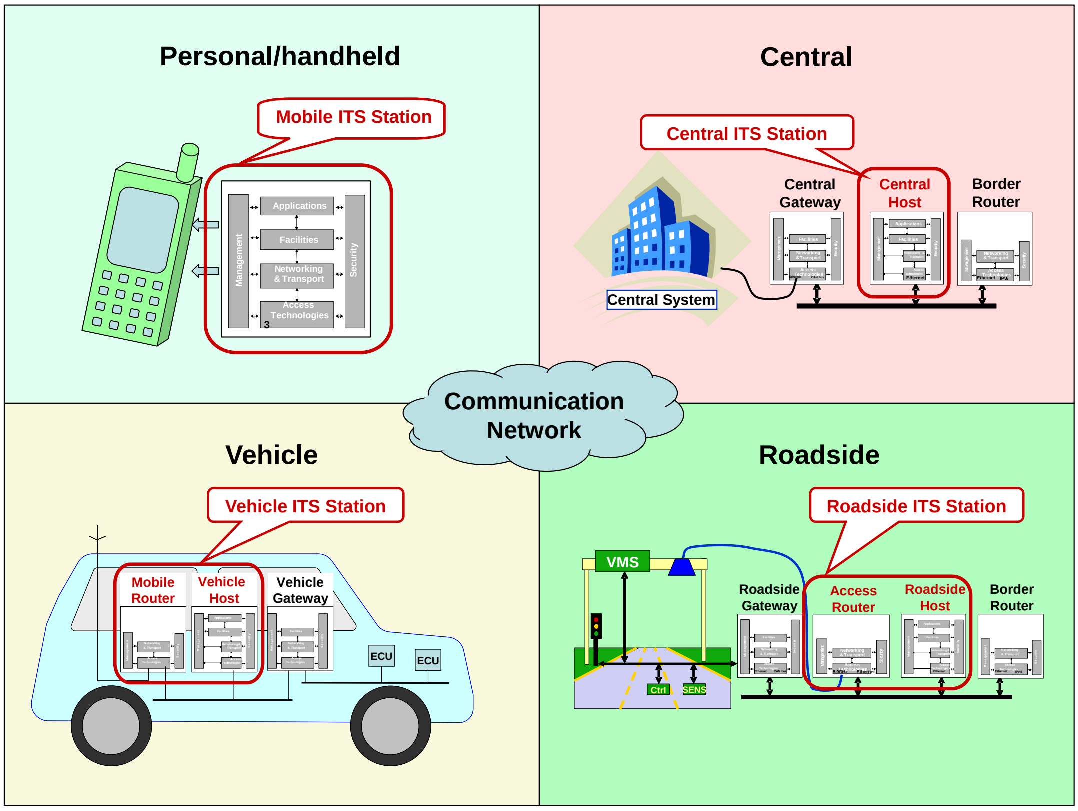

Figure 12 – ETSI ITS Sub-Systems (functional elements)

The same identification of ITS sub-systems is used in eCoMove architecture, as can be seen in the technology layer diagrams in WP3 documentation.

The [ETSI] standard also specifies a reference architecture for ITS stations, as depicted in Figure 13. The ITS station reference architecture follows the principles of the [OSI model] for layered communication protocols which is extended for inclusion of ITS applications.

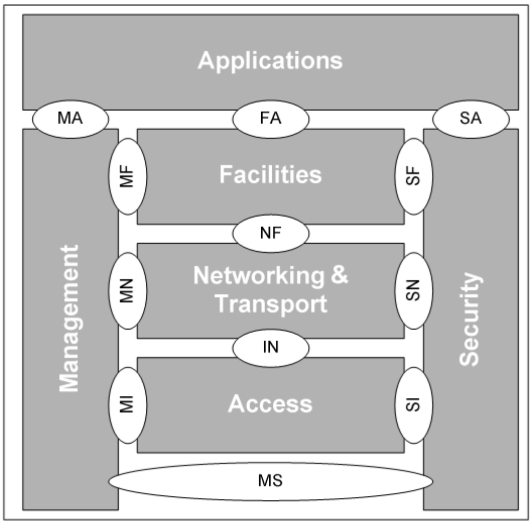

Figure 13 – ETSI standard ITS Station Reference Architecture

As this reference architecture is also used in eCoMove, the block “Applications” presents the eCoMove applications making use of the eCoMove and other ITS services to connect to one or more other eCoMove / ITS applications, which provides an eCoMove service to a user of eCoMove. They are described in the following sections of this chapter.
The block “Facilities” layer is providing support to the eCoMove applications, which can share generic functions and data according to their respective functional and operational requirements. The facilities developed in eCoMove are part of the core technologies described in this chapter, and we will be identified as being facilities in the accompanying texts.

As the eCoMove project is an application driven project, where applications make use of the available technologies from previous European ITS projects described in Section 3.2 of this document, the other blocks identified in the diagram are considered provided services on the platforms used in the project. They are identified, assessed and incorporated in Communication Platform and ecoMessage work packages tasks and deliverables described here in this chapter (section 4.1.4 SP2: Core Technologies) and in future eCoMove deliverables [D2.3], [D2.4] and [D2.5].

4.1.1. SP3: Passenger Car Applications & Technologies

The objective in SP3 architecture was to design an integrated system providing information and feedback to drivers, leading to both:

- eco driving **motivation**, i.e. making all drivers perceive the benefits of eco driving from their own personal perspective, and
- eco driving **coaching**, i.e. giving needed contextualised information and instructions to drivers to adopt in short terms and maintain in the long terms an eco driving behaviour.

The designs have all been based on the collected Use Cases & Requirements which apply to the ecoSmart Driving subproject (SP3) activities: [D2.1] and [D3.1]. The overall High Level Business Model in SP3 is depicted in Figure 14.

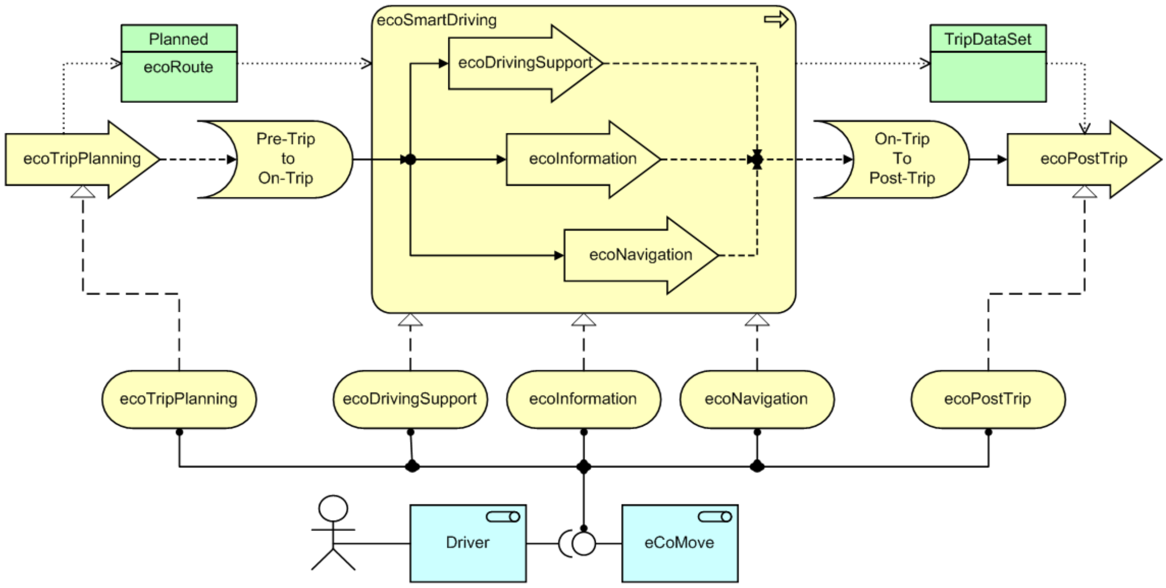

Figure 14 – High Level Business Layer of the ecoSmart Driving subproject (SP3)

Figure 14, which shows the services provided to car drivers who interact with the eCoMove system, depicts the following concepts:

4.1.1.1. ecoTripPlanning [D3.2]

The ecoTripPlanning application helps in planning the trip for the user and enables ecoRouting complemented with relevant information that can support the reduction of fuel consumption like suggested time slot. The ecoTripPlanning can be done both in vehicles and out of vehicles.
The application uses input from a driver profile, vehicle states retrieved via an OEM gateway, input from the ecoMap, traffic information from a TMC and an eCoMove calculate route service (described below) to present a list of travel options to the driver. The driver is given the opportunity to select the most fuel efficient time and route to travel. Once selected, the plans are communicated to the other applications.

4.1.1.2. ecoNavigation (part of ecoSmartDriving) [D3.2]

The ecoNavigation application has two core functionalities: calculating a fuel efficient route and guiding the driver. For the first functionality, it takes all available information that might influence fuel usage and computes the most fuel efficient route (i.e. the one with the lowest absolute fuel consumption from departure to arrival) to a given destination. For the second, gives turn-by-turn instructions to the driver, using the calculated route. The application provides calculate route service as it is used by ecoTripPlanning.

4.1.1.3. ecoDrivingSupport (part of ecoSmartDriving) [D3.2]

The ecoDrivingSupport is the application providing recommendations to the driver on how to drive more efficiently. Recommendations are derived from the current and predicted driving state (including the traffic environment), which is provided by the ecoSituationalModel core technology (described in subsection 4.1.4.5). The ecoDrivingSupport calculates an optimised velocity profile and derives recommendations on the driving style for the current and upcoming specific driving situation.

4.1.1.4. ecoInformation (part of ecoSmartDriving) [D3.2]

The ecoInformation application continuously monitors the vehicle state and its energy consumption. It analyses the data and checks if inefficiencies in vehicle configuration and state can be addressed by the driver (e.g. low tire pressure, open windows, high electrical consumption). Once it has identified an inefficiency it sends a message to the driver to check the parameter and address the issue.

4.1.1.5. ecoPostTrip [D3.3]

The ecoPostTrip application provides the driver with post-trip feedback on his or her on-trip behaviour related to fuel efficiency. The focus of the performed analysis is driver behaviour compared to optimally efficient driving, taking into account the driving situation the driver was in. It then provides recommendation to the driver on improving his/her eco driving for future trips.
The ecoPostTrip application takes various data from driven trips into account, such as vehicle data (e.g. speed, accelerator pedal position, brake pedal position, selected gear), map data, route data from the routes calculated by the ecoNavigation, driver preferences and driver behaviour.

The following two applications are not depicted in Figure 14, as they are not applications with which the user of the eCoMove system has direct interaction. However, they are crucial in-vehicle applications supporting the others by providing services and collecting data and are contained in SP3 design.

4.1.1.6. ecoCooperativeHorizon [D3.2]

The ecoCooperativeHorizon has the task of providing in-vehicle components with a logical view of the road ahead of the vehicle. It extracts data from the ecoMap and organises it along the predicted path of the vehicle. This restructuring of map-related data along the path instead of organised by geographic position or link ID, provides applications with a simplified and practical view of the situations ahead. The ecoCooperativeHorizon provides its services to both applications and other core technologies.

4.1.1.7. ecoMonitoring [D3.3]

The ecoMonitoring application is responsible for having the in-vehicle eCoMove system send the ecoFVD message (described in subsection 4.1.4.3) to the Traffic Control Centre and to the other vehicles. It does so in a fully anonymous way to protect drivers' privacy. In the on-Trip phase the ecoMonitoring process collects the VehicleParameters, the VehicleData, the ecoRoute, the current position and the path related traffic information present in to ecoCooperativeHorizon and prepares the ecoFVD; the ecoFVD are sent to ecoFVD transmission service from the Send ecoFVD Data process.

As indicated by subsection titles, detailed application designs of all applications are provided in [D3.2] and [D3.3], which contain the descriptions of the components, processes and interfaces. Deliverables [D3.2] and [D3.3] also provides a overview of deployment, depicted here in Figure 15.

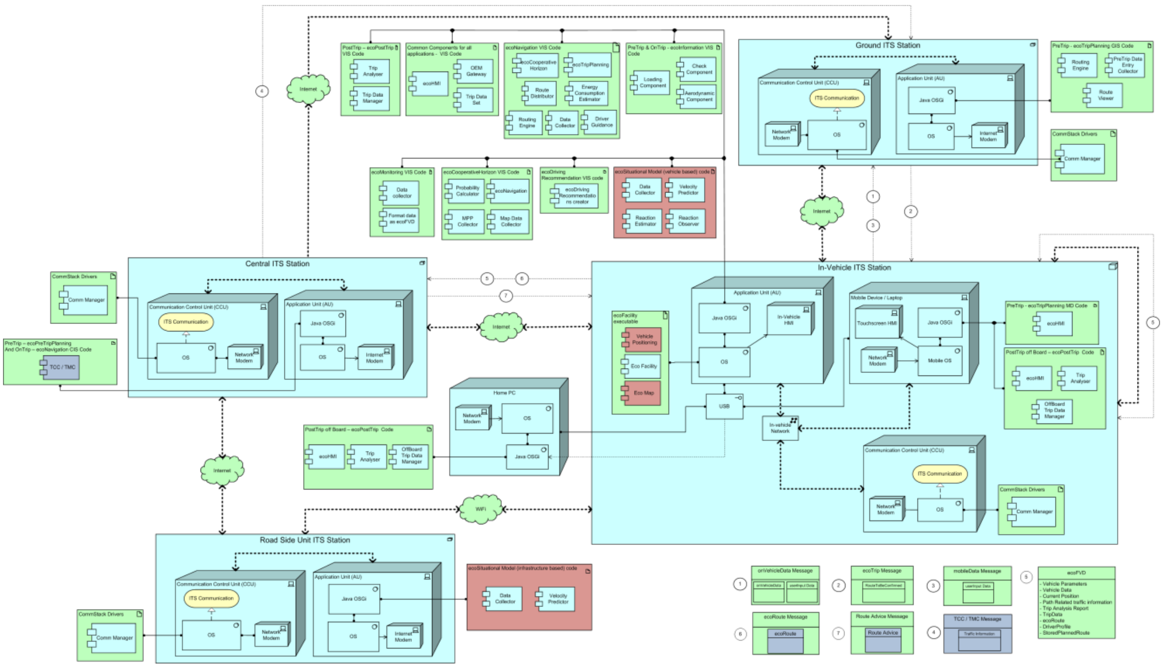

Figure 15 – Overview Technological Layer of the ecoSmart Driving subproject (SP3)

This Figure has been included for referential purposes as the amount of information is too detailed to depict properly here. An A3 size version is provided in Appendix A.

4.1.2. SP4: Fleet Applications

The objective in SP4 architecture was to define the overall solution architecture for the total integrated project in collaboration with Core Technology & Integration (SP2) subproject and based on the eCoMove use cases and requirements. The designs have all been based on the collected works in use cases and requirements that apply to ecoFreight & Logistics subproject (SP4) activities: [D2.1] and [D4.1]. The overall high level business model in SP4 is depicted in Figure 16 (next page).

4.1.2.1. ecoTourPlanning [D4.2]

The Truck ecoTourPlanning has four core engine processes. The ecoTour Creation engine takes available and relevant information that influence infrastructure state and availability and calculates the most efficient tour station sequence for given transport orders and fulfilling given restrictions. The Mission Authorization engine receives an authorisation request from the tour creator and checks its conformance to the Local Authority policy requirements set through the "Defining Policy" functionality of the City Logistics system. Then, the ecoTour Realisation engine strives to execute the authorised route profile and inform the tour creator about events while mission execution and changes "and deviations" affecting the initial planned tour. Finally, the Carbon footprint calculation engine provides an initial carbon footprint estimate based on the initially available and relevant information that is used to find the most efficient route to destination.

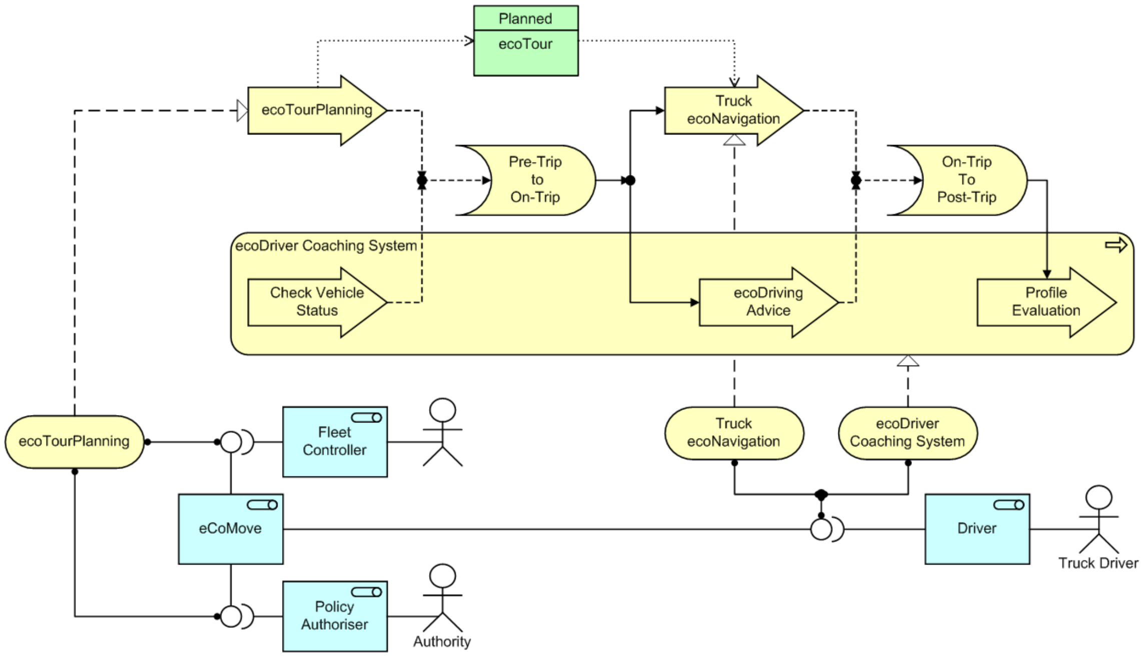

Figure 16 – ecoFreight & Logistics subproject (SP4) High Level Business Layer

4.1.2.2. Truck ecoNavigation [D4.2]

The Truck ecoNavigation application is an extension on the ecoSmart Driving (SP3) ecoNavigation. Hence, it also has two core functionalities: calculating a fuel efficient route and guiding the driver. Given the inputs from the SP3 ecoNavigation application, it also uses SP4 related data inputs to provide navigation tailored to SP4 requirements and business models.

4.1.2.3. ecoTourPlanning [D4.2]

The Truck ecoTourPlanning has four core engine processes. The ecoTour Creation engine takes available and relevant information that influence infrastructure state and availability and calculates the most efficient tour station sequence for given transport orders and fulfilling given restrictions. The Mission Authorization engine receives an authorisation request from the tour creator and checks its conformance to the Local Authority policy requirements set through the "Defining Policy" functionality of the City Logistics system. Then, the ecoTour Realisation engine strives to execute the authorised route profile and inform the tour creator about events while mission execution and changes "and deviations" affecting the initial planned tour. Finally, the Carbon footprint calculation engine provides an initial carbon footprint estimate based on the initially available and relevant information that is used to find the most efficient route to destination.

4.1.2.4. Truck ecoNavigation [D4.2]

The Truck ecoNavigation application is an extension on the ecoSmart Driving (SP3) ecoNavigation. Hence, it also has two core functionalities: calculating a fuel efficient route and guiding the driver. Given the inputs from the SP3 ecoNavigation application, it also uses SP4 related data inputs to provide navigation tailored to SP4 requirements and business models.

4.1.2.5. ecoDriver Coaching System [D4.2]

The ecoDriverCoaching System has three main services, as depicted in Figure 16. The Vehicle status checker checks the status of the vehicle and all the fuel-affecting organs (e.g. tyre pressure, spoiler position, energy consumers…) when the driver enters his vehicle and before starting his trip. Where checks cannot be automated with sensors, the driver is reminded of the organ to check manually. The On-trip ecoDriving advice service uses the ecoSituational Model service together with ecoCooperativeHorizon and vehicle data to assess the current driving situation. The system computes anticipations advices and correction advices. Using the Post-trip profile evaluation service, the driver has the possibility to enter comments to explain any exceptional circumstances which happened during his trip and which can have cause irregularities in the driving profile. The driver is presented a direct feedback with his strong and weak points and tips on how to improve his eco-driving. His commented driver profile is sent to the back office ecoFleetBusiness service for evaluation.

As indicated by subsection titles, detailed application designs of all applications are provided in [D4.2], which contains the descriptions of the components, processes and interfaces. The deliverable [D4.2] also provides an overview of deployment on page 39, depicted here in Figure 17, of which there is an A3 size version in Appendix A.

