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SEVENTH FRAMEWORK PROGRAMME

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Executive Summary

The functional architecture defined in this document describes on a general level the functional blocks that are required for the teams to be able to participate in the GCDC 2016. The architecture is explained by means of the main components: Communication, Scenarios and Vehicle architecture.

The Communication architecture follows EU standards on the Cooperative Intelligent Transportation System standard (C-ITS). C-ITS defines a layered communication architecture with detailed functional definitions for each layer. It introduces a general ITS-Station that can be configured to suit the needs of control centre, roadside and vehicle communication. Although vehicles, roadside and control centre are different in nature and have a different functionality, they share the same Communication architecture. As an example, an C-ITS prototype is explained in more detail.

For each of the three i-Game scenarios (Cooperation on highway, Cooperative intersection and Emergency vehicle) a state flow chart is presented that explains the required functionality in terms of required manoeuvring events and messages from the interaction protocol. The explained functionality provides a general guideline to facilitate the implementation by the teams.

Finally, a modularised vehicle functional architecture is presented. It describes the main function blocks including an application block where ITS applications are conducted to perform the scenarios, a negotiation block where vehicles interact and coordinate with each other, and a perception block where vehicles sense and interpret the surroundings based on different information sources. Drivers interact with the vehicles through the human machine interaction module and may initiate safety procedures through emergency input and abort the challenge.

The functional architecture presented in this document is abstracted and the aim is to support both the organizers and the teams in fulfilling the requirements for a safe and successful participation in the GCDC 2016. Detailed design and development of each of the functionalities included in this document will be performed in the deliverables from Work Packages 2 and 3.

Table of contents

1 Introduction

The i-GAME project

The objective of i-GAME is to develop technologies that speed-up the real-life implementation of automated driving, which is supported by communication between the vehicles and between vehicles and roadside equipment.

The main purpose of this document is to establish a nomenclature of the functionality of the competition vehicles to be developed by the competing teams and of the reference vehicle developed by the organizers. Thus, the purpose is also to provide a framework for the other work packages in order to form a common functional architecture to build around and to clarify what work package is responsible for the different parts within the functional architecture. The document also provides information on what the teams can expect from the organizers in terms of the functional architecture.

Background to functional architecture

The functional architecture is defined to support the participating teams in fulfilling the requirements of the scenarios to be performed in the Grand Cooperative Driving Challenge, GCDC 2016, being organized within the i-GAME project. The architecture defines the main types of ITS-Stations for the challenge, the communication architecture, the functionalities to enable the scenarios, as well as the prototyping methods for the ITS-Stations. The functional architecture is closely in line with the ETSI standards for the cooperative intelligent transport systems. The description of the architecture is generic without detailed specifications for implementation. Further details such as the interaction protocol, the communications message sets, and so on will be defined in future work packages.

This deliverable specifies generic functional architectures that support the GCDC challenge in 2016. The document provides a generic framework and serves as a general guideline for detailed implementation of future work packages. It is supposed to be read by the GCDC participating teams. Meanwhile, it gives readers working in the area of cooperative systems an overview of GCDC 2016.

Contents and structure of this document

This document consists of an executive summary and the description of the functional architecture of i-GAME, which include a system overview in Chapter 2, the communication architecture in Chapter 3, the scenario functionalities in Chapter 4 and the modularized in-vehicle platform in Chapter 5. Finally Chapter 6 concludes.

2 i-GAME System Overview

i-GAME is promoting the automated and cooperative driving in realistic scenarios. The system architecture is based on the ETSI cooperative intelligent transport systems (C-ITS) standards. C-ITS introduces ITS-Station (ITS-S) that is the core sub-system for enabling communications between vehicles, infrastructures, control entities, etc. Four types of ITS-S systems are defined in ETSI EN 302 665 as shown in Figure 1.

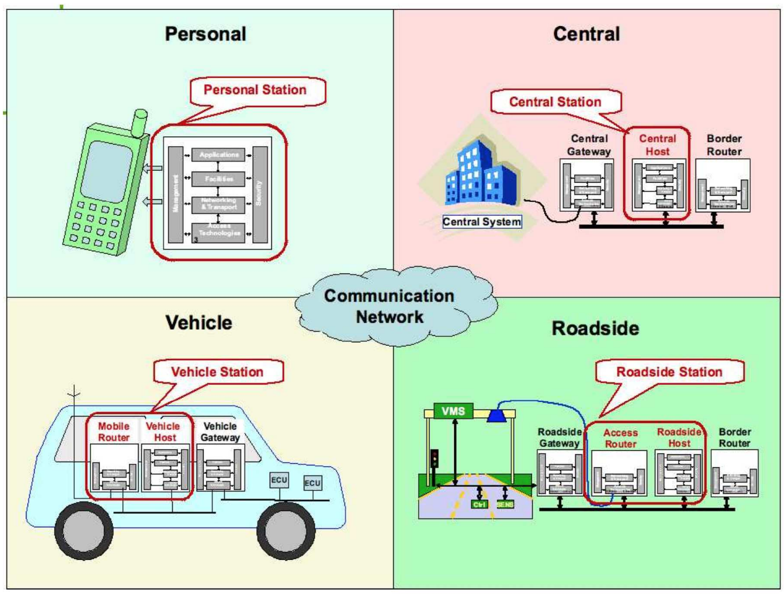

Figure 1: ETSI C-ITS components

- Vehicle ITS-S (V-ITS-S): The moving vehicles such as cars, trucks, busses, and so on.
- Roadside ITS-S (R-ITS-S): The geographically fixed units integrated within the road infrastructures.
- Central i-GAME ITS-S: The control centre of the ITS, hosted at traffic management organizations, such as road operators, transport authorities.
- Personal ITS-S: This is mostly for including road users such as pedestrian, cyclists, etc.

