Cooperative ITS - EU standards to accelerate cooperative mobility

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Abstract—**With intensive research and field operational tests over the intelligent transportation area and the advancements of information and communication technologies, intelligent transportation systems reach the stage of deployment. EU focuses on cooperative intelligent transportation systems and confirms the finalization of the first release of the standards, paving the way for deployment in the coming years. This paper presents the concept of EU's cooperative intelligent transportation systems and describes in detail the functional architecture, together with highlights of related standards that have been finalized in Release 1. Latest updates of the cooperative intelligent transportation systems are provided for both industry and academia, aiming at helping to accelerate cooperative mobility.**

I. Introduction

A fully cooperative intelligent transportation system (C-ITS), enabled by the advancement of sensor and communication technologies, will significantly contribute to the future sustainable societal and economical development. To deal with the challenges of transportation and enable a sustainable society, EU has invested over EUR 180M in C-ITS, from the very early conceptual development [1, 2, 3] to the recent large scale field operational test (FOT) projects [4, 5]. Significant effort has been done for the harmonization of the standards on intelligent transportation systems (ITS) for its worldwide interoperability. As a first and critical step towards the realistic deployment, European Committee for Standardization (CEN) and European Telecommunications Standards Institute (ETSI) confirmed the finalization of the basic set of standards for the C-ITS in 2014 and published TR 101 607, e.g., Release 1, followed closely by the US legislation of vehicle-to-vehicle (V2V) communications [6]. In this paper, a detailed description of C-ITS Release 1 is given, together with the introduction of on-going FOT projects within EU. C-ITS Release 1 will be referred to as C-ITS R1 here and after.

II. ITS standardization

To support the implementation of ITS, standardization organizations including International Organization for Standardization (ISO), European standardization organization CEN and ETSI, Institute of Electrical and Electronics Engineers (IEEE), as well as industrial consortium such as Car-to-Car Communication Consortium (C2C-CC) have been working on a common functional architecture for the cooperative system. This has resulted in the main series of standards including the IEEE Wireless Access in Vehicle Environments (WAVE), ISO Communications Access for Land Mobiles (CALM), as well as the EU standards Cooperative ITS.

IEEE standardizes WAVE and publishes through the IEEE 1069 series. WAVE architecture corresponds to the ISO Open System Interconnection (OSI) model [7] layer 1 to 4, e.g., from physical layer to the transport layer. Physical access is based on IEEE 802.11p, which is a Dedicated Short Range Communication (DSRC) technology working at 5.9 GHz. Media access and logical link control are based on IEEE 802.11 and IEEE 802.2 standards, respectively. Network & transport layer support IPv6 and TCP/UDP. For safety-critical ITS applications, WAVE defines WAVE Short Message Protocol (WSMP) to satisfy the requirements of high priority and low latency. WAVE also includes security and management layers along with the above mentioned layers. There are no application layer defined in WAVE. Instead, WAVE introduces a Resource Manager (RM) which connects the applications to the On-Board Unit (OBU) or Road-Side Unit (RSU), allowing applications to access to the system resources.

ISO standardizes CALM and publishes through the ISO 21217 series. CALM defines four protocol blocks including access, network, application and management, which also corresponds to the OSI model. Besides the support of widely used access technologies such as cellular, WLAN, broadcast, etc, CALM defines CALM-IR based on infrared communication and CALM-millimeter based on millimeter wave communication. Furthermore, CALM provides support for IEEE WAVE through CALM-M5 based on 802.11p. At the network and transport layer, CALM mainly supports IPv6 based protocols. Meanwhile, for the time-critical ITS application, CALM defines CALM-FAST to supports single-hop V2V communication with low latency. Industrial protocols are also supported. Different applications including CALM-aware, non-CALM-aware, IP and non-IP based are defined and supported. A cross-layer management layer is defined in CALM, while no security layer has been defined so far.

Besides the standardization organizations, industrial alliances such as C2C-CC also defines their standards to accelerate the industrial deployment of cooperative ITS. The C2C-CC protocol stack is very similar to CALM. It defines IEEE 802.11p based V2V communication and IEEE 802.11 a/b/g based vehicle-to-infrastructure (V2I) communication. The safety critical applications are supported by the so called C2C transport protocol, while TCP/UDP/IP are used for non-safety related applications. The network protocol is based on geographical

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DOI 10.1109/ICCVE.2014.69

addressing, and is further developed and integrated with the ETSI C-ITS standard.

