Chapter 1
Introduction

1.1 Principles and Challenges

Intelligent Transportation Systems (*ITSs*) promise to hugely improve safety, efficiency and sustainability of our transportation system, by means of a massive adoption of Information Communication Technologies (ICTs) [1–3]. Not surprisingly, in last decades ITSs have attracted the worldwide interest of researchers, automotive companies, and governments. In order to create an economically sustainable ITS ecosystem, a large number of projects have been conducted by institutions from all around the world [4]. For instance, the Advanced Safety Vehicle (ASV) program in Japan [5], the IntelliDrive project in the United States [6], and, in Europe, the numerous projects coordinated by the Car 2 Car Communications Consortium (C2C-CC) [7], strongly supported by the European Commission [8] and by the European Telecommunications Standards Institute (ETSI) [9].

In the marketplace, ITSs boast a long series of success histories, carried out by either car manufacturers (with active safety systems), toll road infrastructures operators (with Electronic Tolling Systems), insurance companies (with black boxes), Internet companies (with traffic information systems). However, current ITS hardware, software, and communication technologies are closed, i.e., unable to share data and cooperate together. In other words, current ITS applications are implemented as "silos", thus yielding to equipment duplication and no data sharing. Such a fragmented approach is typical of the first development phase of new technologies, where innovation is driven by pioneers. Figure 1.1 illustrates some significant ITS applications, implemented according to the stand-alone or not-cooperative approach.

Next years' biggest challenge will be to achieve a *Cooperative ITS* (*C-ITS*) ecosystem, where secured data are shared across several ITS applications developed by independent actors, leveraging on a solid basis of international standards, as represented in Fig. 1.2. Such a C-ITS ecosystem would facilitate actions and decisions that improve transportation safety, sustainability, efficiency and comfort beyond that achievable by stand-alone ITS systems.

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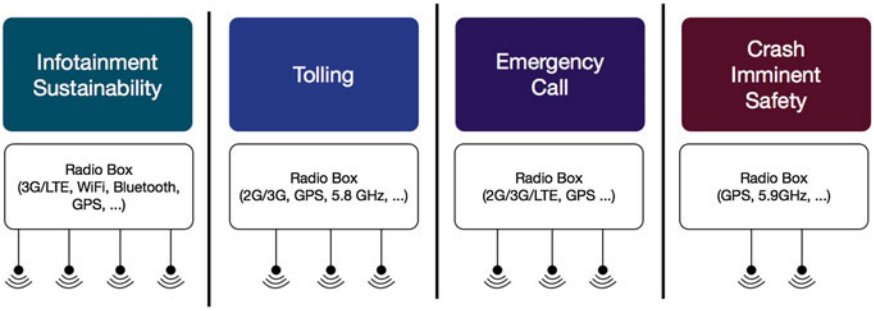

Fig. 1.1 Stand alone ITS

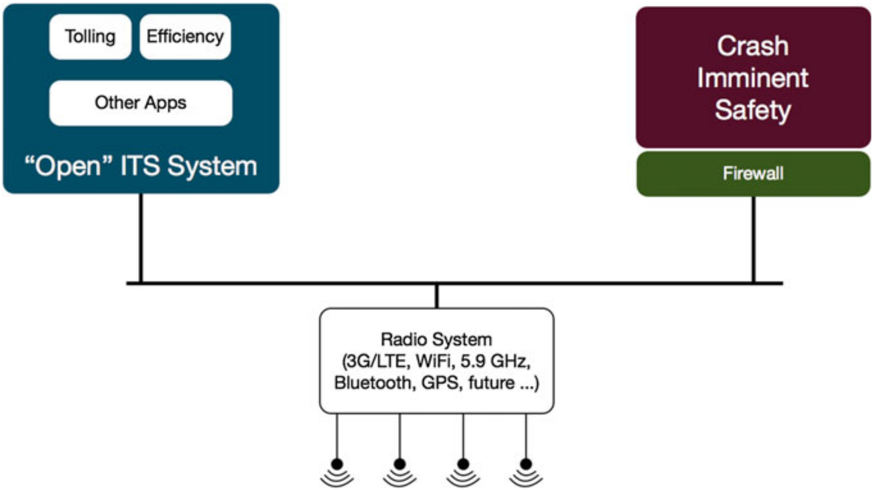

Fig. 1.2 Cooperative ITS

Future integrated ITSs will exploit vehicles provided with sensorial, cognitive, decision and communication functionalities. Therefore, such *smart* vehicles will be able to perceive the surrounding environment, collecting both public-interest information (e.g., air pollution measurements) or obtaining data for the autonomous real-time management of the vehicle itself [10–13]. Current vehicles are equipped with a large number of sensors—over 100, but it depends on the maker and model. Examples are oxygen sensor, crankshaft and camshaft position sensors, mass air flow (MAF) sensor, coolant temperature sensor, etc. All these sensors send data to the *Engine Control Units* (*ECUs*), which are embedded systems that control one or more of the electrical systems/subsystems of the vehicle. In a recent interview, Bill Ford, executive chairman of Ford Motor Company, observed that as computer involvement becomes more active, cars will drive themselves in platoons—groups of vehicles linked on the highway for efficiency, eliminating traffic accidents at intersections.[1]

1.2 Standardization History and Open Issues

The realization of ITSs involves an exceptionally high number of stakeholders, including public administrations, transportation authorities and companies coming from a variety of industrial sectors (vehicles manufacturers, OEM and tier-1 producers, telecommunications companies, consumer electronic, service providers). From both technological and industrial perspectives, ITSs are one of the hardest challenge faced by ICT community. The presence of worldwide harmonized standards is a key requirement to drive the success of ITSs and exploit all their potentiality.

Since the end of '90s, industrial stakeholders as well as European Union (EU), United States of America (USA), Asia governments have invested a huge amount of economical resources in the standardization process of ITSs, involving numerous Standards Development Organizations (SDOs)—IEEE, ISO, European Committee for Standardization (CEN), CENLEC, ETSI, IETF, Society of Automotive Engineers (SAE), FCC, and others.

