Standardizing smart transportation systems

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Abstract:
The field of transportation is in the throes of a revolution owing to digital technology. All forms of transport are becoming "smart", a process that involves the drafting of new standards for the digital technology used. Road transportation is a major focus given the number of possible applications (road safety, logistics, "electromobility", driverless vehicles…). Stakeholders in smart transportation systems are working out their solutions, while standardization allows for developing the ecosystem. A few examples of standardization organizations in this field are presented, as well as their standards for direct communication between vehicles, cooperative systems, urban mobility, emergency calls, the Internet of vehicles, and automatic urban rail systems. Complementary aspects of this standardization are pointed out: tests of interoperability; international harmonization and competition between organizations; the definition of a data semantics; and the sharing of the frequency spectrum between the uses and forms of technology.

Smart transportation systems

Digital technology has been introduced in our everyday lives and, now, in transportation.[1] This new technology is more efficient and user-friendly while increasing the safety of the persons and goods being transported. This revolution is affecting all forms of transit.[2] The total market is estimated at several billion dollars.

Digital technology has enabled us to cope with the growth in air traffic while keeping security high; it has helped us protect ships against collisions or from pirates on the seas; and the ceaseless exchanges between trains and control centers provide instantaneous information about each train and monitors passenger movements. Electronic technology also helps us coordinate all these forms of transportation thanks to multimodal transit and ticketing systems.

Smart highway transportation

Road transportation is not dragging its feet, quite to the contrary! Digital technology is already optimizing the shipment of goods by road, thanks to freight tracking and identification systems. As for the management and maintenance of fleets of trucks, vehicles can be equipped to inform the driver or manager about technical problems or, more simply, send a reminder for inspections. Furthermore, navigation systems process in real time the data received from the highway network. A monitor can follow connected vehicles, detect their speeds and assess traffic flow. Many applications are possible, whether for managing safety, traffic, distractions, information or "electromobility".

[1] This article has been translated from French by Noal Mellott (Omaha Beach, France). The translation into English has, with the editor's approval, completed a few bibliographical references. All websites have been consulted in April 2019.

[2] See the European Commission website "Mobility and Transport, Transport Modes" at https://ec.europa.eu/transport/modes_en.

Improving rider safety and drastically reducing by 2050 the number of deaths caused by accidents are among the objectives of cooperative intelligent transportation systems (ITS-C) or, in broader terms, of an autonomous, connected cooperative mobility.[3] In an ITS-C system, various entities in road traffic exchange information in order to extend their knowledge of traffic beyond their visual field, whence the idea of an extended horizon.

ITS players

The ITS station is the basic element in ITS-C architecture.[4] There are four types of ITS stations: vehicle stations, roadside stations, personal devices (*e.g.*, smartphones) and the central station, which manages the road and digital networks (*cf*. Figure 1). The major difference between them is the type of mobility (fast, slow, stationary) and their functions in the system of cooperation.

Figure 1: Different types of ITS stations

This technology comes with high economic stakes. Consequently, competition sometimes carries over into the process of standardization, which, by overseeing the interoperability of the equipment made by different firms, gives a boost to certain forms of technology. ITS solutions fall into one of two categories: proprietary solutions (which a firm adopts as part of its sales pitch to customers) and standardized solutions (which enable the market to grow and make manufacturers and service-providers compete). In the first case, the objective is to turn a product into a *de facto* standard so as to occupy a dominant position in the market. However standardization, when justified, is impartial with respect to the market's equilibrium and evolution.[5] It opens market doors to small and medium-sized businesses, allows for improving products and their compatibility, and thus produces economies of scale. For these reasons, standards should have a scope restricted to specifications for performance or interfaces so as not to clip the wings of invention.

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[3] Communication from the European Commission (2008) "Action plan for the deployment of Intelligent Transport Systems in Europe", COM(2008) 886 final, 15p. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1554897925680&uri=CELEX:52008DC0886.

[4] ETSI EN 302 665 (2010) "Intelligent Transport Systems (ITS) – Communications architecture", available via https://www.etsi.org/deliver/etsi_en/302600_302699/302665/01.01.01_60/en_302665v010101p.pdf.