III. CEN-ETSI C-ITS

EU aims at a multi-vendor and globally interoperable cooperative transportation system. Thus, C-ITS is largely based on the harmonization work of the ISO CALM, IEEE WAVE, and that of the industrial alliances. EU funded projects including SAFESPOT [1], CVIS [2], COOPERS [3], COMeSafety [8], etc, have contributed to the development and validation of a common communication architecture and related functionalities that support different ITS applications.

An illustration of the C-ITS system is shown in Fig. 1. C-ITS comprises physical entities that correspond to all major actors within the transportation system, e.g., the mobile actors (vehicles, pedestrians, cyclist, and so on), the infrastructure and the control center. C-ITS focuses on the cooperative aspects and introduces a generic component, e.g., the ITS-Station, which resides on the physical entities within the transport systems.

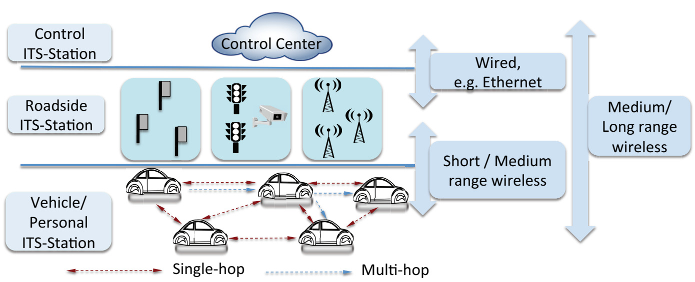

Fig. 1: C-ITS conceptual architecture

The ITS-Station consists a number of functions and a set of devices implementing those functions. All C-ITS physical entities include ITS-Stations, while detailed functions and their implementations differ depending on where the ITS-Station resides. C-ITS defines a generic layered communication architecture for the ITS-Station, as shown in Fig. 2. For clarification, layer interface between two layers are denoted by their representative letters here and after. For example, in Fig. 2, FA denotes the interface between the layers of Facilities (F) and Applications (A), while NF denotes the interface between the layers of Facilities (F) and Networking & Transport (N), etc.

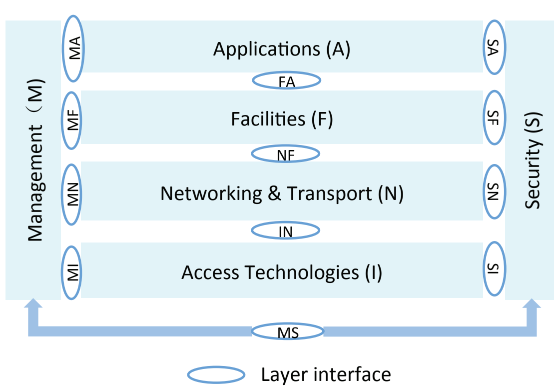

Fig. 2: ITS-Station communication architecture

The architecture is tailored for ITS applications, while functionalities can be mapped to the OSI model. The architecture includes four horizontal layers, which from bottom to top are access layer, network & transport layer, facilities layer and application layer. Two vertical layers, management layer and security layer, are defined that include cross-layer functionalities for enabling efficient information exchange between the horizontal layers for an optimized system operation.

A general summary of the finalized basic standards is shown in Table I. *In the current release R1, C-ITS finalizes the C-ITS communication architecture in EN 302 665, the GeoNetworking architecture in TS 102 636-3 and EN 302 636-3, user and application requirements in TS 102 894-(1-2) series, the C-ITS over public cellular networks in TR 102 962, and the interoperability testing standards in EG 202 798.*

Standard	Specifications
EN 302 665	ITS Communication arcitecture
TS 102 731	Security services and architecture
TS 102 894-(1-2)	Users and application requirements
TS 102 636-3, EN 302 636 -3	GeoNetworking architecture
TR 102 962	Public mobile networks in C-ITS
EG 202 791	Testing specifications

TABLE I: General specifications for C-ITS

In addition, specific standards are finalized and published for each of the communications layers. The following part will present in detail the layered architecture of C-ITS and their corresponding specifications in C-ITS R1.