i-GAME consists of three major sub-systems including V-ITS-S, R-ITS-S and i-GAME Central ITS-S. The Personal ITS-S will not be included in i-GAME due to that the main goal is on accelerating the introduction of cooperative and automated driving. Involving vulnerable road uses would take focus from this goal and are therefore not considered here. The system is illustrated in Figure 2, together with their mapping to the i-GAME scenarios defined in D1.1.

V-ITS-Ss communicate with each other based on ITS-G5 to resolve the complicated operations within the scenarios. To align with the C-ITS standards, ITS-G5 is mandatory in GCDC 2016, while the use of other communication technologies will be allowed i-GAME places R-ITS-Ss along the site, e.g., cameras, that equipped with certain communication functionalities for communicating with V-ITS-Ss and the i-GAME Central ITS-S, such as broadcasting warning messages, recording the challenge, etc. Communications between V-ITS-Ss and R-ITS-Ss are based on ITS-G5. R-ITS-Ss may connect with each other through existing backbone networks. The i-GAME control centre is used for general control and supervision of the challenge, where it connects with the R-ITS-Ss through Ethernet. It is noticed that performing the i-GAME scenarios mostly relies on the locally V2V communications, therefore V-ITS-Ss implemented by the participating teams are fully functional ITS-Stations. R-ITS-Ss and Central i-GAME ITS-Ss deployment is not aiming at a fully functional deployment, but rather to deploy certain functionalities to support the challenge.

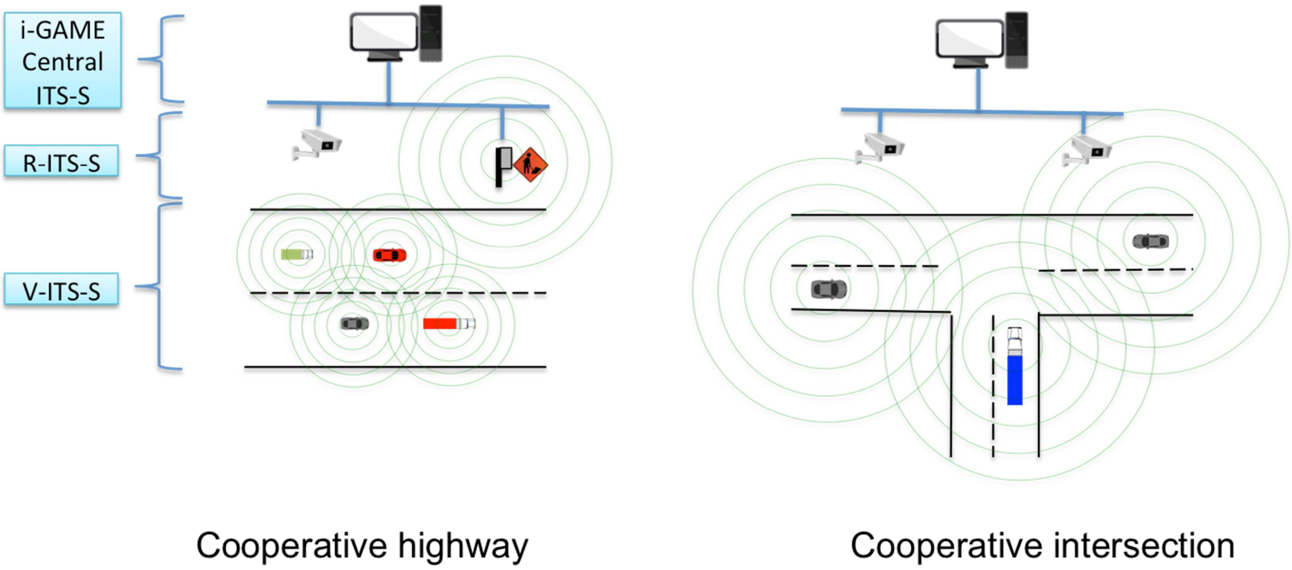

Figure 2: Illustration of i-GAME system architecture

3 The Communication Architecture

ETSI defines a layered communication architecture for C-ITS, which closely connects to the ISO OSI network model and is tailored for the ITS domain. To be multi-vendor interoperable, i-GAME aligns its design of the communication architecture to C-ITS. Meanwhile, as i-GAME scenarios are beyond the basic ITS applications defined by ETSI, i-GAME will extend related functionalities, such as the design of new facilities, to fulfil the requirements of the scenario and potentially contribute to the future ETSI standards. Figure 3 illustrates the layered communication architecture of the i-GAME ITS-Station in ETSI EN 302 665 and a general description is shown in the following subsections. It is assumed that each team implements their communication device, V-ITS-S, depending on its own preferences and capacities. And they will make sure their implementations are interoperable with other teams'. As can be seen, the security layer (block with dash line) is left out. The main reason for this is that the vehicles within the challenge are known beforehand and that the introduction of a security layer may increase complexity of the implementations.