1.2.1 Worldwide Standardization Process

ISO/TC 204 is the ISO workgroup responsible for the overall system aspects and infrastructure aspects of ITSs, as well as the coordination of the overall ISO Work Program in this field, including the schedule for standards development, taking into account the work of existing international standardization bodies. Standardization efforts in ISO TC 204 produced the Communications Access for Land Mobiles (CALM) concept—defined in standard ISO 21217:2010 and subsequent ISO 21217:2013 [14] by the Work Group 16 (WG16)—and ETSI TC ITS, based on the recent European ITS Communication Architecture. CALM and ETSI TC ITS have paved the way towards C-ITS.

The CALM System Architecture, illustrated in Fig. 1.3, is a layered solution, enabling continuous Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and even Infrastructure-to-Infrastructure 2I communications. It is based on multi-channel terminals capable of connecting to a wide range of potential carriers, and on IPv6, as an unification layer of underlying technologies. Moreover, it is able to select the optimal wireless telecommunications media that are available in any particular location, and to switch to a different media when necessary. Validated by the European project called CVIS, CALM has been conceived to be able to exploit a large number of different media: Cellular Networks (2G, 3G), Infrared (highly directive

[1] http://www.wired.co.uk/news/archive/2012-02/28/bill-ford-mwc.

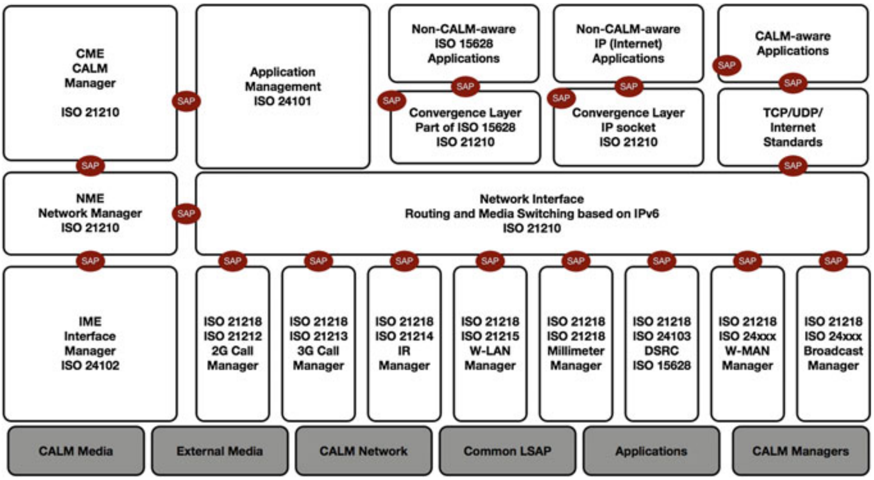

Fig. 1.3 Communications access for land mobiles (CALM) architecture

beams), Microwave CALM M5 ISO 21215—i.e., IEEE 802.11 a/b/g (WiFi) and IEEE 802.11p (mobile WiFi), providing roughly 6 Mbps up to 300 m radius—, Millimeters waves (CALM MM), and Microwaves CEN DSRC.

1.2.2 European Vision

Historically, Europe has been a worldwide leader in ITS development, principally for being the homeland of many important vehicle manufacturers. In last decades, several initiatives have been promoted either by public governments, industrial entities and standardization bodies.

1.2.2.1 Government Actions

Since long time, the European Union (EU) is quantitatively aware of the negative effects of traffic congestion, in terms of Gross Domestic Product (GDP) loss, energy efficiency reduction and CO_2 emission boost. ITSs are considered very important instruments to cope with these issues. The interest on ITSs has been materialized in a series of important political acts, with huge economical resources granted to international research projects.

One of the first European political act supporting ITSs was the foundation of the *Ertico-ITS* Europe organization in 1991, an initiative of leading members of the European Commission (EC), Transport Ministries and European companies. The goal of Ertico-ITS Europe is to bring intelligence into mobility, working together in public/private partnerships towards zero accidents, zero delays, reduced impact on the environment, fully informed people, with affordable and seamless services, respected privacy and ensured security [15].

On June 2005, the EC started the *European Information Society 2010* (*i2010*) initiative, a comprehensive strategy for modernizing and deploying all EU policy instruments to encourage the development of the digital economy. i2010 consists of three pillars: a Single European Information Space, Innovation and Investment, and an Inclusive European Information Society. The *Intelligent Car Initiative* is one of the three Flagship initiatives proposed within the third pillar, with the objective to raise the visibility of the vital contribution of ICT to the quality of life. The Intelligent Car Initiative on smart, safe and clean transport, focuses on road vehicles and addresses safety and environmental challenges caused by increased road use.

Then, in 2008 the EC took a major step towards the deployment and use of ITS in road transport, by adopting a dedicated Action Plan [16], whose goal was to create the momentum necessary to speed up market penetration of rather mature ITS applications and services in Europe. As a direct consequence of the Action Plan, in July 2010, the European Parliament and the European Council adopted the Directive 2010/40/EU [17], establishing a legal framework for the deployment of ITSs in the field of road transport and for interfaces with other modes of transport. The Directive 2010/40/EU is an important instrument for the coordinated implementation of ITS in Europe, aiming to establish interoperable and seamless ITS services while leaving Member States the freedom to decide which systems to invest in. According to the requirements of the Directive 2010/40/EU, the EC has to define and adopt, by 2017, specifications for compatibility, interoperability and continuity of ITS solutions across the EU. The main priorities are traffic and travel information, the eCall emergency system and intelligent truck parking.

Figure 1.4 summarizes the sequence of ITS programmes funded by the European Commission (EC) in the last two decades. The first ITS project was the famous *PROgraMme for a European Traffic of Highest Efficiency and Unprecedented Safety* (*PROMETHEUS*) [18], started in 1987, that was the largest R&D project ever in the field of driverless cars. Then, there was a series of projects focused on all aspects of ITS. The first program with interventions in the field of vehicular communication has been the Fifth Framework Programme (FP5), in the 2000–2003 period, where projects like FleetNet and CarTalk2000 have been carried out. In subsequent FPs (FP6, FP7), many other projects related to car communications have been founded, such as Safespot, NoW, Coopers, GeoNet and CVIS.

