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Executive Summary

The wireless communication basic specification document describes on a general level the communication specifications that are required for the teams to be able to participate in the Grand Cooperative Driving Challenge (GCDC) organised in 2016. The focus is on the lower communication layers: Access, Networking and Transport.

The communication architecture follows EU standards on 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.

The i-GAME communication architecture includes ITS-Stations for the vehicles that are the major players within the GCDC 2016. The focus for the teams is on interoperable Vehicle-to-Vehicle and Vehicle-to-Infrastructure (V2V and V2I, collectively called V2X) communications to successfully participate in the challenge. While at the same time, functionalities are deployed at the roadside ITS-Stations and at the i-GAME control centre that are used to support the challenge. All ITS-Stations share the same architecture, while having different roles within the GCDC 2016.

For each of the scenarios, the required functionalities are presented in order to perform the challenge. The interactions needed for the manoeuvring are defined in the interaction protocols. The messages needed for the V2X communication, are defined in extensions of current ETSI CAM and DENM message sets. Also a new interaction message set is defined in order to fully support the i-GAME scenarios. The details on the i-GAME scenarios, interaction protocols and i-GAME specific messages sets are documented in separate deliverables and are referenced to in this document.

The ITS-Station specifications, from the C-ITS standard are presented in Chapter 3. This describes an ITS-Station host that includes the ITS application, ITS-Station router for communication between different ITS protocols as well as OEM gateway that allows the ITS-Station to access the in-vehicle proprietary network.

The basic communication specifications presented in this document aims 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 as included in this document will also be used in other work package tasks and documented in their deliverables.

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, supported by communication between the vehicles. This objective is realized by enabling reliable interoperable communication in a multi-vendor, multi-network, multi-service environment all within the context of a Grand Cooperative Driving Challenge (GCDC). The GCDC consist of different scenarios (highway and urban), in which the participating teams and their vehicle implementation are judged in a competitive setting.

Background to Wireless communications basic specifications document
This wireless communication basic specification document will function as a guideline for the participating teams as they develop and equip their competition vehicles. The purpose of the document is to help the teams in creating cooperative automated vehicles using interoperable wireless communications. The level of details in the requirements can assist the teams with implementing interoperable cooperative communications between vehicles. The interoperable wireless Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) (collectively referred to as V2X) communications is based on ETSI C-ITS standards. The basic available message sets are extended with a new message especially developed by the i-GAME project team, to support and comply to the interactions in the GCDC scenarios.

The teams can equip their vehicles with communication equipment that they buy themselves or, for example, get through sponsorship agreements from vendors/partners. As long as the equipment support the required standards described in these documents and can also support some additional and special requirements (like the non-standard, i-GAME specific message sets), the teams are expected to successfully participate in the GCDC2016, from a communication point of view.

The next chapter focuses on the general i-GAME communication requirements. Chapter 3 defines the communication architecture that is used for the GCDC2016 by outlining the ITS reference architecture, the communication platform components and specific parameter settings. Chapter 4 is dedicated to the specific communication requirements complete with the references to the related documents. Finally Appendix A concludes the document with a list of equipment that can fulfil the teams' communication needs.

2 I-GAME communication requirements

i-GAME is building knowledge on cooperative and automated driving in order to speed up implementation of such systems in real life traffic. Thus, one of the most important parts of i-GAME and the GCDC is V2X communication. This can be V2V communication or V2I communications. The illustration below is an example of some of the most common components within Intelligent Transport Systems (ITS).

Figure 1: Overview of ITS systems

In order to accelerate the realistic deployment of cooperative system and multi-vendor interoperability, V2X communication aligns with the ETSI C-ITS standard (Cooperative-Intelligent Transport Systems). C-ITS focus on communications both between vehicles, and between vehicle and the deployed infrastructure, e.g. Road Side Units (RSUs).

2.1 Cooperative ITS (C-ITS)

Detailed specifications for C-ITS communications standards are defined in the ETSI TR 101 607 (a) report. This technical report identifies the documents that form Release 1 of C-ITS standards. The C-ITS standards are divided in:

General standards: defining basic requirements and procedures

Application requirements: Standards developed for V2V and V2I message sets and applications covering both safety and traffic efficiency applications as well as Value Added Services and other comfort applications.

Facilities:

Facilities provide services and common functionalities to enable different ITS applications and include the general message set standards. The ITS applications are primarily supported by the V2V and V2I communications. Additional testing standards for this layer are also available.

Network and Transport:

Standards for the network and transport layer related to protocols such as the basic transport protocols (BTP) and GeoNetworking (GN). Also additional testing standards for this layer are available.

Access and Media:

Standards developed for the access and media layer are based on 5.9 GHz spectrum usage, multichannel operation and Decentralized Congestion Control (DCC). This layer also has additional testing standards included.

Management:

Standards developed for management and cross layer issues.

Security:

Standards for implementing security and privacy, also with additional testing standards.

For i-GAME the sets of importance are: the general basic requirements; GeoNetworking and Basic Tranport Protocol (needed for V2X communications); facility layer standards with the general message sets specifications; and specific i-GAME extensions to facility layer message sets. See Chapter 3 for detailed information on the C-ITS reference architecture.