1) Access Technologies: The access layer of C-ITS corresponds to layer 1 and 2 in the OSI model, e.g., physical layer and data link layer. The ITS-Station physical access technologies supports generally all possible access methods. Wireless access includes short range communications such as the EU version of DSRC ITS-G5, WiFi, IR, etc., wide range communications including 3GPP cellular based GSM/GPRS, UMTS, 4G-LTE, etc., as well as broadcasting systems such as GPS, digital broadcasting, and so on. Ethernet is also supported and is mainly for the usage at roadside and central ITS-Stations. A detailed illustration of the access layer is shown in Fig. 3.

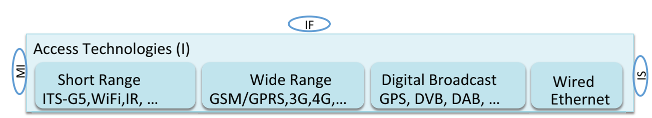

Fig. 3: Access layer of the ITS-station communication architecture

In R1, C-ITS specifies access technologies based on IEEE 802.11p over 5.9GHz frequency band in standards ES 202 663 and EN 302 663, e.g., ITS-G5. For a successful deployment of intelligent transportation system, European commission allocated 5.9 GHz frequency band from 5.855 GHz to 5.925 GHz that is dedicated for ITS. Among this ITS band, subband from 5.875 GHz to 5.905 GHz are referred to ITS-G5A including one control channel G5CC and two service channels G5SC1 and G5SC2. ITS-G5A is used for safety related applications, where high priority and low latency are required. Non-safety applications, such as traffic efficiency, multi-hoping, etc., will operate on ITS-G5B, which is the sub-band from 5.855 GHz to 5.875 GHz. A third sub-band, the ITS-G5D from 5.905 GHz to 5.925 GHz, is reserved for future applications. An illustration of the spectrum allocation is shown in Fig. 4. A fourth sub-band, ITS-G5C ranging from 5.470 GHz to 5.725 GHz, is used for broadband radio access, which is not shown in the figure. Since 802.11p based DSRC has been standardized by CEN and widely deployed for Electronic Toll Collection (ETC), to minimize the potential interferences within the 5 GHz frequency range, ETSI specifies detailed methods for managing the coexistence of CEN DSRC and ETSI ITS-Stations. Transmission power of the ITS-Station will be limited in certain scenarios, such as approaching the tolling zones, for achieving interference-free operations. *C-ITS R1 details the harmonized spectrum usage within the 5 GHz frequency band in TS 102 792.*

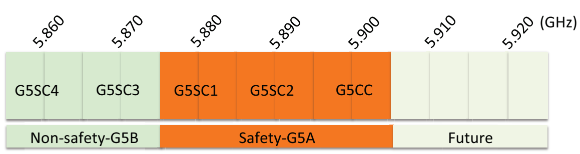

Fig. 4: C-ITS spectrum allocation

C-ITS defines a decentralized congestion control (DCC) architecture for ensuring the network stability and resource efficiency of the systems. DCC includes cross-layer functionalities that resides on the access layer, the networking & transport layer, the facilities layer, as well as the management layer. Those functionalities work together for performing tasks such as optimal radio resource allocation, channel load balancing, etc. *C-ITS R1 defines detailed DCC functionalities for the access layer in TS 102 687 including power control, rate control, sensitivity control, access control, as well as transmit and receive model. The harmonized channel utilization based on the DCC specifications such as the mapping of different traffic streams to different channels at the physical layer is specified in TS 102 724.*

As a summary, the specifications that have been finalized in C-ITS for the access technologies are shown in Table II.

Standard	Specifications
ES 202 663, EN 302 663	ITS 5 GHz band specification
TS 102 687	DCC in access layer
TS 102 792	Co-working with CEN DSRC
TS 102 724	Harmonized ITS channel utilization
TS 102 916-(1-3), TS 102 917-(1-3)	Testing specifications

TABLE II: Access layer specifications in C-ITS

2) Network & Transport Layer: The network & transport layer of C-ITS corresponds to the network layer (layer 3) and the transport layer (layer 4) in the OSI model. C-ITS defines data communications between vehicles without the need of infrastructure support, e.g., point-to-point and non-IP based. Meanwhile, communications between ITS stations via IP-based generic domains, such as through the cellular network, are also supported. Fig. 5 illustrates the modules within the network & transport layer.