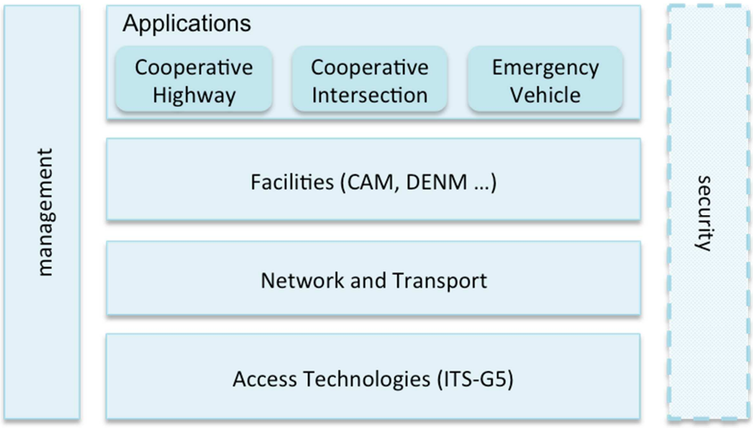

Figure 3: i-GAME communication architecture

3.1 Access technologies

i-GAME focuses on the traffic safety and efficiency in realistic environment where vehicles with or without communication are able to co-exist. Scenarios defined within i-GAME are to be performed through vehicle interaction and coordination, which require high priority and low latency communication. C-ITS defines physical layer access based on different technologies, however, from the safety point of view, communication based on ITS-G5 is the most proper choice. i-GAME will base V2V and V2I communications on the IEEE 802.11p based ITS-G5 standard specified in ETSI ES 202 663 and EN 302 663. The implementation will follow closely the definition in the C-ITS standard. Other communication technologies, such as the cellular communications, are optional.

3.2 Networking and Transport

C-ITS standard defines support to different protocols in this layer including GeoNetworking, CALM-FAST for communications in the ITS-domain, and TCP/UDP/IP protocols in the IP domain. Depending on the requirements, the i-GAME communication platform may support one or more of the protocols. The choice of protocols will be based on the current standard and will consider modifications to accommodate the future cooperative system. The detailed design of communication platform, as well as the choice of protocols for this layer will be done in (work package) WP3 and will be specified in D3.1.

3.3 Facilities

Facilities provide services and common functionalities to enable different ITS applications. The main components of the facilities are the cooperative awareness (CA) that generates the cooperative awareness message (CAM), and decentralized environmental notification (DEN) that generates decentralized environmental notification message (DENM). CAM is the heartbeat message which is sent out frequently with information of the vehicles' own status. The purpose is to notify the surroundings about vehicles' existence with certain vehicle information. DENM is an environmental triggered message, which is used to inform related vehicles of certain events, such as roadwork. i-GAME communication architecture will support both CAM (see ETSI EN 302 637-2 and TS 102 637-2) and DENM (see ETSI 302 637-3 and TS 102 637-3). A tailored communication message set will also be developed if necessary by extending the CAM and DENM to fulfil the functional requirement for performing the i-GAME scenarios.

For supporting an efficient environmental perception, C-ITS defines local dynamic maps (LDM) at the ITS-Station facilities layer. LDM builds a dynamic local map showing in detail the surrounding environment by information provided from the static map data, the vehicles' sensor system, as well as the information shared via V2X communications from surrounding vehicles and infrastructure. LDM provides a detailed temporary database for environmental perception and vehicle coordination. For the i-GAME challenge, static site information will be provided by the organizers, it is then the teams' own choice for the usage of LDM.

3.4 Applications

At the top level in the communication architecture are the applications. i-GAME focuses on the cooperative aspects and the close-to-reality applications, where two realistic scenarios are defined based separately on the urban and highway context. The urban scenario aims to improve the intersection efficiency through vehicle coordination. i-GAME defines Cooperative Intersection Passing for vehicles to communication and coordinate with each other to pass the intersection efficiently and comfortably. The highway scenario aims to improve the traffic efficiency through platoon operations. i-GAME defines a Cooperative Platoon Merge application, where vehicles from two platoons communicate and coordinate to pass a roadwork site safely and efficiently.

Besides the i-GAME defined applications, a subset of the applications defined in the basic set of applications in ETSI TR 102 638 from the C-ITS standards will also be included in the i-GAME architecture. In the urban scenarios for an efficient intersection passing, the Intersection Collision Warning is potentially to be included. In the highway scenario, basic applications such as Collision Warning, maybe included for the safety purpose. Roadwork is a very common scenario in realistic traffic. Therefore, i-GAME uses roadwork to trigger the platoon merge on highways. Under this context, the Roadwork Warning application defined in the C-ITS standards is included in the i-GAME architecture.