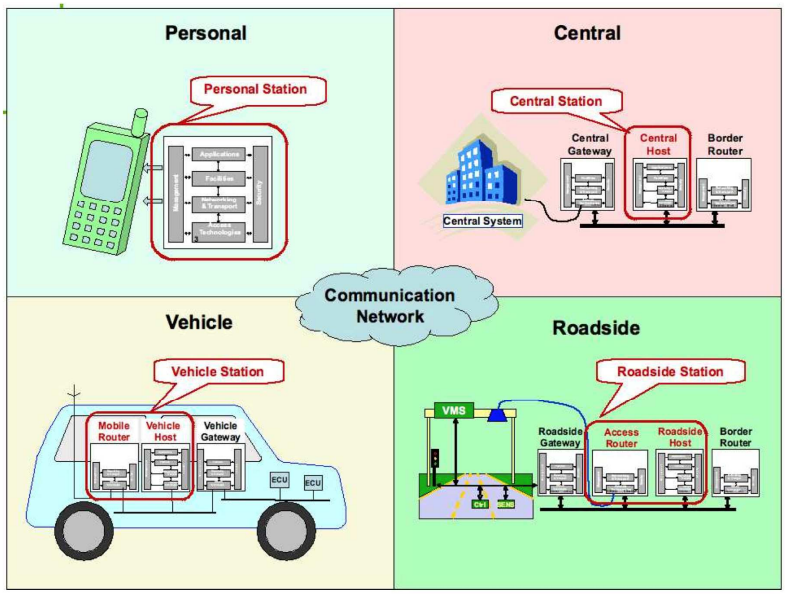

Figure 2: ETSI C-ITS station types

As mentioned in the i-GAME D1.3 Functional Architecture document [1] the relevant C-ITS stations (b) are

- Vehicle ITS-S: The moving vehicles such as cars, trucks, busses, and so on. Sometimes referred to as onboard units (OBUs)
- Roadside ITS-S: The geographically fixed or stationary units integrated within the road infrastructures. Also known as RSUs

- Central ITS-S: The control centre of the ITS, mostly back office environments from traffic management organizations, such as road operators, transport authorities.
- Personal ITS-S: This is mostly for including road users such as pedestrian, cyclists, etc.

The Personal ITS-S is out of scope within i-GAME. The main goal is on accelerating the introduction of cooperative and automated driving, the scenarios in i-GAME do not involve vulnerable road users. The usage of ITS stations depends on the i-GAME scenarios as described in the i-GAME D1.3 Specification of scenarios document [2]. For a successful participation, starting point for the teams is successful implementation of the V2V communication. Additional Roadside ITS-S or Central ITS-S are not a primarily part for the teams executing the scenario, but these are needed for GCDC management (start/stop a scenario), judging and/or logging functions. For instance, a Road Works Warning message will be used to trigger the merging process in the Highway scenario. The specific communication requirements for the different scenarios are available in Section 4.1.

2.2 General communication requirements

i-GAME D1.2 Draft report on requirements specification [3] already formulated some basic general communication requirements as listed below:

- All vehicles shall support ITS-G5 standard and the frequency specification accordingly
- All vehicles' transmitter power profile shall follow the C-ITS standard and related EU regulations
- All vehicles must ensure a proper communication (both sending and receiving messages) range of at least 200 meters in all directions through a proper setting of antenna height and transmission power (this with the absence of obstacles for the radio waves)
- Latency of the received valid estimate/measured values <= 200 ms[1]
- Time synchronization to GPS time <= 10 ms
- All vehicles shall ensure a maximum communication delay of 100 ms[2]. The actual end-to-end delay at the Access and Media layer is much smaller (typical around 5 ms)
- All vehicles shall ensure a certain periodic message frequency (typically >= 10 Hz)
- Information included in the communicated messages (GPS coordinates, velocity, etc.) shall match that provided by the vehicle sensors

The communication platform for enabling an interoperable cooperative driving environment will be specified in later sections. But the starting point is interoperability, meaning that the project doesn't regulate any specific communication unit. The aim will be, to have preferable multiple types of communication platforms working together as long as the correct versions of the C-ITS standards are being used.

Communication performance is very depending on the environmental conditions and certain requirements may not be fulfilled during the challenge. It is therefore important , to test the communication performance on forehand in the pre-contest verification. The complete communication process will be logged in detail during the execution of the scenario's for further analysis and evaluation. i-GAME (at this time) does not require implementation of communication security and the shared data will solely be used for research- and judging purposes.

[1] This is the latency between sensor reading and reception of it on application control level by another vehicle

[2] This is the delay from reception to processing it at the actual vehicile control action level

3 Communication architecture

The basic communication architecture and functional blocks are defined in the i-GAME D1.3 Functional architecture document [4]. See Figure 3 for an overview of the i-GAME functional blocks and their relations. The bottom block will be drawn up with low-level discriptions from a communication point of view, in relation with the interaction protocol message sets and the supported scenarios.

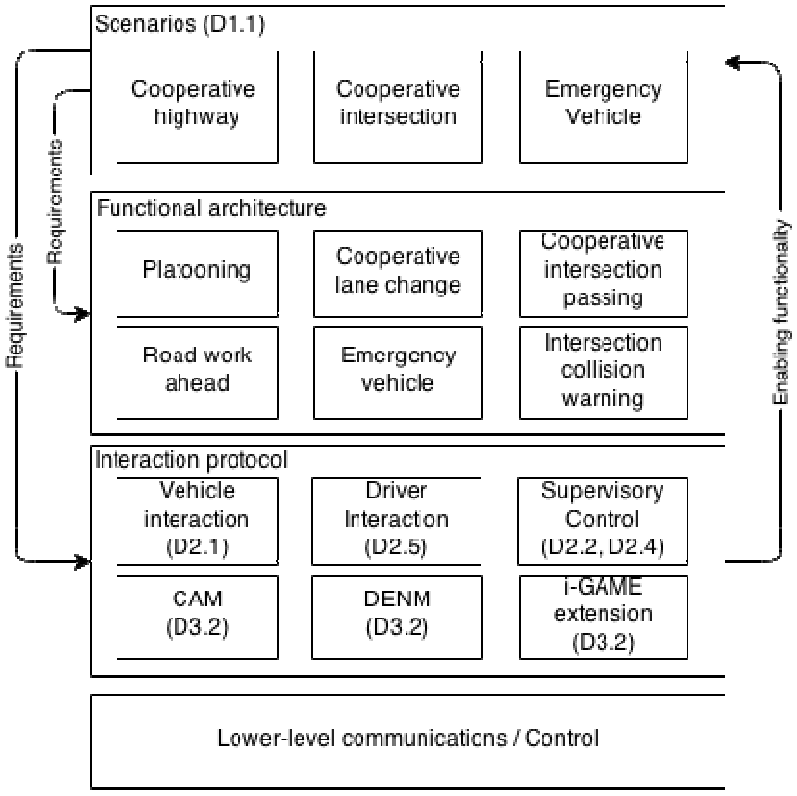

Figure 3 i-GAME functional blocks

The lower-level communication block will be defined in a generic matter in the following sections of this chapter, also scenario specific requirements are listed in this chapter. Message sets and interaction protocol are referred to in Chapter 4 together with more GCDC specific details.