ITS specific V2V communications are safety-critical and require high priority and low latency information exchange. C-ITS bases the network & transport protocol on GeoNetworking. Instead of recognizing a vehicle by its IP address (as in the generic domain network), GeoNetworking identifies a vehicle in the network by its geographical position. GeoNetworking is a fully distributed network protocol that needs no infrastructure support. It is well suited to exchange information efficiently for the safety-critical ITS applications, such as the periodically sent Cooperative Awareness Messages (CAMs) and Decentralized Environmental Notification Messages (DENMs). Furthermore, GeoNetworking operates with infrastructures as well, and supports heterogeneous applications such as those for traffic efficiency and infotainment. *C-ITS R1 details the GeoNetworking protocols in standards TS 102 636 and EN 302 636.*

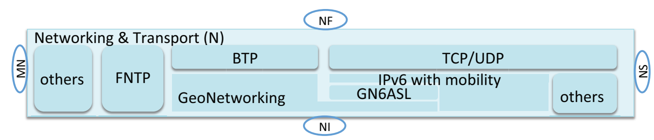

Fig. 5: Network & transport layer of the ITS-station communication architecture

There are two main functions in GeoNetworking, Geo-addressing and Geo-forwarding. Geo-addressing is the addressing scheme that uses the geographical positions of the network nodes to identify them. While Geo-forwarding is the message distribution scheme for the vehicle network by which the packets are continuously forwarded until the destinations are reached.

Within GeoNetworking, C-ITS defines a light-weight transport protocol, e.g., the Basic Transport Protocol (BTP). BTP provides an end-to-end data transport service for the ITS ad-hoc network. Similar to the UDP protocol, BTP provides a best-effort transport scheme where no guarantee schemes are provided for end-to-end packet transmission. *BTP is specified in TS 102 636-5-1 and EN 302 636-5-1 in C-ITS R1.*

Since most current deployed communications system are based on IP protocol, C-ITS defines an adaptation sub-layer, the GN6ASL, for the purpose of integrating IP protocols with GeoNetworking. This allows the generic IPv6 packets to be distributed over the vehicle ad-hoc networks. The integration of IPv6 and GeoNetworking via GN6ASL is fully compatible with the IPv6 implementation and requires no additional modifications of the IPv6 protocol. *Detailed specification of GN6ASL can be found in C-ITS R1 TS 102 636-6-1 and EN 302 636-6-1.*

C-ITS supports the Fast Network and Transport Protocol (FNTP) [9] defined in CALM, as well as the WSMP defined by IEEE 1069 series for safety-critical ITS applications. The harmonization work of those protocols is in progress and the related standards will be finalized in the future. Meanwhile, protocols for generic domain communications, e.g., TCP, UDP, IP, are supported and are mostly used by non-safety critical ITS applications such as traffic safety, efficiency, infotainment, etc.

Current C-ITS R1 focuses on the GeoNetworking. A collection of the finalized specifications for GeoNetworking protocol is shown in Table III.

Standard	Specifications
EN 302 636-1, TS 102 633-1	Requirements
EN 302 636-2, TS 102 636-2	Scenarios
EN 302 636-4-1, TS 102 636-4-2, TS 102 663-4-1,	Geo-addressing and forwarding
EN 302 636-5-1, TS 102 636-5-1	Basic transport protocol
EN 302 636-6-1, TS 102 636-6-1	IPv6 over GeoNetworking
TS 102 870-(1-3), TS 102 871-(1-3), TS 102 859-(1-3), TR103 061-(3-5)	Testing standards

TABLE III: GeoNetworking specifications in C-ITS

3) Facilities layer: The facilities layer of C-ITS corresponds to the session layer, the presentation layer and the application layer, e.g., layer 5 - 7 in the OSI model. It derives functionalities from the OSI model with modifications for fitting the ITS context. The main purpose of this layer is to provide common services, such as generic functionalities, positioning, timing, etc., for facilitating ITS applications. Facilities can be classified into mainly three categories, namely application support, information support and communication support. Application support provides facilities for Human Machine Interaction (HMI), Local Dynamic Map (LDM), positioning, time, and so on. Information support provides facilities to support relevance checking (whether the received message is relevant to the context), vehicle data, vehicle monitoring, traffic message interpretation, and so on. Communication support includes facilities supporting the message generation, extraction and management (such as CAM, DENM), addressing, information dissemination schemes (unicast, broadcast, geocast, ...), radio access choices (ITS G5A, cellular, WLAN ...), and so on. An illustration of the facilities within this layer is shown in Fig. 6.