1.2.2.2 Industrial Cooperation

In the ITS domain, European industries and companies have carried out a profitable cooperation since a long time. The most brilliant example, in the field of cooperative vehicular communications, is represented by the *CAR 2 CAR Communication Consortium* (*C2C-CC*),[2] a nonprofit, industry-driven organization initiated by European

[2] http://www.car-to-car.org.

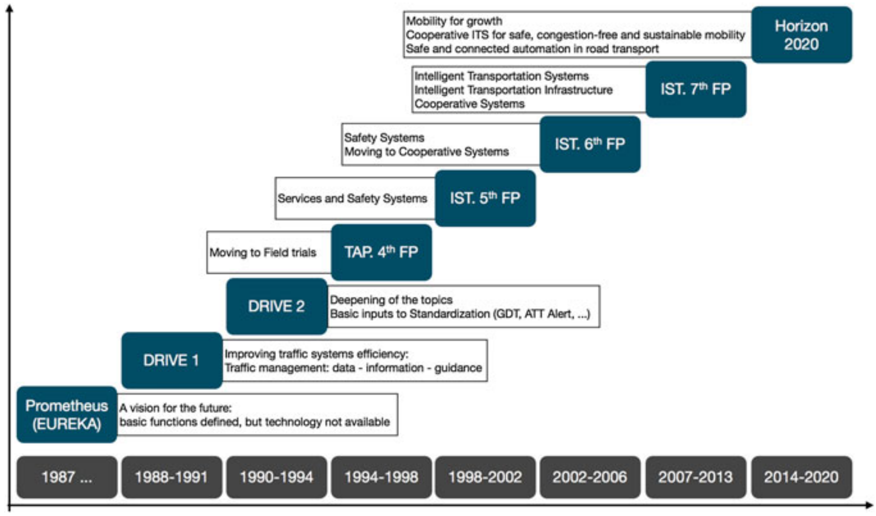

Fig. 1.4 European union roadmap on ITSs

vehicle manufacturers and supported by equipment suppliers and research organizations. C2C-CC, directly or through its partners, is usually involved in R&D projects funded by the EC, and actively cooperate with standardization bodies. The mission and the objectives of the CAR 2 CAR Communication Consortium are:

- to create and establish an open European (possibly worldwide) industry standard for CAR 2 CAR Communication Systems;
- to guarantee inter-vehicle operability;
- to enable the development of active safety applications by specifying, prototyping and demonstrating the CAR 2 CAR system;
- to promote the allocation of a royalty free European-wide exclusive frequency band for CAR 2 CAR applications;
- to push the harmonization of CAR 2 CAR Communication standards worldwide;
- to develop deployment strategies and business models to speed-up the market penetration.

Recently, C2C-CC has constituted another voluntary cooperation platform of leading European ITS stakeholders, denoted as *The Amsterdam Group*.[3] Other important members of C2C-CC are: the European professional association of operators of toll road infrastructures (ASECAP), the European organization for national roads administration (CEDR), the network of European cities and regions working together to develop innovative technologies and policies for local transport (POLIS). All the members of Amsterdam Group have signed a Memorandum of Understanding (MoU), which creates a framework for the harmonized implementation and deployment of cooperative ITS in Europe by 2015.

[3] https://amsterdamgroup.mett.nl.

1.2.3 American Vision

1.2.3.1 Government Actions

ITS development in the USA has followed an evolutive process which in in most aspects overlaps with the European and Japanese ones. In the same period of the launch of the first European ITS projects (namely Drive and Prometheus), and the second wave of Japan projects (i.e., RACS), a number of initiatives started all around the USA, under the initiative of private companies, universities, State Governments and the Federal Government. Just to name a few, we recall Smart Corridor, Pathfinder, GuideStar, and the Partners for Advanced Transportation TecHnology (PATH) projects [19]. However, at least in first years, in the USA the amount of public funds dedicated to ITS projects was significantly smaller than in Japan and Europe [19].

The principal organ of the Federal Government involved in ITS development has always been the United States Department of Transportation (USDOT), which has ofter operated through one of their agencies, such as Federal Highway Administration (FHWA), National Highway Traffic Safety Administration (NHTSA), and the Research and Innovative Technology Administration (RITA), which was created in 2005 with the mission to advance transportation science, technology, and analysis, and to improve the coordination of transportation research within the Department and throughout the transportation community. Furthermore, under the USDOT initiative, in 1991 the *Intelligent Transportation Society of America* (*ITS America*),[4] the largest organization dedicated to advance the research, development and deployment of ITSs, was founded. ITS America has played a major role in laying the groundwork at the Federal Communications Commission (FCC) and other agencies, for the use of the electromagnetic spectrum and other telecommunication infrastructures as the foundation for almost all ITSs. Thanks to such an effort, in 1999, a 75 MHz spectrum in the 5.9 GHz bandwidth was set aside by the FCC. The idea was to allocate a spectrum that could be used for the development of Vehicle-to-X (V2X) communications, without fearing potential signal interference from non-automotive users.

1.2.3.2 The ITS Strategic Research Plan

Since 2009, the strategic directions of USDOT's ITS are established in a 5-years long program, denoted as ITS Strategic Research Plan. At the time of writing this book, the ITS Strategic Research Plan 2010–2014 is being completed, while the subsequent 2015–2019 program is in course of definition. The vision of the ITS Program for 2010–2014 is to provide USA with a national, multimodal transportation system, which delivers connectivity among vehicles of all types, the infrastructure, and portable devices, thus realizing an integrated connected vehicle environment [20]. The expected outcomes of such a research include the determination of the potential

[4] http://www.itsa.org/.

benefits of connected vehicle technologies and evaluation of driver acceptance of vehicle-based safety systems, as well as the identification of research gaps and the ways to address them. Other outcomes include factual evidence needed to support a 2013 NHTSA agency decision on the deployment of these technologies for light vehicles. The ITS strategic research plan involves several ITS research areas, including connected vehicles, mobility, environment, road weather management, integrated corridor management, ITS asset viewer and multimodal transportation systems. The Connected Vehicle project is a pillar of current ITS plan and will be discussed in next section.