3.1 ITS reference architecture

The general standards in the ITS Communication Architecture document (b) give the reference architecture for an ITS station with examples of possible elements in such a station.

The three lower blocks in the middle of Figure 4 contain functionality of the OSI communication protocol stack with:

- "Access" representing OSI layers 1 and 2,
- "Networking & Transport" representing OSI layers 3 and 4,
- "Facilities" representing OSI layers 5, 6 and 7.

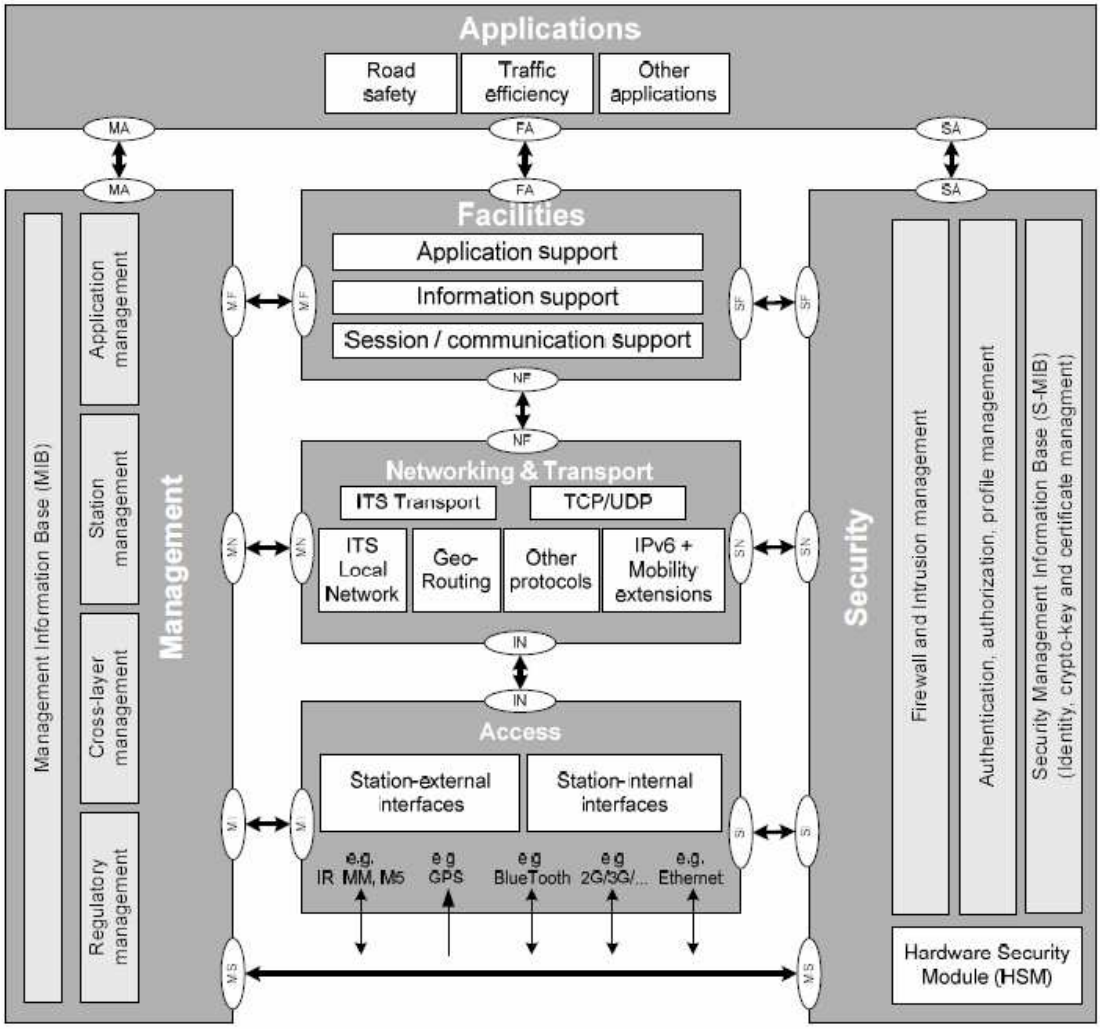

Figure 4: ITS reference model

3.1.1. Access technologies

i-GAME focuses on the traffic safety and -efficiency in a realistic environment where vehicles with or without communication are able to co-exist. The scenarios in i-GAME are to be performed by vehicle interaction and -coordination, requiring high priority and low latency communication. C-ITS defines physical layer access based on different technologies, however, i-GAME will use only ITS-G5. V2V and V2I communications are based on the IEEE 802.11-2012[3] standard specified in ETSI ES 202 663 (c) "ITS European profile standard for the physical and medium access control layer of Intelligent Transport Systems operating in the 5 GHz frequency band" and EN 302 663 (d) "ITS Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band". The implementation will follow closely the definition in the C-ITS standard. The GCDC organization will provide the communications infrastructure (RSUs) for V2I

[3] The IEEE 802.11p amendment is superseded and enrolled in IEEE 802.11-2012: "IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks-Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

communication, but this infrastructure is only for support and management of the scenarios. Other communication technologies, such as cellular communications, are optional. See also Section 0 for more specifications.