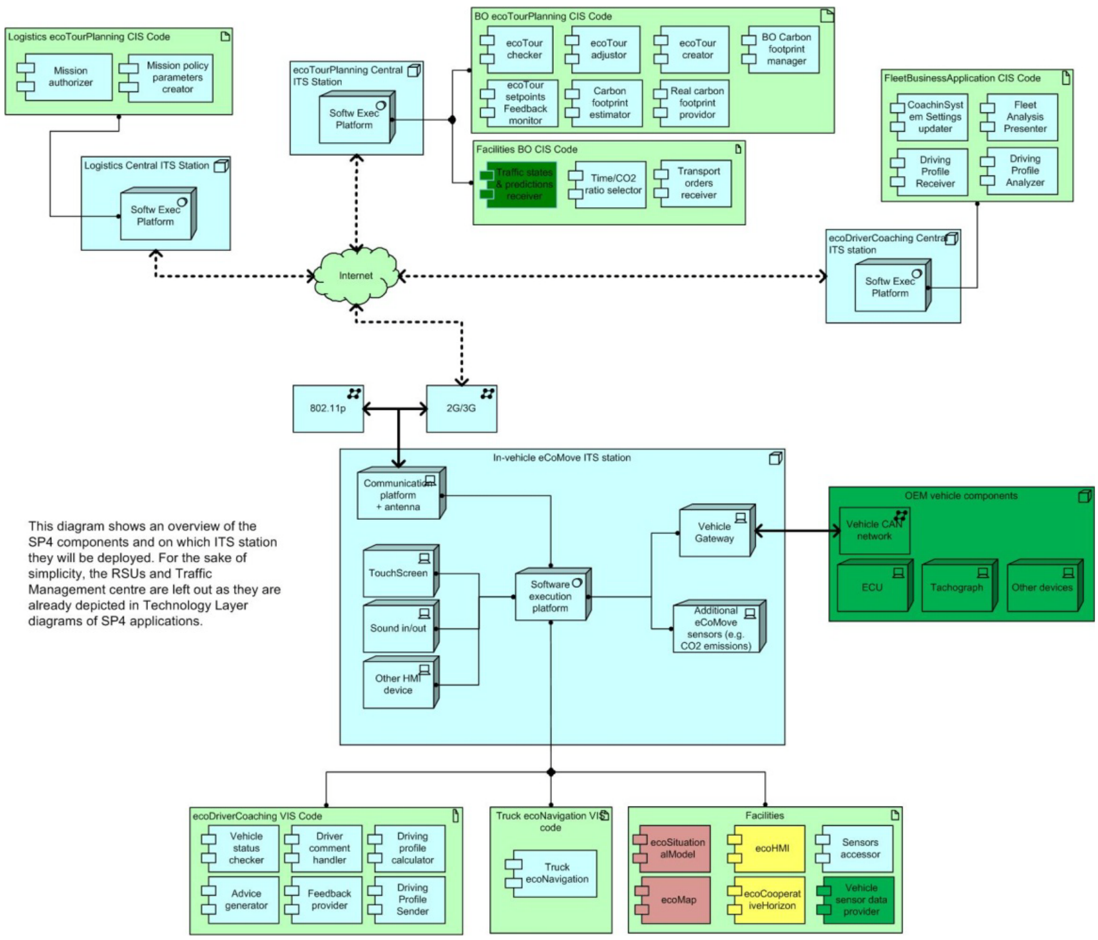

Figure 17 – ecoFreight & Logistics subproject (SP4) Technological Layer Overview

4.1.3. SP5: Traffic Management Applications

The objective in SP5 architecture was to define the specific functional and physical architecture for ecoTraffic Management & Control (SP5) applications and components as a blueprint for prototype development. This specifically includes the interfaces between traffic management and control and the vehicle systems and the interface between central traffic management systems and distributed control systems. The designs have all been based on the collected use cases and requirements, which apply to SP5 activities: [D2.1] and [D5.1].

In contrast to the other application SP's, the overall high level business model is not best depicted by a sequence of processes related to services on interfaces as users and processes in the SP5 operational domain are on the strategic scale and processes are active on pre-, on- and post-trip phases in parallel.
The overall high level architecture in SP5 is better depicted by the SP5 Application Layer Diagram for System Overview, which is directly taken from [D5.2] page 34 and shown here in Figure 18.

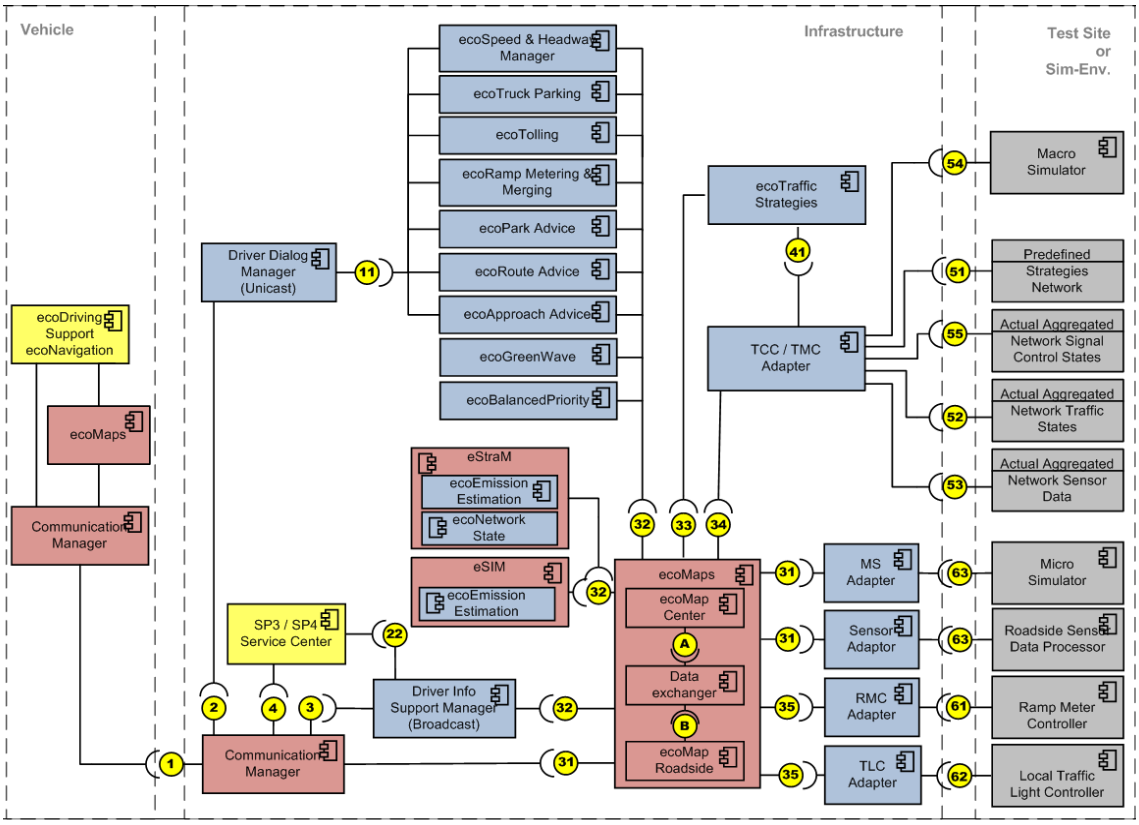

Figure 18 – SP5 Application Layer Diagram for System Overview

Figure 18 clearly shows the central relationship of the SP5 applications between in-vehicle systems and Test Sites or Simulation Environments. The central Infrastructure block does not show a deployment distinction between central back office infrastructure and road-side infrastructure, as this picture depicts the application interaction and interfaces regardless of deployment.

In SP5 architecture activities, this diagram has also been used to identify three SP5 systems which overlap each other but define three major targets in the traffic management domain of eCoMove: ecoAdaptive Balancing and Control ("ecoABC"), ecoMotorway Management ("ecoMM"), and ecoAdaptive Traveller Support ("ecoATS").

The objective of ecoABC is to balance traffic demand and network capacity at strategic (network), tactical (area) and operational (local) levels by combining vehicle generated data and road-side sensor data. It addresses the paradigm of travel time versus CO_2, with consideration of traffic safety, comfort, reliability and other pollutions.

The objective of the ecoMM system is to reduce fuel consumption and CO_2 emissions by smooth traffic control in motorways systems; it combines energy-optimised speed and flow management measures with tools to improve metering and merging assistance at individual vehicle level. This system coordinates measures that are implemented on a motorway system. It contains a monitoring and state estimation and prediction component, as well as emission estimation and prediction.

The objective of ecoATS is to improve traveller information to enable new or improve existing applications supporting the driver or driver assistance systems. It addresses the paradigm of lack of information, which is often a drawback for applications as routing and navigation, smart driver assistance as green wave assistance systems.

All three of these SP5 systems consist of a collaboration between the SP5 applications, which are described here.

4.1.3.1. ecoRoute Advice [D5.2]

The ecoRouting Advice application guides vehicles through a network in the most fuel efficient way, including small scale re-routing (e.g. one block) if necessary due to changing traffic conditions. It takes into account the current, future and desired traffic state and the route pattern. As an infrastructure-based application, the focus is to optimise fuel consumption in the whole network, by assigning the vehicles to different routes considering the optimal origin-destination route. It reduces the number of saturated intersections and minimising the chance of bottlenecks in the network.

4.1.3.2. ecoParking advice [D5.2]

The ecoParking Advice application guides vehicles through a network on microscopic level in the most fuel efficient way. The ecoParking Advice builds on the advised routes from ecoRoute Advice and it includes re-routing on micro level, if necessary due to occupancy rates of public parking locations and/or changing traffic conditions on micro level. As an infrastructure-based application, the focus is to optimise fuel consumption in the whole network, by assigning the vehicles to different available parking locations en routes considering the optimal distribution over the area.

4.1.3.3. ecoGreenWave [D5.2]

The ecoGreenWave application synchronises subsequent signalised intersections and seeks to influence the spatial-temporal structure of the traffic flows as it forms platoon shapes depending on traffic volume and vehicle characteristics. These control measures are accompanied by direct driver assistance by the ecoSmart Driving subproject (SP3) in-vehicle systems.

By using cooperative technologies ecoGreenWave will have more information about the spatiotemporal state of moving platoons and their composition and, as a consequence, it will even incorporate this platoon data in the control mechanisms. With this application, green waves will emerge and dissolve on demand with elastic coordination speed in reaction to current or expected traffic conditions.

4.1.3.4. ecoBalanced Priority [D5.2]

The ecoBalanced Priority application controls signalised intersections by balancing the needs of the approaching vehicles in a way that minimises fuel consumption without affecting safety. The approach is based on detailed knowledge about the demands and characteristics of individual vehicles approaching an intersection that are transmitted by means of short-range communication. The algorithm optimises the traffic signal programs for multiple criteria: reliability of public transport travel times, total CO_2 emission of all modes and streams, total time lost for private transport. The strategy is based on the utilisation of remaining capacity in order to balance the demands of road users and road operators with difference interests. Measures include introducing variability in the signal group sequence, allow higher maximum waiting times, and dynamic determination of the minimum values for green times, yellow times and clearance time.

4.1.3.5. ecoRamp Metering [D5.2]

The goal of ecoRamp Metering is to extend the horizon of current ramp control technologies to better anticipate to changes in the traffic situation and traffic demand, and so reduce wasted fuel. By using roadside sensors and collecting ecoFVD, it takes into consideration multiple control variables, both macroscopic (i.e. traffic flow) and microscopic (i.e. vehicle), applies different strategies for different designs of on-ramps, informs vehicles about the best driving strategy before and after the ramp meter, and controls in-flow and spillback to the urban network in the optimisation process. Green frequencies will vary based on the current conditions, vehicles receive speed recommendations and priority schemes differentiate between light and heavy vehicles.

4.1.3.6. Support Merging [D5.2]

In close collaboration with ecoRamp Metering application, the Support Merging application monitors traffic flows at merging points on their traffic volumes, density, relative speeds of vehicles and following distances. Using vehicle trajectory data the number of lane changes at merging sections is estimated. The overall traffic flow performance is optimised where the importance of the different traffic flows is carefully weighted, advices will be adapted to the number of mergers at that time while the mergers themselves receive individualised recommendations for their speed and merging instant. Right after the merging point drivers will receive an advice that stimulates them accelerate in order to best use the available road capacity.

4.1.3.7. ecoSpeed & Headway Manager [D5.2]

Speed and Headway Management gathers information about speeds and headways of vehicles in the traffic flow. Based on this information the stability of the traffic flow is judged. In particular in unstable conditions the system recommends speeds and headways for certain road sections or road users individually, which allows drivers to adapt to smoother, more comfortable and fuel efficient driving behaviour. The aim is to prevent disturbances in traffic that could lead to congestion as they propagate upstream.

4.1.3.8. ecoTruck Parking [D5.2]

Road user perspective: Frequently the availability of spaces for trucks to park along motorways (truck park area available in rest areas) is not known, and the truck is not allowed to park on the side of the motorway. The result is that the process of finding a place to park is very inefficient for a truck driver as he/she has to drive unnecessary kilometres looking for a parking facility that has space available, or having to exit the motorway to find a place to park.

The ecoTruck application addresses this inefficiency by obtaining information on available parking spaces in urban and inter-urban environments and providing a service to in-vehicle navigation systems where information regarding the parking availability can be retrieved.

4.1.3.9. ecoTolling [D5.2]

The ecoTolling application applies monitoring and management of a better traffic distribution to fuel efficient lanes on existing toll gates to mitigate stop-and-go CO_2 emissions. To improve fuel efficiency, the purpose of ecoTolling is to deploy dedicated toll lanes that allows passing at a nominal speed, which compromises between stop-and-go behaviour and fuel efficiency. The aim is threefold: improvement of travel time, decrease CO_2 emissions, and decrease toll congestion through higher traffic distribution. To achieve these goals in-vehicle systems will inform drivers about which lane and speed to choose, while electronic toll tag detection takes care of registration aspects.

4.1.3.10. ecoApproach Advice [D5.2]

The main functionality of ecoApproach Advice is the short-term prediction of vehicle trajectories in conjunction with the optimal determination of lane choice and the computation of optimal speed profiles for vehicles that approach intersections. All this is important for energy efficient driving, as there is the potential to reduce fuel consumption and emissions by adjusting the vehicles' speed on a temporally very detailed level. The goal of the application is to minimise the number of stops, unnecessary acceleration and deceleration, resulting in continuous stop-and-go traffic in order to minimise fuel consumption.

As indicated by subsection titles, detailed application designs of all applications are provided in [D5.2], which contains the descriptions of the components, processes and interfaces.

4.1.4. SP2: Core Technologies

The objective in Core Technology & Integration (SP2) architecture work package is to define the high level architecture by decomposing the architecture into key functional components, analyse interoperability and integration of the total concept. The designs have all been based on the collected works in eCoMove use cases and requirements which apply to SP2 activities, e.g. [D2.1], [D3.1], [D4.1] and [D5.1], as well as the collected requirements from the architecture designs in the subprojects ecoSmartDriving (SP3), ecoFreight & Logistics (SP4) and ecoTraffic Management & Control (SP5), which have been documented in the deliverables [D3.2], [D3.3], [D4.2] and [D5.2].

4.1.4.1. eCoMove Software Execution Platform

Given the system-wide architectural decision to support multi-platform application deployment (Section 3.2), a Software Execution Platform task force was created at the consortium meeting in Brussels mid-November 2010 to collect specifications of simTD and CVIS software environments and to specify an eCoMove Software Execution environment which would incorporate technologies form both platforms where they were suited to support eCoMove applications.

A result from the task force, which has been the result of collaboration between the task force and the SP2 architecture work package (WP2.3), is the specification of the eCoMove Development Reference Platform, or eDRP. This result is of major importance to the overall eCoMove architecture as it specifies the software execution environment independent of any specific ITS platforms selected for eCoMove deployment. The diagram in Figure 19 shows a technical layer of the eDRP.

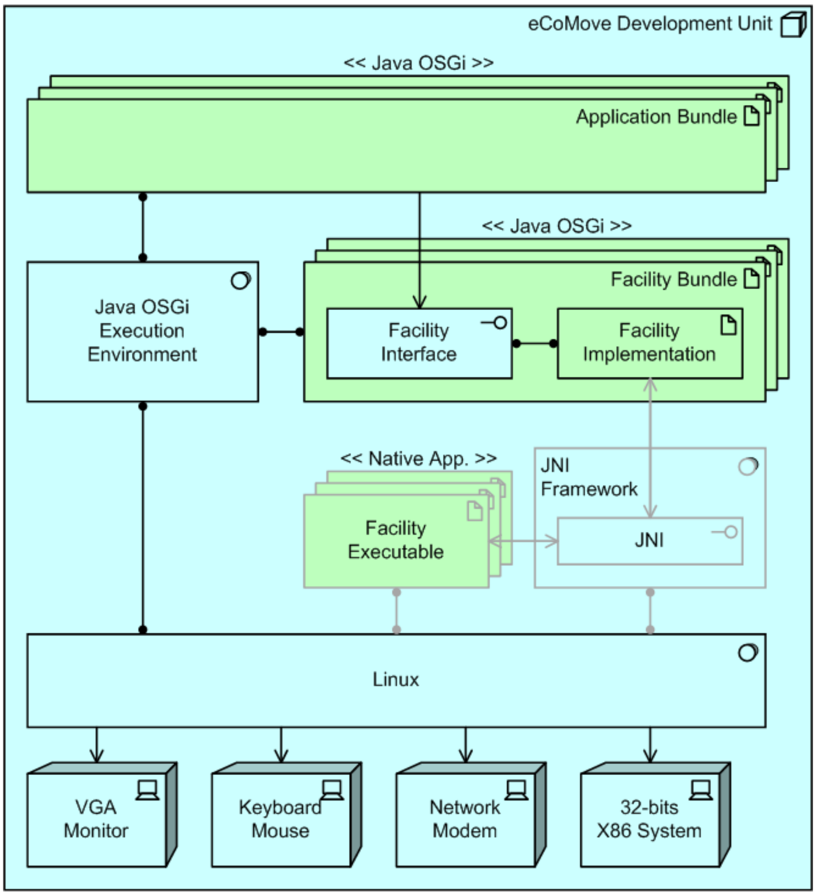

Figure 19 – eCoMove Development Reference Platform

In the diagram in Figure 19, the eDRP is divided into 5 layers: the hardware layer, the OS Layer, the Java Native Interface (JNI) layer, the Execution environment layer (containing Facility interfaces and reference implementations), and the Application Layer.

In eCoMove, the application environment consists of a **Java OSGi** framework. Based on what has been used in previous projects, the current framework choices under consideration are ProSyst or Knopflerfish. The usage of a platform independent OSGi application environment also introduces centralised Host Management functionality.

The JNI Framework allows native applications to directly interact with Java executables. This construct is highly necessary as some of the facilities which are provided by partners in the eCoMove project are available solutions.

The platform technical specifications are chosen to be compatible with most workstations in any office. From the development point of view, this means that developers do not need to purchase specific hardware to be able to test their applications in their runtime environment. However, from an architecture point of view, this approach is also chosen as the specification is compatible with ITS platforms on which eCoMove applications are expected to be deployed. Finally, it is aligned with the ETSI reference architecture depicted in Figure 13 [ETSI]. Detailed specifications on the software environment can be found in [eDH].

4.1.4.2. Communication Platform Services

Based on the application requirements, the required communication channels are IPv6 long range and IEEE 802.11p. The European ITS Communication Architecture constitutes the basis for communication platform architecture specifications, depicted in Figure 20, as it is the result of ETSI TC ITS, COMeSafety and other European R&D projects and based on the results from ISO (CALM), IEEE and IETF.

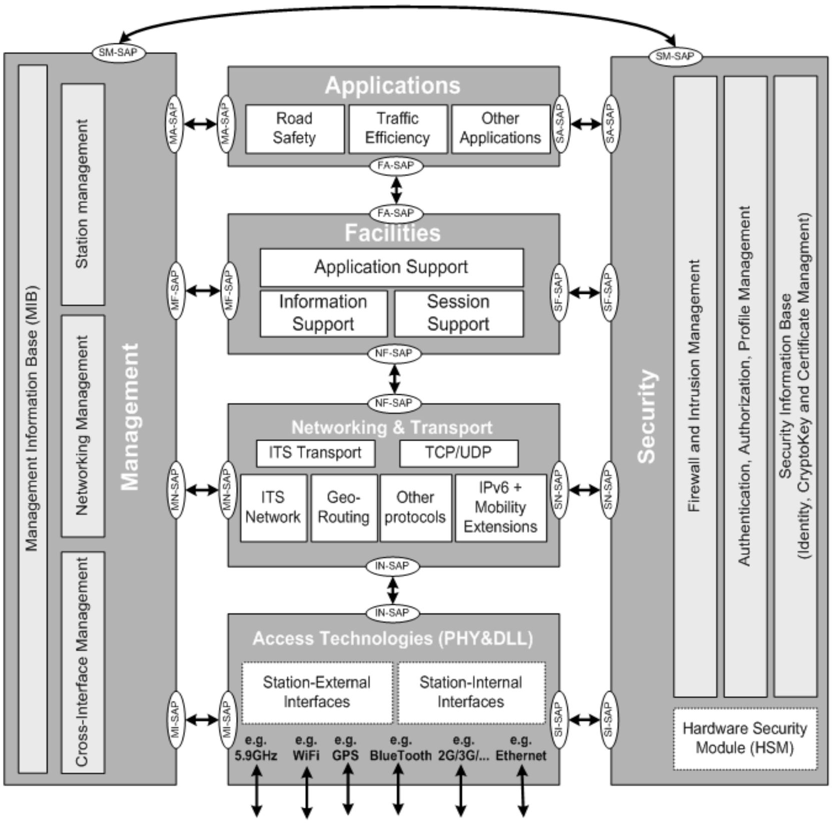

Figure 20 – ETSI ITS Station Reference Model Architecture

In the eCoMove project, a minimum level of interoperability is required on:

- Radio
  - ITS-G5
  - Single transceiver operating on the CCH
  - 802.2 (w/o modifications)
- Networking
  - Georouting: Single-hop broadcast
  - IPv6 and legacy IPv4 support
- Facilities
  - CAM based on ETSI current version
  - Limited DENM
  - Positioning

A subset of the current ETSI standards is used to cover as many eCoMove apps as possible. Over the course of the development process, depending on development needs, further points are added (e.g. service advertisements).