1.2.3.3 Connected Vehicle Program

The Connected Vehicle program is a large set of research activities related to vehicles equipped with communications and processing power, able to communicate with each other and with the surrounding infrastructure. V2V connections allow for crash prevention, while V2I connections enable safety, mobility, and environmental benefits. Moreover, connections among vehicles, infrastructure, and wireless devices to provide continuous real-time connectivity to all system users.

The Connected Vehicle project supports both non-DSRC and DSRC technologies, but for all security-related applications it does strongly rely on DSRC, because of its high availability and very low latency characteristics. For this reason, USDOT has participated in the development of all DSRC-related standards that are critical to the connected transportation environment, including IEEE 802.11p (amendment to IEEE 802.11) [21], the vehicle-centric IEEE 1609 series (known as IEEE 1609.x) [22] and the SAE J2735 DSRC message set standard [23].

Connected vehicle safety applications are designed to increase situational awareness and reduce or eliminate crashes, by means of V2V and V2I data communications. Connected vehicle mobility applications provide a data-rich travel environment. Such communications should support driver advisories, driver warnings, and vehicle and/or infrastructure controls, by capturing real-time data from automobiles, trucks, and buses, and within the transportation infrastructure. Data are transmitted wirelessly and are used by transportation managers in a wide range of dynamic, multi-modal applications, to manage the transportation system for optimum performance. As part of this, connected vehicle environmental applications both generate and capture environmentally relevant real-time transportation data, and use such data to support and facilitate green transportation choices, thus reducing the environmental impact of each trip. In August 2012, the USDOT started the Connected Vehicle Safety Pilot project, a 1-year length trial involving over 2,800 vehicles, in Ann Arbor (Michigan, USA). The goal of the trial is to assess the capacity of vehicular communication technology to improve safety. In detail, the pilot is not only testing the technical reliability of Dedicated Short-Range Communications (DSRC) devices in real-world conditions, but also how drivers adapt to the technology, and how they respond to in-vehicle warnings. The trial was initially supposed to last one year, but it has been extended by another 6 months. At the end, National Highway Traffic

Safety Administration (NTHSA) will use the results from the Safety Pilot to decide whether to advance the technology through regulatory proposals, additional research, or a combination of both. The cost of the trial is 25 million dollars, 80 % funded by the USDOT.

1.3 ITS Architecture

1.3.1 A Global Standardization Effort

As discussed in previous sections, in last decades governments and private companies have been involved in global ITS standardization and harmonization efforts, coordinated by a large number of SDO. Thanks to this long cooperation history, nowadays there is a general consensus about the ITS architecture and related communication protocols, but we are still far from having market-ready implementations.

In order to enable effective collaboration, by establishing a common vocabulary, experts from a number of SDOs developed the concept of *ITS station* (*ITS-S*), which is described in standard ISO 21217 (CALM). At the highest level of abstraction, an ITS-S is a set of functionalities in a bounded, secured, managed domain, which provides communication services to resident applications (ITS-S applications). From an architectural perspective, an ITS-S is a set of functionalities in an Open Systems Interconnection (OSI)-like layered model (from ISO/IEC 7498-1). Example functionalities are those to securely manage applications and communication resources. The ITS-S concept and its architecture have been adopted by CEN TC278, by ETSI TC ITS and by ISO TC204, and is discussed in next section. A different approach is the WAVE one, which is discussed in a dedicated section.

1.3.2 ISO/ETSI ITS Station Architecture

Starting points for the definition of a common ITS Communication (ITSC) architecture are the ETSI EN 302 665 standard [24], and the Communications Access for Land Mobiles (CALM) [25] family of standards—in particular, ISO 21217:2013 and its predecessor ISO 21217:2010 [14].

The ITSC architecture is designed around the concept of ITS station (ITS-S), a modular computing unit provided by communication capabilities, which can be installed virtually anywhere. As shown in Fig. 1.5, the ETSI EN 302 665 standard defines four main ITS-S types:

- Vehicle ITS Stations: embedded or after-market devices in road-enabled vehicles (cars, trucks, bus, motorcycles), both in motion or parked;
- Roadside ITS Stations: installed at the roadside, at road gateways, on traffic lights;

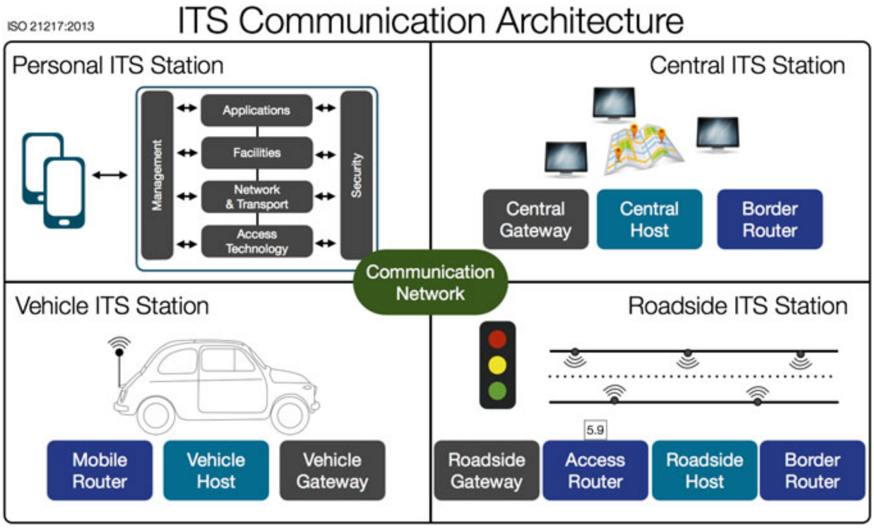

Fig. 1.5 Main ITS components

- Central ITS Remote Stations: installed in back offices, it is a key component of the centralized ITS management/service systems, needed to coordinate the whole system and to collect, store, and process information;
- Personal ITS Stations: handheld or nomadic devices such as smartphones and tablets.

With the exception of the Personal ITS-S, which it is composed by a single ITS-S host entity, all stations are based on a number of independent entities, which can be classified as hosts, gateways, routers and border routers. Hosts have both applicative and communication functionalities, while other entities have only specific communication functionalities, namely, protocol translation for the gateways, and routing for the routers. For example, in Fig. 1.6 it is shown the architecture of a vehicle ITS-S composed by a gateway, a host and a router. The gateway translates messages interchanged with the proprietary internal network of the vehicle, while the router is charged of routing packets through a series of heterogeneous networks.