3.1.2. Networking and Transport

The networking and transport layers provide thee low-latency communications and keeps the signalling, routing and packet forwarding overhead low. These layers also provide reliable communications with fairness among different nodes with respect to bandwidth or priority type. C-ITS standard defines the support of different protocols in these layers. i-GAME uses GeoNetworking (GN) for communications in the ITS-domain (e), and TCP/UDP/IP protocols in the IP domain e.g. for management purposes. The GN standard consist of multiple parts with sub-parts, the most important parts for the GCDC are :

- GN Protocol, defined in *Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications, Sub-part 1 Media-independent functionalities*
- BTP Protocol, defined in *Part 5: Transport Protocols, Sub-part 1: Basic Transport Protocol*

The networking and transport layer should have a low complexity and must also enable interoperability for: different hardware platforms and vendors, different ITS stations and different software/applications. For usage of GN over different ITS access technologies the protocol is split into a media-independent and a media-dependent part for ITS-G5. For the GCDC2016 only the media-independent functionalities are relevant.

Part 5 sub-part 1 focuses on transport protocols with the Basic Transport Protocol (BTP). BTP provides an end-to-end connectionless transport service for transmission of packets via GN. For the facilities layer protocol entities such as Cooperative Awareness Messages (CAM) and Decentralized Environmental Notification Messages (DENM). BTP provides access services for GN and to pass protocol control information. Message multiplexing and demultiplexing is based on source and destination ports. BTP is designed as a lightweight protocol with a 4-byte protocol header and requires minimal processing. It provides an unreliable transport of packets. As a result, it is also possible that packets arrive out-of-order, appear to be duplicated or can be lost during transport. The design of BTP assumes that entities, using the protocol are tolerant against the unreliable packet transport or provide appropriate mechanisms for reliable communication in their protocols. In the GCDC2016 the only transport protocol being used is BTP. Also for the GCDC2016 IPv6-based communications is not used. IP communication is not mandatory but it can be essential for management and testing functions like troubleshooting, logging, configuration management and remote-access.

3.1.3. Facilities

Facilities provide the services and common functionalities to enable different ITS applications. The main components of the facilities are the Cooperative Awareness (CA) that generates CAMs, and Decentralized Environmental Notification (DEN) that generates DENMs. CAM is like a heartbeat message, it is sent out frequently with status information of the sending vehicle. The purpose is to inform the surrounding vehicles or other entities about the existence of the vehicle with its relevant information. Note that the periodic transmission of CAM messages has become mandatory. DENM is an environmental triggered message, which is used to inform related vehicles of certain events, such as roadworks. The i-GAME communication architecture supports both CAM (f) and DENM (g).

A tailored communication message set will be developed by adapting the CAMs and DENMs and, define a new set of messages to fulfil the functional requirement that are needed for performing the i-GAME scenarios. See Chapter 4.5 for more information related to the i-GAME message sets.

Facilities layer includes Layer 6 “Presentation” of the OSI model, which translates the data between a networking service and an application, including character encoding, data compression and

encryption/decryption. CAM and DENM standards mandate that ASN.1 (Abstract Syntax Notation 1) must be used in the presentation layer. ASN.1 will also be used to encode the i-GAME-specific messages.

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.

3.1.4. Applications

The applications are at the top level in the communication architecture. i-GAME focuses on the cooperative aspects and the close-to-reality applications, where three realistic scenarios are defined based separately; one on a urban- and two on a 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 scenarios aims to improve the traffic efficiency through platoon operations. The first scenario defines a Cooperative Platoon Merge application, where vehicles from two platoons communicate and coordinate to pass a roadwork site safely and efficiently. The second scenario defines an Emergency vehicle passing through a traffic jam. This last scenarios is only for demonstration purposes and will not be judged.

Besides the i-GAME defined applications, a subset of applications is defined in the Basic Set of Applications (BSA) in ETSI TR 102 638 (h) from the C-ITS standards. Some parts of the BSA are also relevant in the i-GAME architecture set-up. In the urban scenarios for an efficient intersection passing, this is the Intersection Collision Warning. In the highway scenario, basic applications such as Collision Warning, maybe included for the safety purpose. Roadworks are a very common scenario in realistic traffic. Therefore, i-GAME uses roadwork warning (RWW) to trigger the platoon merge on highways. Within this context, parts of the Roadwork Warning application defined in the C-ITS standards is included in the i-GAME architecture. More specific application requirements specifications are available in:

ETSI TS 101 539-1 ITS V2X applications part 1 Road Hazard Signalling (RHS) application requirements specifications (i);

ETSI TS 101 539-2 ITS V2X applications part 2 Intersection Collision Risk Warning (ISCW) application requirements specifications (j);

ETSI TS 101 539-3 ITS V2X applications part 3 Longitudinal Collision Risk Warning (LSCW) application requirements specifications (k);

Summering, 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 obliged by 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 adapted message set will become available for the emergency vehicle warning use case, which includes information about how the emergency vehicle wants the other vehicles to manoeuvre.

3.1.5. Management

The management layer defines interfaces between each of the communication layers, as well as the cross-layer control mechanisms. The horizontal communication layers have only interfaces to its neighbour layers, while the 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. The layer 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 (l) and TS 102 890 series (m), as well as relevant ISO standards for detailed specifications of the layer interfaces.

3.1.6. Security

The security layer provides security and privacy services for different layers of the communication stack. This can be management of security identities, credentials, crypto-keys and certificates. The layer also includes aspects for secure platforms like firewalls, intrusion management and tamper-proof hardware. At this time no security functions (certificates, signing, secure payload) are mandated or planned for the GCDC2016.

