Chapter 1
The History of Vehicular Networks

Marco Annoni and Bob Williams

Abstract The chapter begins by providing a short historical description of the evolution of the technologies and the standards enabling a vehicle to communicate with other vehicles and the surrounding environment and become part of an extended intelligent transportation system (ITS) communication system able to support a wide range of services by using different communication media. In the following, the evolution from the V2I (vehicle to infrastructure) toward the V2X (vehicle to any) scenarios is discussed as an extension of the original vehicular ad hoc network (VANET) concept. The reference architecture of the ITS-station is then introduced by highlighting the roles and the contributions of the main standard development organizations involved in the development and consolidation of the concept. Finally, some consideration on the role of the regulatory environment and the related open issues are reported.

Keywords VANET • ISO • ETSI • CEN • IEEE • WAVE • CALM • ITS • C-ITS • V2V • V2I • V2X • ITS Station • Cooperative ITS • C-ITS

1.1 Motivation and History of VANETs

The general definition of the term VANET (vehicular ad-hoc network) refers to the possibility of having a communication node on-board a vehicle able to establish a wireless communication with other surrounding communication nodes visible in the radio range. Another implicit concept is that the vehicles are, by definition, mobile objects and, as a consequence, the network topology is randomly variable in time even if, in this particular scenario, some predictions can be made on the motion of communication nodes since any vehicle is supposed to be moving along predefined trajectories (i.e., roads).

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The concept of using radio communications to communicate from a vehicle in order to improve the safety has been around well before the advent of the digital radio communications we are familiar with today. One example is the patent "Radio Warning Systems for use on Vehicles" submitted on 1922 and issued in 1925 [8], based on the concept of peer-to-peer radio communication between equal devices installed on two different vehicles (see Fig. 1.1).

In its simplicity, the proposed solution anticipated some of the requirements for vehicular safety that have driven the demand for development of communication among vehicles in more recent years. It was not yet a wireless networking technology as we know today, but was aiming at one of the very similar needs, which, it turns out, we are still considering today and which motivated the development and the consolidation of the VANET technology.

Outside of the military, nothing much happened however, for nearly half a century, until the 1980s and 1990s, by which time most vehicles were already sold with a "radio-set" as standard. Of course, by this time, the radio provided broadcasts through local radio stations, advising motorists of weather conditions and major incidents, but simply via the voice of the presenter. So it was not networking of any sort, just a broadcast.

Radio data system (RDS), a communication protocol standard for embedding small amounts of digital information in conventional Frequency Modulation (FM) radio broadcasts, in 1984, became the first digital infrastructure to vehicle (I2V) communication, and was introduced in the USA as radio broadcast data system (RBDS) a few years later. In 1990, RDS became a European Standard.

Both RDS and RBDS carry data at 1,187.5 bits per second on a 57 kHz subcarrier, so there are exactly 48 cycles of subcarrier during every data bit. The RBDS/RDS subcarrier was set to the third harmonic of the 19 kHz FM stereo pilot tone to minimize interference and inter-modulation between the data signal, the stereo pilot and the 38 kHz Double-sideband suppressed-carrier (DSB-SC) stereo difference signal. The stereo difference signal extends up to $38\,\text{kHz} + 15\,\text{kHz} = 53\,\text{kHz}$, leaving 4 kHz for the lower sideband of the RDS signal.

The data is sent with error correction. RDS defines many features including how private (in-house) or other undefined features can be "packaged" in unused program groups. However, it is unidirectional, and not a network.

Around 2005, following long trials, RDS was enhanced to provide RDS-Traffic Message Channel (TMC). Each traffic incident is binary-encoded and sent as a TMC message. Each message consists of an event code, location code, expected incident duration, affected extent and other details.

The message is coded according to the Alert C standard and contains a list of up to 2,048 event phrases that can be translated by the receiver into the user's language. Some phrases describe individual situations such as a crash, while others cover combinations of events such as construction causing long delays.

RDS-TMC is also a low-bandwidth system, with each RDS-TMC message comprising 37 data bits sent at most 1–3 times per second, using a basic data channel primarily designed for FM radio tuning and station name identification. Compressing traffic incident descriptions in multiple languages into 16 bits for a location,