Figure 1.7 shows the layered architecture of the ITS-S Host, which is the most significant entity. The ITS-S Host is constituted by four horizontal logical layers and two vertical layers. Starting from the bottom, one first encounters the access technologies layer, which groups together the corresponding physical and link layers of the ISO/OSI stack. Networking and Transport can be straightforwardly mapped with the homonym layers of the ISO/OSI stack. The transport layer includes TCP, UDP and dedicated ITS transport protocols, such as the ETSI Basic Transport Protocol (BTP) [26]. The networking layer includes a large variety of protocols, such as GeoNetworking [27], IPv6 networking with mobility support, developed at IETF and ISO specified in [28], IPv6 over GeoNetworking as specified in [29], CALM

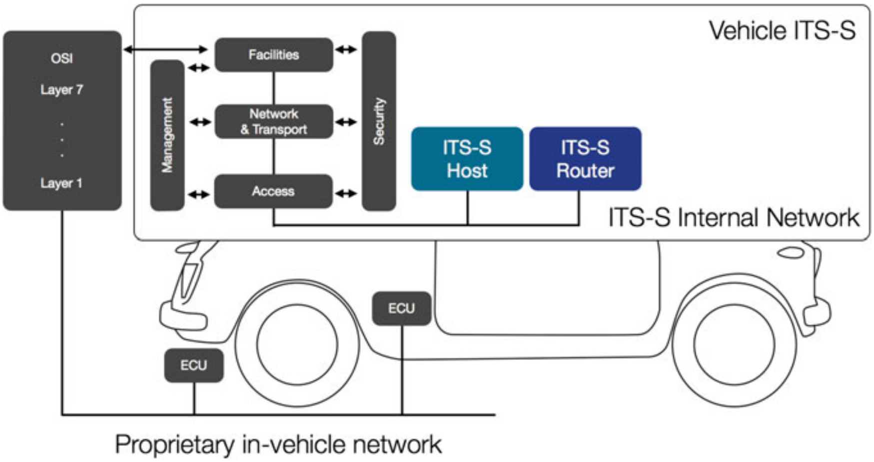

Fig. 1.6 Architecture of a vehicle ITS station

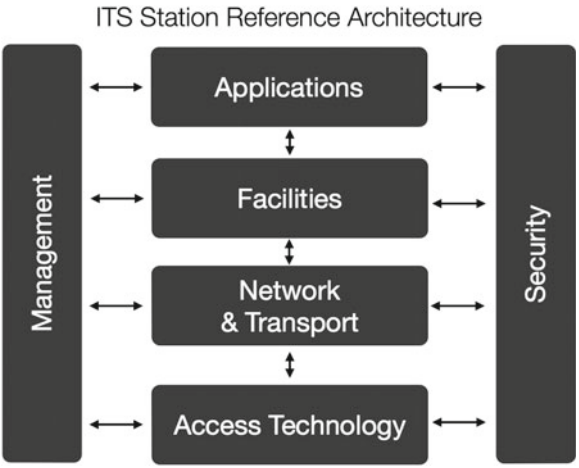

Fig. 1.7 Architecture of an ITS host

FAST protocol, as specified in [30], also known as Fast Networking and Transport Layer protocol (FNTP),[5] Fast Service Advertisement Protocol (FSAP), which follows closely the functionality of IEEE for WAVE Service Advertisement (WSA).

The ITSC Facilities layer contains functionalities from the OSI application layer, the OSI presentation layer (e.g., ASN.1 encoding, decoding and encryption) and the OSI session layer (e.g., inter-host communication), with amendments dedicated to ITSC. Within ITSC Facilities also lie some functionalities not directly related to

[5] The IEEE WSMP protocol is closely related, and there are serious attempts to harmonize FNTP and WSMP.

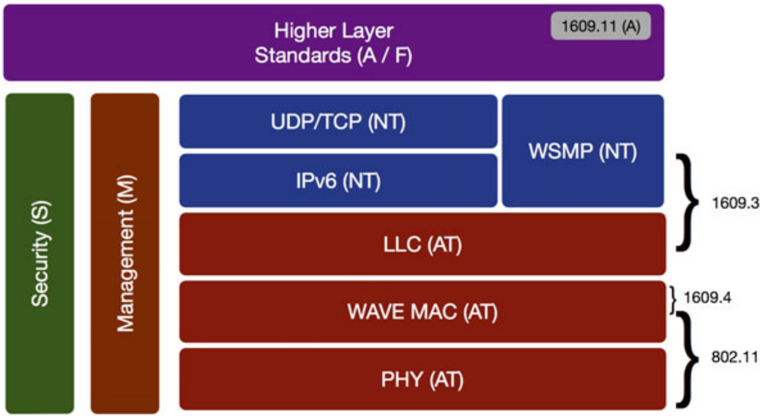

Fig. 1.8 Architecture of a WAVE ITS-S

communications, such as the Human Machine Interface functionality. The Applications layer is composed by all ITS-S applications, built on top of the previous three layers. Finally, the architecture explicitly includes management and security stacks, which are interrelated with all the previous.

1.3.3 WAVE Station Architecture

While the IEEE WAVE reference architecture standard P1609.0 has yet to be published, Fig. 1.8 has been adopted by the IEEE 1609 WG and contains a subset of the functionalities shown in the CEN/ETSI/ISO ITS station architecture presented in Sect. 1.3.2. Note that the current IEEE WAVE reference architecture does not explicitly include Facilities or Applications layer functions. The colors indicate the correspondences with the ITS station architecture from CEN/ETSI/ISO in a relaxed way. The CEN/ETSI/ISO approach is intended to support (but does not require) multiple network stacks from the outset, while IEEE work is focused on a 5.9 GHz radio interface.