[5] ABDELKAFI N., BOLLACEES R., LANTING JM., RODRIGUEZ-ASCASO A., THUNS M. & WETTERWALD M. (2018) *Understanding ICT Standardization: Principles and Practice* (Sophia Antipolis: ETSI) 276p. available via https://Fwww.etsi.org/images/files/Education/Understanding_ICT_Standardization_LoResPrint_20190125.pdf.

Examples of standards

Let us look at a few standards that are contributing to ITS and to cooperation or sometimes competition between standards organizations.

IEEE: Wireless local area network (LAN)

The IEEE is mainly known for its standard 802.11, the grounds for Wi-Fi.[6] In practice, standardization by the IEEE covers many fields, among them: the Internet of things (IoT), e-health and robotics. Standard 802.11 provides for local area networks under the control of an access point. It allows for *ad hoc* links between two or more nodes (meshed network). Automakers borrowed and developed this feature to design the variant of ITS-C called 802 11p or 802.11-OCB ("*outside the context of a basic service set*"). This amendment allows for communication between fast moving vehicles (or ITS stations) by adapting the technical properties of communications at the radio, physical and logical levels. In particular, it adjusts for the Doppler effect, which can be important when, for example, one vehicle passes another coming from the opposite direction.

ETSI: Cooperation between vehicles

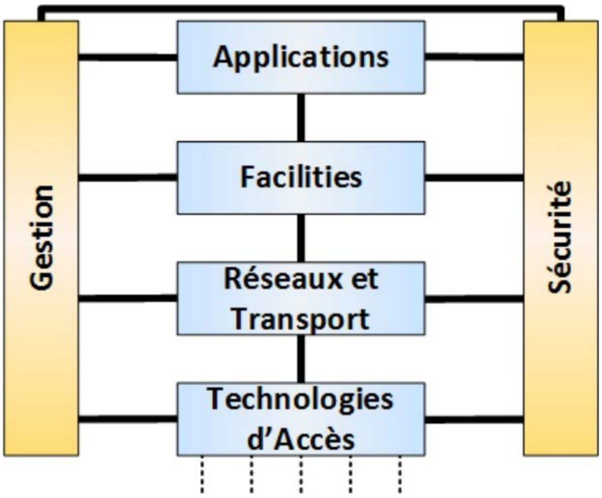
Basing its work on IEEE 802.11-OCB, ETSI's ITS technical committee has, at the European Commission's request in 2009, developed a set of standards for cooperation among vehicles.[7] These standards are articulated in an architecture based on the ISO's model and divided into four independent layers (Figure 2) — applications; facilities (or services); networks and the transportation (of data); and access (to networks) — along with two vertical dimensions for, on the one hand, the management of stations and coordination between layers and, on the other hand, the security of communications.[8] Thanks to this model, ITS stations can transmit messages for cooperation, send notifications (of events) and activate signals (inside the vehicle). The knowledge that vehicles and drivers have about their environment is thus continually enhanced.

[6] IEEE 802.11-2016, "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" available at https://standards.ieee.org/standard/802_11-2016.html.

[7] EUROPEAN COMMISSION (2009) "Standardisation mandate M/453 addressed to CEN, CENELEC and ETSI in the field of electrotechnology, information technology and telecommunications to support the interoperability of cooperative systems for intelligent transport in the European Community" available at http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=434.

[8] WETTERWALD M. (2015) *Les normes européennes dans les STI coopératifs*, Dossier n°TRP1007, Base Documentaire: Technologies Avancées et Système de Transport, Les Techniques de l'Ingénieur, February.

__Figure 2__: Layers in the ITS station model



This layered model allows for sending messages via various network protocols (such as GeoNetworking[9] or the better known IP) and various types of network access points. The European Committee for Standardization has developed another set of standards with a similar purpose (CEN TC 278 WG16 in partnership with ISO TC 204 WG18).