If the security layer becomes a part of GCDC2016 due to the available local infrastructure (RSUs) supporting the security header and certificates (n). The i-GAME organization will provide the needed certificates.

3.2 Communication platform and components description

As defined in the GN Network Architecture standard ITS-S consists of two types of sub components. This are the Communication and Control Unit (CCU) and the Application Unit (AU). The CCU has all the communication functions and executes the communication protocol stack. It implements the Acces, Network and Transport and the Facilities layer. The AU runs the ITS application or a set of applications, which corresponding to the ITS Application layer.

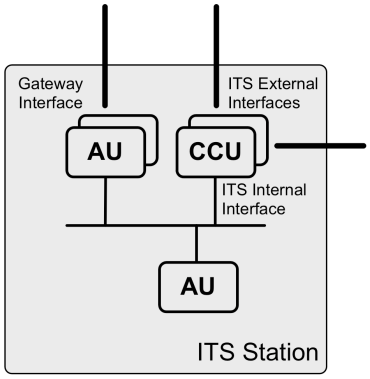

Figure 5 Components of an ITS station

The AU and CCU may be implemented in one physical unit. The CCU has at least one external interface to provide connectivity to the ITS-G5 network. Internal interfaces are available to connect the AUs and CCUs.

For V2V communications the main type of operating for a CCU is the ad hoc router function for routing and forwarding the ITS ad hoc network traffic based on GN.

Requirements:

Access technologies based generally on (b) ETSI ITS-G5 EN 302 665, the standards developed for the access and media layer are based on features such as:

- 5.9 GHz spectrum usage
- Multichannel operation (not used in the GCDC2016)
- Decentralised congestion control (DCC) (not used in the GCDC2016)
- Coexistence of ITS and DSRC services in the 5.8/5.9 GHz band (not used in the GCDC2016)

Spectrum usage

For the GCDC2016 the used frequency ranges are the European ITS-ITS-G5A band ranging from 5875 – 5905 MHz with 10 MHz channels. The ITS-G5A frequency band is set aside for ITS road traffic safety applications and it is only allowed to be used by ITS-G5 compliant stations. The relevant publication is the European Profile standard on ITS G5, EN 302 663 (b).

Table 1 European channel allocation

Channel Type	Center frequency	Channel number	Channel spacing	Default data rate	Tx Power limit	Tx Power Density limit
G5-CCH	5 900 MHz	180	10 MHz	6 Mbit/s	33 dBm EIRP	23 dBm/MHz
G5-SCH2	5 890 MHz	178	10 MHz	12 Mbit/s	23 dBm EIRP	13 dBm/MHz
G5-SCH1	5 880 MHz	176	10 MHz	6 Mbit/s	33 dBm EIRP	23 dBm/MHz

More details on the channel configurations and operations for the service channels (SCH1, SCH2) and the control channel (CCH) can be found in TS 102 724.

Decentralized Congestion Control (DCC)

ITS applications, in particular the safety-related applications, have high requirements on the reliability and the latency of the data transmission. Due to the MAC protocol of IEEE 802.11-2012, and the limited bandwidth of ITS-G5, the data load on the wireless channels can exceed the available capacity in some situations. Therefore, decentralized congestion control (DCC) methods are introduced to control the channel load and avoid unstable behaviour of the system are specified in (o) TS 102 687. For the GCDC2016 DCC is NOT required in ITS-G5 stations implementations.

Network and transport

GeoNetworking ETSI EN 302 636-4-1 (p), EN 302 931 (q), ITS-G5 specified in ETSI EN 302 663 (b) and ETSI EN 302 636-5-1 (r) Basic Transport Protocol.

Functions

- Must implement Geonetworking based on the latest ETSI standards (as specified above)
- Must implement BTP-B based on the latest ETSI standards (as specified above)
    - BTP-A is for interactive usage and BTP-B for non-interactive usage.
- Must allow arbitrary and/or non-standard messages for arbitrary BTP port numbers (i-GAME specific messages uses port 2010), as long as they do not coincide with well known BTP port numbers
- Use single hop broadcast (SHB) for CAM messages and geo-broadcast for DENM messages

System integration

- An i-GAME Simulation Test Tool (iSTT) for remote online testing will become available for the teams (it is not mandatoryro use it). Using the tool is possible if the CCU is able to redirect its GN traffic from the wlan interface into a virtual tap interface and has an ability to run an openvpn client. More details on the requirement for connecting to the tool and the iSTT itself can be found in Section 0.
- The vehicle must be able to use system time running on UTC for all time related functions. For iSTT, the (simulated) vehicle must be able to run on the externally-controlled time (iSTT server will send *tick* timing messages).

Security

Informational: some related technical specifications are: ETSI ITS Security ETSI TS 102 941 (s) , ETSI TS 102 731 (t), ETSI TS 102 940 (u) and ETSI TS 103 097 (n).

At this time we do not mandate any security functions for ITS-G5 communications.

C-ITS Facilities

Cooperative Awareness Message (CAM) ETSI EN 302 637-2 (f)

Distributed Environment Notification Message (DENM) ETSI EN 302 637-3 (g)

Non-standards message set and extension to CAM and DENM (i-GAME D3.2 [5])

3.3 Parameter settings, interface to lower and higher layers

For i-GAME the communication stack is build on the communication layers mentioned in the previous section. The i-GAME applications form the top layer for the Merging, Intersection and Emergency vehicle scenario. The facility layer will have CAM and DENM based on the current ETSI C-ITS standards, and a dedicated i-GAME message set based on scenario requirements and the interaction protocol implementation. These message sets will be provided as software libraries or only in a ASN.1 format so teams can compile the message sets for their own communication platform. This is the (non-runtime layer) ASN.1 layer in Table 2 below. With the i-GAME ASN.1 definitions teams can compile their own software libraries with e.g. open source ASN.1 comipler asn1c[4]. Otherwise commercial tools[5] will be provided by the GCDC organization to the particpating teams.