Further documentation on the communication platform can be found in [D2.3] and [D2.4].

4.1.4.3. ecoMessages

In the ecoMessages work package (WP2.4.2), the objective is to define messages, protocols and interfaces that are used to exchange information for eco traffic management and control as well as supporting eco-driving of individual vehicles. The starting point of this task is the system concept description as found in [D2.1], from which Figure 2 is directly taken. The eCoMove communication channels and associated standards are depicted in Figure 21.

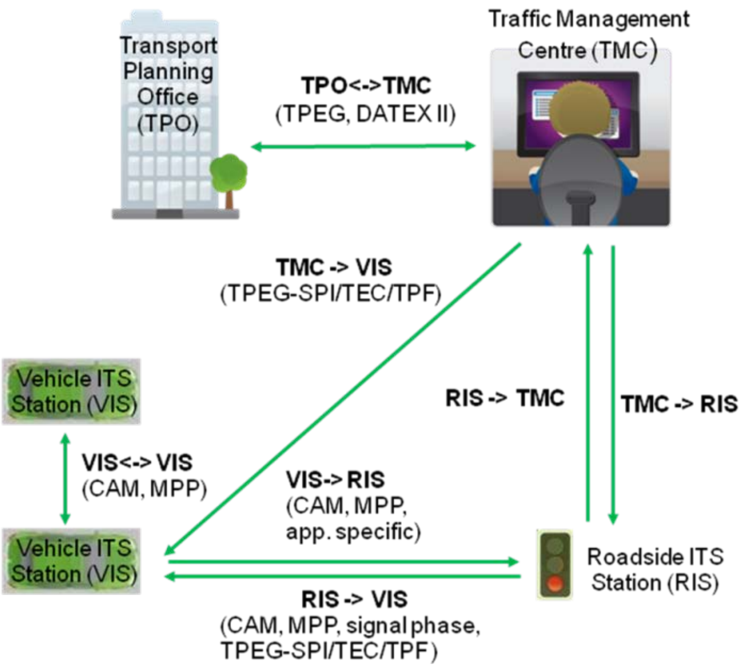

Figure 21 – Overview of ecoMessage interfaces

The ecoMessages specified by WP2.4.2 include the Eco-Floating Vehicle Data (ecoFVD) and Eco Traffic Situational Data (ecoTSD), as specified in the DoW. The EcoFVD is used to collect and disseminate data from vehicles for eco traffic management and control as well as for eco-driving of individual vehicles and fleet management. The data can be disseminated via V2V communication to other vehicles and via V2I to roadside unit and to central database. The EcoFVD will be capable to include locally collected data such as vehicle destination, planned route, current fuel consumption and vehicle operation data from CAN BUS, as well as information obtained from other vehicles and the infrastructure. The EcoFVD will further extend the Cooperative Awareness Message CAM and Decentralised Environmental Notification Message DENM developed in related projects and standardisation bodies with the capability to address eco-driving.

The ecoTSD is used to collect and disseminate data from infrastructure for eco-driving of individual vehicles. It will adapt and extend the TPEG messages to allow messages sent from the infrastructure to vehicles using short-range wireless communications to disseminate the latest traffic situation in a small area. EcoTSD data will include data related to road congestion, delay, traffic control information and traffic flow, speed predictions, etc. More documentation on ecoMessages can be found in [D2.5].

4.1.4.4. ecoMaps

The ecoMap component is a facility for the eCoMove applications, providing the applications with the means to store, retrieve and exchange map-related data in a single ITS station. It will consist of a digital map database enhanced with extra attributes needed to support eCoMove driver assistance applications for energy efficiency.

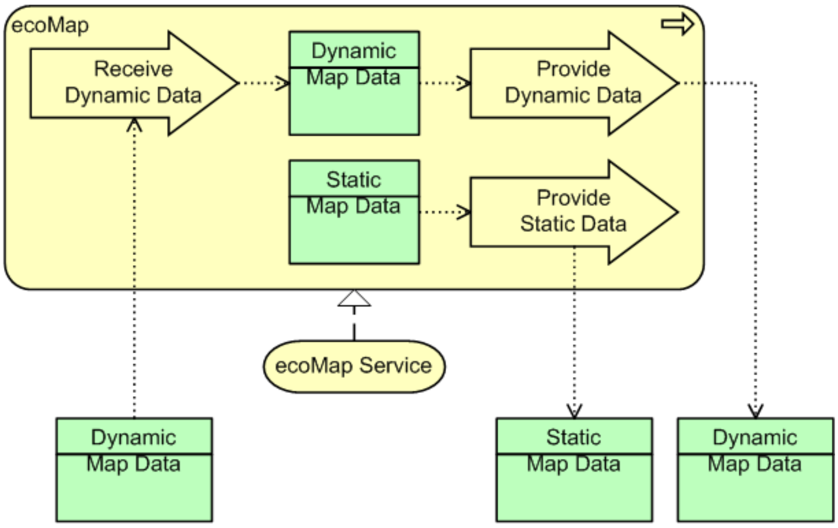

Figure 22 – ecoMap Business Layer

The design of the ecoMap has been based on the application requirements. The Business Layer diagram in Figure 22 shows the basic ecoMap service as it has been included in the Business Layer diagrams in [D3.2], [D3.3], [D4.2] and [D5.2].
The ecoMap will provide one common API for ecoMap on the multiple platforms, implementations per map provider. The high level design to ecoMap implementations adheres to the application layer design depicted in Figure 23.

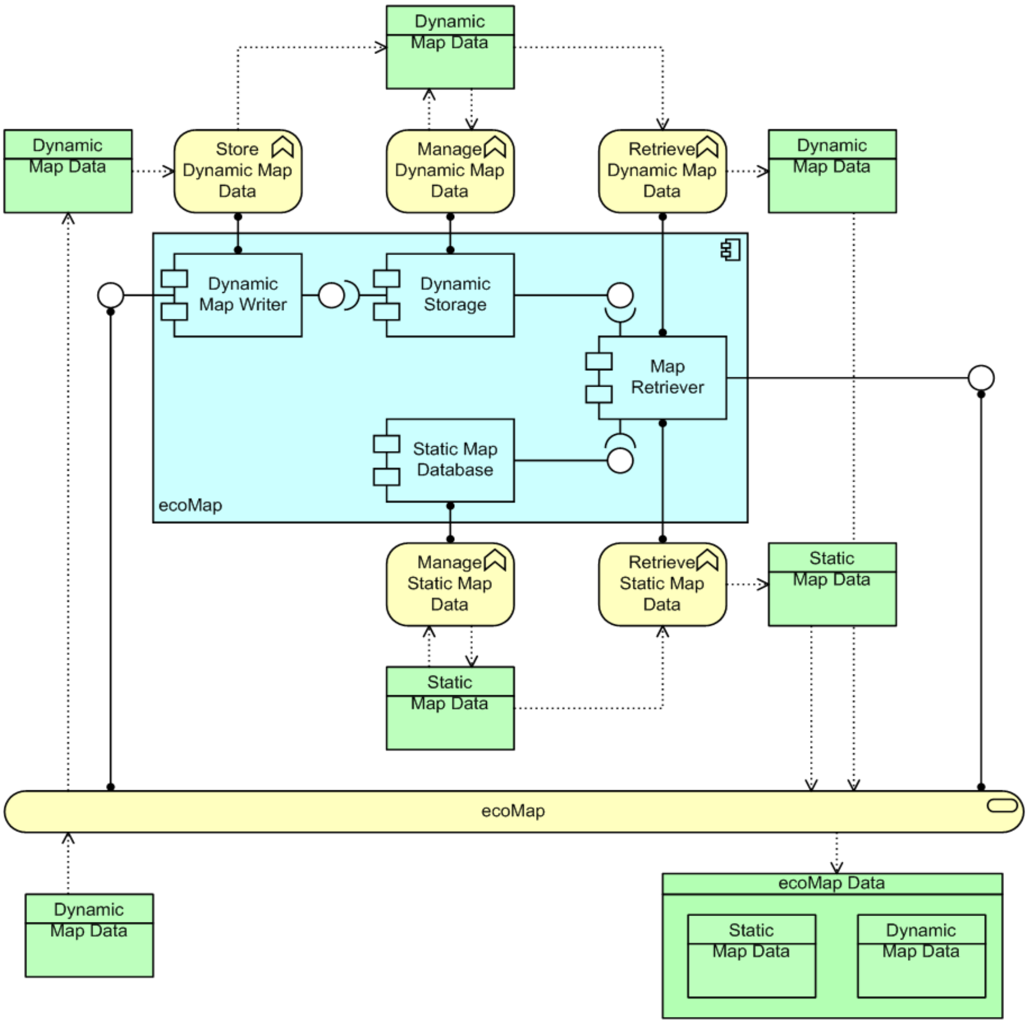

Figure 23 – ecoMap Application Layer

- As can be seen, both static and dynamic data is available via a single common interface, which is based on an agreed listing of data objects from the ecoTraffic Management & Control subproject (SP5). The interface provided also allows applications to submit dynamic map data. The interface is described in Chapter 5 of this document.
- Management of both static and dynamic map data is handled by two different components, as the means for storing the data will be different as well. Static data will be available via a map database, while dynamic data is stored in-memory.

Detailed design description of the ecoMap application and ecoMap API are described in [D2.6].

4.1.4.5. ecoModels

There are two ecoModels designed as core technologies, the ecoSituational Model (eSiM) and the ecoStrategical Model (eStraM), which describe and provide information about the current and predicted traffic and driving situations. The models will serve as a basis for the determination of eco driving strategies, traffic management and control strategies and prediction of fuel consumption.

The first one, the ecoSituational Model, has the task to describe the current driving situation and to provide the relevant information with regard to fuel consumption such as speed limit, inclination etc. Additionally the situational model predicts how the situation will evolve in different time horizons (100m, 500m, 1000 m etc.). The purpose of this model is to provide all relevant information to the ecoSmart Driving subproject (SP3) and ecoFreight & Logistics subproject (SP4), which is necessary to determine the optimal driving strategy taking into account the current driving and traffic situation and how this will change in the time scope, which is still in the reaction horizon of the driver.

The eSiM component is deployed on both in-vehicle and road-side equipment, as it provides predictions of traffic situations to SP3 and SP4 applications in-vehicle and to ecoTraffic Management & Control (SP5) applications on the road-side. Given the difference between the available services in both stations (e.g. the ecoCooperative Horizon is not available road-side) there is a difference between the inputs which the eSiM facility requires to produce its predictions.

The vehicle based eSiM pursues three different approaches for prediction:

- Statistical approach: Based on historic map data the velocity profile is predicted
- Driver model: A driver Model is used to predict the specific driving behaviour.
- Situation catalogue: Situations highly relevant for fuel consumption are examined in test drives and listed in a catalogue, which can be used for prediction.

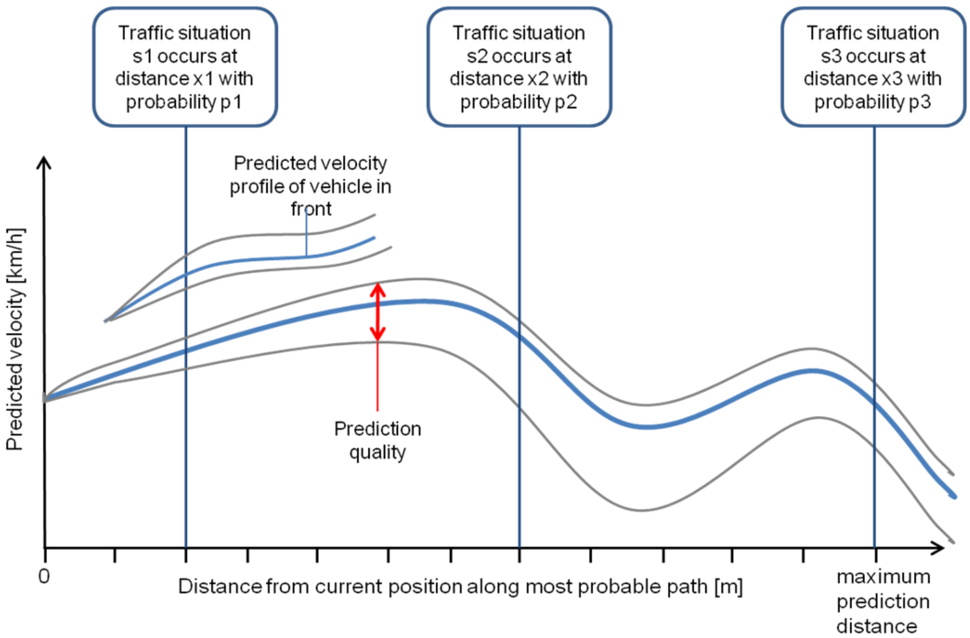

Figure 24 – Output data of the vehicle based eSiM

Regarding what information is currently available, the eSiM algorithm calculates a prediction based on a specific combination of these approaches. The output data of the vehicle based eSiM is visualised in Figure 24.

The vehicle based ecoSituational Model describes the current vehicle and traffic state and also predicts the velocity profile of the host car. If additional information on the vehicle driving in front (in general not equipped with an eCoMove system), such as its velocity and acceleration are available, the model also predicts the velocity profile of the front vehicle.

The in-vehicle eSiM design is an integrate part of the ecoDriving Support application in SP3, hence its detailed design is provided in [D3.2].

On the Road-Side, the infrastructure based ecoSituational Model uses sensor data provided by infrastructure elements as well as information from the infrastructure based ecoMap to predict the velocity profile for every specific vehicle detected by infrastructure sensors or, in case this will not be feasible, for a group of those vehicles.

The situation classes, interfaces and other relevant information of the eSiM will further be described in [D2.9].

The ecoStrategical Model (eStraM), deployed at the central side, is needed as a basis for the traffic management and control strategies in SP5. Where the eSiM works on the microscopic level, the strategic model translates the knowledge (included in the situational level) about what causes fuel consumption to be high or low to the macroscopic level (a route or a network). The strategic model thus provides information about hot spot events that have a major impact on fuel consumption. These events can be related to the topography/topology of the network (such as steep inclines, areas with many traffic lights in a row, etc.) or to the traffic and driving conditions (e.g. stop & go traffic, inefficient merging, etc.).

The focus of eStraM is on traffic in a network (i.e. large numbers of vehicles) rather than the individual movement of vehicles (eSiM-in-vehicle) or the movement of a small number of vehicles or small platoons in a small area, e.g. an intersection (eSiM-infrastructure). The eStraM builds on the knowledge generated with eSiM; it can also use other sources of information such as loop detector data.

Its corresponding situation classes, interfaces and other relevant information to be used by components from the ecoTraffic Management & Control subproject (SP5) for the intended green driving applications will be described in [D2.10].

4.1.4.6. SP2 HLA Technological Layer

The following figure, Figure 25, shows a technological deployment scheme of the core technologies as envisioned by eCoMove architecture. Note that the image displays two In-Vehicle ITS Stations, which are identical; the depiction on the left, however, is more detailed and further expands on concepts like system software and components contained in the software deployments.

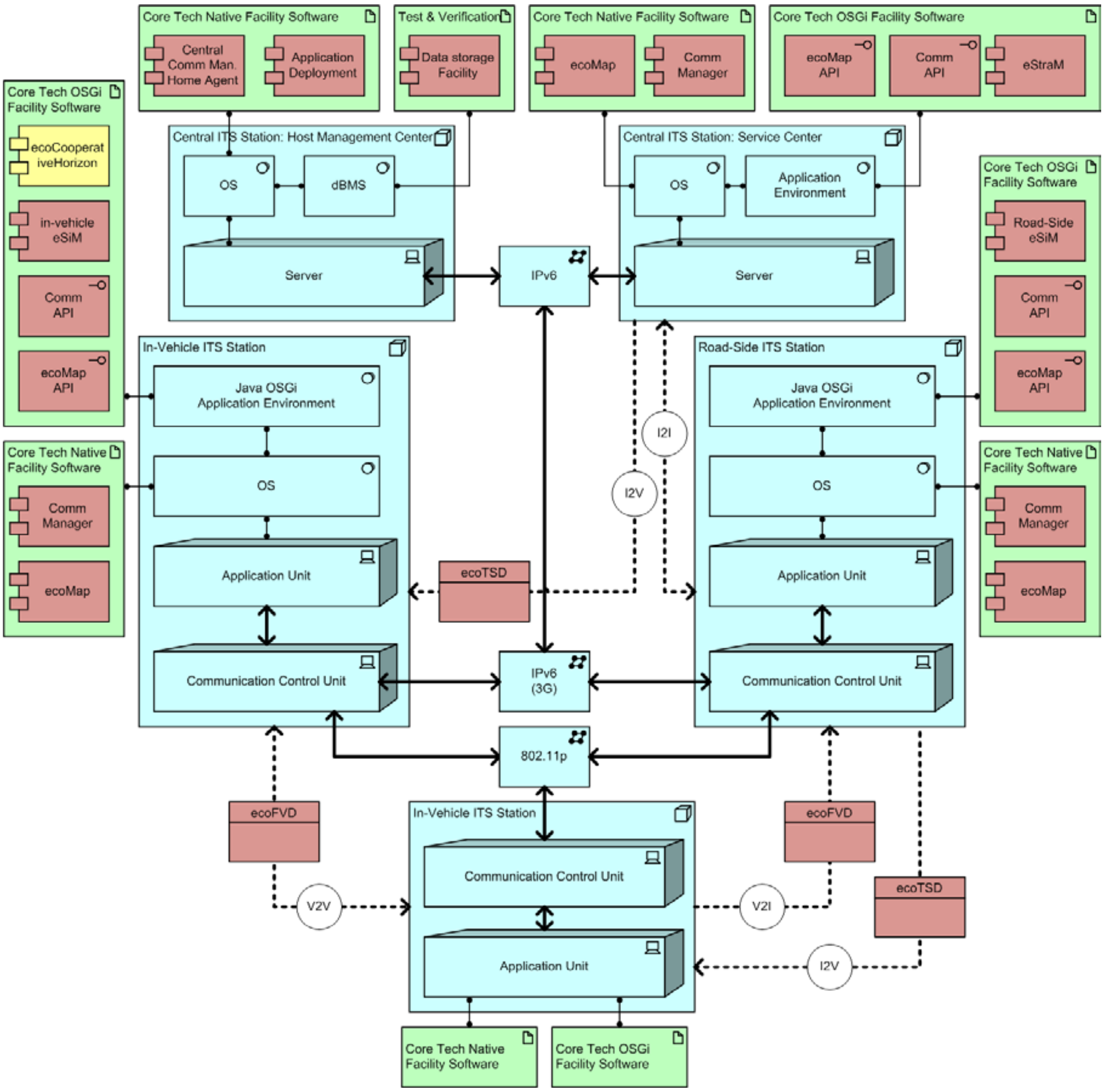

Figure 25 – Core Technology & Integration (SP2) High Level Technological Layer

4.1.5. All SP High Level Product Deployment Overview

The following two figures, Figure 26 and Figure 27, show an overview of all eCoMove SP's and their relation to the ETSI specified ITS Stations: In-Vehicle, Road-Side and Central [ETSI]. This overview is added to provide a summary of deployment and interconnectivity of the complete eCoMove system. In the first figure, Figure 26, connectivity between identified ITS stations, amongst others derived from Figure 21, is depicted. It shows a colouring of the inter-ITS Station communication channels indicating ecoMessage work package involvement.

Note that in both figures In-Vehicle ITS Stations have been divided into two categories: 'In-Car' for ITS stations deployed in passenger cars and 'In-Truck' for ITS Stations deployed in trucks.