As a summary, the application and use cases that should be considered within the vehicles and the roadside units are:

- Driving assistance – Cooperative awareness
  - Emergency vehicle warning
  - Intersection collision warning
- Driving assistance – Road Hazard Warning
  - Roadwork warning
  - Collision risk warning
- Speed management
  - Regulatory/contextual speed limits notification

These applications are not required from the organization however, to be interoperable and for the safety of the challenge, it is required that vehicles have the abilities to interpret the messages received. An updated message set will be available for the emergency vehicle warning use case, which includes information about how the emergency vehicle wants the other vehicles to manoeuvre.

3.5 Management

The management layer defines interfaces between each of the communication layers, as well as the cross-layer control mechanisms. The horizontal communication layers only have interfaces to its neighbour layers, while management layer interacts with all other layers and manages all layer interfaces. Management layer functionalities are indispensable for data flow from upper layers to lower layers, and vice versa. It is also necessary for the management of resources such as dynamic allocation of radio resources. The teams are encouraged to refer to ETSI standards TS 102 723 and TS 102 890 series, as well as relevant ISO standards for detailed specifications of the layer interfaces.

3.6 ITS-S Prototyping

All communication components in the C-ITS system share the same architecture. The differences lie on the functionalities within each of the communication layers. This section describes a possible prototype.

In the case of vehicles, V-ITS-S is responsible for both in-vehicle networking and external communications. It uses in-vehicle communications (e.g. CAN, FlexRay) to collect vehicle data, percept the environment and support ITS applications. External communications, such as communicating with other ITS-Stations, communicating with network entities outside the ITS domain, are the basic functionalities for the ITS-Station. In the case of roadside unit, R-ITS-S is responsible for communicating with V-ITS-Ss, running ITS applications on the infrastructure side, as well as accessing to the Internet.

One potential prototyping of the ITS-S is shown in Figure 4, as suggested in ETSI C-ITS standards. In general, according to the C-ITS specification, an ITS-S has functionalities residing in entities such as hosts, routers, and gateways (GW).

- ITS-S host: The ITS-S host has the full communication architecture and hosts the ITS applications. In the context of i-GAME, applications to perform the scenarios of Cooperative Highway and Cooperative Intersection reside on the ITS-station host. The host accesses to the vehicle ad-hoc network through ITS-G5. Meanwhile, it accesses to internal system, the in-vehicle network in case of V-ITS-S and roadside network in case of R-ITS, for communicating with other modules or fetching related information.
- ITS-S router: ITS-S router has the functionalities to enable communications between different ITS protocol stacks. It is also responsible for converting the protocols if necessary, such as when different protocol stacks are used for networking and transport (such as between CALM-FAST and GeoNetworking), or when ITS-Station communicate with network entities outside the ITS domain.
- OEM Gateway: The ITS-S needs information from the vehicles' proprietary network or the roadside proprietary network. OEM modules are not open and might have firewalls for protection. OEM gateway provides the functionalities for accessing the OEM module to get necessary data to support the ITS applications.

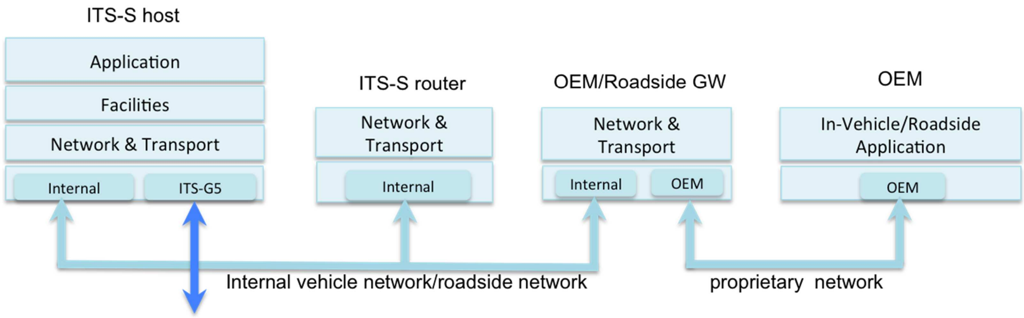

Figure 4: Illustration of possible vehicle V-ITS-S implementation

It is noticed that the above motioned prototyping scheme is for the illustration purpose. It is by no means the way a V-ITS-S or R-ITS-S should be implemented. For implementation, depending on the requirements, ITS-S router and gateway functionalities can be embedded within the ITS-S host. There might exist several ITS-S hosts where each of them hosts a different ITS application. The participant teams have full flexibilities for designing their own communication system, as long as the requirements specified in D1.2, D1.4 and the communication requirements from D3.1 are satisfied.