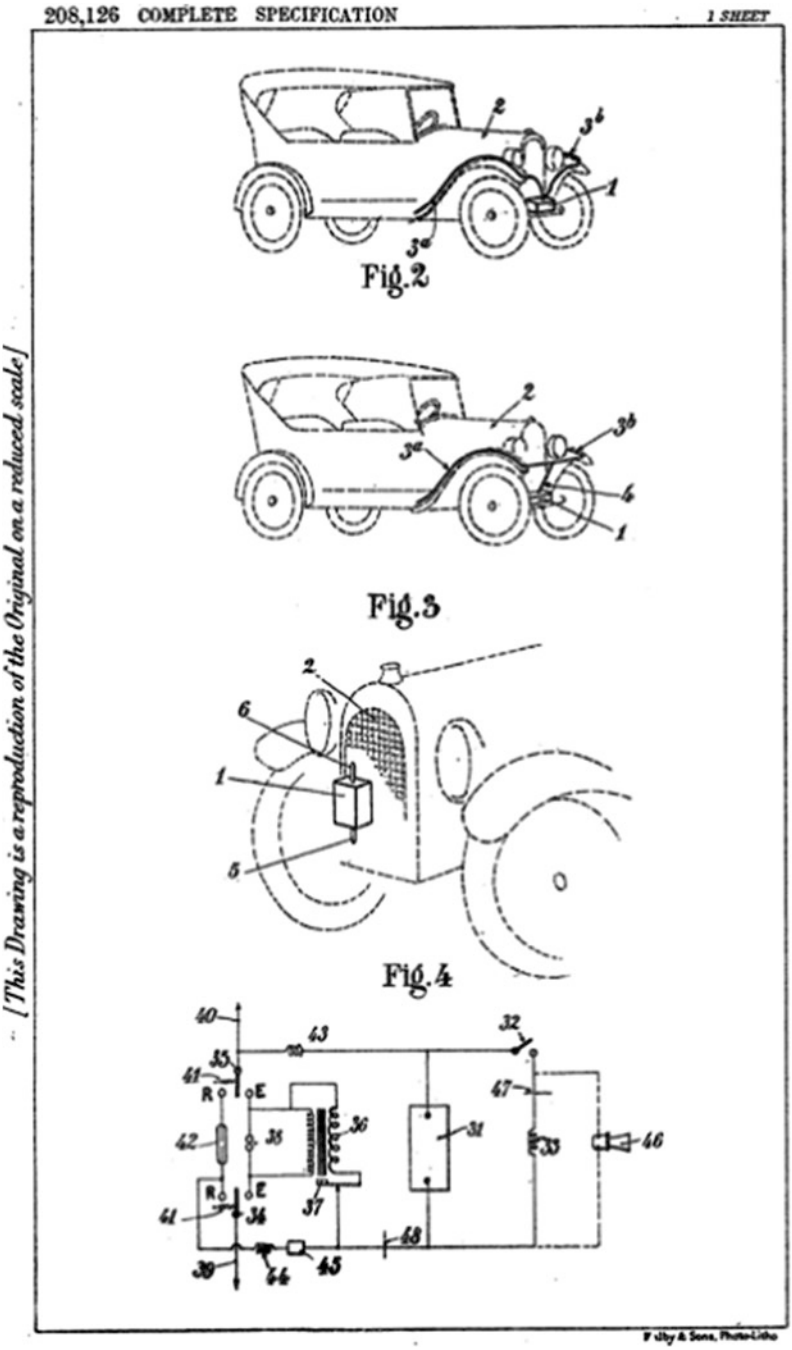


Fig. 1.1 Drawing from "Radio Warning Systems for use on Vehicles" [8]

11 bits for an event code, plus 5 bits for an extent and a few more bits for the duration and system management was necessary due to constraints in the RDS standard.

Sources of traffic information typically include police, traffic control centres, camera systems, traffic speed detectors, floating car data, winter driving reports and roadwork reports.

But these communications remained unidirectional, and not networks.

The first effective bidirectional systems came in the 1980s with tolling systems introducing Radio Frequency IDentification (RFID) tags into vehicles (initially at 2.45 GHz, then migrating to 5.8 GHz in Europe and subsequently, much of the world, and at 915 MHz in the USA). These were the first bidirectional, if primitive, communications, in which, in its simplest form, the infrastructure interrogated RFID tags passing under beacons and the tag responded with its identification. More complex systems, such as that devised by Philips, could store and transmit entry and exit data as well.

It was first envisioned that the 5.8 GHz dedicated short range communications (DSRC) system, invented by Philips in the early 1990s as an adaptation of its 2.45 GHz system, would become the basis for what was then (and probably still more appropriately) called "Intelligent vehicle-highway systems" (IVHS) communications. The DSRC In-vehicle system was able to make different types of transactions, so in the limited telephony and internet world of the 1990s it was envisioned that it would become the obvious means of IVHS service delivery. The concept of an infrastructure controlled "Network" evolved.