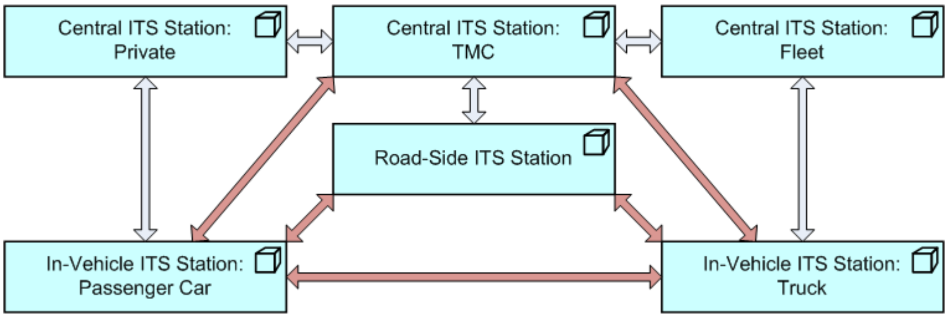

Figure 26 – ITS Station Connectivity (red arrows indicate ecoMessages)

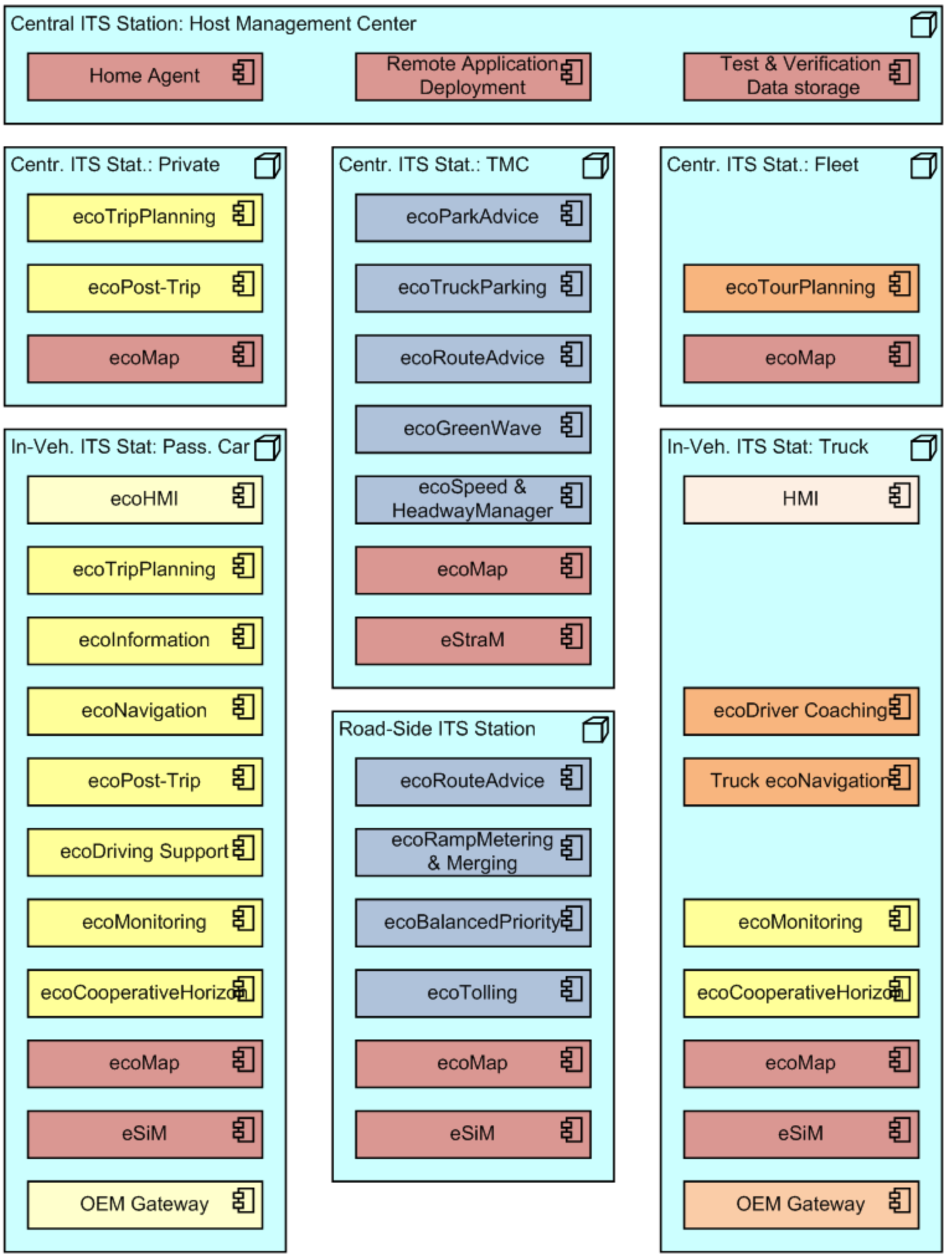

Figure 27 – Overview of All SP Application Deployment

In Figure 27 (previous page 49) deployment of all applications is shown, based on the documentation in the architecture deliverables. In this Figure, the colouring indicates to which SP the applications belong and the ITS Station placement mirrors that of Figure 26. Both figures together provide a view of the cooperation between all applications and services provided by the SP's.

4.1.5.1. eCoMove Product Breakdown Structure (ePBS)

A final diagram shown here, Figure 28, provides a product breakdown structure which provides an exhaustive, hierarchical tree structure of deliverables that make up the eCoMove project, arranged in whole-part relationship. The diagram also shows product delivery from core technology and passenger car products to other product lines. There is a A3 size version of Figure 28 in Appendix A.

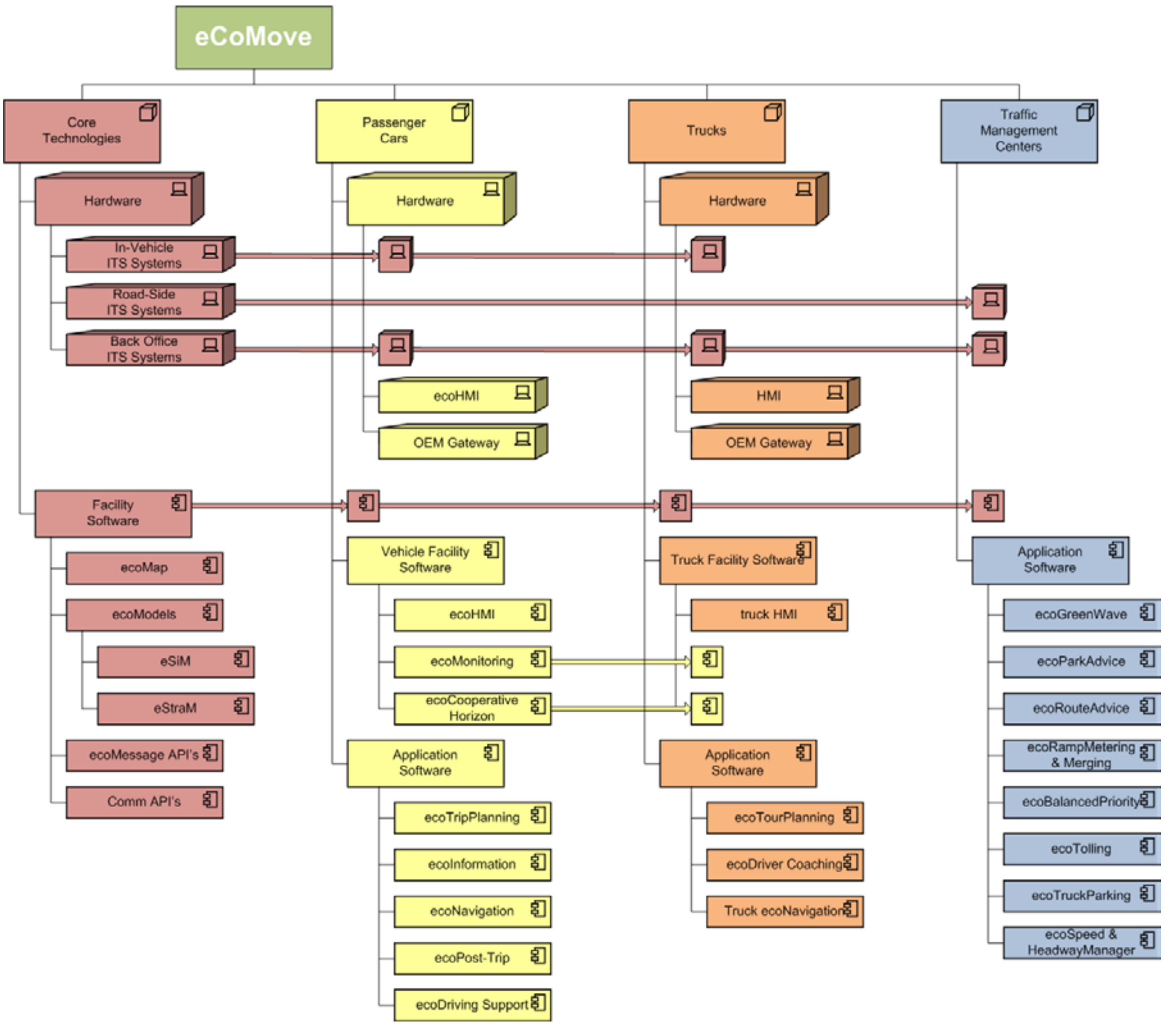

Figure 28 – eCoMove Product Breakdown Structure (ePBS)

4.2. Concept of Execution

This section describes the informational flows between applications and facilities in and between the different types of ITS stations. The overall strategy to address the inefficiencies identified in [D2.1] is a cyclic process which continuously involves:

- analysis of vehicle states and traffic situations on different time and area scales of operation,

- creation of policies to minimise the difference between the measured situations and the desired optimal situations (i.e. minimisation of fuel consumption),
- implementation of the change by ultimately giving recommendations to drivers via the cooperative capabilities of the ITS platforms, and
- measurement of the new situation and comparison of the results against the expected results to ascertain any differences.

This sequence of steps in process improvement is related to the cyclic Plan-Do-Check-Act (PDCA) problem solving strategy known as the Deming Cycle (or Shewhart Cycle). A visualisation of this cycle in eCoMove terms is provided in Figure 29.

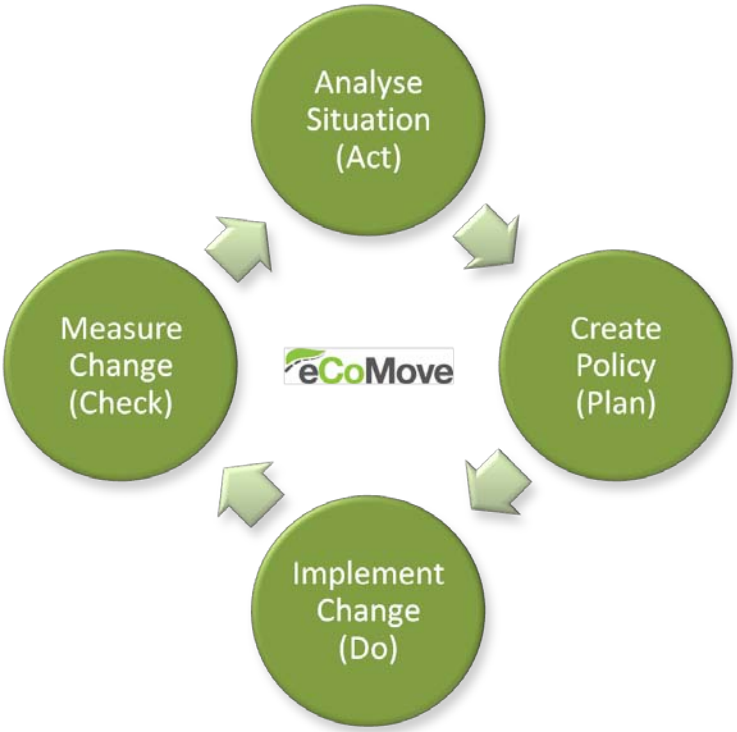

Figure 29 – The Deming Cycle in eCoMove

The applications in eCoMove not necessarily execute the complete cycle whilst addressing the inefficiencies. Most applications play a roles in single steps (e.g. ecoNavigation implements changes in navigation based on the policies provided by traffic management, while ecoMonitoring is solely measuring vehicle states and traffic situations). However, by working together in the cooperative environment the process cycle is completed which results in improved energy efficiency in traffic situations.

4.2.1. Information Flows

The type and characteristics of data flow between components and applications depends highly on whether the data needs to be transmitted between ITS stations or remains locally inside a single ITS Station. The need for transmitting data from ITS station to the other greatly increases the number of interfaces and physical devices involved, which also has great influence on the number and type of requirements which need to be taken into account in the design. This section describes the information flow between components and applications and the performance characteristics related to the designs.

4.2.1.1. Intra-ITS Station information flow

This section describes these information flows within ITS stations, traversing the interfaces described in Chapter 5.

In-Vehicle Information Flow

The following figure, Figure 30, depicts the information flow channels between facilities and the applications deployed on an in-vehicle ITS station.

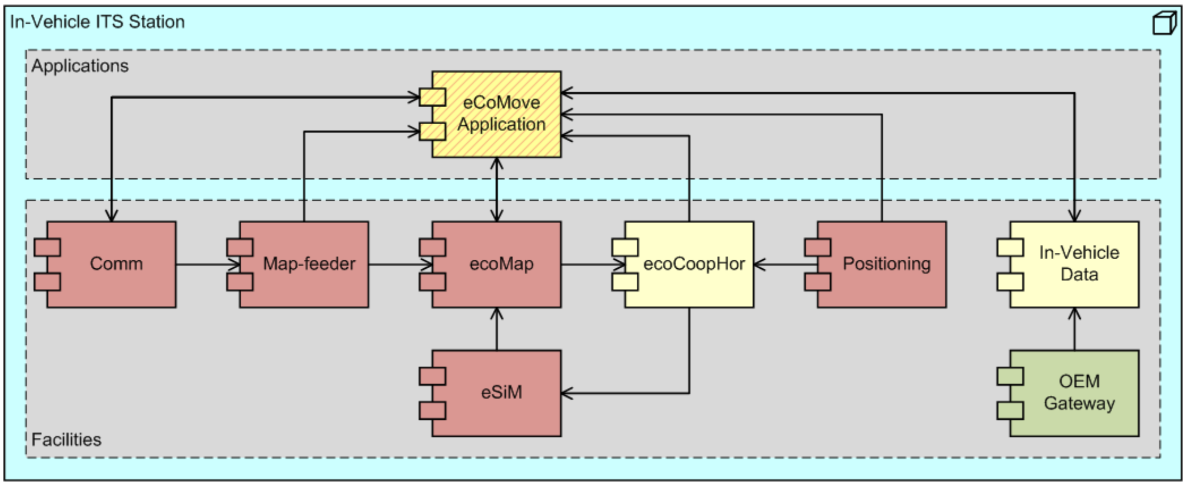

Figure 30 – In-Vehicle Information Flow

The software components have been categorised according to [ETSI] structure, where the applications are supported by the facilities provided by the platform. The following points are to be noted:

- The Communication facility is not used by other facilities in-vehicle. All inter ITS communication from vehicles is initiated by applications; e.g. the ecoMonitoring application, which will trigger the broadcast of ecoFVD messages as described in [D3.3] or the ecoTourPlanning application, which will notify Fleet Control on changes in the mission as described in [D4.2].
- A information flow cycle is created between the ecoMap, ecoCooperativeHorizon and the ecoSituationalModel (eSiM). This is by design: the ecoMap acts as storage for map-related data, the ecoCooperativeHorizon structures the data along the most probable path (see [D3.2]), and the eSiM predicts future situations based on the information gathered from the ecoCooperativeHorizon, which it stores in the ecoMap.
- The In-Vehicle Data Storage component is used to provide a means of data flow exchange between the applications in need of data shared by many applications (e.g. vehicle state, fuel usage, etc.).
- Data contained within received ecoMessages is retrieved by a Map-Feeder component. This component will store the data on the ecoMap.

Road-Side Information Flow

The following figure, Figure 31, depicts the information flow channels between facilities and the applications deployed on a Road-Side ITS station.

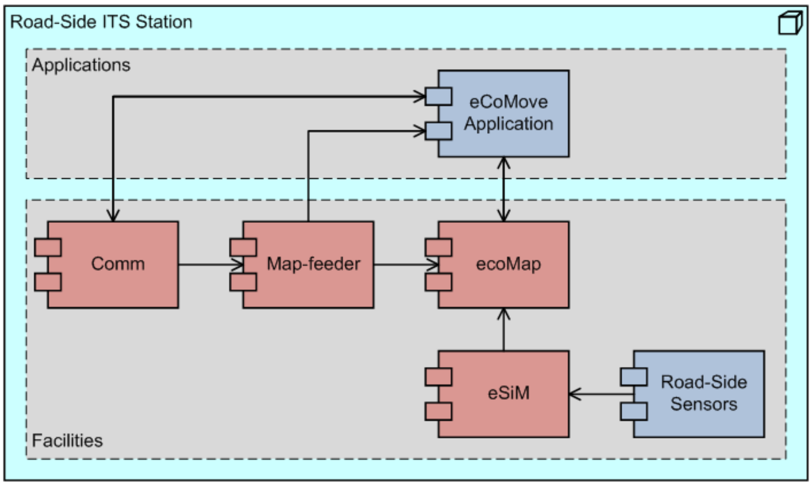

Figure 31 – Road-Side Information Flow

Again, the software components have been categorised according to [ETSI] structure, where the applications are supported by the facilities provided by the platform. The following points are to be noted:

- The Communication facility is not used by other facilities. All inter ITS communication from Road-Side equipment is initiated by applications; e.g. the Driver Info Support Manager application, which will trigger the broadcast of ecoTSD messages, and the Driver Dialogue Manager application which will set up unicast communication to specific vehicles [D5.2].
- The eSiM predicts future situations based on the information gathered from sensors connected to the road-side unit.

Central Information Flow

The following figure, Figure 32, depicts the information flow channels between facilities and the applications deployed on a Central ITS station. For this Figure, the following points are to be noted:

- The Communication facility is not used by other facilities. All inter ITS communication from Central ITS stations is initiated by applications; e.g. the Driver Info Support Manager application and the Driver Dialogue Manager application [D5.2].
- Data contained within received incoming data packages is retrieved by a Central Side specific Map-Feeder component, which is different from the In-Vehicle Map-feeder: this component will be a variant of the In-Vehicle/Roadside Map-feeder.
- Information from Test Sites or Simulation Environments is stored in the ecoMap by Adapter components.
- The ecoStrategical Model (eStraM) retrieves and stores data in the ecoMap. Applications directly access the eStraM when necessary.

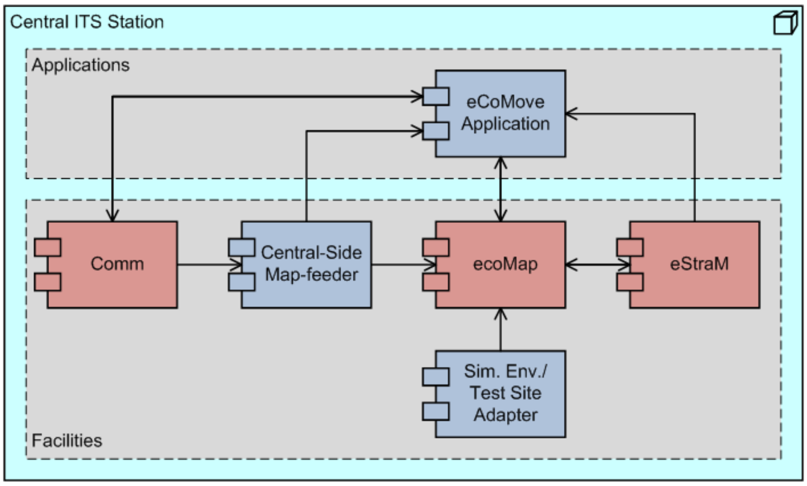

Figure 32 – Central Information Flow

4.2.1.2. Inter-ITS Station Information Flow

The information shared between applications and facilities which is transmitted between ITS stations has a completely different flow, as it has to be transmitted over air (or wire). This requires the use of radio equipment and the implementation of standards. This section describes these information flows, which make use of the standardised communication channels and ecoMessages described in Chapter 5.

IEEE 802.11p Information Flow

The following figure, Figure 33, depicts the information flow channels between in-vehicle and road-side ITS stations via IEEE 802.11p.

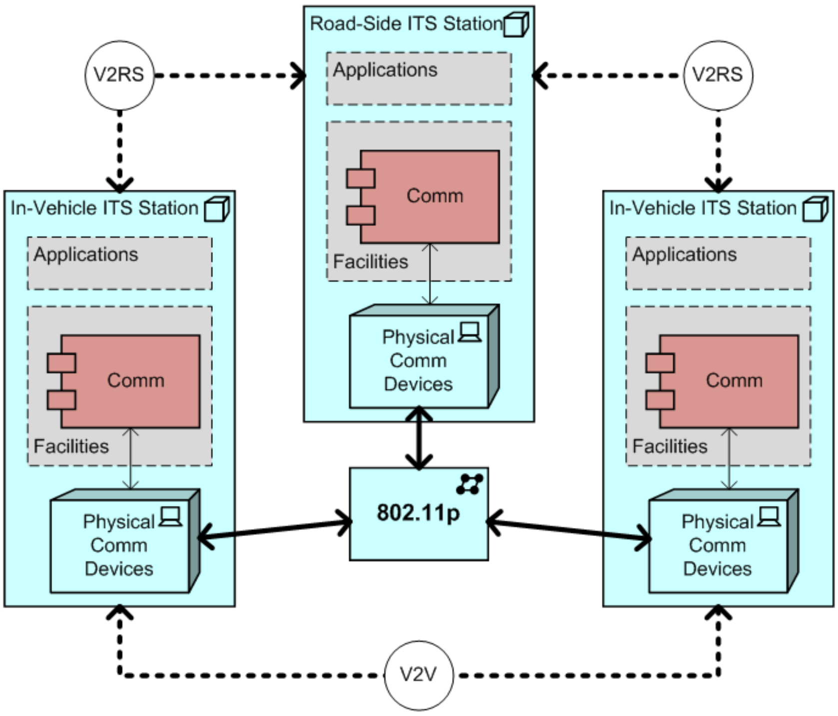

Figure 33 – IEEE 802.11p Information Flow

For this Figure, the following points are to be noted:

- For bi-directional communication between vehicles (Vehicle to Vehicle, or V2V) and bi-directional communication between vehicles and road-side units (Vehicle to Road-Side, or V2RS) IEEE 802.11p is used, which is an approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments. Further documentation on the standards and implementation in eCoMove can be found in [ETSI], [D2.3] and [D2.4].
- The ecoMessages will be transmitted via the communication channels depicted in this Figure. The vehicles will transmit ecoFloating Vehicle Data (ecoFVD) over V2V and V2RS communication channels, whilst road-side units will transmit ecoTraffic Situational Data (ecoTSD) via V2RS communication channels.