4 Scenario operational functionalities

To successfully perform i-GAME scenarios and the related applications, a number of functionalities need to be developed and integrated within the communication platform. The functional architecture provides a general guideline to facilitate the purpose of implementation. The details are described in the corresponding work packages and their deliverables. To clarify how the functions relate to the scenarios, state flow charts based on cooperative ITS applications are provided for each of the scenario, together with a general description of the functionalities involved. The i-GAME organization will provide an interaction protocol, enabling safe and reliable negotiation and coordination of vehicles during the challenge. The teams should implement the protocol and a supervisory controller capable of executing the manoeuvres described in the following section and in D1.1.

4.1 Cooperation on highway

This first scenario concerns cooperation on highway involving two platoons performing a two-lane merge to be able to pass a roadwork. Two platoons in different lanes on a highway receive broadcasted roadwork ahead warning messages from an R-ITS-S. Vehicles from the two platoons communicate and coordinate to form one single platoon to pass the roadwork site. It is expected that the merge should be performed with a minimum loss of speed, a maximum usage of road space and a maximum of safety and comfort to the passengers.

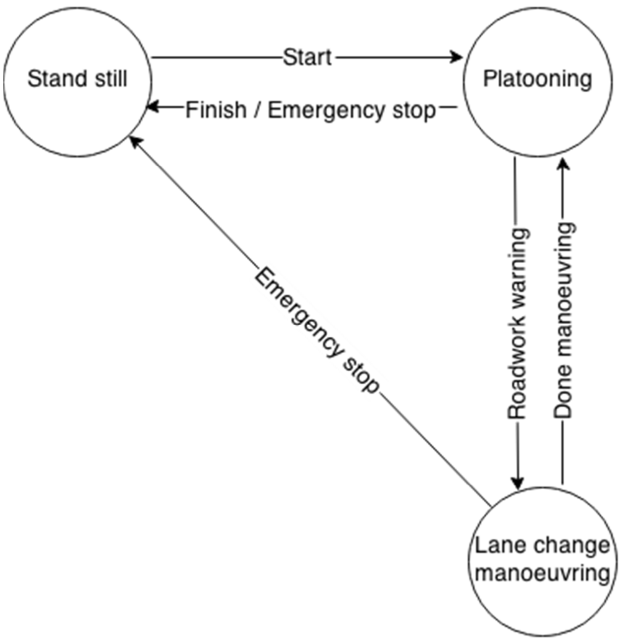

Figure 5: State flow chart of the Cooperation on highway scenario

Figure 5 illustrates the main states involved in this scenario and the operational flow. The arrows indicate messages sent from both the R-ITS-S (organizers) and the competing vehicles.

Platooning is the basic applications to be supported by the participating vehicles. Platoons are formed upon the start of the scenario and then kept until lane change is triggered. This scenario will involve basic platooning functions and related interactions between vehicles such as

- Platoon joining,
- Platoon lane keeping,
- Open gap
- Platoon leaving, etc.

Lane changing is triggered by roadwork warning message broadcasted from the R-ITS-S. Upon receiving the roadwork warning, V-ITS-Ss check the relevance of the warning and prepare to take actions accordingly. Vehicles in platoons on the roadwork lane will communicate and interact with vehicles on the other lane to coordinate lane change. A series of interactions will happen between the vehicles, e.g.,

- Vehicles from the platoon on the roadwork lane (left lane) will need to perform lane change and request to join the platoon on the other lane (right lane).
- Vehicles from the platoon on the right lane will need to assess the relevance and decide if agree to open gaps for lane change.
- If platoon merge is agreed, vehicles on the right lane open gaps for vehicles from the left lane to join.
- If platoon merge is refused, vehicles on the right lane acknowledge the requesting vehicle with indicating the potential danger or other reasons.
- Lane change is done mutually with continuous communication, interaction, and coordination between the involving vehicles.

4.2 Cooperative intersection

The cooperative intersection scenario involves vehicles that are approaching a busy main road with no traffic control infrastructure. One vehicle intends to make a left turn onto the main road and cooperates with approaching vehicles from both directions on the main road to allow a safe and comfortable passage through the intersection. The scenario targets complicated intersection and involves a major ITS application, namely the Cooperative Intersection Passing, which requires intensive communication and interaction between the involving vehicles. State flow is shown in Figure 6, followed by descriptions of the involving functionalities.