IEEE 1609 is defined by four sub-protocols, with different functions and a different grade of maturity. More specifically, IEEE 1609.1 is a sufficiently mature standard (it dates 2006) and it basically defines a resource manager [31] acting as an "outsourcing" manager. In other words, it allows to physically separate the applications from the physical radio interfaces, either Road Side Units (RSUs) or On-Board Units (OBUs). For example, an application can run on an external device, such as a smartphone or a Global Positioning System (GPS) [32] navigator, without adding computational load and complexity to the OBU. This should allow to reduce the cost and increase the reliability of the OBU and RSUs.

The IEEE 1609.2 standard [33] defines security services for the WAVE networking stack and for applications that are intended to run over the stack, such as authentication of STAs and encryption of messages. IEEE 1609.2 provides mechanisms to authenticate WAVE management messages, to authenticate messages that do not require anonymity, and to encrypt messages to a known recipient.

The IEEE 1609.3 defines the networking services for IVCs, but its specifications are still in draft form [34]. The WAVE networking services can be divided into two sets: (i) data-plane services, with data-bearing functions; (ii) management-plane services, charged of the system configuration and maintenance. WAVE supports both two network-layer protocols: (i) the traditional IPv6 routing protocol [35], together with the transport protocols associated with it; (ii) the new WAVE Short Message Protocol (WSMP), expressly designated for accommodate high-priority, time-sensitive communications [36].

The IEEE 1609.4 specification, that is still a draft, defines the organization of multiple channels operations [37], and therefore it has a strong relation to the EDCA mechanism, better described in Sect. 2.5.3. IEEE 1609.4 envisions the presence of a single Control CHannel (CCH), reserved for system control and safety messages, and up to six Service CHannels (SCHs) used to exchange non-safety data packets (e.g., IP traffic) and WAVE-mode Short Messages (WSM). According to the multichannel operation, all vehicular devices have to monitor the CCH during common time intervals (the CCH intervals), and to (optionally) switch to one SCH during the SCH intervals. The described operation allows the safety warning messages to be transmitted on CCH using the WSM protocol, while non-safety data applications, either running over IP or WSM packets, use the SCHs.

1.4 ITS Applications

As vehicles become integrated in an ITS, their "horizon of awareness" drastically increases and an entirely new ecosystem of applications can be created, and even pre-existent applications can greatly enhance their efficiency [38]. New applications, especially which in the domain of transportation safety and efficiency, are the main drivers for the development of new systems. These applications shall cope with new challenges created by high vehicle speeds and highly dynamic operating environments, and shall guarantee high packet delivery rates and low packet latency.

As represented in Fig. 1.9, ITS applications can be classified in three categories acting in three primary directions [39]: transportation safety, transportation efficiency, and user services delivered to the vehicles, typically in the field of connectivity and convenience. Due to their nature, safety applications require to be executed in dedicated reliable hardware, while the remaining applications can be delivered through consumer electronic devices such as smartphones, or in-vehicle embedded devices. Obviously, a better integration with the vehicle can provide

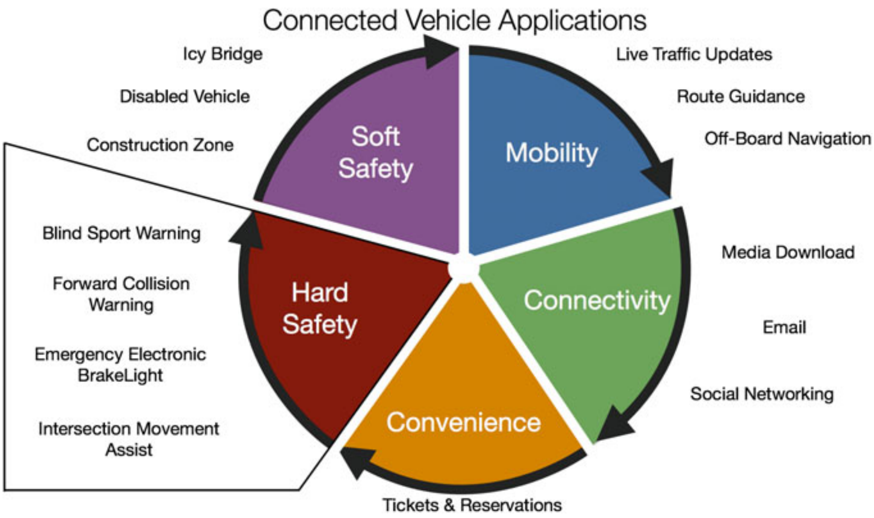

Fig. 1.9 Applications classification

additional advantages. The vehicles display and sound system can offer a user interface designed to minimize driver distraction.

Hard safety applications are targeted to avoiding imminent crashes and minimizing the damage when these crashes become unavoidable. These applications impose the most stringent requirements on the communication system. The communication latency has to be minimized in order to offer the driver sufficient time to take action and the communication system must provide high levels of reliability such as high message reception probabilities. There is also a subset of safety-applications, with less time-critical requirements, that can be denoted as soft-safety applications. These applications increase driver safety but do not require immediate driver reaction, because the hazards are not imminent. Examples include warning the driver of weather, road, traffic, icy roads, construction zones, reduced visibility, pot holes, and traffic jams. Typical actions in response to soft safety application alerts would be to proceed with caution or take alternate routes to avoid the dangerous conditions ahead.

Transportation efficiency applications focus on improving traffic flow. Examples include navigation, road guidance, traffic information services, traffic assistance, and traffic coordination. The last family of general purposes applications focus on making driving more enjoyable and providing greater convenience. Examples include point-of-interest notification, email, social networking, media download, and applications update. All these applications can tolerate long delays but may occasionally demand high data throughput.

1.4.1 Traffic Information Services

Traffic information Services combine historical, real-time, and predictive information, to enable optimized (re-)routing and reliable Estimated Time of Arrival computing. Major navigation brands, such as Nokia (with HERE Drive) and Google (with Google Maps), leverage probe data from their customer base, to offer free traffic updates. Smaller vendors, like TomTom, shifted to lifetime traffic offers, bundled with the navigation device.

TIS rely on Embedded On-board Infotainment Systems (OISs), which combine entertainment, multi-media and driver information functions in one module; on unintegrated information systems, such as smartphones and tablets, which may extend the functionalities of OISs, or operate independently of them; on general-purpose communication infrastructures, such as the cellular network; on dedicated communication infrastructures, such as Road Side Units (RSUs) based on IEEE 802.11p; and on remote services (e.g., cloud-based) which provide/collect and process information collected by RSUs and/or vehicles.