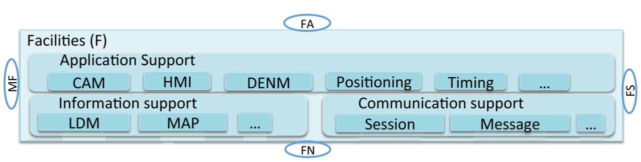

Fig. 6: Facilities layer of the ITS-Station communication architecture

In C-ITS R1, standard for the facilities of Cooperative Awareness (CA) is finalized in TS 102 637-2 and EN 302 637-2. Decentralized Environmental Notification (DEN) is finalized in TS 102 637-3 and EN 302 637-3, while LDM is finalized in EN 302 895. Facilities for position and time are specified in TS 102 890-3. A summary of the specifications for the facilities layer in C-ITS is shown in Table IV.

Standard	Specifications
EN 302 637-2, TS 102 637-2	Cooperative awareness (CA)
EN 302 637-3, TS 102 637-3	Decentralized environmental notification (DEN)
EN 302 895	Local dynamic map (LDM)
TS 102 890-3	Position and time facility
TS 102 8868-(1-3), TS 102 869-(1-3), TR103 061-(1-2)	Testing standards

TABLE IV: Facilities layer specifications in C-ITS

CA is a mandatory facility of ITS-Stations for announcing and perceiving the existence of other surrounding ITS-Stations. CA generates the heartbeat messages, e.g., CAMs, that consist information of the vehicles basic status such as position, driving dynamics, etc. CAMs are broadcasted typically with a frequency of 1 Hz to 10 Hz, depending on the applied scenarios.

DEN facility is used for supporting applications related to the environment events, such as road hazard, that potentially will impact the traffic safety and efficiency. DEN generates and manages event triggered messages, e.g., DENMs, that consist information related to the concerning event information. Those messages are used to warn vehicles of certain events so that they can take precautions ahead of time. Thus, transmission of DENMs may require multi-hop message forwarding for reaching a larger area.

Based on information from CAMs, DENMs and other sources, LDM facility within the ITS-Station maintains a data base for supporting related ITS applications. Typical information within LDM include surrounding vehicles, stationary road infrastructures, etc. Information stored in LDM is usually time and location dependent. LDM provides a secure access mechanism for the ITS applications to access the data, where the data is provided as it is from the data providers.

Position and time facilities provide common functionalities for preparing geographical coordinates of the vehicles to be used by ITS applications, as well as time synchronizations.

4) Application layer: Application layer hosts the ITS applications that are expected to contribute to a safer, more efficient, and comfort transportation system. For accelerating the deployment of C-ITS, a Basic Set of Applications (BSA) are identified. BSA are chosen by considering the requirements of different stakeholders including vehicle manufactures, equipment suppliers, road authorities, etc. Meanwhile, the societal and economic effect including business potential, technology maturity, deployment, etc are considered. BSA are day-1 ITS applications that are expected to be deployed in the coming three years after the finalization of C-ITS R1. Main classes of applications in BSA include cooperative road safety, cooperative traffic efficiency, cooperative local and global services. A summary of major applications in BSA is shown in Fig. 7.