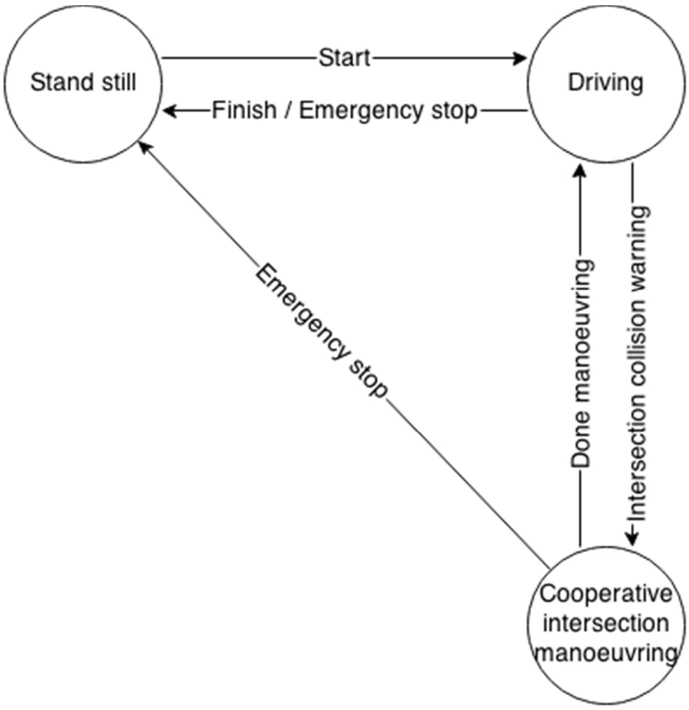

Figure 6: State flow chart of the Cooperative intersection scenario

Upon entering the competing zone, vehicles start exchanging information. The vehicles need to assess the intersection and interact with each other to reach a mutual decision for passing the intersection safely and comfortably. R-ITS-Ss exist at the intersection for assistance, such as broadcasting intersection maps, regulatory instructions. R-ITS-Ss may also coordinate the traffic if necessary. Major interaction and coordination procedures are

- Vehicles exchange information about their driving dynamics and intentions
- Vehicles assess the situation, interact with each other to mutually decide the passing sequence and speed
- Vehicles may perform ITS applications such as intersection collision warning
- Vehicles adjust speed according to the decision and pass the intersection

4.3 Emergency vehicle (demonstrator)

This scenario concerns an emergency vehicle that is approaching a condensed traffic situation from behind. It communicates the intention to pass the vehicles and in which position on the road it prefers to have a free passage. The vehicles collaborate and change lanes to allow free passage for the emergency vehicle, while keeping driving throughout the process. The state flow of the scenario is shown in Figure 7 and major functions and interactions are described as follows.

- An emergency vehicle is driving on a two-lane road approaching two occupied lanes ahead
- The emergency vehicle triggers the event and broadcasts its vehicle type and driving intensions
- The vehicles give way cooperatively and safely according to the emergency vehicle's intention without stopping
- The emergency vehicle passes freely
- The emergency vehicle cancels the warning for the vehicles it has past
- The vehicles in the two lanes return to their initial driving status

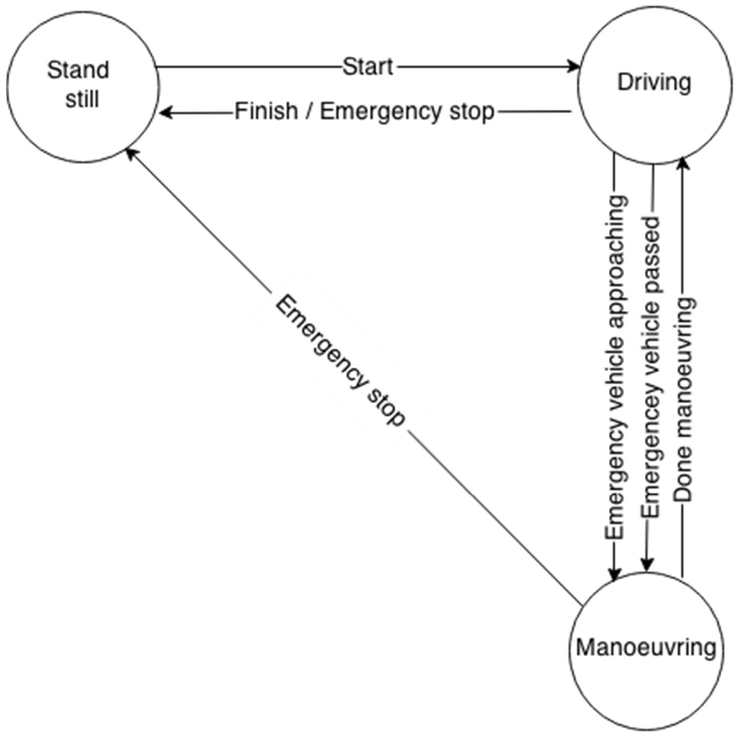

Figure 7: State flow chart of the emergency vehicle scenario

4.4 Functional blocks

To successfully perform the scenarios defined in D1.1, V-ITS-S and R-ITS-S need to support a number of functionalities. Based on the discussion in the previous chapter, an overview of the functionalities is illustrated in Figure 8.