3G/Ethernet Information Flow

The following figure, Figure 34, depicts the information flow channels between central ITS stations and in-vehicle or road-side ITS stations via 3G or Ethernet networks.

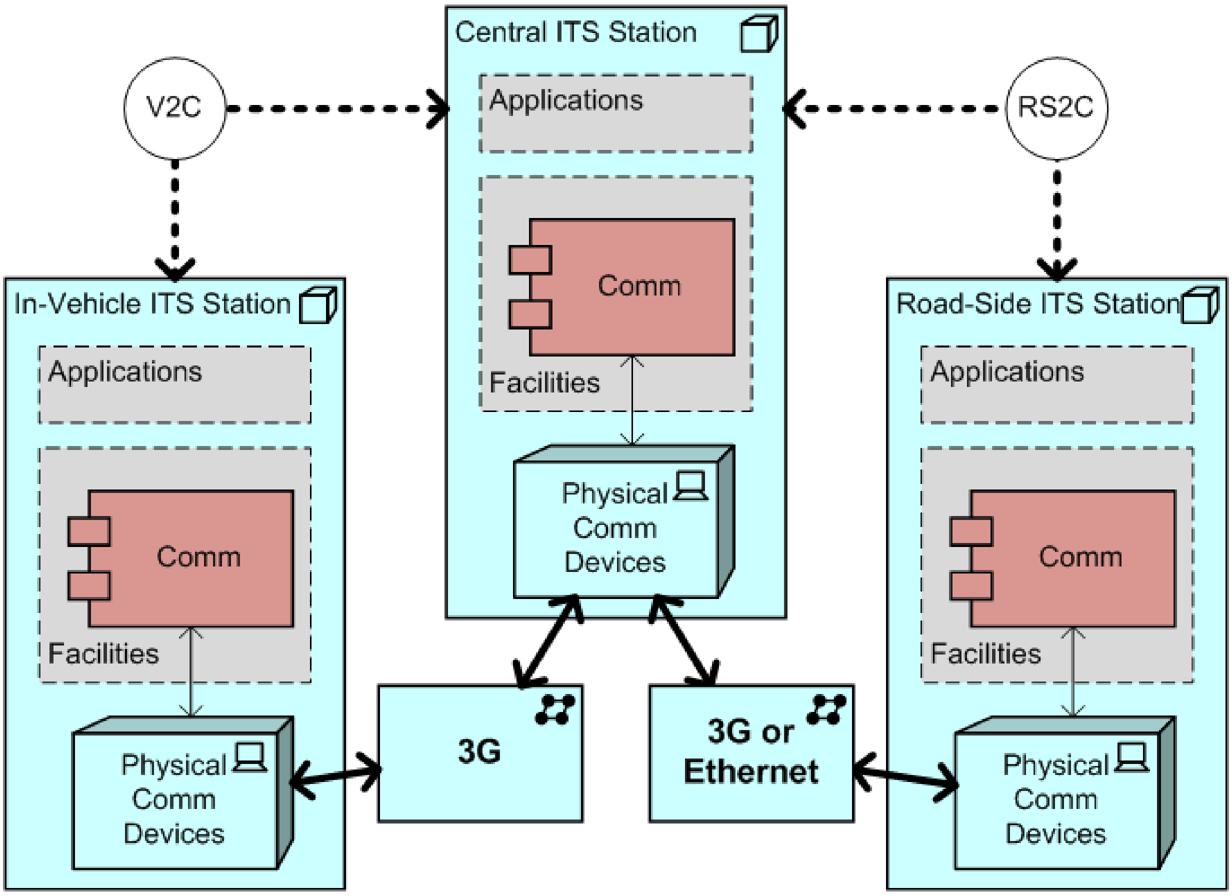

Figure 34 – 3G/Ethernet Information Flow

For this Figure, the following points are to be noted:

- For bi-directional communication between vehicles and central ITS stations (Vehicle to Central, or V2C) 3G is used, which is the 3rd generation of mobile telecommunication standards fulfilling the International Mobile Telecommunications-

2000 specifications by the International Telecommunication Union. For bi-directional communication between road-side units and central ITS stations (Road-Side to Central, or RS2C) either 3G or a direct Ethernet connection is used, depending on the availability of direct connections to the world wide web on road-side infrastructure. Further documentation on the standards and implementation in eCoMove can be found in [ETSI] and [D2.3] respectively.

4.2.1.3. Combined ITS Station Information Flow

The following diagrams depict the data flows after combining inter- and intra-ITS Station Information Flow views. Again, as the images are too detailed to depict on a single page here, readable versions of these are provided in Appendix A.

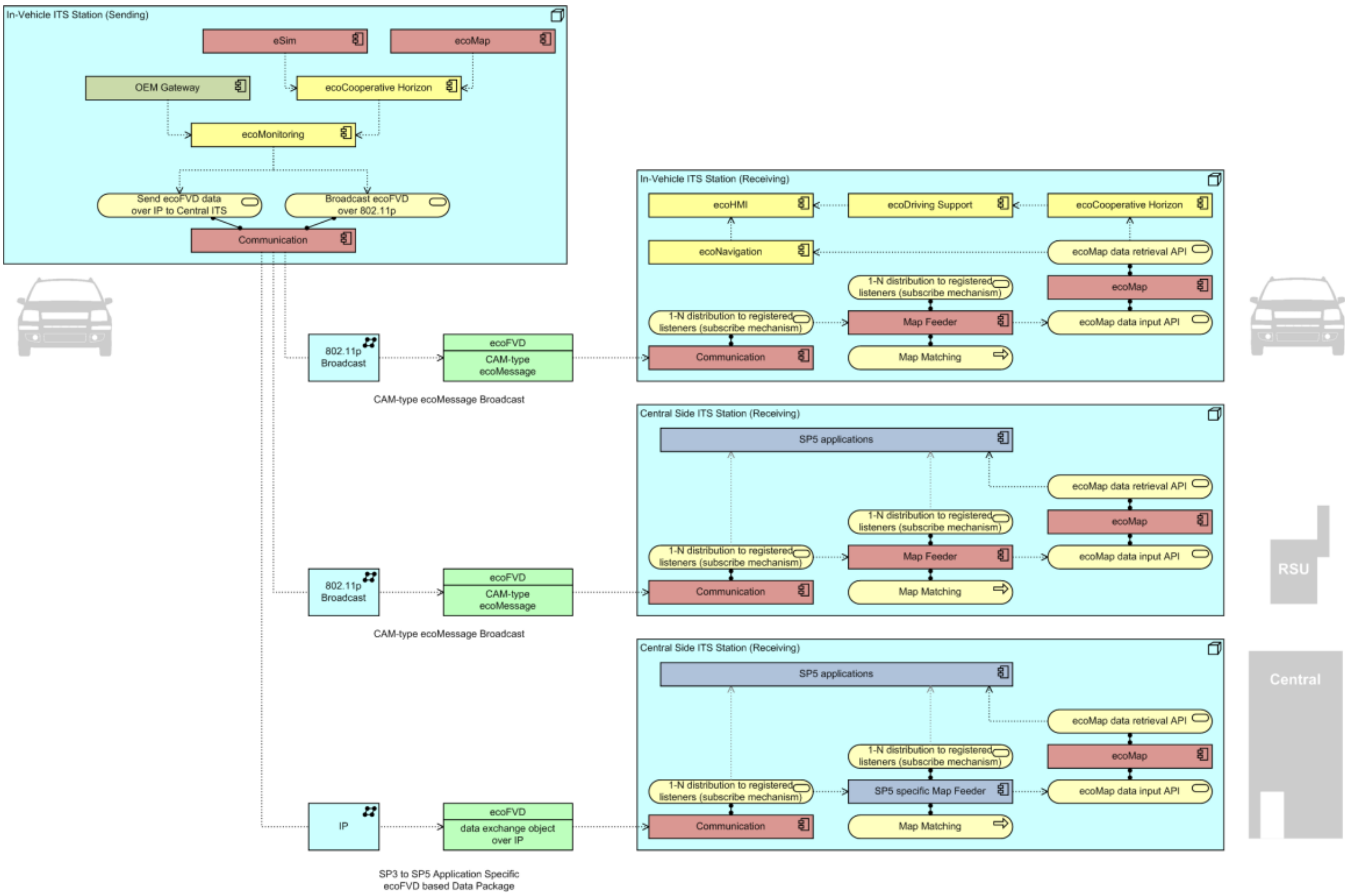

Figure 35 – In-Vehicle ITS Station Originated Data Flow Diagram

The diagram in Figure 35 (and Figure 42) displays that, by design, the ecoMonitoring application triggers ecoFVD broadcasts over 802.11p from In-Vehicle ITS stations to any other radio enabled ITS Station in range. It also shows that the ecoMonitoring application triggers the data exchange to the TMC Central ITS Station as this is expected by designs in SP5. However, sending frequencies and data package size must be much lower than CAM-type distribution over 802.11p, given the specifications of the communication API in [D2.3].

On the receiving side (In-Vehicle & RSU): applications have the possibility to access received communicated data as direct output from the communication API (raw FVD Data), the Map-Feeder (map matched FVD Data) and from the ecoMap (ecoMap Data). In-Vehicle application designs currently specify that SP3 applications retrieve data from the ecoMap and the ecoCooperative Horizon ([D3.2] and [D3.3]).

In the following diagram, depicted in Figure 36 (and Figure 43), it is shown that unicast transmitted data from Road-Side to In-Vehicle ITS Stations (e.g. a tailored speed advice) is also received by the Map-feeder, as that data is destined for the ecoMap. From there it is again placed by the ecoCooperative horizon on a most probable path such that the ecoDriving Support application can create appropriate recommendations to the driver on the ecoHMI.

Data that needs to be exchanged between Road-side and Central ITS stations is communicated via application specific unicasts over IP. Traffic management centres will have a Central Map-feeder which will be a variant of the In-Vehicle Map-feeder. The Central Map-feeder will be developed in the ecoTraffic Management & Control subproject (SP5).

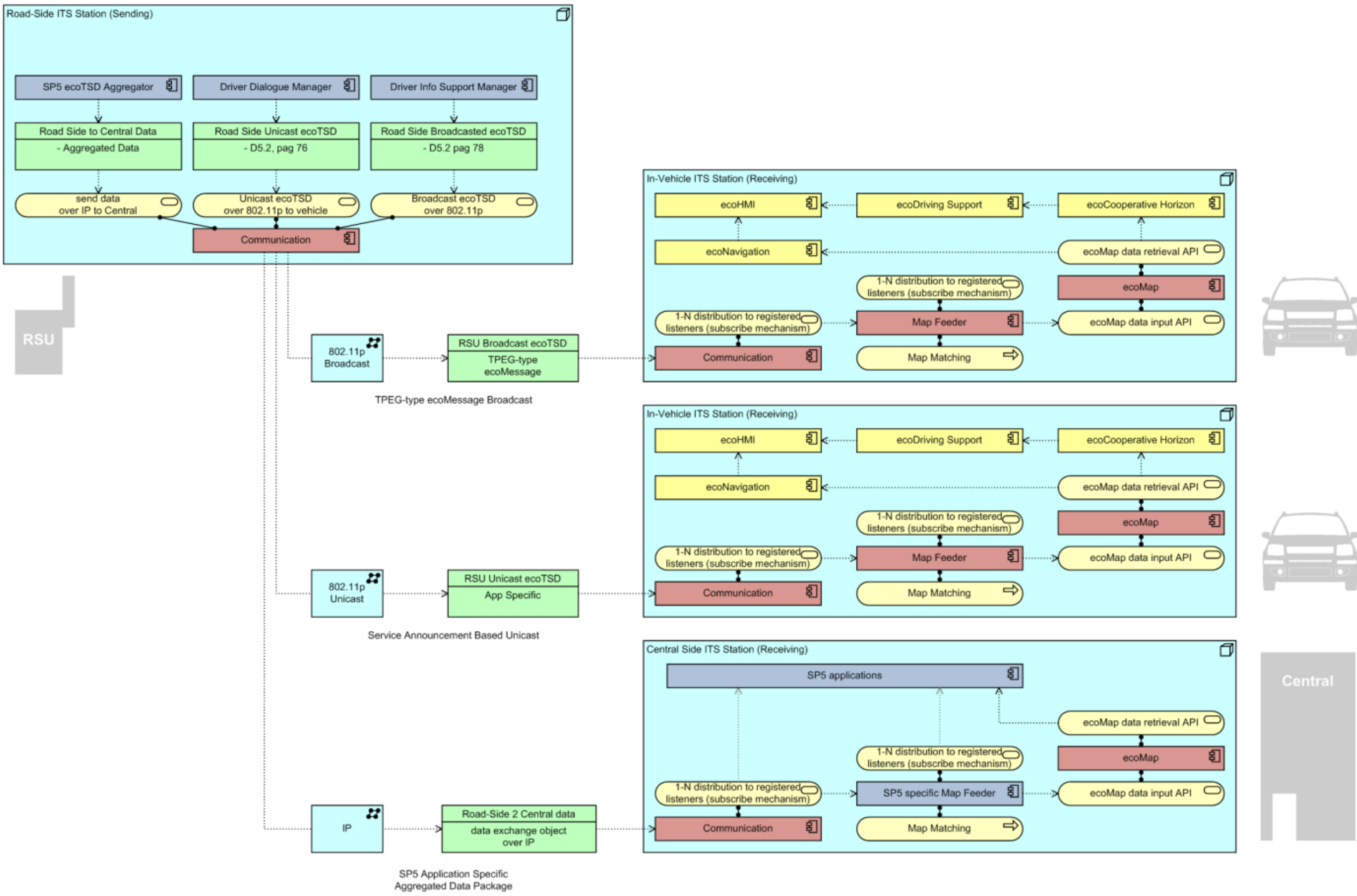

Figure 36 – Road-Side ITS Station Originated Data Flow Diagram

As is depicted in the diagram in Figure 37 (and Figure 44), all communications to In-Vehicles and Road-Side ITS Stations is over IP. This limits the possibilities for doing broadcasts. Hence, all data that needs to be broadcasted from central-side to multiple vehicles (e.g. a

Traffic Jam warning to multiple vehicles on a specific road), will be unicasted to registered vehicles. More specifications on the strategies available are described in [D2.3].

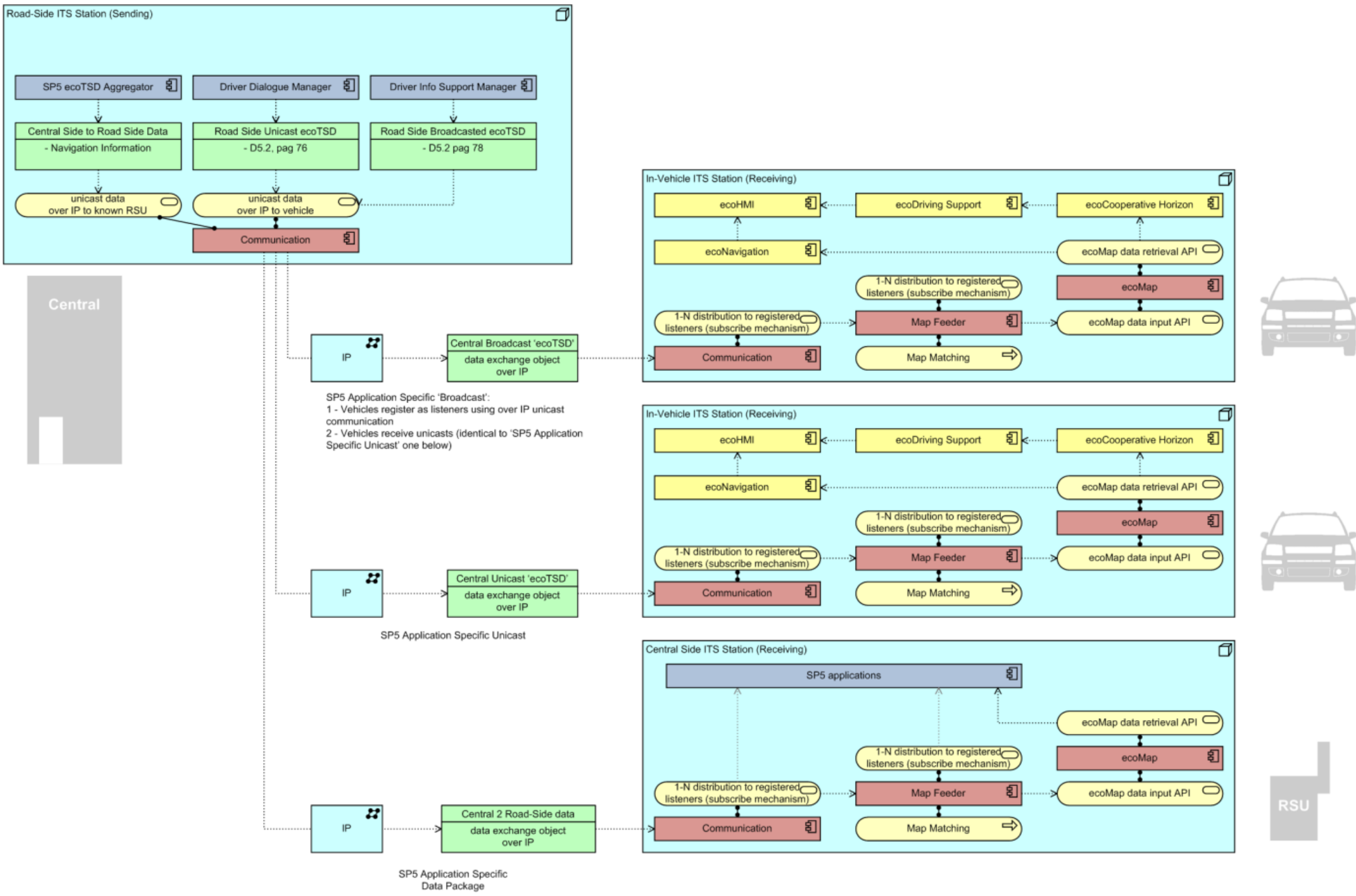

Figure 37 – Central-Side ITS Station Originated Data Flow Diagram

5. Interface Design

This chapter provides information on the interfaces between components and applications.

5.1. Communication API Usage by Applications and Facilities

The following diagram, depicted in Figure 38, indicates the different data flows between the ITS Stations. To make it possible to identify which applications will be triggering the data transfer and which facilities will be on the receiving side, entry and exit points have been numbered. Each number indicates required usage of the Communications API, described in [D2.3].

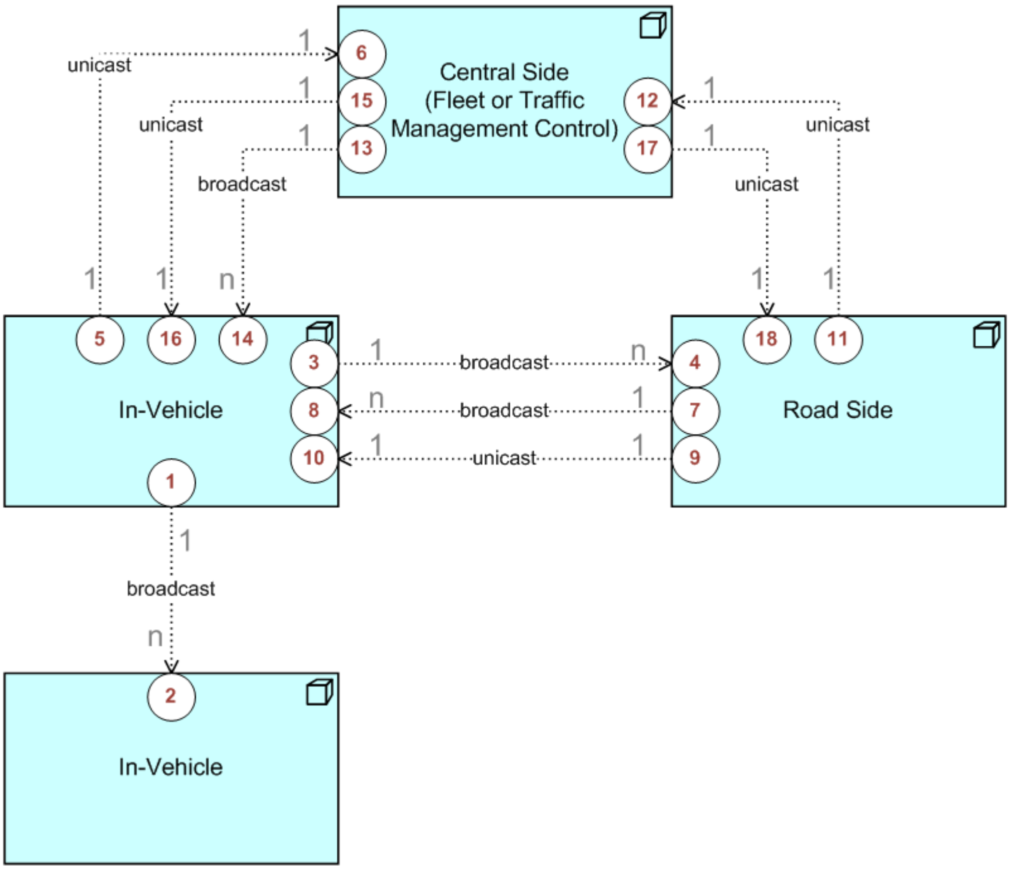

Figure 38 – Numbered Communication API Usage between ITS Stations

Given the numbering in Figure 38, the following two tables describes the following:

- **Nr –** The number depicted in the circles in Figure 38.
- **From –** Describes data transfer origin ITS Station.
- **To –** Describes data transfer destination ITS Station.
- **Type –** Broadcast (1-n) or Unicast (1-1) communication channel.
- **Triggering Application –** The application which initiates the transfer of data.
- **Send Interface –** The Communication API used to initiate data transfer.
- **Receive Interface –** The Communication API used to receive data transfer.
- **Receiving Application –** The application which receives transferred of data.