In this architecture, a network of beacons, operating at 500 kbit/s / 250 kbit/s, would hold short communications sessions with vehicles as they passed within the short (2.5–10 m) range of the beacons, and the controlling infrastructure would ask what services were required, and pass on the benefit of the updated information it was constantly receiving throughout its centrally connected and managed network.

But the cars did not communicate with each other so there was not even a vehicle network, let alone an ad-hoc network, and the expensive and fixed nature of the downlink beacons meant that there was nothing "ad-hoc" about that infrastructure either. The technology was infrastructure driven, in a master–slave relationship.

And the bandwidth was too limited, and the range too short, and by then the three principal developers of the Comité Européen de Standardization (CEN) Standards for DSRC had got embroiled in trying to lock the technology into their proprietary protocols (at least two of the three, with the third fighting for non-proprietary protocols).

But the fundamental weakness lay in the business case. There was no business case, other than road tolling, that could bear the required infrastructure cost.

Following one of the many legal disputes, and the eventual compromise and flawed standard, a couple of the competitors, together with one of the lead consultants at the time, sat down to work out how to avoid this mess in the future world of ITS communications.

They came up with an idea which was, at the time evolutionary, but, unknown to them, similar design issues were facing internet developers, and the eventual solution they conceived, was similar to those that have become the norm for the internet as well—i.e., to separate the applications from the communications means, and introduce an on-board communication and network management function. The advantage of this system is that it would work with any standardized wireless media, and all that was needed was a tailored "Service Access Point" for each wireless medium, which controlled the opening, management and closing of each communication session. It was then realized that the protocols had to be standardized, and so they adopted the IPv4 (later IPv6) protocols, and introduced the concept to International Standards Organization (ISO) TC204 (Wide Area Communications). From 2000–2013 ISO, working with IEEE, and latterly also with ETSI [6], developed a set of standards to manage these communication sessions.

Early developments had considered the issues of Infrastructure: vehicle communications (V2I) being an extension of the 5.8 GHz DSRC master/slave relationships with vehicle/vehicle (V2V) being peer/peer relationships. But in the ITS world, a police car can be a vehicle at one moment, and after an incident become a node of the infrastructure. The communication structure turned out, in fact, to be more simple, and as with the rest of the new architecture, the application, and the "roles" of the application had to be separated from the communications architecture. All ITS communications, were, as with any mobile communications between actors, peer/peer communications.

By 2013 the ISO Standards had evolved to the concept of ITS-station communications as shown in Fig. 1.2.

This peer-to-peer relationship could involve two or any number of ITS-stations in peer-to-peer, broadcast, or unicast communications (see Fig. 1.3). Communications could also "hop", extending the range of an end-to-end communication.

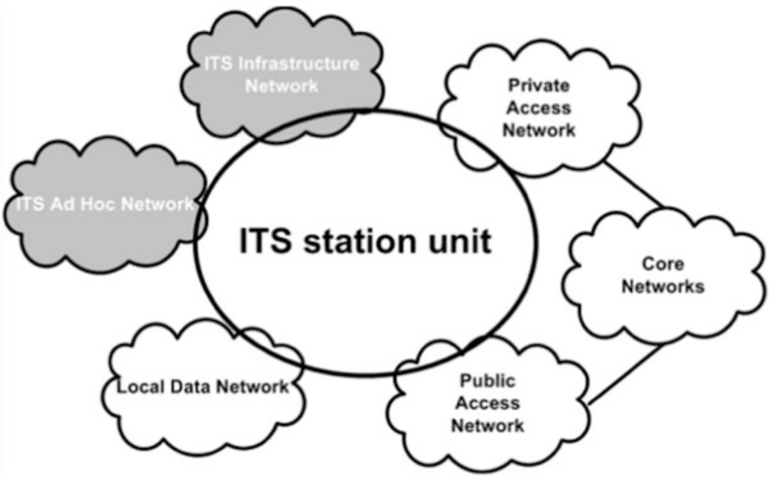


Fig. 1.2 Networking view of ITS communications [10]

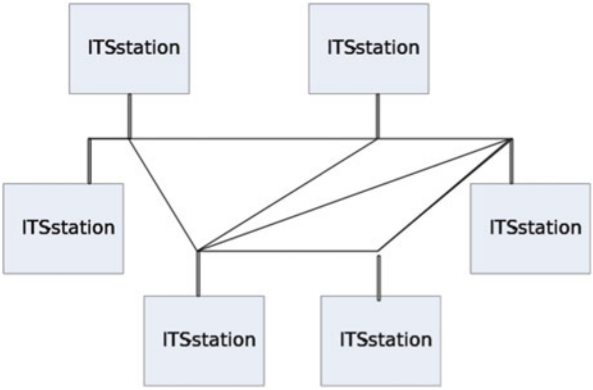


Fig. 1.3 Peer-to-peer, broadcast, unicast ITS-station communications (*source* CSI (UK) Ltd)