Table 2 Communication layers and protocols

Layer	*Protocol*	*Comments/examples*
Application	Platoon Merge; Intersection; Emergency Vehicle	Defined in D1.1 and D2.1
Facility	CAM, DENM, i-GAME custom	Defined in D3.2
Presentation	ASN.1	asn1c / GCDC asn1 / OSS Nokalva / Objective Systems / …
Transport	BTP	BTP is usually a part of GeoNetworking implementation
Network	GeoNetworking	CarGeo6 / GCDC GeoNetworking / Appendix A
Access	ITS-G5 based on 802.11-2012 (802.11p)	AR54xxx+ath5k / AR92xx/AR93xx +ath9k / Appendix A

[4] available at https://github.com/vlm/asn1c

[5] a list of commercial tools is available, for example at http://www.itu.int/en/ITU-T/asn1/Pages/Tools.aspx

The Basic Transport Protocol (BTP) provides an end-to-end, connection-less transport service. It offers a minimal non-guaranteed transport service for the higher protocol entities coming from the ITS Facilities layer. The main protocol entities are the CA basic service and the DEN basic service. The BTP layer has direct access to the services provided by the GeoNetworking protocol. BTP has two types, BTP-A for interactive usage and BTP-B for non-interactive usage. For GCDC2016 BTP-B is used.

Destination and Destination port information fields carried within the BTP-B header are:

Field name	Description
Destination port	Identifies the protocol entity at the destination's facilities layer
Destination port info	Provides additional info if Destination port is a well-known port, default setting is 0.

Coming from the standardization on ITS facilities entities some well-known BTP port numbers are available. In the table below the well-known ports for CAM and DENM message are listed.

Well-known BTP port	ITS facility entity	Related standard
2001	CAM	ETSI EN 302 637-2 (f)
2002	DENM	ETSI EN 302 637-3 (g)
2010	i-GAME Cooperative Lane Change Message (iCLCM)	Non-standard, will be provided by the i-GAME organisation. Details in D3.2.

For i-GAME the standardized CAM and DENM message set are adapted to support the i-GAME scenarios, and a new ITS facility entity the i-GAME Cooperative Lane Change Message (ICLCM) is defined to support the interactions needed in the scenarios, using a non-standard port number 2010. For details see i-GAME D3.2 Proposal for extended message set for supervised automated driving [5].

The GeoNetworking protocol in the Networking and Transport layer and Access layer can be a *blackbox* when teams come with a CCU provided by a communication gateway vendor. However, the teams can have an own implementation as long as its compatible with the mentioned ETSI ITS-C standards. For the GCDC2016 it is needed to support single hop broadcast (SHB) for CAM and i-GAME messages and geo-broadcast for DENM messages. For example, at least two open-source libraries are available for GN/BTP: geonetworking (github.com/alexvoronov/geonetworking) and CarGeo6 (www.cargeo6.org). The GN/BTP software can run on the own embedded systems boards of the teams as long as the access layer is compatabile with the mentioned ITS-G5/802.11-2012 standards.

The GeoNetworking protocols support circular, rectangular and ellipsoidal geographical target areas and may support other types of geographical target areas if needed by applications/i-GAME scenarios. See also ETSI EN 302 931 Geographical Area Definition (q).

i-GAME GeoNetworking addressing

The Vehicle ITS station implementing the GeoNetworking protocol shall have at least one unique address at the ITS-S networking & transport layer. The address may be based on each individual ITS stations' identity. The GeoNetworking protocols will also allow manual address configuration for the i-GAME address plan. Internet Protocol networking is not needed for GN to function, and it will be only used for management functions (remote-access, configuration, troubleshooting, logging etc.). For now the proposal is to use the IP

address of the units as CAM station ID as both identifiers are 4 byte long. Addressing is be based on the private address spaces (10.0.0.0/8, 172.16.0.0/12 or 192.168.0.0/16).

Table 3 IP address table template

Address used for the GCDC2016			
Address Blocks	Items	IP adress	Comments
Reserved	RSUs		Based on station ID
	i-GAME Vehicles		Based on station ID
	Management		
	Other		
Teams	Team #1		Based on station ID
	Team #2		Based on station ID
	Team #N		Based on station ID
Specials	Item #1, Item #2		TBD

The actual address plan used for the GCDC will be constructed during preparations for the GCDC2016 and is not available at this time. This information will be provided to the teams in due time.

3.4 List of suitable communication platforms for the GCDC2016

The i-GAME team worked on an open source GeoNetworking implementation as mentioned in the previous section, as well as on a reference communication unit device with this GN software. This GN implementation has been successfully tested during the ETSI Plugtest in March 2015.

For the reference hardware we used an Alix APU1D board with Atheros/Qualcomm mPCIe wifi card and ath9k drivers. We used Voyage linux with an open source IEEE 802.11p stack by CTU-IIG with modifications to the kernel, the iw tool and entries added for ITS-G5 operation in the regulatory database. See Appendix A for more details on the used software and hardware. More information will be available on the team section of gcdc.net, or can be provided on request.

The project team is also activily looking for sponsors who can provide equipement and/or software to support the i-GAME project and the GCDC 2016 organization and particpating teams. Potential equipement sponsors should support the listed requirements in this document.

In Appendix A a list of platforms (or software) is presented. This list is not complete, can be outdated as new products are introduced in the market. Also the equipement is not tested for compatibility with our requirements. The organisers do not have any preferences and do not mandate the teams to use this equipment, or other equipement that is not on this list.

4 Specific communication requirements

This section will focus on the i-GAME specific communication requirements for the teams to be able to succesfully participate in the GCDC 2016. In order to keep this document highly accessible, timely available and with a focus on the low level communication aspects for the GCDC 2016, mostly references are made to the relevant documents.