Sending:

Nr	From	To	Type	Triggering Application	Send Interface
1	Vehicle	Vehicle	Broadcast	ecoMonitoring	In-Vehicle/RSU Comm API
3	Vehicle	RSU	Broadcast	ecoMonitoring	In-Vehicle/RSU Comm API
5	Vehicle	Central	Unicast	ecoMonitoring	In-Vehicle/RSU Comm API
7	RSU	Vehicle	Broadcast	Driver Info Support Manager	In-Vehicle/RSU Comm API
9	RSU	Vehicle	Unicast	Driver Dialog Manager	In-Vehicle/RSU Comm API
11	RSU	Central	Unicast	ecoTSD SP5 Aggregator	In-Vehicle/RSU Comm API
13	Central	Vehicle	Broadcast	Driver Info Support Manager	Central Comm API
15	Central	Vehicle	Unicast	Driver Dialog Manager	Central Comm API
17	Central	RSU	Unicast	SP5 Application	Central Comm API

Table 6 – Numbered Communication API Usage from Sending ITS Stations

Receiving:

Nr	From	To	Type	Receive Interface	Receiving Application
2	Vehicle	Vehicle	Broadcast	In-Vehicle/RSU Comm API	Map-feeder
4	Vehicle	RSU	Broadcast	In-Vehicle/RSU Comm API	Map-feeder
6	Vehicle	Central	Unicast	Central Comm API	Central Side Map-feeder
8	RSU	Vehicle	Broadcast	In-Vehicle/RSU Comm API	Map-feeder
10	RSU	Vehicle	Unicast	In-Vehicle/RSU Comm API	Map-feeder
12	RSU	Central	Unicast	Central Comm API	Central Side Map-feeder
14	Central	Vehicle	Broadcast	In-Vehicle/RSU Comm API	Map-feeder
16	Central	Vehicle	Unicast	In-Vehicle/RSU Comm API	Map-feeder
18	Central	RSU	Unicast	In-Vehicle/RSU Comm API	Map-feeder

Table 7 – Numbered Communication API Usage from Receiving ITS Stations

Note that this section describes usage of the Communication API, which covers all required communication scenarios by related application designs. Detailed specification of the communication API is described in [D2.3].

A different ordering of the previous two tables summarises the relationship between the sending and receiving applications (see Table 8 to Table 10). Combined with the application subproject designs, the following relationships can be concluded:

- ecoFVD transmission from In-Vehicle to Road-Side and Central ITS Stations is initiated by the ecoMonitoring application.
- Traffic Management and Control data transmission from Road-Side and Central to In-Vehicle ITS stations is initiated by:
  - The Driver Info Support Manager for all broadcasts
  - The Driver Dialogue Manager for all unicasts
- Data in transmissions initiated by the aforementioned applications are ultimately received by:
  - In-Vehicle and Road-Side ITS Stations: the Map-feeder component (SP2)
  - Central ITS Stations: Central Side Map-feeder component (SP5)

Sending from Vehicles:

Nr	From	To	Type	Triggering Application	Send Interface
1	**Vehicle**	Vehicle	Broadcast	**ecoMonitoring**	In-Vehicle/RSU Comm API
3	**Vehicle**	RSU	Broadcast	**ecoMonitoring**	In-Vehicle/RSU Comm API
5	**Vehicle**	Central	Unicast	**ecoMonitoring**	In-Vehicle/RSU Comm API

Table 8 – Numbered Comm API Usage from Sending In-Vehicle ITS Stations

Receiving on all sides:

Nr	From	To	Type	Receive Interface	Receiving Application
2	Vehicle	**Vehicle**	Broadcast	In-Vehicle/RSU Comm API	**Map-feeder**
4	Vehicle	**RSU**	Broadcast	In-Vehicle/RSU Comm API	**Map-feeder**
6	Vehicle	**Central**	Unicast	Central Comm API	**Central Side Map-feeder**
8	RSU	**Vehicle**	Broadcast	In-Vehicle/RSU Comm API	**Map-feeder**
14	Central	**Vehicle**	Broadcast	In-Vehicle/RSU Comm API	**Map-feeder**
10	RSU	**Vehicle**	Unicast	In-Vehicle/RSU Comm API	**Map-feeder**
16	Central	**Vehicle**	Unicast	In-Vehicle/RSU Comm API	**Map-feeder**
12	RSU	**Central**	Unicast	Central Comm API	**Central Side Map-feeder**
18	Central	**RSU**	Unicast	In-Vehicle/RSU Comm API	**Map-feeder**

Table 9 – Numbered Comm API Usage from Receiving ITS Stations

Sending from Infrastructure:

Nr	From	To	Type	Triggering Application	Send Interface
7	**RSU**	Vehicle	**Broadcast**	**Driver Info Support Manager**	In-Vehicle/RSU Comm API
13	**Central**	Vehicle	**Broadcast**	**Driver Info Support Manager**	Central Comm API
9	**RSU**	Vehicle	**Unicast**	**Driver Dialog Manager**	In-Vehicle/RSU Comm API
15	**Central**	Vehicle	**Unicast**	**Driver Dialog Manager**	Central Comm API
11	**RSU**	Central	**Unicast**	**ecoTSD SP5 Aggregator**	In-Vehicle/RSU Comm API
17	**Central**	RSU	**Unicast**	**SP5 Application**	Central Comm API

Table 10 – Numbered Comm API Usage from Sending Infrastructure ITS Stations

Note that the communication platform supports application-specific communications to which the previous concusions not necessarily apply [D2.3].

5.2. Application Data Exchange Between Subprojects

This section describes the data objects that are exchanged between the eCoMove applications as well as the core technologies. The lists are collected versions of those delivered in the architecture deliverables from the application SP's. The tables listed in each section contain a listing of exchanged data objects, the headers are to be interpreted as follows:

- **SP** – The number of the subproject to which the application producing/requiring the data belongs.
- **Diagram –** The application of which the diagrams contain the Object description.
- **Object –** The Object to be exchanged between applications.

- **Delivered To / Required From** – The Application or Service to which the Object is either sent or from which it is required.
- **SP** – The subproject to which the referenced Application or Service belongs.
- **Reference Diagram** – The diagram of the Application or Service in which the Object is produced/used.

5.2.1. Data Exchange in ecoSmart Driving (SP3) and ecoFreight & Logistics (SP4) subprojects

This section lists the data object exchange tables from [D3.2], [D3.3] and [D4.2] listing produced and required data objects.

5.2.1.1. SP3 and SP4 Application Produced Data

SP	Diagram	Object	Delivered To	SP	Reference Diagram
SP3	ecoNavigation	ecoRoute	TCC/TMC	SP5	Improve Network Usage
SP3	ecoCooperative Horizon	Current Position	ecoSituational Model	SP2	ecoSituationalModel
SP3	ecoCooperative Horizon	Most Probable Path	ecoSituational Model	SP2	ecoSituationalModel
SP3	ecoCooperative Horizon	Road Segment Probabilities	Truck EcoNavigation	SP4	Truck ecoNavigation
SP3	ecoCooperative Horizon	Path related static map data	Truck EcoNavigation	SP4	Truck ecoNavigation
SP3	ecoCooperative Horizon	Path related traffic information	ecoDriver Coaching System	SP4	ecoDriver Coaching System
SP3	ecoCooperative Horizon	Path related situational data	Parking Guidance	SP5	Parking Guidance
SP3	ecoCooperative Horizon	Path related Map eco-data	Parking Guidance	SP5	Parking Guidance
SP3	ecoCooperative Horizon	Path related Base Map Data	Parking Guidance	SP5	Parking Guidance
SP3	ecoMonitoring	ecoFVD	Data Exchange	SP2	Communication system
SP4	ecoTourPlanning	ecoTour	Truck ecoNavigation	SP4	Truck ecoNavigation
SP4	ecoTourPlanning	ecoTour	Mission Authoriser	SP4	Truck ecoNavigation
SP4	Truck ecoNavigation	ecoRoute	Traffic Management	SP5	Improve Network Usage
SP4	Truck ecoNavigation	ecoRoute	ecoCooperativeHorizon	SP3	ecoCooperative Horizon
SP4	Truck ecoNavigation	ecoRoute	ecoTour Planning	SP4	ecoTourPlanning
SP4	Truck ecoNavigation	ETA	ecoTour Planning	SP4	ecoTourPlanning
SP4	ecoDriverCoaching	Driving Profile	Fleet evaluation	SP4	ecoDriverCoaching
SP4	ecoDriverCoaching	Carbon footprint	Carbon footprint	SP4	ecoTourPlanning
SP4	ecoDriverCoaching	ecoDriving advice	ecoHMI	SP3	

Table 11 – SP3 and SP4 Application Produced Data

5.2.1.2. *SP3 and SP4 Application Required Data*

SP	Diagram	Object	Req. From	SP	Reference Diagram
SP3	ecoNavigation	dynamic map data	ecoMap	SP2	ecoMap & related Services
SP3	ecoNavigation	dynamic map data	ecoMap	SP2	ecoMap & related Services
SP3	ecoNavigation	static map data	ecoMap	SP2	ecoMap & related Services
SP3	ecoNavigation	Route Advice	TCC/TMC	SP5	Improve Network Usage
SP3	ecoDrivingSupport	Current traffic situation	ecoSituational Model	SP2	ecoSituationalModel
SP3	ecoDrivingSupport	Predicted velocity profile	ecoSituational Model	SP2	ecoSituationalModel
SP3	ecoDrivingSupport	Predicted traffic situation	ecoSituational Model	SP2	ecoSituationalModel
SP3	ecoCooperative Horizon	road segment	Vehicle Positioning	SP2	
SP3	ecoCooperative Horizon	position on segment	Vehicle Positioning	SP2	
SP3	ecoCooperative Horizon	Map eco-data	ecoMap	SP2	ecoMap
SP3	ecoCooperative Horizon	Base Map Data	ecoMap	SP2	ecoMap
SP3	ecoCooperative Horizon	ecoFVD	ecoMap	SP2	ecoMap
SP3	ecoCooperative Horizon	Road information	ecoMap	SP2	ecoMap
SP4	ecoTourPlanning	traffic state and prediction	EcoATS	SP5	EcoTourPlanning
SP4	ecoTourPlanning	Mission authorisation	Mission Authoriser	SP4	EcoTourPlanning
SP4	ecoTourPlanning	Carbon footprint	post-trip driving feedback	SP4	ecoDriverCoaching
SP4	ecoTourPlanning	Route update information (event based)	Truck ecoNavigation	SP4	Truck ecoNavigation
SP4	Truck ecoNavigation	Map-Matched Situational Data	ecoMap	SP2	ecoMap
SP4	Truck ecoNavigation	Map-Matched Traffic Information	ecoMap	SP2	ecoMap
SP4	Truck ecoNavigation	Route Advice	Traffic Management	SP5	Improve Network Usage
SP4	Truck ecoNavigation	Current Position	ecoCooperative Horizon	SP3	ecoCooperative Horizon
SP4	Truck ecoNavigation	Vehicle Parameters	ecoTour Planning	SP4	ecoTourPlanning
SP4	Truck ecoNavigation	Trip Data	ecoTour Planning	SP4	ecoTourPlanning
SP4	Truck ecoNavigation	Vehicle Parameters	ecoHMI	SP3	

SP	Diagram	Object	Req. From	SP	Reference Diagram
SP4	Truck ecoNavigation	Trip Data	ecoHMI	SP3	
SP4	ecoDriverCoaching	ecoSituational Data	ecoSituational Model	SP2	ecoSituationalModel
SP4	ecoDriverCoaching	ecoCooperativeHorizon	ecoCooperative Horizon	SP3	ecoCooperative Horizon
SP4	ecoDriverCoaching	vehicle data	vehicle sensors	SP4	ecoDriverCoaching
SP4	ecoDriverCoaching	ecoDriver Coaching settings	ecoFleet Business	SP4	ecoDriver Coaching

Table 12 – SP3 and SP4 Application Required Data

5.2.2. Data Exchange in SP2 Core Technology Subproject

This list provides the data objects that the Core Technologies have to produce to support the applications in their process executions.

5.2.2.1. SP2 Core Technologies Produced Data

SP	Produced By	Diagram	Object	SP	Reference Diagram
SP2	ecoMap	ecoMap & related Services	dynamic map data	SP3	ecoNavigation
SP2	ecoMap	ecoMap & related Services	dynamic map data	SP3	ecoNavigation
SP2	ecoMap	ecoMap & related Services	static map data	SP3	ecoNavigation
SP2	ecoSituational Model	ecoSituational Model	Current traffic situation	SP3	ecoDrivingSupport
SP2	ecoSituational Model	ecoSituational Model	Predicted velocity profile	SP3	ecoDrivingSupport
SP2	ecoSituational Model	ecoSituational Model	Predicted traffic situation	SP3	ecoDrivingSupport
SP2	Vehicle Positioning		road segment	SP3	ecoCooperative Horizon
SP2	Vehicle Positioning		position on segment	SP3	ecoCooperative Horizon
SP2	ecoMap	ecoMap	Map eco-data	SP3	ecoCooperative Horizon
SP2	ecoMap	ecoMap	Base Map Data	SP3	ecoCooperative Horizon
SP2	ecoMap	ecoMap	ecoFVD	SP3	ecoCooperative Horizon
SP2	ecoMap	ecoMap	Road information	SP3	ecoCooperative Horizon
SP2	ecoMap	ecoMap	Map-Matched Situational Data	SP4	Truck ecoNavigation
SP2	ecoMap	ecoMap	Map-Matched Traffic Information	SP4	Truck ecoNavigation
SP2	ecoSituational Model	ecoSituational Model	ecoSituational Data	SP4	ecoDriverCoaching

Table 13 – SP2 Core Technologies Produced Data

5.2.2.2. SP2 Core Technologies Required Data

SP	Diagram	Object	Req. From	SP	Reference Diagram
SP2	Communication Platform	ecoFVD	ecoMonitoring	SP3	ecoMonitoring
SP2	ecoSituational Model	Current Position	ecoCooperative Horizon	SP3	ecoCooperative Horizon
SP2	ecoSituational Model	Most Probable Path	ecoCooperative Horizon	SP3	ecoCooperative Horizon

Table 14 – SP2 Core Technologies Required Data

5.2.3. Data Exchange in SP5 ecoTraffic Management & Control Subproject (SP5)

The SP5 architecture deliverable contains a more detailed approach used for interface definitions. The specification of the interfaces in SP5 can be found in [D5.2].
The following list has been compiled given the previous tables describing the expected delivered and required data objects to SP5 applications.

5.2.3.1. SP5 ecoTraffic Management & Control Produced Data

SP	Diagram	Object	Delivered To	SP	Reference Diagram
SP5	Improve Network Usage	Route Advice	Data Collector	SP3	ecoNavigation
SP5	EcoTourPlanning	traffic state and prediction	Traffic State & Prediction Receiver	SP4	ecoTourPlanning
SP5	Improve Network Usage	Route Advice	Data Collector	SP4	Truck ecoNavigation

Table 15 – SP5 ecoTraffic Management & Control Produced Data

5.2.3.2. SP5 ecoTraffic Management & Control Required Data

SP	Diagram	Object	Req. From	SP	Reference Diagram
SP5	Improve Network Usage	ecoRoute	Data Collector	SP3	ecoNavigation
SP5	Parking Guidance	Path related situational data	ecoCooperative Horizon	SP3	ecoCooperative Horizon
SP5	Parking Guidance	Path related Map eco-data	ecoCooperative Horizon	SP3	ecoCooperative Horizon
SP5	Parking Guidance	Path related Base Map Data	ecoCooperative Horizon	SP3	ecoCooperative Horizon
SP5	Improve Network Usage	ecoRoute	Data Collector	SP4	Truck ecoNavigation

Table 16 – SP5 ecoTraffic Management & Control Required Data

6. Requirements Traceability

This chapter provides two-way traceability between architecture components and requirements, and includes references to documentation if applicable. If references are not applicable, it means the requirement applies to eCoMove documentation which by definition is self referencing.

6.1. Requirement to Document/Application Traceability

This section provides traceability from the requirements specified in [D2.1] to documents, applications and components.

6.1.1. High Level system requirements

6.1.1.1. Efficiency applications

Requirement	Document/Application	Reference
ECOM-RQ-IP-0090	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0091	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0092	ecoDrivingSupport	D3.2
ECOM-RQ-IP-0092	ecoDriver Coaching System	D4.2
ECOM-RQ-IP-0093	ecoInformation	D3.2
ECOM-RQ-IP-0093	ecoDriver Coaching System	D4.2
ECOM-RQ-IP-0094	ecoDriver Coaching System	D4.2
ECOM-RQ-IP-0095	ecoABC, ecoMM, ecoATS	D5.2

Table 17 – Traceability: Efficiency applications

6.1.1.2. Architecture Properties

Requirement	Document/Application	Reference
ECOM-RQ-IP-0001	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0002	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0003	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0004	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0005	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0006	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0007	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0008	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0009	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0010	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0011	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0014	D2.2, D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0016	D2.2, D3.2, D3.3, D4.2, D5.2	-

Table 18 – Traceability: Architecture Properties

6.1.1.3. Data Exchange

Requirement	Document/Application	Reference
ECOM-RQ-IP-0017	D2.2, D3.2, D3.3, D4.2, D5.2	-

Requirement	Document/Application	Reference
ECOM-RQ-IP-0018	D2.2	-
ECOM-RQ-IP-0019	ecoMap	See D2.6 for traceability.
ECOM-RQ-IP-0020	D2.2	-
ECOM-RQ-IP-0021	D3.2, D3.3, D4.2, D5.2	-
ECOM-RQ-IP-0022	Communication Platform	D2.3
ECOM-RQ-IP-0023	Communication Platform	D2.3
ECOM-RQ-IP-0023	ecoMessages	D2.5
ECOM-RQ-IP-0024	Communication Platform	D2.3
ECOM-RQ-IP-0025	Communication Platform	D2.3
ECOM-RQ-IP-0025	ecoMessages	D2.5
ECOM-RQ-IP-0026	Communication Platform	See D2.3 for traceability.