OISs, also known as In-Vehicle Communications and Entertainment System (IVCES), combine entertainment, multi-media and driver information functions in one module. They offer AM/FM or satellite radio, DC/DVD player for music and video, navigation system, data and multi media ports (USB, Bluetooth, line in, line out, video in) as well as general and vehicle status information. Recent OISs are also networked, e.g., by means of 802.11n, an amendment which improves upon the previous 802.11 standards by adding multiple-input multiple-output antennas (MIMO), operating at a maximum net data rate from 54 to 600 Mbit/s [40].

An OIS is an embedded hardware module, powered by dedicated embedded operating systems and middleware, able to provide passengers with several services, including audio/video entertainment, navigation assistance, telephony, car setup and diagnostic, driver information, Internet connectivity, and smartphone integration. To achieve these results, an OIS must interact with the diagnostic and multimedia buses of the vehicle (CAN BUS, FlexRay, MOST), to offer a multimodal friendly HMI (including touch-screens, steering wheel buttons, vocal controls). On the basis of the desired level of functionality, an OIS could also be equipped with a certain number of network interfaces (Bluetooth, WiFi, 3G/4G, USB), auxiliary inputs and positioning systems (i.e., GPS).

From a historical perspective, the need for entertaining car passengers was born with cars themselves. The first car radio, developed by Motorola, appeared on the market during the 1930s [41].[6] However, during the whole 20th century, OISs have been devices able to offer a limited set of functionalities—mainly audio entertainment, diagnostics and navigation services (the latter, only in last decades)—without interoperability and connectivity capabilities. Since the appearance of the Bluetooth technology,[7] in 2000, OISs became more and more influenced by mobile phone

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[6] http://www.motorola.com/us/consumers/about-motorola-us/About_Motorola-History-Timeline/About_Motorola-History-Timeline.html.

[7] http://www.bluetooth.com/Pages/History-of-Bluetooth.aspx.

technologies. Later, the Bluetooth technology triggered the development of a new generation of OISs able to offer integrated phone services, interoperating with mobile phones. The smartphone revolution started with the launch of the iPhone, in 2007, and forced a further change of paradigm for OISs manufacturers. Smart devices, such as smartphones and tablets, have quickly achieved a pivotal role in vehicle infotainment, thanks to their flat Internet connectivity, their application stores with thousands of apps, and their vertically integrated cloud services.

According to many external observers, the producers of OISs cannot compete with mobile phone companies from a technologically perspective, and soon or later smart devices will become the core of car infotainment, leaving a mere auxiliary role to OISs. However, car manufacturers have not yet accepted this idea, and are figuring out a business model able to guarantee all the advantages of the smart devices ecosystem, without loosing the control of the chain value. For this reason, it is possible to find in the market many different examples of integration between OISs and smart devices. Typically, the integration goal is to leverage on OISs' HMI capabilities to exploit smart devices' resources, including basic phone functionalities (phone call, contact list, SMS), navigation assistance (i.e., Google send-to-car), multimedia resources, Internet connectivity offered by smart devices or by OISs (typically through WiFi access points), total integration—a smart device and an OIS device operate as an unique platform. The latter approach is followed, for example, by MirrorLink [42], which offers seamless connectivity between a smartphone and the OIS itself, allowing to gain access to phone applications through car controls.

The contamination between mobile phones and vehicles clearly emerges by observing the software conception of modern OISs, which can be classified according to the following categories:

- monolithic software that can be expanded only by replacing the whole firmware (Fiat Blue&ME [43]);
- software expandable through apps realized by the car manufacturer itself (i.e., Mercedes-Benz Apps Store [44]);
- software expandable through apps realized by independent developers, by using the official SDK (Ford AppLink [45], BMW ConnectedDrive [46], Renault R-Link [47]);
- full mirroring with the smart device: in this scenario, the applications of the OIS are the applications (at least a subset) of the smart device itself (i.e., MirrorLink approach).

1.5 Chapter Outlines

The remainder of this book has the following organization. Chapter 2 presents the state of the art in ITS-enabling communication technologies, network topologies, as well as centralized and decentralized approaches. Chapter 3 illustrates novel wireless communication strategies for VANETs. Chapter 4 describes a hierarchical architecture for cross layer ITS communications. Chapter 5 focuses on the application layer, describing a structured overlay network called DGT, and a DGT-based architecture enabling ITS services—in particular, TIS services. Appendix A illustrates DEUS, the simulation tool we used to evaluate the algorithms illustrated in Chap. 5. Appendix B provides an overview of the mathematical methods we adopted throughout the book. Appendix C illustrates in detail the group key distribution protocol used in Chap. 4.