These two sets of protocols are rivals for market endorsement. The first standard for vehicular communication was drawn up by ETSI in association with European automakers: ITS-G5 (the European equivalent of IEEE 802.11-OCB). More recently, mobile telephone operators have come to realize the worth of this market and have formed an alliance with international manufacturers of electronic chips and telecommunication products to propose to the 3rd Generation Partnership Project (3GPP) LTE/V2X, a rival standard under which mobile networks based on 4G manage access.[10] New international players have joined the process for standardizing ETSI's ITS, and they demand "technological neutrality" so as to be able to compete with the initial standard. Their objective is to use the radio band 5.9 GHz, reserved for ITS-C. This calls for a new infrastructure, different from the one used for mobile telephony, which uses lower frequencies. Besides, these two forms of technology cannot reside on the same frequency without interfering with each other.

ISO: Urban mobility

The movement of goods and persons is an important issue for smart cities. In 2016, the European Commission issued a mandate (M/546) requesting European standardization organizations to set standards for multimodal transport, traffic management and urban logistics.[11] This mandate is mainly executed by CEN TC 278 WG17. The standards being drafted focus on: the needs for a harmonization of the geographical areas covered; the quality of traffic management systems; and the management of emissions in urban areas.

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[9] ETSI (2014) "Intelligent Transport Systems (ITS) – Vehicular Communications – GeoNetworking – Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications – Sub-part 1: Media-independent functionality, EN 302 636-4-1",

[10] 3GPP (2018) "Architecture enhancements for V2X services (Release 14), TS 23.285" available at https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3078.

[11] European Commission Implementing Decision of 12.2.2016 on a standardization request to the European standardization organizations as regards Intelligent Transport Systems (ITS) in urban areas in support of Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport. Available via: http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=select_attachments.download&doc_id=1623

CEN: Emergency calls (eCall)

This European initiative, eCall, has the objective of providing rapid assistance to motorists in case of collision. When the system detects a collision (via the airbags for example) or is activated manually, it dials 112 for rescue services (Figure 3). The call is transmitted with a set of data about the vehicle, its location and even the passengers or load. The operator calls the vehicle to communicate with the driver and assess the situation.

Figure 3: eCall, a system for emergency calls.
Source: European Commission (2018) "The interoperable EU-wide eCall" at https://ec.europa.eu/transport/themes/its/road/action_plan/ecall_en.

The European Committee for Standardization (CEN) has standardized this technology in cooperation with 3GPP.[12] The standards contain specifications for: the system's operation; the contents and format of the minimum set of data to be transferred during emergency calls; the methods for transferring calls over the cellular network; and tests for validating equipment. This technology has been made available for several years now in up-scale vehicles (sold by BMW, PSA and Volvo) via proprietary solutions that communicate with the automaker's customer service platform. A standardized, interoperable system will be generalized to all new models of motor vehicles as of April 2018, thus extending this offer to all vehicle drivers in the EU.[13]

IETF: Vehicles and the Internet

Some vehicles already have connections with the Internet, mainly via the driver's smartphone and the platforms of big Internet firms. The Internet Engineering Task Force (IETF) has set up a work group (IPWAVE) to study how to connect vehicles or other ITS stations to a network using Internet Protocol (IP). ITS-C messages are designed to be transmitted with lighter, more suitable network protocols. IPWAVE is also analyzing how to adapt IPv6 features to support a highly dynamic network

[12] CEN (2015) "Intelligent transport systems - ESafety - ECall minimum set of data - This European", EN 15722:2015. Available at https://www.en-standard.eu/csn-en-15722-intelligent-transport-systems-esafety-ecall-minimum-set-of-data/.

[13] European Union (2015) "Regulation (EU) 2015/758 of the European Parliament and of the Council of 29 April 2015 concerning type-approval requirements for the deployment of the eCall in-vehicle system based on the 112 service and amending Directive 2007/46/EC" available at https://eur-lex.europa.eu/eli/reg/2015/758/oj.

topology (with an impact on the detection of nearby stations) with very short connection times (sometimes barely a few seconds). The procedures for configuring the address have to be simplified. Initially, this work group focused on the state of the art and related problems; and it wrote a Request for Comments (RFC) about how to use IPv6 in 802.11-OCB.

This work group has close ties with other standardization organizations (ETSI, ISO TC 204 or IEEE P1609) and contributes to their standards.