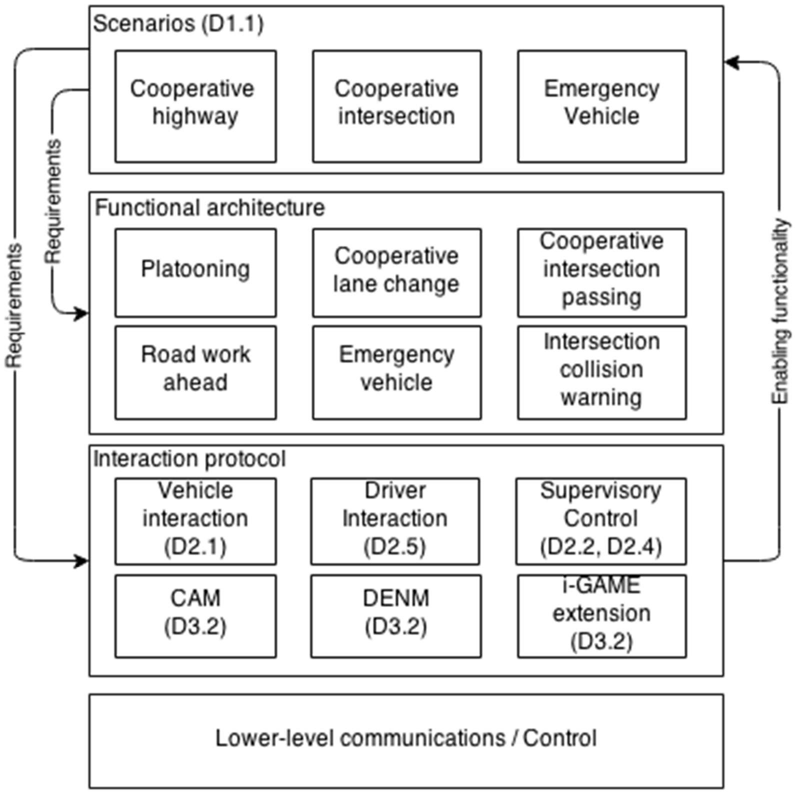

Figure 8: i-GAME functional blocks

Based on the scenarios (top in Figure 8), a number of ITS applications need to be performed. Major functionalities involved in i-GAME include platooning, cooperative lane change, intersection collision warning, etc., as shown in the functional architecture block in Figure 8. To support those functionalities, communication and interaction among vehicles are needed. Vehicle interaction serves as the upper layer of supervisory control and is indispensable for vehicle coordination. The interaction logic and the related protocol will be developed in WP2 and specified in D2.1, where consideration of the traffic rules and the safety boundary conditions will be included. Real time mixed criticality control mechanisms will be designed and specified in D2.2 and D2.4. One challenge is the safe and smooth transition of manual and automated driving during the challenge. Interaction protocols for this purpose will be developed and specified in D2.5.

In summary, in a top-down manner, specific requirements are set over functionalities and interaction protocol based on the scenarios. While in a bottom-up view, interaction protocol enables coordination among vehicles, leading to the realization of the i-GAME scenarios.

All the interactions are supported by the lower-level communication platform, which will be defined in D3.1 Wireless communication basic communication document. CAM and DENM message sets for i-GAME are derived from the C-ITS standards with modifications to accommodate the i-GAME scenarios. Potential extensions of the C-ITS message sets or new message sets for the purpose of interaction and coordination will be developed and defined for supporting the i-GAME scenarios. Detailed message development will be specified in D3.2.

4.5 Safety

Safety is of utmost importance to perform a successful i-GAME challenge. The design of the interaction protocol and the supervisory control consider the safety as an integrated part. Vehicle interactions will ensure that safety is guaranteed throughout the challenge. Driver interaction will ensure that the transition from automated driving and manual driving is absolute safe. In addition, emergency procedure will be performed to abort the challenge through any of the following methods.

- Organizers abort the challenge by contacting drivers in the vehicles in case of potential danger are detected, so that all vehicles switch to manual driving immediately, thus aborting the challenge
- CAMs have information indicating the driving mode (manually or automatic driving). Vehicles will check the information and switch to manually driving if any vehicle is found driving manually, thus aborting the challenge.

5 The Vehicle Functional Architecture

i-GAME focuses on the vehicle coordination for resolving realistic traffic scenarios. Minimum required functionalities including perception, supervisory control and the support for the i-GAME applications should be implemented for entering the challenge. As for the detailed deployment, the participating teams have full flexibilities to implement the related functionalities, as long as the requirement specified D1.2 and D1.4 could be achieved. A general i-GAME vehicle architecture is shown in Figure 9 and described as follows.

- Perception: Perception is done based on the information collected from on-board devices such as GPS, sensors, cameras, radars and other types of information collection methods. V2X communications provide more detailed information about the surrounding vehicles beyond the capabilities of conventional sensors. The collected information is used for the perception functionalities to judge the environment and provide support for other functionalities, such as the construction of LDM and the support for supervisory control.

- Supervisory control: Supervisory control will involve interacting and negotiating with the ITS applications, the other vehicles through V2V, as well as the lower control modules for achieving physical maneuverers. Supervisory control is the key component that enables the vehicle coordination, which is indispensable for the vehicles to participate i-GAME challenge. The negotiation and supervisory control will be further developed in WP2 and the deliverable D2.2.

  In the current standards for C-ITS, V2X communications are for the purpose of notifying the vehicles' existence. The CAM and DENM are broadcasted messages where no acknowledgements from other vehicles are needed. i-GAME goes beyond the current standards and will develop new facilities (such as new message sets) for enabling two-way communications, e.g., dialog, among vehicles. Vehicles should be able to "talk" and interact with each other and make mutual solutions for resolving the traffic scenario safely and efficiently based on their own perception and the exchanged information. Supervisory control takes controlling setting from the ITS applications, combining with the coordination results from vehicle interaction and then coordinating the setting and interacting with lower level controllers. The whole process is a communication rich dynamic process. To be more specific, for the scenario of cooperative highway, the vehicles on the left and right lane should be able to coordinate when and where the merge should start. In the scenario of cooperative intersection, the involving vehicles should be able to communicate and coordinate and mutually decide the order and the speeds for passing the intersection.