4.1 i-GAME scenarios

All requirments are drafted up to support the scenarios of the GCDC2016. Detailed information on the scenario is available in i-GAME D1.1 Specifications of scenarios document [6].

1) Scenario Cooperative Highway: The scenario involves cooperatively merging with two platoons approaching a road works site on a highway.
2) Scenario Cooperative intersection: This scenario demonstrates a complicated intersection crossing activity in a urban setting.
3) Scenario Emergency vehicle (demo): An emergency vehicle (EV) is approaching a congested traffic situation and signals the intent to pass the traffic congestion in a given direction (left / middle / right side).

4.2 Participant communication requirements

As also mentioned in Section 2.3.4 of D1.2 Draft report on requirements specification [7]and data logging, especially from the communication, is important for analysing the performance of the cooperation between the vehicles during the challenge. It will also play a central role in the juding process. Log files helps the development of individual vehicles, and it also improves the development of a common interaction protocol and message sets since it enables thorough investigation of the spread of the transmitted data. The files also enables tracing about the vehicles behaviour according to the transmitted and received data. The logged i-GAME data will only be used for research purposes. In addition to the data logging and monitoring methods deployed by the GCDC organizations, participating teams are also required to deploy related functionalities for proper data logging.

- All vehicles must be able to log time-stamped in-vehicle data such as GPS location data, sensor data, and so on for future reference
- All vehicles must be able to log time-stamped communication messages for the purpose of analysis
- In vehicel data log frequency and format must follow the specifications presented in D2.6 Benchmark Vehicle implementation [8].

4.3 Interfacing to i-GAME Simulation Test Tool

This i-GAME Simulation Test Tool (iSTT) platform will become available for the teams to test the communication interaction needed in the GCDC2016 scenario. The iSTT has two parts, the basic idea is an online platform called the Interaction Test Tool (ITT) to connect multiple Vehicle Simulator (VeS) of the teams to test interactions. The ITT is a central server to which VPN tunnels connect to transfer the ITS-G5 messages. And the ITT provides a World Model which distributes Ground Truth data to provide all participants with the data needed to emulate sensor signals. The use of iSTT is optional. For details see D2.3 Simulation toolset for evaluation of supervisory control systems for cooperative driving [9].

4.4 Interaction requirements

As also stated in D1.2 [3] the communication enables interaction between vehicles. This is crucial for the success of GCDC challenge. All scenarios to be conducted in GCDC 2016 are based on interaction and cooperation between the involved vehicles. All vehicles must be able to receive, analyse, interact and negotiate with each other. Mutual decisions shall be achieved through the negotiation and the corresponding scenario will be resolved safely and successfully. For facilitating the interaction, a set of interaction protocol will be developed and tested, see D2.1 Interaction protocol [10] for the details.

4.5 Message sets for the GCDC 2016

For the interaction protocols needed to execute the scenarios, extensions are developed to the current CAM and DENM message formats. For the complex interactions needed for the automated manoeuvring complete new interaction message formats are defined to support the interaction protocol. This a CAM-like message called the i-GAME Cooperative Lane Change Message (iCLCM) These message sets are documented and made available as ASN.1 definitions or as a software library. All the details on i-GAME message sets are listed in D3.2 Proposal for extended message set for supervised automated driving [5].

4.6 Workshops for the teams

In the preparation phase for the GCDC2016 different workshop for the teams are being organised. This to support the participant on topics related to the assessment of interaction implementation, the evaluation of the developed interaction protocols, validation of message set interoperability and using the tools provided by the i-GAME team. Planned workshops at this time are:

1) Workshop on validation of message level interoperability, Septemeber 28 – 29th 2015, 1st Face-to-face workshop with the teams, to kick-off preparation phase towards the GCDC2016
2) Workshop on validation of interaction performance: first implementation of teams available to test interaction performance
3) Safety Workshop

These workshops will be announced via the website: http://www.gcdc.net/ and in seperate phone conferences with the teams.

List of references

i-GAME GCDC References:

[1] i-GAME D1.3 Functional Architecture document

[2] i-GAME D1.3 Functional Architecture document

[3] i-GAME D1.2 Draft report on requirements specification

[4] i-GAME D1.3 Functional architecture document

[5] i-GAME D3.2 Proposal for extended message set for supervised automated driving

[6] i-GAME D1.1 Specifications of scenarios document

[7] i-GAME D1.2 Draft report on requirements specification

[8] i-GAME D2.6 Benchmark Vehicle implementation

[9] i-GAME D2.3 Simulation toolset for evaluation of supervisory control systems for cooperative driving

[10] i-GAME D2.1 Interaction protocol

ETSI standards references

a) ETSI TR 101 607 Technical report on C-ITS release 1 version, v1.1.1 (2013-05)

b) ETSI EN 302 665 ITS Communication Architecture, v1.1.1 (2010-09)

c) ETSI ES 202 663 ITS European profile standard for the physical and medium access control layer of ITS operating in the 5 GHz frequency band, v1.1.0 (2009-11)

d) ETSI EN 302 663 ITS Access layer specification for ITS operating in the 5 GHz frequency band, v1.2.1 (2013-07)

e) ETSI EN 302 636 ITS Vehicular Communications GeoNetworking, multi-parts standard.