ETSI: Automatic urban rail traffic

To enable railroads to control and manage their traffic, the use of wireless communications is necessary to guarantee safety and long-term sustainability. For the safety of urban rail lines, communications-based train control (CBTC) uses the train's location and the communications between the train and track equipment. In this system (used in the subway system, for example), automatic devices along the track and on board the train assume the functions of protection, operation and supervision.

The CBTC system follows standard IEEE 1474.1, which sets the rules of operation.[14] Communications are based on IEEE 802.11 (using the frequencies 2.4 GHz or 5.9 GHz). ETSI's Rail Transport Committee, which drafted the standard on GSM for trains, is examining updates to this technology and the specifications for CBTC radio performances, especially for coexistence with ITS-C.

Other aspects

Validation of standards and tests of interoperability

While standards are being drafted, prototypes are made to validate specifications. For ITS-C, several full-scale tests have been successfully carried out since the first demonstrations of vehicle-to-vehicle (V2V) communications up to plans for pilot deployment on thousands of vehicles: SCOOP@F in France, Eco-AT in Austria and C-ROADS in Europe. ETSI also regularly organizes tests of interoperability.

In November 2016, the fifth testing campaign demonstrated the maturity of ITS-C on roads of access to the port of Livorno in Italy.[15] Use cases such as warnings that the number of traffic lanes was being reduced, that the vehicle had run a red light or that there was a risk of collision (Figure 4) were tested along with the solutions proposed by twenty-five equipment-makers and six test tool-vendors and support companies. Since the LTE/V2X standards had not yet been drafted, these tests were conducted using equipment compliant with ITS-G5.

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[14] IEEE (2004) "Standard for communications-based train control (CBTC): Performance and Functional Requirements", IEEE 1474.1-2004 available at https://standards.ieee.org/standard/1474_1-2004.html.

[15] ETSI CTI (2016) "5th ITS Cooperative Mobility Services Plugtests Report; Livorno, IT, 9-18 November 2016", technical report V1.1.1 2016-11 -Sophia Antipolis: ETSI), 44p. available via https://portal.etsi.org/Portals/0/TBpages/CTI/Docs/5th_ITS_CMS_PLUGTEST_REPORT_FINAL.pdf.

Figure 4: Warning: Risk of collision

A test campaign scheduled for 2019 is to concentrate on the interoperability of security procedures: certificates and anonymization of vehicles to avoid tracking.

International harmonization

Several standardization organizations have teams working on ITS. In the United States, IEEE P1609 in collaboration with the Society of Automotive Engineers (SAE) has drafted a set of protocols for ITS-C. There are several pilot zones (New York, Wyoming, etc.) with a large number of vehicles.

Since 2009, an EU-US partnership — managed along with the US Department of Transportation[16] and extended since then to other countries (such as Japan and Australia) — has harmonized the format of the data to be conveyed in messages. Harmonization Task Group 7 (HTG7) is analyzing standards in various regions on the globe in order to identify omissions, differences and duplicates.

Data exchanges and semantics

ITS-C allows for exchanging messages containing static and dynamic data about the vehicle and the road. However these raw data are not, as such, worth using. A semantics has to be associated with them, *i.e.*, a set of metadata about types of data, measurement units, the scales used, etc. It is important to define this semantics and a paradigm for a set of common data, both for the data coming from ITS-C entities and the data transferred from the highway system, which applies its own standards (CEN DATEX II, CENELEC RDS-TMC). For interoperability with automaker platforms, standards are drafted using formal languages. The data for ITS-C are, for example, defined in a data dictionary that also uses the standards from the highway system.[17] ETSI is busy defining the semantic

[16] Intelligent Transportation Systems Joint Program Office: https://www.its.dot.gov/index.htm.

[17] ETSI (2018) *Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary*, TS 102 894-2 available via https://www.etsi.org/deliver/etsi_ts/102800_102899/10289402/01.02.01_60/ts_10289402v010201p.pdf.