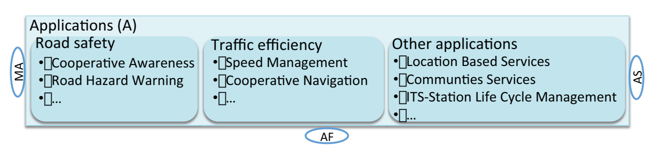

Fig. 7: Application layer of the ITS-Station communication architecture

Traffic safety applications aims at improve the safety of road users. Applications in C-ITS R1 focus on cooperative awareness and Road Hazard Warning (RHW). Use cases include collision warning, emergency vehicle approaching, signal violation, cooperative overtaking, cooperative lane merging, roadwork warning, etc. Traffic efficient applications aims at solving the transportation challenges in respect to the growing mobility requirements, such as optimizing the traffic flow and maximizing the road usage. Representative applications include speed management, cooperative navigation. Use cases include green light optimal speed advisory, traffic information dissemination, fleet management, route guidance, navigation, etc. The third class of applications are for the purpose of infotainment and convenience. Those applications are mostly based on internet and provide services such as location based services, communities services and ITS station life cycle management. *C-ITS R1 specifies in detail the BSA with corresponding use cases in TR 102 638. Moreover, detailed specifications for applications including road hazard signaling, intersection collision risk warning, and longitudinal collision risk warning are finalized in TS 101 539-(1-3) series. Furthermore, on the infrastructure side, TS 101 556-(1-3) series specify the communications system to support tyre pressure monitoring, energy supply for electric vehicles (EV), as well as EV charging spot notification.* A summary of the standards for ITS applications is shown in Table V.

Standard	Specifications
TR 102 638	Basic set of applications
TS 101 539-1	Road hazard signalling
TS 101 539-2	Intersection collision risk warning
TS 101 556-1	EV charging spot notification
TS 101 556-2	Tyre pressure monitoring system
TS 101 556-3	EV energy supply planning and reservation

TABLE V: ITS applications specifications in C-ITS

5) Management layer: Cross-layer information exchange provides an efficient method for improving the overall system performance. Management layer of C-ITS is one of the two layers defined with cross-layer functionalities. This layer provides management functionalities for all C-ITS communication layers, where optimal decision can be made by collecting and share information among all the other C-ITS layers. Main tasks for the management include management and maintenance of the policies for the other layers, the dynamic radio interface selection and transmission power allocation, security and privacy function management, as well as the cross-layer resource optimization. It is expected that the cross-layer management will fulfill the requirements of both safety critical applications and non-safety applications. C-ITS defines five modules for the management layer, which are illustrated in Fig. 8.

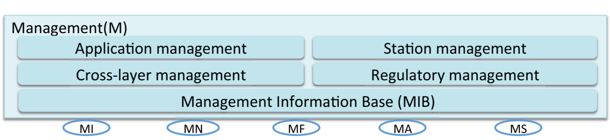

Fig. 8: Management layer of the ITS-Station communication architecture

Application management is responsible for the installation, configuration, as well as the maintenance and updating of the applications running on the ITS-Stations. Station management manages the ITS-Station such as control of hosts and routers in one station, control of communications with other stations, initialization and configuration of the station, inter-unit management communications within the station, the maintenance of the LDM, the dynamic interface allocations, and so on. Cross-layer management handles the cross-layer functions that enable all the layers to share and exchange information to maximize the performance. Regulatory management defines the a set regulatory information (RI) requirements, and ensures that the operation, such as the spectrum usage, should follow the regulations. Management information database (MIB) stores all the related information, such as the variables, profiles, policies, data sets, and so on, for the purpose of management. Vendor specific information can also be stored here to accommodate vendor dependent requirements.

In C-ITS R1, a management framework is specified in TS 102 860. Communication management and services announcement are detailed in TS 102 890-(1-2) series. Interfaces between the management layer and the rest layers including the access layer, the network & transport layer, the facilities layer, as well as interface between access and network & transport layer are defined in TS 102 702-3, TS 102 702-4, TS 102 702-5, and TS 102 723-10, respectively. Other interface specifications are either not frozen or can be referred to in ISO standards [10]. Management layer DCC entity is defined in TS 103 175, forming part of the DCC mechanism of the ITS-Station for general congestion control and resource optimization. Details of MIB are standardized in TS 102 723-3. A summary of the finalized standards for management layer is shown in Table VI.

Standard	Specifications
TR 102 707, TR 102 965, TS 102 860	ITS application objects
TS 103 175	Cross-layer DCC
TS 102 723-1	Cross-layer architecture and addressing
TS 102 723-2	Management information base
TS 102 723-3	Management and access interface (MA)
TS 102 723-4	Management and network & transport interface (MN)
TS 102 723-5	Management and facilities interface (MF)
TS 102 890-1	Facility layer communication management
TS 102 890-2	Facility layer services announcement

TABLE VI: Management layer specifications in C-ITS

6) Security layer: The security layer of C-ITS is also defined with cross-layer functionalities that interact with all other layers. This layer is a crucial and indispensable layer that is responsible for secure V2V and V2I communications and privacy protection. It is generally required that the security methods will make sure that all information communicated in the network are correct and trustworthy, and that the vehicle's privacy should be protected. Meanwhile, the communication should be extremely robust and fail-safe, even under the most critical scenarios. C-ITS defines four main modules for the security layer as illustrated in Fig. 9.