Table 19 – Traceability: Data Exchange

6.1.1.4. Adaptability

Requirement	Document/Application	Reference
ECOM-RQ-IP-0027	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0028	ecoMap	D2.2
ECOM-RQ-IP-0028	All SP5 components	D5.2
ECOM-RQ-IP-0029	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0030	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0031	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0032	All components	D2.2, D3.2, D3.3, D4.2, D5.2

Table 20 – Traceability: Adaptability

6.1.1.5. Constraints

Requirement	Document/Application	Reference
ECOM-RQ-IP-0034	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0035	All components	D2.2, D3.2, D3.3, D4.2, D5.2

Table 21 – Traceability: Constraints

6.1.1.6. Continuity

Requirement	Document/Application	Reference
ECOM-RQ-IP-0036	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0037	All components	D2.2, D3.2, D3.3, D4.2, D5.2

Table 22 – Traceability: Continuity

6.1.1.7. Cost/benefit

Requirement	Document/Application	Reference
ECOM-RQ-IP-0038	Core Technologies	D2.2
ECOM-RQ-IP-0038	ecoCooperative Horizon	D3.2
ECOM-RQ-IP-0038	In-Vehicle Data	D3.2, D3.3
ECOM-RQ-IP-0039	OBSOLETE (duplicate requirement)	ECOM-RQ-IP-0038
ECOM-RQ-IP-0040	Communication Platform	D2.3

Requirement	Document/Application	Reference
ECOM-RQ-IP-0041	All components	D2.2, D3.2, D3.3, D4.2, D5.2

Table 23 – Traceability: Cost/benefit

6.1.1.8. Expandability

Requirement	Document/Application	Reference
ECOM-RQ-IP-0042	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0043	All components	D2.2, D3.2, D3.3, D4.2, D5.2

Table 24 – Traceability: Expandability

6.1.1.9. Maintainability

Requirement	Document/Application	Reference
ECOM-RQ-IP-0044	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0045	All components	D2.2, D3.2, D3.3, D4.2, D5.2

Table 25 – Traceability: Maintainability

6.1.1.10. Quality of Data Content

Requirement	Document/Application	Reference
ECOM-RQ-IP-0046	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0047	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0048	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0049	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0050	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0051	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0052	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0053	All components	D2.2, D3.2, D3.3, D4.2, D5.2

Table 26 – Traceability: Quality of Data Content

6.1.1.11. Robustness

Requirement	Document/Application	Reference
ECOM-RQ-IP-0054	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0055	Not applicable to eCoMove components: none fall under referenced requirements.	-
ECOM-RQ-IP-0056	Not applicable to eCoMove components: none fall under referenced requirements.	-
ECOM-RQ-IP-0057	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0058	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0059	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0060	All components	D2.2, D3.2, D3.3, D4.2, D5.2

Table 27 – Traceability: Robustness

6.1.1.12. Safety

Requirement	Document/Application	Reference
ECOM-RQ-IP-0061	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0062	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0063	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0064	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0065	All components	D2.2, D3.2, D3.3, D4.2, D5.2

Table 28 – Traceability: Safety

6.1.1.13. Security

Requirement	Document/Application	Reference
ECOM-RQ-IP-0066	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0067	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0068	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0069	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0070	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0071	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0073	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0074	Communication Platform	D2.3
ECOM-RQ-IP-0075	Communication Platform	D2.3
ECOM-RQ-IP-0077	Communication Platform	D2.3
ECOM-RQ-IP-0078	Communication Platform	D2.3
ECOM-RQ-IP-0078	all SP4 components	D4.2

Table 29 – Traceability: Security

6.1.1.14. User Friendliness

Requirement	Document/Application	Reference
ECOM-RQ-IP-0080	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0081	ecoHMI	D3.2, D3.6
ECOM-RQ-IP-0082	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0083	ecoHMI	D3.2, D3.6
ECOM-RQ-IP-0084	All components	D2.2, D3.2, D3.3, D4.2, D5.2
ECOM-RQ-IP-0085	ecoHMI	D3.2, D3.6

Table 30 – Traceability: User Friendliness

6.1.2. Additional Requirements

6.1.2.1. Integration of eco traffic management centres

Requirement	Document/Application	Reference
ECOM-RQ-IP-0088	SP5 Components	D5.2
ECOM-RQ-IP-0089	SP5 Components	D5.2

Table 31 – Traceability: Integration of eco traffic management centres

6.1.3. Core technology requirements

6.1.3.1. Communication platform

Requirement	Document/Application	Reference
ECOM-RQ-SP2-0001	D2.2	Subsection 4.1.4.1
ECOM-RQ-SP2-0002	Communication Platform	D2.3
ECOM-RQ-SP2-0002	ecoMessages	D2.5
ECOM-RQ-SP2-0003	Communication Platform	D2.3
ECOM-RQ-SP2-0003	ecoMessages	D2.5
ECOM-RQ-SP2-0004	Communication Platform	D2.3
ECOM-RQ-SP2-0004	ecoMessages	D2.5
ECOM-RQ-SP2-0005	Communication Platform	D2.3
ECOM-RQ-SP2-0005	ecoMessages	D2.5
ECOM-RQ-SP2-0006	Communication Platform	D2.3
ECOM-RQ-SP2-0007	ecoMessages	D2.5
ECOM-RQ-SP2-0008	Communication Platform	D2.3

Table 32 – Traceability: Communication platform

6.1.3.2. Communication system

Requirement	Document/Application	Reference
ECOM-RQ-SP2-0009	Communication Platform	D2.3
ECOM-RQ-SP2-0010	Communication Platform	D2.3
ECOM-RQ-SP2-0011	Communication Platform	D2.3
ECOM-RQ-SP2-0012	Communication Platform	D2.3
ECOM-RQ-SP2-0013	Communication Platform	D2.3
ECOM-RQ-SP2-0014	Communication Platform	D2.3

Table 33 – Traceability: Communication system

6.1.3.3. ecoSituational model

Requirement	Document/Application	Reference
ECOM-RQ-SP2-0015	eSiM	D2.9
ECOM-RQ-SP2-0016	eSiM	D2.9
ECOM-RQ-SP2-0017	eSiM	D2.9
ECOM-RQ-SP2-0018	eSiM	D2.9
ECOM-RQ-SP2-0019	eSiM	D2.9

Table 34 – Traceability: ecoSituational model

6.1.3.4. ecoMessage

Requirement	Document/Application	Reference
ECOM-RQ-SP2-0020	ecoMessages	D2.5
ECOM-RQ-SP2-0021	ecoMessages	D2.5
ECOM-RQ-SP2-0022	ecoMessages	D2.5
ECOM-RQ-SP2-0023	ecoMessages	D2.5
ECOM-RQ-SP2-0024	ecoMessages	D2.5

Table 35 – Traceability: ecoMessage

6.1.3.5. *ecoMap*

Requirement	Document/Application	Reference
ECOM-RQ-SP2-0025	ecoMap	D2.6
ECOM-RQ-SP2-0026	ecoMap	D2.6
ECOM-RQ-SP2-0027	ecoMap	D2.6
ECOM-RQ-SP2-0028	ecoMap	D2.6
ECOM-RQ-SP2-0029	ecoMap	D2.6
ECOM-RQ-SP2-0030	ecoMap	D2.6
ECOM-RQ-SP2-0031	ecoMap	D2.6
ECOM-RQ-SP2-0032	ecoMap	D2.6
ECOM-RQ-SP2-0033	ecoMap	D2.6
ECOM-RQ-SP2-0034	ecoMap	D2.6
ECOM-RQ-SP2-0035	ecoMap	D2.6
ECOM-RQ-SP2-0037	ecoMap	D2.6
ECOM-RQ-SP2-0038	Positioning	D2.3

Table 36 – Traceability: ecoMap

6.1.4. Interface requirements

6.1.4.1. *SP3 – SPX interfaces*

Requirement	Document/Application	Reference
ECOM-RQ-SP3-0001	ecoTripPlanning	D3.2
ECOM-RQ-SP3-0001	TrafficStatePredictions	D5.2
ECOM-RQ-SP3-0011	ecoTripPlanning	D3.2
ECOM-RQ-SP3-0011	TrafficStatePredictions	D5.2
ECOM-RQ-SP3-0002	ecoNavigation	D3.2
ECOM-RQ-SP3-0002	ecoMap	D2.6
ECOM-RQ-SP3-0003	ecoNavigation	D3.2
ECOM-RQ-SP3-0003	ecoMap	D2.6
ECOM-RQ-SP3-0004	ecoNavigation	D3.2
ECOM-RQ-SP3-0004	ecoMap	D2.6
ECOM-RQ-SP3-0005	ecoNavigation	D3.2
ECOM-RQ-SP3-0005	ecoCooperativeHorizon	D3.2
ECOM-RQ-SP3-0006	ecoNavigation	D3.2
ECOM-RQ-SP3-0007	ecoMonitoring	D3.3
ECOM-RQ-SP3-0007	ecoMessages	D2.5
ECOM-RQ-SP3-0008	ecoMonitoring	D3.3
ECOM-RQ-SP3-0009	ecoMessages	D2.5
ECOM-RQ-SP3-0009	ecoGreenWave	D5.2

Table 37 – Traceability: SP3 – SPX interfaces

6.1.4.2. *SP4 – SPX interfaces*

Requirement	Document/Application	Reference
ECOM-RQ-SP4-0001	ecoTour Planning	D4.2
ECOM-RQ-SP4-0002	Truck ecoNavigation	D4.2

Requirement	Document/Application	Reference
ECOM-RQ-SP4-0003	ecoDriver Coach	D4.2

Table 38 – Traceability: SP4 – SPX interfaces

6.1.4.3. SP5 – SPX interfaces

Requirement	Document/Application	Reference
ECOM-RQ-SP5-0003	ecoMessages	D2.5
ECOM-RQ-SP5-0003	All SP5 applications	D5.2
ECOM-RQ-SP5-0004	ecoMessages	D2.5
ECOM-RQ-SP5-0004	All SP5 applications	D5.2

Table 39 – Traceability: SP5 – SPX interfaces

6.2. Document/Application to Requirement Traceability

This section provides traceability from documents, applications and components to the requirements specified in [D2.1].

6.2.1. Documentation

Document/Application	Reference	Requirement
D2.2	Subsection 4.1.4.1	ECOM-RQ-SP2-0001
D2.2	Subsection 4.2	ECOM-RQ-IP-0018
D2.2	Subsection 4.2	ECOM-RQ-IP-0020
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0001
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0002
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0003
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0004
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0005
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0006
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0007
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0008
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0009
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0010
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0011
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0014
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0016
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0017
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0090
D2.2, D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0091
D3.2, D3.3, D4.2, D5.2	-	ECOM-RQ-IP-0021

Table 40 – Traceability: Documentation

6.2.2. Applications/Components

6.2.2.1. All SP's

Document/Application	Reference	Requirement
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0027
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0029
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0030
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0031
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0032
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0034
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0035
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0036
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0037
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0041
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0042
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0043
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0046
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0047
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0048
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0049
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0050
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0051
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0052
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0053
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0054
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0057
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0058
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0059
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0060
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0061
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0062
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0063
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0064
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0065
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0066
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0067
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0068
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0069

Document/Application	Reference	Requirement
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0070
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0071
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0073
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0080
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0082
All components	D2.2, D3.2, D3.3, D4.2, D5.2	ECOM-RQ-IP-0084

Table 41 – Traceability: All SP's

6.2.2.2. SP2: Core Technologies

Document/Application	Reference	Requirement
All Core Technologies	D2.2	ECOM-RQ-IP-0038
ecoMessages	D2.5	ECOM-RQ-IP-0025
ecoMessages	D2.5	ECOM-RQ-SP2-0002
Communication Platform	D2.3	ECOM-RQ-IP-0022
Communication Platform	D2.3	ECOM-RQ-IP-0023
Communication Platform	D2.3	ECOM-RQ-IP-0024
Communication Platform	D2.3	ECOM-RQ-IP-0025
Communication Platform	D2.3	ECOM-RQ-IP-0026
Communication Platform	D2.3	ECOM-RQ-IP-0040
Communication Platform	D2.3	ECOM-RQ-IP-0074
Communication Platform	D2.3	ECOM-RQ-IP-0075
Communication Platform	D2.3	ECOM-RQ-IP-0077
Communication Platform	D2.3	ECOM-RQ-IP-0078
Communication Platform	D2.3	ECOM-RQ-SP2-0002
Communication Platform	D2.3	ECOM-RQ-SP2-0003
Communication Platform	D2.3	ECOM-RQ-SP2-0004
Communication Platform	D2.3	ECOM-RQ-SP2-0005
Communication Platform	D2.3	ECOM-RQ-SP2-0006
Communication Platform	D2.3	ECOM-RQ-SP2-0008
Communication Platform	D2.3	ECOM-RQ-SP2-0009
Communication Platform	D2.3	ECOM-RQ-SP2-0010
Communication Platform	D2.3	ECOM-RQ-SP2-0011
Communication Platform	D2.3	ECOM-RQ-SP2-0012
Communication Platform	D2.3	ECOM-RQ-SP2-0013
Communication Platform	D2.3	ECOM-RQ-SP2-0014
ecoMap	D2.6	ECOM-RQ-IP-0019
ecoMap	D2.2	ECOM-RQ-IP-0028

Document/Application	Reference	Requirement
ecoMap	D2.6	ECOM-RQ-SP2-0025
ecoMap	D2.6	ECOM-RQ-SP2-0026
ecoMap	D2.6	ECOM-RQ-SP2-0027
ecoMap	D2.6	ECOM-RQ-SP2-0028
ecoMap	D2.6	ECOM-RQ-SP2-0029
ecoMap	D2.6	ECOM-RQ-SP2-0030
ecoMap	D2.6	ECOM-RQ-SP2-0031
ecoMap	D2.6	ECOM-RQ-SP2-0032
ecoMap	D2.6	ECOM-RQ-SP2-0033
ecoMap	D2.6	ECOM-RQ-SP2-0034
ecoMap	D2.6	ECOM-RQ-SP2-0035
ecoMap	D2.6	ECOM-RQ-SP2-0037
ecoMap	D2.6	ECOM-RQ-SP3-0002
ecoMap	D2.6	ECOM-RQ-SP3-0003
ecoMap	D2.6	ECOM-RQ-SP3-0004
ecoMessages	D2.5	ECOM-RQ-SP2-0003
ecoMessages	D2.5	ECOM-RQ-SP2-0004
ecoMessages	D2.5	ECOM-RQ-SP2-0005
ecoMessages	D2.5	ECOM-RQ-SP2-0007
ecoMessages	D2.5	ECOM-RQ-SP2-0020
ecoMessages	D2.5	ECOM-RQ-SP2-0021
ecoMessages	D2.5	ECOM-RQ-SP2-0022
ecoMessages	D2.5	ECOM-RQ-SP2-0023
ecoMessages	D2.5	ECOM-RQ-SP2-0024
ecoMessages	D2.5	ECOM-RQ-SP3-0007
ecoMessages	D2.5	ECOM-RQ-SP3-0009
ecoMessages	D2.5	ECOM-RQ-SP5-0003
ecoMessages	D2.5	ECOM-RQ-SP5-0004
eSiM	D2.9	ECOM-RQ-SP2-0015
eSiM	D2.9	ECOM-RQ-SP2-0016
eSiM	D2.9	ECOM-RQ-SP2-0017
eSiM	D2.9	ECOM-RQ-SP2-0018
eSiM	D2.9	ECOM-RQ-SP2-0019
Positioning	D2.3	ECOM-RQ-SP2-0038

Table 42 – Traceability: SP2: Core Technologies

6.2.2.3. SP3: Vehicle Applications/Components

Document/Application	Reference	Requirement
ecoCooperative Horizon	D3.2	ECOM-RQ-IP-0038
ecoDrivingSupport	D3.2	ECOM-RQ-IP-0092
ecoHMI	D3.2, D3.6	ECOM-RQ-IP-0081
ecoHMI	D3.2, D3.6	ECOM-RQ-IP-0083
ecoHMI	D3.2, D3.6	ECOM-RQ-IP-0085
ecoCooperative Horizon	D3.2	ECOM-RQ-SP3-0005
ecoInformation	D3.2	ECOM-RQ-IP-0093
ecoMonitoring	D3.3	ECOM-RQ-SP3-0007
ecoMonitoring	D3.3	ECOM-RQ-SP3-0008
ecoNavigation	D3.2	ECOM-RQ-SP3-0002
ecoNavigation	D3.2	ECOM-RQ-SP3-0003
ecoNavigation	D3.2	ECOM-RQ-SP3-0004
ecoNavigation	D3.2	ECOM-RQ-SP3-0005
ecoNavigation	D3.2	ECOM-RQ-SP3-0006
ecoTripPlanning	D3.2	ECOM-RQ-SP3-0001
ecoTripPlanning	D3.2	ECOM-RQ-SP3-0011
In-Vehicle Data	D3.2, D3.3	ECOM-RQ-IP-0038

Table 43 – Traceability: SP3: Vehicle Applications/Components

6.2.2.4. SP4: Fleet Applications/Components

Document/Application	Reference	Requirement
All SP4 components	D4.2	ECOM-RQ-IP-0078
ecoDriver Coach	D4.2	ECOM-RQ-SP4-0003
ecoDriver Coaching System	D4.2	ECOM-RQ-IP-0092
ecoDriver Coaching System	D4.2	ECOM-RQ-IP-0093
ecoDriver Coaching System	D4.2	ECOM-RQ-IP-0094
ecoTour Planning	D4.2	ECOM-RQ-SP4-0001
Truck ecoNavigation	D4.2	ECOM-RQ-SP4-0002

Table 44 – Traceability: SP4: Fleet Applications/Components

6.2.2.5. SP5: Traffic Management Applications/Components

Document/Application	Reference	Requirement
All SP5 applications	D5.2	ECOM-RQ-SP5-0003
All SP5 applications	D5.2	ECOM-RQ-SP5-0004
All SP5 components	D5.2	ECOM-RQ-IP-0028
ecoABC, ecoMM, ecoATS	D5.2	ECOM-RQ-IP-0095

Document/Application	Reference	Requirement
ecoGreenWave	D5.2	ECOM-RQ-SP3-0009
SP5 Components	D5.2	ECOM-RQ-IP-0088
SP5 Components	D5.2	ECOM-RQ-IP-0089
TrafficStatePredictions	D5.2	ECOM-RQ-SP3-0001
TrafficStatePredictions	D5.2	ECOM-RQ-SP3-0011

Table 45 – Traceability: SP5: Traffic Management Applications/Components

6.2.3. Other Requirements

6.2.3.1. Redundant requirements

Document/Application	Reference	Requirement
Not applicable to eCoMove components: none fall under referenced requirements.	-	ECOM-RQ-IP-0055
Not applicable to eCoMove components: none fall under referenced requirements.	-	ECOM-RQ-IP-0056
OBSOLETE (duplicate requirement)	ECOM-RQ-IP-0038	ECOM-RQ-IP-0039

Table 46 – Traceability: Redundant requirements

7. Final Justification

The eCoMove architecture described in this document, supported by the Architecture described in the deliverables [D3.2], [D3.3], [D4.2] and [D5.2], has been produced according to the project work descriptions and standards referenced. As a result, architects have used the outcome of previous work packages as input and have specified eCoMove architecture. This architecture can be traced back to inefficiencies described in the Use Case & Requirement Work Package deliverables (collected in [D2.1]) and the eCoMove objectives described the Description of Work [DoW].

Provided that the architecture specified in the related deliverables at the end of Architecture work package activities is complete and sufficient for successful development and integration activities throughout the eCoMove project, this architecture is capable of achieving the eCoMove objective of reducing fuel consumption by 20% using Cooperative ITS technologies.

Appendix A – Reformatted Images

The following pages in this appendix provides images in reformatted versions to make them more readable.

When printing this document on paper:
As these images are referred to repeatedly in the document at the related sections, it is recommended to bind this Appendix as a separate document so these images can kept next to the texts while reading them.

A3 Size eCoMove Product Breakdown Structure (ePBS)

This image shows the eCoMove product breakdown structure on a single A3 page to show the delivery relations in a more readable format.

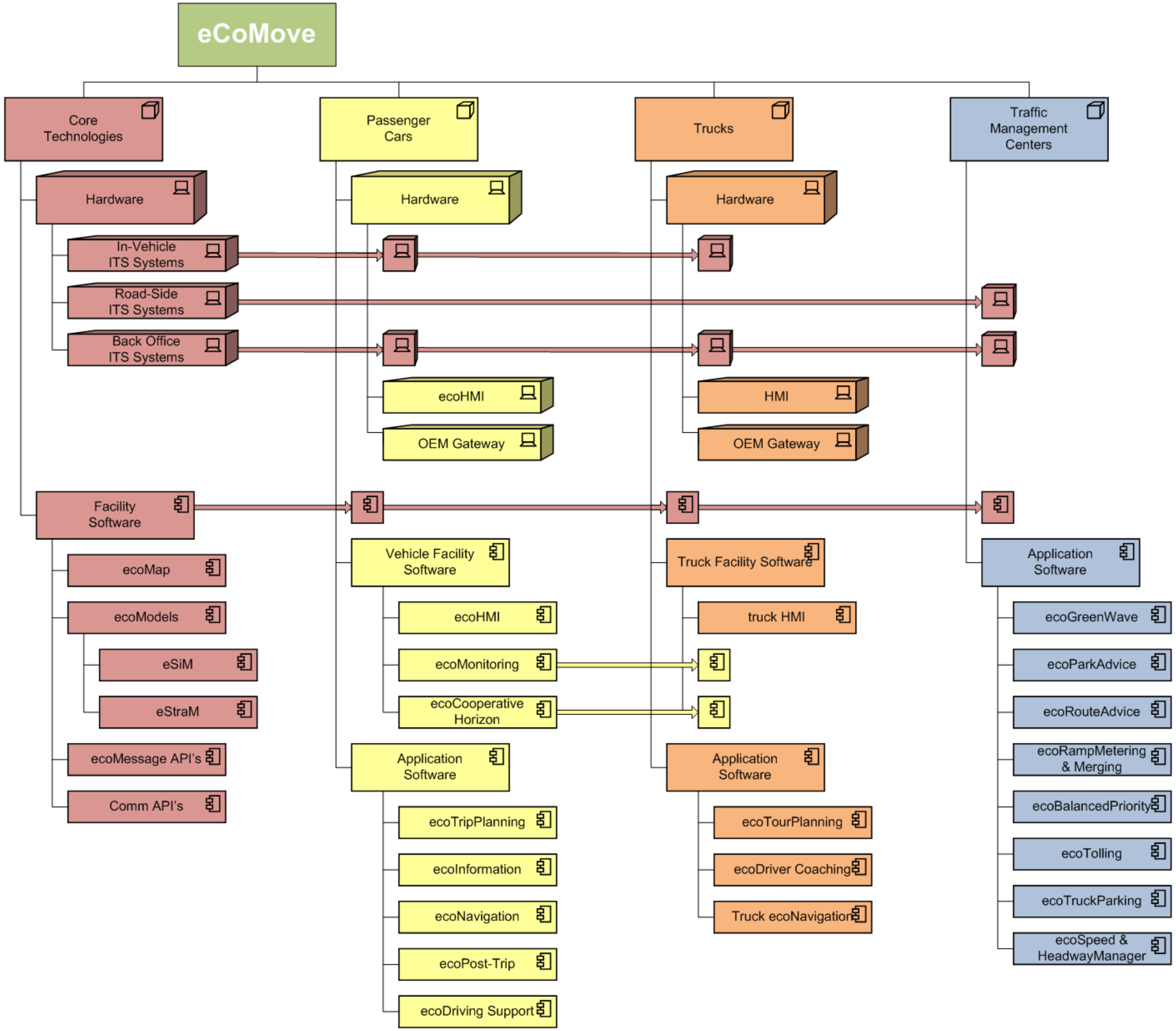

Figure 39 – A3 Size eCoMove PBS

A3 Size SP3 Technological Layer Overview

This image shows the eML SP3 Technological Layer Overview on a single A3 page.