f) ETSI EN 302 637-2 ITS Vehicular Communications: Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service, v1.3.2 (2014-11)

g) ETSI EN 302 637-3 ITS Vehicular Communications: Basic Set of Applications; Part 3: Specification of Decentralized Environmental Notification Basic Service, v1.2.2 (2014-11)

h) ETSI TR 102 638 ITS Vehicular Communications: Basic Set of Applications Definitions, v1.1.1 (2009-06)

i) ETSI TS 101 539-1 ITS V2X applications part 1 Road Hazard Signalling (RHS) application requirements specifications, v1.1.1 (2013-08)

j) ETSI TS 101 539-2 ITS V2X applications part 2 Intersection Collision Risk Warning (ISCW) application requirements specifications

k) ETSI TS 101 539-3 ITS V2X applications part 3 Longitudinal Collision Risk Warning (LSCW) application requirements specifications, v1.1.1 (2013-11)

l) ETSI TS 102 723 ITS OSI cross-layer topics, multi-parts standard

m) ETSI TS 102 890 ITS Facilities layer function, multi-parts standard

n) ETSI TS 103 097 ITS Security: Security header and certificate formats, v1.1.1 (2013-04)

o) ETSI TS 102 687 ITS Decentralised Congestion Control mechanisms for ITS operating at 5GHz range: Access layer part, v1.1.1 (2011-07)

p) ETSI EN 302 636-4-1 ITS Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multi-point communications; Sub-part 1: Media-independent functionality, v1.2.1 (2014-07)

q) ETSI EN 302 931 ITS Vehicular Communications; Geographical Area Definition, v1.0.0 (2010-12)

r) ETSI EN 302 636-5-1 ITS Vehicular Communications; GeoNetworking; Part 5: Transport protocols; Sub-part 1: Basic Transport Protocol, v1.2.0 (2013-10)

s) ETSI TS 102 941 ITS Security; Trust and Privacy management, v1.1.1 (2012-06)

t) ETSI TS 102 731 ITS Security; Security Services and Architecture, v1.1.1 (2010-09)

u) ETSI TS 102 940 ITS Security; ITS communications security architecture and security management, v1.1.1 (2012-06)

Appendix A List of Communication equipment manufacturers/providers

List of available (commercial) communication units for possible usage for the GCDC. This list is not complete, and the equipement is not tested, nor preferred or has the compatibility with our requirements checked.

Manufacturer	Hardware	Software	Comments
Autotalks http://www.auto-talks.com/solutions/development-platform/	PANGAEA4 V2X Comm. Module	Option: ITS ETSI G5 (EU) V2X software stack by qualified 3rd party vendor	
Arada Systems http://www.aradasystems.com/locomate-obu/	LocoMate OBU	Linux/Unix compatible SDK with C libraries	5.85 – 5.925 GHz AND 5.7 – 5.8 GHz (Europe)
Commsignia http://www.commsignia.com/devices/	LGN-00-11 LGN-20 LGN-20-10	APIs/firmware C-ITS SDK	V2X comm. stack ISO / ETSI / IEEE / C2C-CC
Componentality http://www.componentality.com/flexroad/	FlexRoad OBU		IEEE 802.11p V2X comm.
Denso	DENSO WSU/miniWSU	C2CC protocol stack	5,9GHZ WSU US-only(?)
Imtech GN implementation	Imtech hardware or run on x86 alix board	Licence agreement needed	Update after/during ETSI plug test in March 2015
i-GAME Open source Geonetworking implementation https://github.com/alexvoronov/geonetworking	Run on x86 Alix APU1D platform http://www.pcengines.ch/apu1d.htm	Open source. Not a complete GN implem.	Supports the GCDC. Tested during ETSI plugtests, March 2015
ITRI	Iwcu0-2 (RSU) IWCU-2-o (OBU)		802.11p/its-g5
Kapsch http://www.kapsch.net/ktc/downloads/datasheets/in-vehicle/5-9/Kapsch-KTC-DS-OBU-TS3306?lang=en-US	Ts3306		ETSI ITS-G5 Also have RSUs (MTX-9450)
Lesswire http://www.lesswire.com/en/products/wireless-modules/	Radio modules WiBear, WiBear ITS Car2X transceiver	use of 3rd party frameworks and apps	ITS G5, IEEE 802.11p
Marben http://www.marben-products.com/v2x/v2x-software-solution.html	N.A. Runs on various HW platforms	MARBEN V2X software	802.11p 3G, 4G/LTE
NEC	Linkbird-MX C2X	Car-2-X	Current status

http://www.nec.co.jp/press/en/0811/images/1301-01.pdf	communication platform	communication SDK	and availability?
NXP/Cohda http://cohdawireless.com/Products/Hardware.aspx	MK3, MK4, MK5 TEF5100/SAF5100	Cohda stack, other	
Redpine http://www.redpinesignals.com/Technology/802.11p.php			
Savari http://www.savarinetworks.com/products/mobiwave/	MobiWAVE STREETWAVE	SOBOS (Linux) MobiWAVE SDK	Europe(?)
	EVK-3300 V2X evaluation kit	GUI for config and monitoring	ITS-G5
Siemens http://www.mobility.siemens.com/mobility/global/SiteCollectionDocuments/en/road-solutions/urban/cooperativity-in-motion.pdf	Scalance Communication Unit		RSU
Unex Technology http://www.taiwantrade.com.tw/EP/resources/member/1329/productcatalog/d0653d1b-935d-498f-a61d-0e448586f517_OBU101_datasheet.pdf	OBU-101	Linux OS, SDK	Suited for Europe(?)
802.11p tranceicers/radios			
Autotalks http://www.auto-talks.com/chipset/pluton/	PLUTON (ATK3100)		V2X transceiver 802.11p
ITRI (Industrial Technology Research Institute)	Mini-pci	Linux-driver	
Atheros AR5414/ Qualcomm	Mini-pci	Software driver	Some problems to pass ETSI plug tests, like other transceivers
Atheros AR92xx/AR93xx/AR94	mPCIe for Alix APU	Ath9k driver. These cards should support open source 802.11p stack from CTU-IIG	Only UNEX DHXA-222 wifi card has been tested at this time.
NXP	TEF510x (roadlink line)		Multi-band RF transceiver, targeting (C2X) applications
Lesswire http://www.lesswire.com/en/products/wireless-modules/car2x/wibear-its-car2x/overview/	Wibear 11.p		ETSI ITS G5, IEEE 802.11p