References

1. Bishop, R.: A survey of intelligent vehicle applications worldwide. In: Proceedings of of IEEE Symposium on Intelligent Vehicles (IV 2000), pp. 25–30. Dearborn, MI, USA (2000)
2. Figueiredo, L., Jesus, I., Machado, J., Ferreira, J., Martins de Carvalho, J.: Towards the development of intelligent transportation systems. In: Proceedings of IEEE Conference on Intelligent Transportation Systems, pp. 1206–1211. Oakland, CA, USA (2001)
3. Qu, F., Wang, F.Y., Yang, L.: Intelligent transportation spaces: vehicles, traffic, communications, and beyond. IEEE Commun. Mag. **48**(11), 136–142 (2010)
4. Hartenstein, H., Laberteaux, K.: VANET vehicular applications and inter-networking technologies. Wiley Press, New Jersey (2010)
5. Ministry of Land, Infrastructure, Transport and Tourism, Japan, A.: (2010). Website: http://www.mlit.go.jp
6. Administration, F.H.: IntelliDrive: safer, smarter greener. Public Roads **74**(1), 18–22 (2010)
7. Car-to-Car Communication Consortium: Website: http://www.car-2-car.org/
8. Communication from the Commission to the European Parliament the Council, t.E.E., Committee, S., the Committee of the Regions: Towards Europe-wide safer, cleaner and efficient mobility: The first intelligent car report (2007)
9. European Telecommunications Standards Institute: Website: http://www.etsi.org/
10. Willke, T., Tientrakool, P., Maxemchuk, N.: A survey of inter-vehicle communication protocols and their applications. Commun. Surv. Tutorials IEEE **11**(2), 3–20 (2009)
11. Lee, U., Magistretti, E., Gerla, M., Bellavista, P., Corradi, A.: Dissemination and harvesting of urban data using vehicular sensing platforms. IEEE Trans. Veh. Technol. **58**(2), 882–901 (2009)
12. Kato, S., Tsugawa, S., Tokuda, K., Matsui, T., Fujii, H.: Vehicle control algorithms for cooperative driving with automated vehicles and intervehicle communications. IEEE Trans. Intell. Transp. Syst. **3**(3), 155–161 (2002)
13. Broggi, A.: VisLab's vehicles just reached Siberia: driverless! Now Kazakhstan and then China until Shanghai [ITS events]. Intell. Transp. Syst. Mag. IEEE **2**(3), 43–44 (2010)
14. International Organization for Standardization: ISO 21217:2013 intelligent transport systems—communications access for land mobiles (CALM)—architecture (2013)
15. Europe, E.I.: Ertico vision. http://www.ertico.com/about-ertico-weare/
16. Commission, E.: Action plan and legal frameweork for the deployment of intelligent transports systems (its) in Europe (2008). http://ec.europa.eu/transport/themes/its/road/action_plan/index_en.htm
17. Parliament, E.: Directive 2010/40/EU of the European parliament and of the council on the framework for the deployment of intelligent transport systems in the field of road transport and for interfaces with other modes of transport (2010). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32010L0040:EN:NOT
18. Eureka: Programme for a european traffic system with highest efficiency and unprecedented safety (prometheus). http://www.eurekanetwork.org/project/-/id/45
19. Jurgen, R.K.: Smart cars and highways go global. Spectr. IEEE **28**(5), 26–36 (1991)

20. Research, R., Administration, I.T.: ITS strategic research plan 2010–2014 (2010–2014). http://www.its.dot.gov/strategic_plan2010_2014/
21. IEEE: 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 amendment 6: wireless access in vehicular environments. IEEE Std 802.11p-2010 (amendment to IEEE Std 802.11-2007) pp. 1–51 (2010)
22. Insitute of Electrical and Electronics Engineers: IEEE 1609–2006. IEEE trial-use standard for wireless access in vehicular environments (WAVE) (2006)
23. International, S.: SAE J2735—dedicated short range communications (DSRC) message set dictionary (2009). http://www.sae.org/standardsdev/dsrc/
24. Intelligent Transport Systems (ITS): Communications architecture. ETSI ES 202 665 V1.1.1, pp. 1–44 (2010)
25. Communications Access for Land Mobiles (CALM), I.: Website: http://www.calm.hu/
26. Intelligent Transport Systems (ITS): Vehicular communications; geonetworking; part 5: Transport protocols; sub-part 1: Basic transport protocol. ETSI TS 102 636-5-1, pp. 1–45 (2011)
27. Intelligent Transport Systems (ITS): Vehicular communications; geonetworking. ETSI TS 102 636 V1 (all parts), pp. 1–44 (2011)
28. International Organization for Standardization: ISO/IEC 21210:2012 Intelligent transport systems—communications access for land mobiles (CALM)—ipv6 networking (2012)
29. Intelligent Transport Systems (ITS): Vehicular communications; geonetworking; part 6: Internet integration; subpart 1: Transmission of IPv6 packets. ETSI TS 102 636-6-1, pp. 1–45 (2011)
30. International Organization for Standardization: ISO/IEC 29281:2013 intelligent transport systems—communications access for land mobiles (CALM)—non-ip networking (2013)
31. Insitute of Electrical and Electronics Engineers: IEEE 1609.1-2006. IEEE trial-use standard for wireless access in vehicular environments (WAVE)—resource manager (2006)
32. Kaplan, E., Hegarty, C.: Understanding GPS: Principles and applications. Artech House Publishers, Boston (2006)
33. Insitute of Electrical and Electronics Engineers: IEEE 1609.2-2006. IEEE trial-use standard for wireless access in vehicular environments (WAVE)—security services for applications and management messages (2006)
34. Insitute of Electrical and Electronics Engineers: IEEE 1609.3-2010. IEEE draft standard for wireless access in vehicular environments (WAVE)—networking services (2010)
35. RFC 2460 Internet Protocol: Version 6 (IPv6) specification. The internet engineering task force (IETF)
36. Uzcategui, R., Acosta-Marum, G.: WAVE: a tutorial. IEEE Commun. Mag. **47**(5), 126–133 (2009)
37. Insitute of Electrical and Electronics Engineers: IEEE 1609.4-2010. IEEE draft standard for wireless access in vehicular environments (WAVE)—multi-channel operation (2010)
38. Papadimitratos, P., La Fortelle, A., Evenssen, K., Brignolo, R., Cosenza, S.: Vehicular communication systems: enabling technologies, applications, and future outlook on intelligent transportation. Commun. Mag. IEEE **47**(11), 84–95 (2009)
39. Zhang, T., Delgrossi, L.: Vehicle safety communications: Protocols, security, and privacy. Wiley Press, New Jersey (2012)
40. IEEE Standard for Information technology-Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications amendment 5: Enhancementss for higher throughput. IEEE Std 802.11n-2009, pp. 1–211 (2005)
41. Salcedo, I., Rodriguez, F.J.: Calling all cars: Motorola's early police radios. In: 2010 2nd IEEE Region 8 Conference on the History of Telecommunications Conference (HISTELCON), pp. 1–4. IEEE (2010)
42. Consortium, C.C.: Mirrorlink. http://www.mirrorlink.com/
43. Fiat: Fiat blue&me. http://www.blueandme.net
44. Mercedes-Benz: Mercedes-benz apps. http://apps.mercedes-benz.com/

45. Ford: Ford applink. https://developer.ford.com/
46. BMW: Bmw connecteddrive. http://www.bmw.com/com/en/insights/technology/connected-drive/2013/index.html
47. Renault: Renault r-link. https://ie.rlinkstore.com