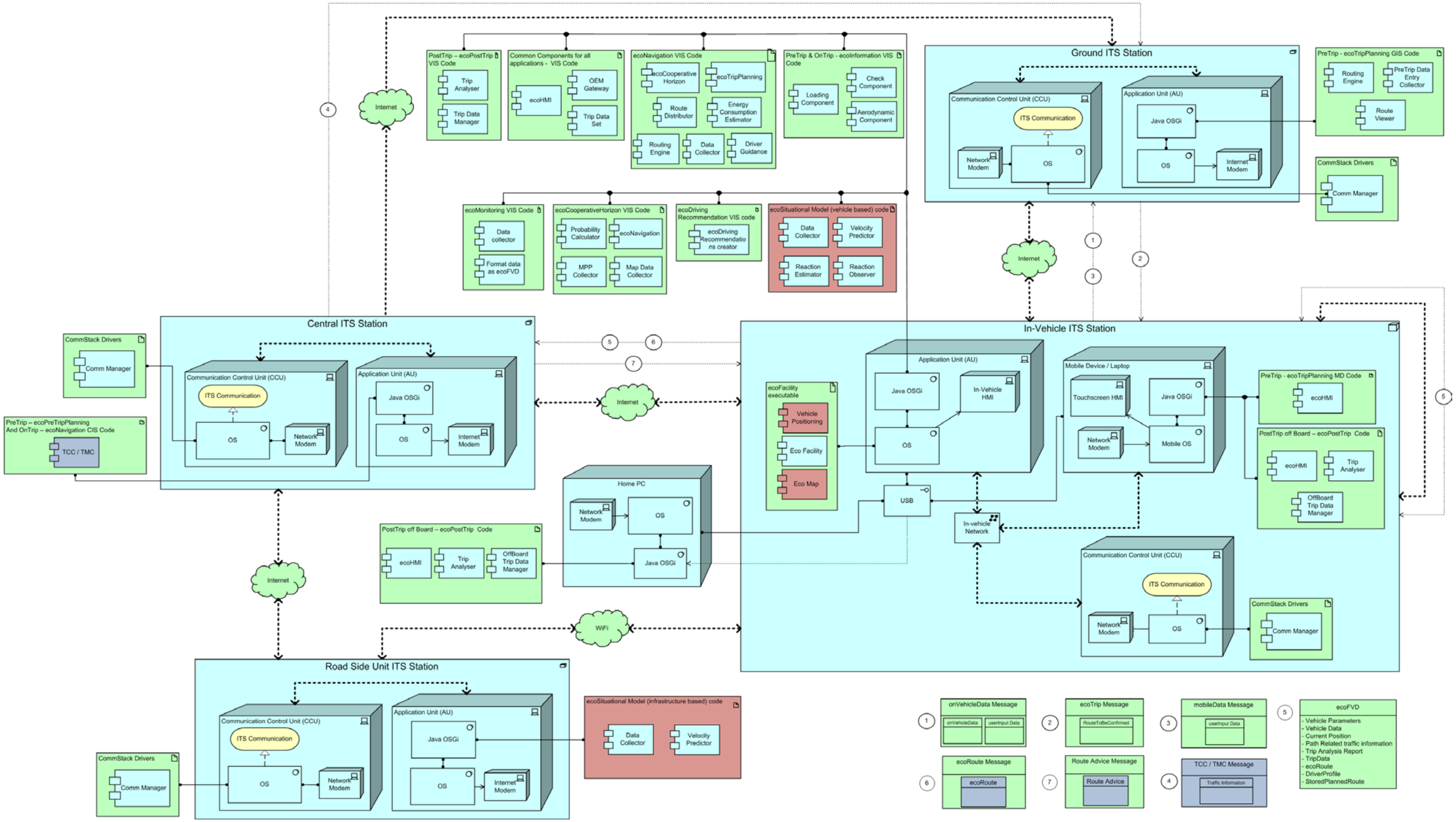

Figure 40 – A3 Size SP3 Technical Layer Overview

A3 Size SP4 Technological Layer Overview

This image shows the eCoMove the eML SP4 Technical Layer Overview on a single A3 page.

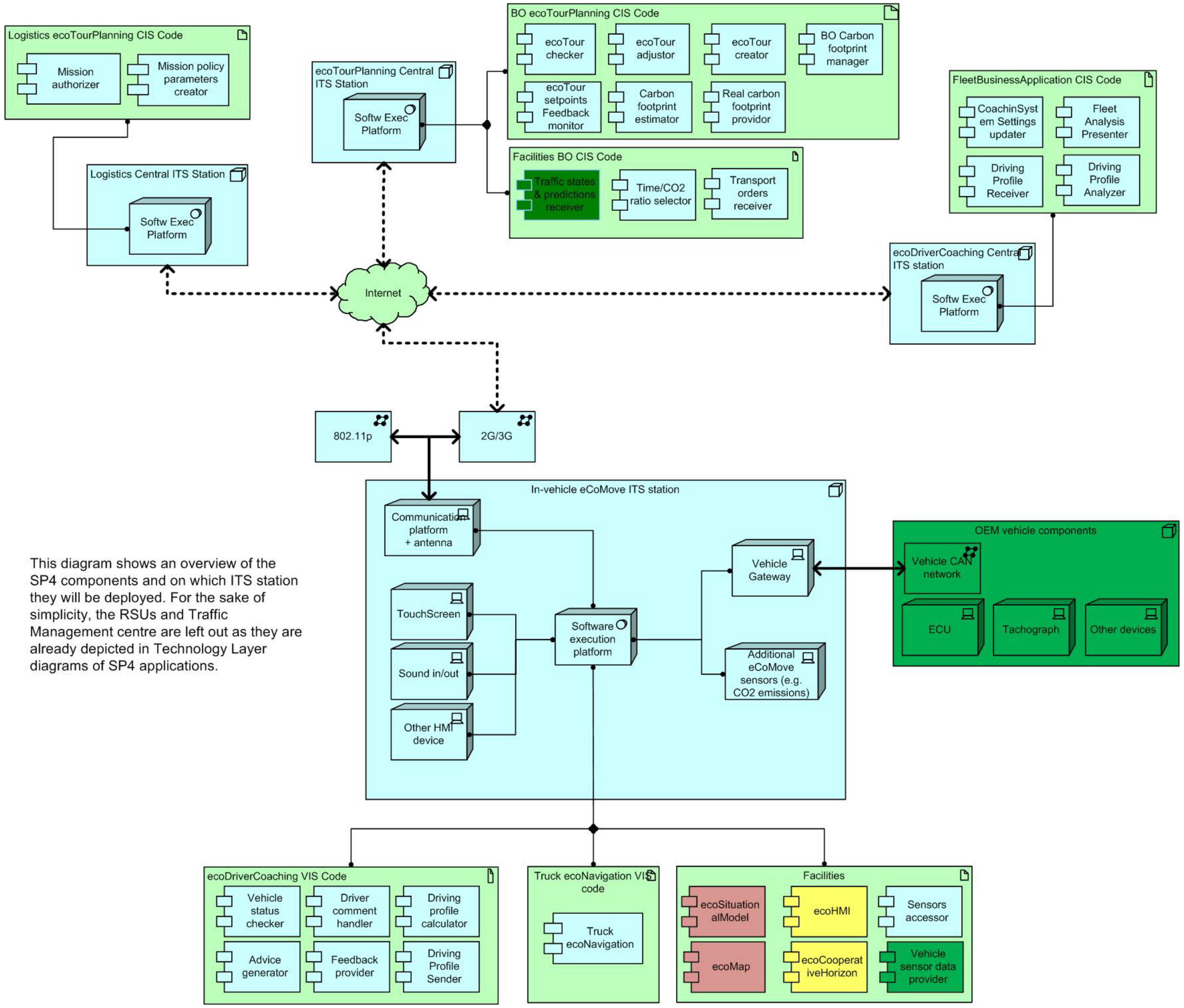

Figure 41 – A3 Size SP4 Technical Layer Overview

A3 Size In-Vehicle ITS Station Originated Data Flow Diagram

This image shows the In-Vehicle ITS Station Originated Data Flow Diagram on a single A3 page.

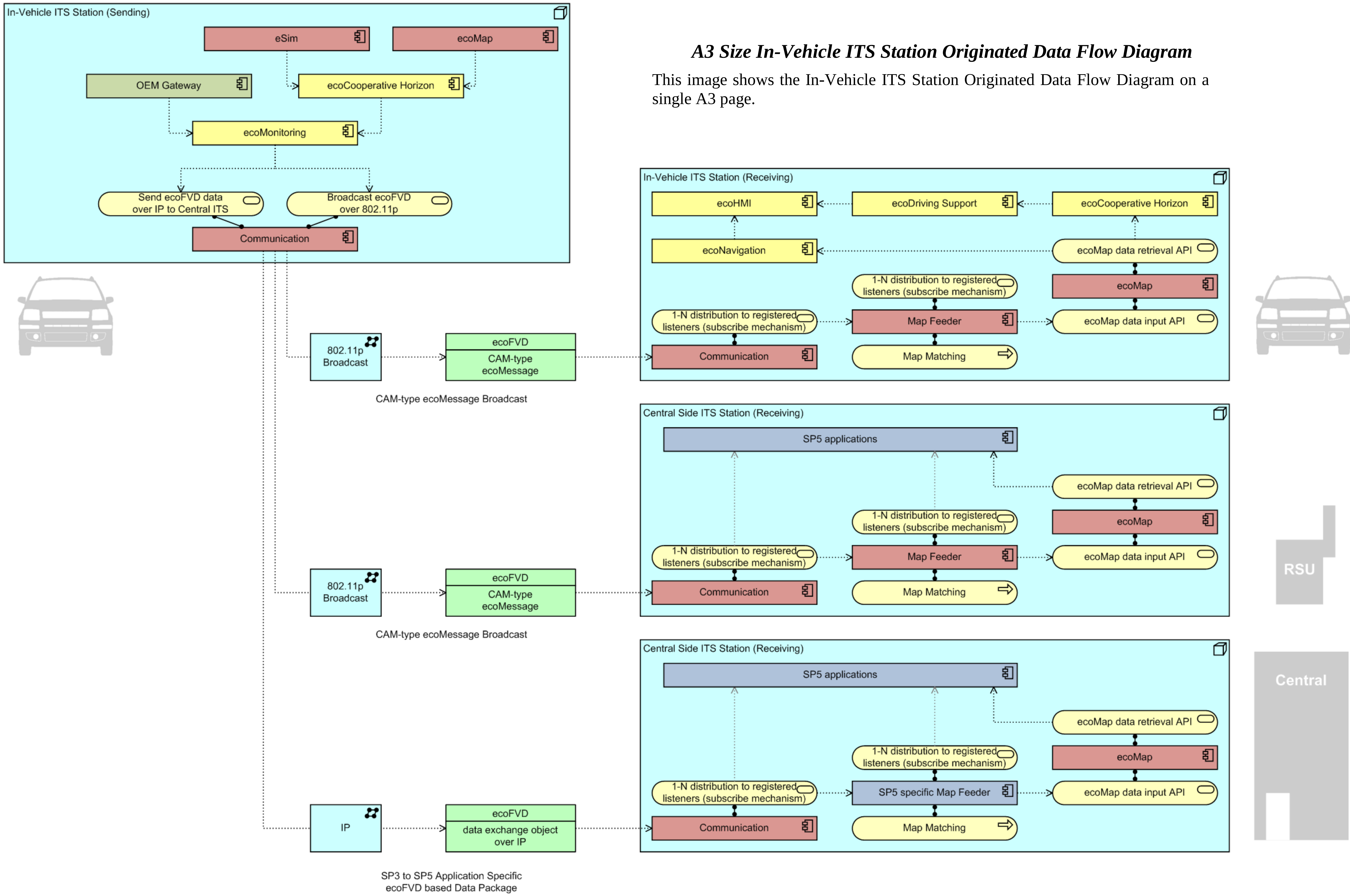

Figure 42 – A3 Size In-Vehicle ITS Station Originated Data Flow Diagram

A3 Size Road-Side ITS Station Originated Data Flow Diagram

This image shows the Road-Side ITS Station Originated Data Flow Diagram on a single A3 page.

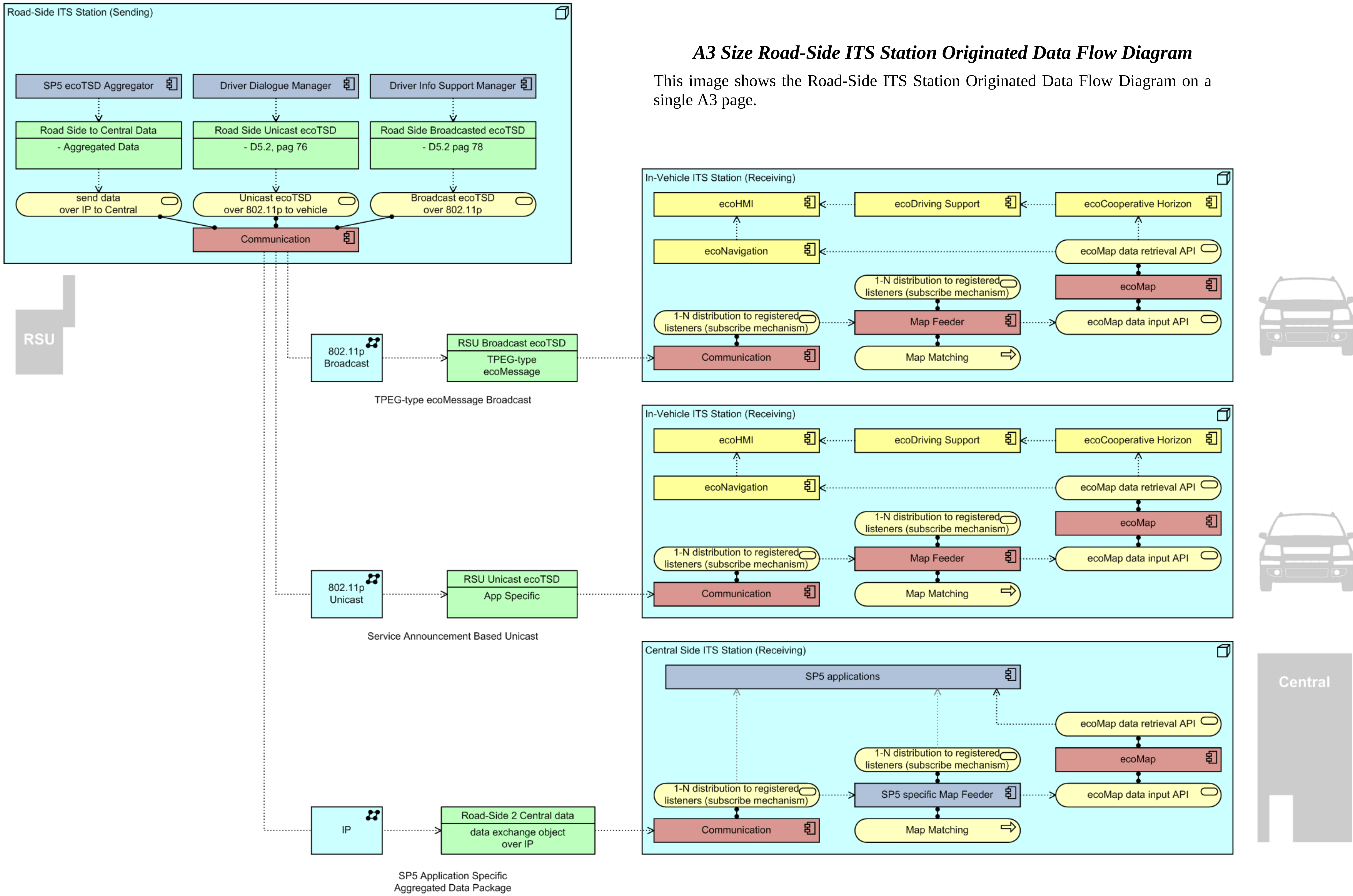

Figure 43 – A3 Size Road-Side ITS Station Originated Data Flow Diagram

A3 Size Central-Side ITS Station Originated Data Flow Diagram

This image shows the Central-Side ITS Station Originated Data Flow Diagram on a single A3 page.

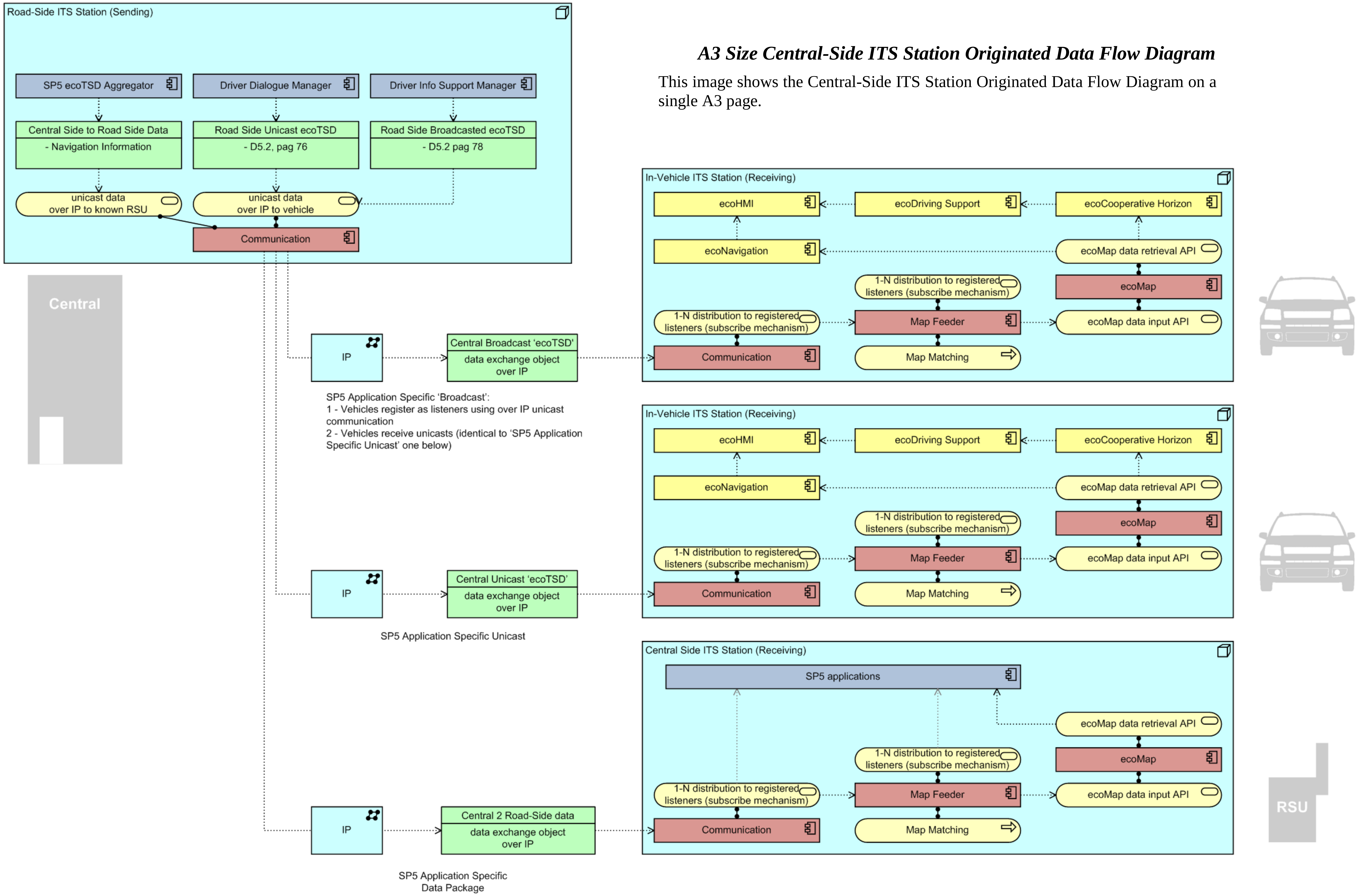

Figure 44 – A3 Size Central-Side ITS Station Originated Data Flow Diagram

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