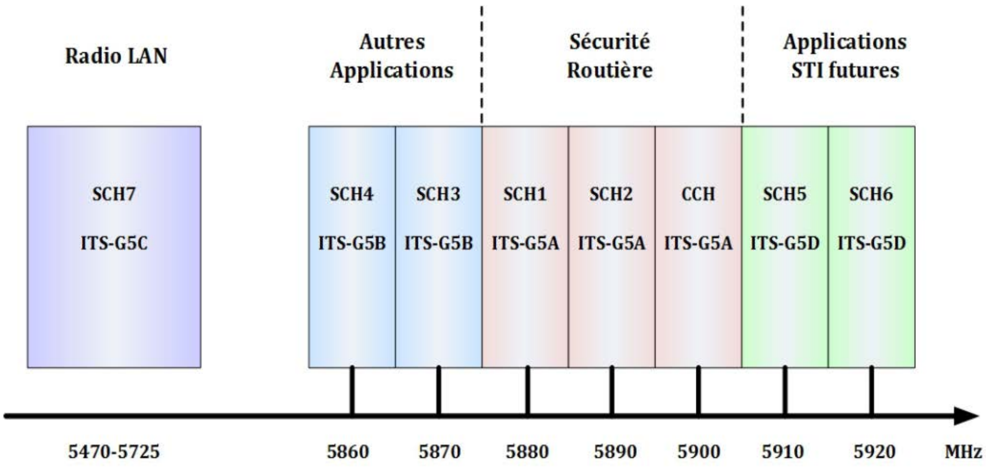
interoperability of data between, on the one hand, the mobility sector and vehicles and, on the other hand, vertical sectors such as smart cities or agriculture.

Allocating the radio spectrum

The radio bandwidth 5.8-5.9 GHz has been allocated for ITS applications with certain bands reserved for road safety (*cf*. Figure 5).[18] This bandwidth, accessible without a license, is put to several uses: ITS applications, broadband Wi-Fi, electronic toll collection, urban rail transit and satellites.

The coexistence of these various applications entails procedures for protecting access so as to avoid lowering the performance, which would jeopardize ITS and the safety of persons. When a Wi-Fi station detects an ITS station, it releases the frequency and switches to another. An ETSI standard (TS 102 792) protects toll collection areas with an ITS-C beacon that makes vehicles reduce the power of the signals they emit.[19] Work is under way to define a similar mutual protection procedure between urban rail transit and ITS-C.

Figure 5: Allocated frequencies in Europe



The problem of the coexistence between forms of access technology based on ITS-G5 and LTE/V2X is more difficult. Cellular access is to use the same frequencies as ITS-G5 for the same use cases, whence the risk — counterproductive — of mutual interference.

[18] ECC: Electronic Communications Committee (2015) "Decision of 14 March 2008 on the harmonized use of the 5875-5925 frequency band for Intelligent Transport Systems (ITS), approved 14 March 2008 and amended 3 July 2015, ECC Decision (08)01 available via http://spectrum.welter.fr/international/cept/ecc-decisions/ecc-decision-(08)01-ITS-5-GHz.pdf; & European Commission (2008) "Commission Decision 2008/671/EC of 5 August on the harmonized use of radio spectrum in the 5875-5905 MHz frequency band for safety related application of Intelligent Transport Systems (ITS)" available at https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32008D0671.

[19] ETSI (2015) "Intelligent Transport Systems (ITS); Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (CEN DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range", TS 102 792 v1.2.1. Available at https://joinup.ec.europa.eu/solution/etsi-ts-102-792-v121-2015-06-intelligent-transport-systems-its-mitigation-techniques-avoid/about.

Conclusion

The now underway digitization of transportation systems is one of the coming revolutions in our society that will bring along various applications. The economic stakes are high. Several organizations are standardizing this new technology — evidence of the efforts of players to gain access to this market. Different work groups actively compete to set standards. In some cases, no clear consensus arises out of the technical criteria based on efficiency. Regional, commercial or political considerations come into play in the choices to be made, choices that will sometimes be incorporated in legislation. The eCall standard provides a good example of this. Its rollout can be set down to a political decision that legally forced automakers to install this system on all new vehicles. Such decisions and regulations are capable, in the short run, of boosting safety for persons and freight thanks to ITS. Lives can be saved even when the commercial interests of players in this market stand in the way.