- Applications: Application will include necessary ITS applications for performing the i-GAME scenarios, e.g., cooperative platoon merge, roadwork warning, cooperative intersection passing, etc. Applications are closely related to the supervisory control. Based on the vehicles driving intention, the perception of the environment, and the interaction from the supervisory control, applications set detailed requirements such as controller settings for achieving a certain maneuverer. This will then feed back to the supervisory control, then to the vehicles' lower control module to realize the expected manoeuvres.

- Low-level Control: The control module takes commands either from the vehicles' automatic system, e.g., from supervisory control, or from the driver in case of emergency. It is the physical module for performing vehicle manoeuvres such as longitudinal and lateral operations.

- Driver: The driver is for the purpose of supervision. He or she will supervise the whole challenge process and take actions in case of emergency.

- Human Machine Interface (HMI): HMI interacts with the vehicle and driver and provides necessary information for supervision.

- Emergency Input: Emergency input defines the methods that will abort the challenge in case of danger or unexpected situations. This may be a command from the organization, the switching to manual driving by any of the vehicles, and so on. The detailed method will be specified in the requirements D1.4.

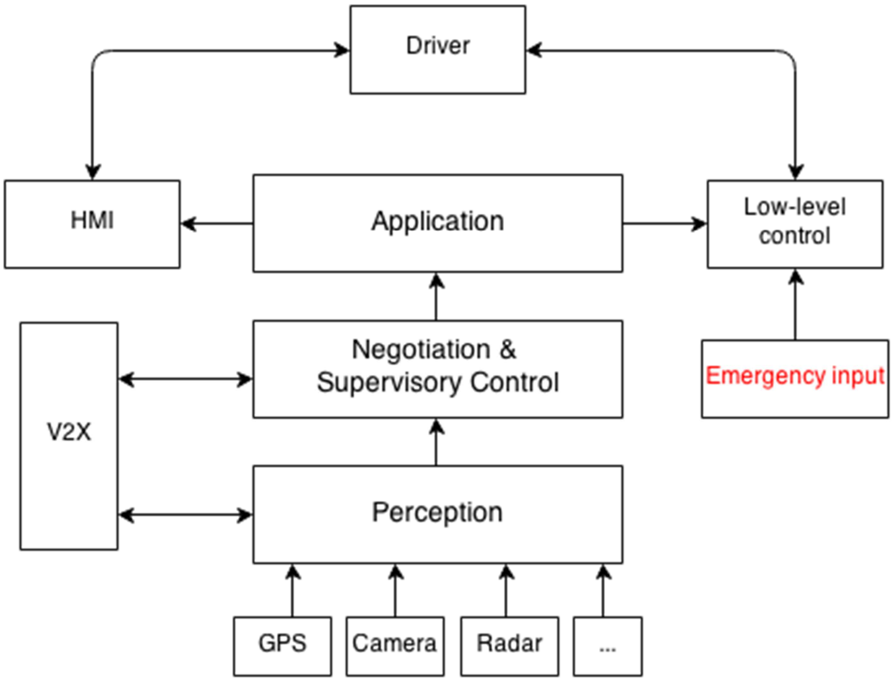

Figure 9: i-GAME In-vehicle functional architecture

6 Conclusion

The functional architecture defined in this document describes on a general level the functional blocks that are required for the teams to be able to participate in the GCDC 2016. The functional architecture presented in this document is abstracted and the aim is to support both the organizers and the teams in fulfilling the requirements for a safe and successful participation in the GCDC 2016. Detailed design and development of each of the functionalities included in this document will be performed in the deliverables from Work Packages 2 and 3.

7 List of abbreviations and terminology

WP	Work Package
ETSI	European Telecommunication Standards Institute
ISO	International Organization for Standardization
LEV 1	Automation level 1 defined in SAE J3016, full longitudinal automation
LEV 2	Automation level 2 defined in SAE J3016, full longitudinal and lateral automation
FV	First vehicles in a platoon
DRMS	Distance Root Mean Square
V2V	Vehicle-to-vehicle communications
V2I	Vehicle-to-infrastructure
V2X	Vehicle-to-vehicle and vehicle-to-infrastructure
OSI	Open system interconnection
C-ITS	Cooperative Intelligent Transportation Systems
ITS-Station/ITS-S	A set of functions and devices included in vehicles, infrastructures, control centres and mobile (pedestrians, cyclist, etc.) that enable V2X communications.
V-ITS-S	Vehicle ITS-Station
R-ITS-S	Roadside ITS-Station
ITS-G5	Communications standard specified by EU for vehicle-to-vehicle communications
CAM	Cooperative Awareness Message
DENM	Decentralized Environment Notification Message
LDM	Local Dynamic Map

8 List of Figures