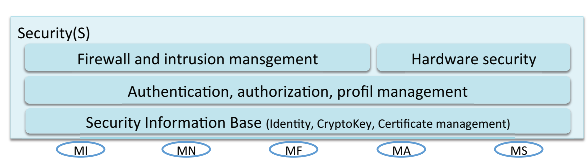

Fig. 9: Security layer of the ITS-Station communication architecture

Firewall and intrusion management module includes Gateway/Firewall for monitoring and checking the consistency of data flow between the communication system and in-vehicle system, thus preventing attacks through vehicle communications. It also includes a intrusion detection system for detecting potential tampering of the in-vehicle systems. Authentication, authorization, confidentiality, profile management module is for the secure communications among ITS-Stations. Information base manages the identities and certificates for all entities involving the vehicle communications. The hardware security module is the hardware where cryptographic material and safeguard data are stored and processed.

C-ITS R1 specifies the security analysis and security functional requirements regarding to the ITS applications within the BSA and a security architecture and management schemes in TS 102 940. TS 102 987 maps the security services in IEEE 1069 standards to the requirements of C-ITS, and identifies the applicability of IEEE standards in C-ITS, as well as security services that needs further developing. Trust between ITS-Stations are based on public key certificates and public key infrastructure. Privacy is protected by mechanisms of pseudonymity and unlinkability. C-ITS trust and privacy schemes are standardized in TS 102 941. Authentication and authorization services are detailed in TS 102 942 to be used for avoiding unauthorized access to CA and DEN services. Confidentiality requirements are specified in TS 102 943. A summary of the finalized standards is shown in Table VII.

Standard	Specifications
TS 103 940	Security architecture and management
TS 103 097	Security header and certificate formats
TS 102 893	Threat, vulnerability and risk analysis
TS 102 941	Trust and privacy
TS 102 942	Access control
TS 102 943	Confidentiality
TS 102 867	Mapping with CALM security mechanisms

TABLE VII: Security layer specifications in C-ITS

IV. On-going projects and future works

The finalization of the C-ITS R1 is expected to accelerate the pan-european deployment of an interoperable intelligent transportation system. A number of EU projects are in progress for initial deployment and validation. To name a few, FOTsis [11] is a large-scale EU FOT project for the deployment of C-ITS. Compass4D [12] is dedicated for testing C-ITS for red light violation warning, road hazard warning and energy efficient intersection. COMPANION [13] is based on ITS-G5 for testing the energy efficiency of platooning. i-GAME [14] aims at accelerating the cooperative driving through challenges and will arrange the second edition of Grand Cooperative Driving Challenge (GCDC) in 2016. AutoNet2030 [15] will develop cooperative automated driving technologies based on the mutual information sharing among nearby vehicles enabled by cooperative communication systems and in-vehicle sensors.

Meanwhile, standardization on C-ITS Release 2 is already in progress. Some topics such as more complicated applications and related facilities, two-way communications for enabling dialog/negotiation between vehicles, more flexible resource management and enhanced congestion control mechanism, and etc., are expected to be included. It is naturally expected that the C-ITS architecture will be continuously updated with functionalities based on the FOT results and the harmonization work with other standards.

Conclusions and Acknowledgment

This work provides in-depth and updated standardization information of C-ITS - EU's cooperative intelligent transport systems. The C-ITS functional architecture, together with detailed description of each of the communication layer are presented. The functionalities that has been finalized in the C-ITS Release 1 are highlighted and presented in detail. The work is expected to provide updated status for industry and academia for the progress of EU's cooperative ITS and accelerate the deployment of C-ITS for enabling cooperative mobility. Further work on the potential extensions of the standardization is in progress and a state-of-art of the cooperative systems is also under preparation. The work has been carried out within the EU project i-GAME, which will arrange the second edition of GCDC.

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