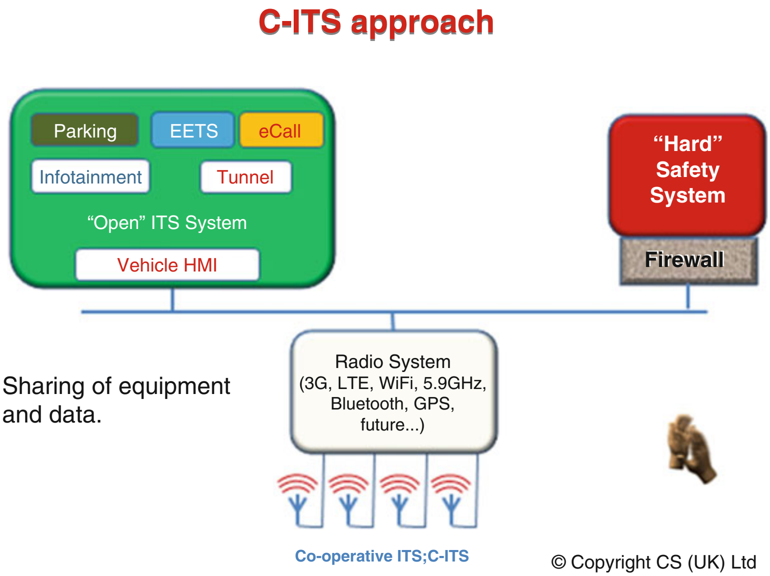


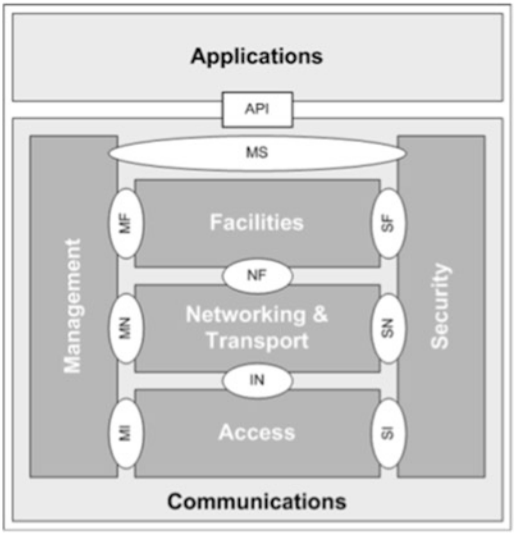
Fig. 1.4 ITS-station with multiple media (*source* ESF GmbH)

The role of any actor in an ITS-stations network (infrastructure, vehicle, street furniture, etc.) was unimportant at the communications level. Furthermore, the medium, though convenient if the same wireless medium, need not be, and the use of multiple media expanded capacity significantly. This approach is represented in Fig. 1.4.

The high level architecture view of each ITS-station was therefore defined as shown in Fig. 1.5.

Security is of course a key feature, especially for safety systems (but also with respect to privacy) and so ISO 21217 [10] espouses the concept of the "Bounded Secure Managed Domain" (BSMD).

Fig. 1.5 Simplified ITS-S reference architecture [10]



However, while some transactions, particularly important safety transactions, need to operate within a BSMD, that is not true for all transactions. Experience from interactive sat-nav systems with traffic information, RDS-TMC, and Variable Message Sign (VMS), has shown that drivers quickly and easily discount redundant and out of date information, even if they find it annoying. An ice alert, for example, carries little downside if it continues to show after the ice has melted, or even if indeed that data was inaccurate. The car and/or driver is simply more alert and cautious to this risk for a while. On the other hand, for collision avoidance, ramp access control, etc., security and faith in the data received, is of time critical, crucial and paramount importance.

Figure 1.6, taken from ISO 17427-1 [9], shows the different levels of security required within a cooperative ITS architecture, managed within the ISO 21217 concepts.

The ISO multiple media supporting ITS-station concept can also be portrayed, as displayed in ISO 21217 as in Fig. 1.7, showing examples of adoption in the vehicle, road side infrastructure, the service centres and the personal devices.

The ISO standards, by now, constitute a comprehensive suite where several management issues are identified:

- Local station management including interference and channel congestion management (ISO 24102-1)
- Access technology management (ISO 21218)
- Remote station management (ISO 24102-2)
- Station-internal management communications (ISO 24102-4)
- Application management

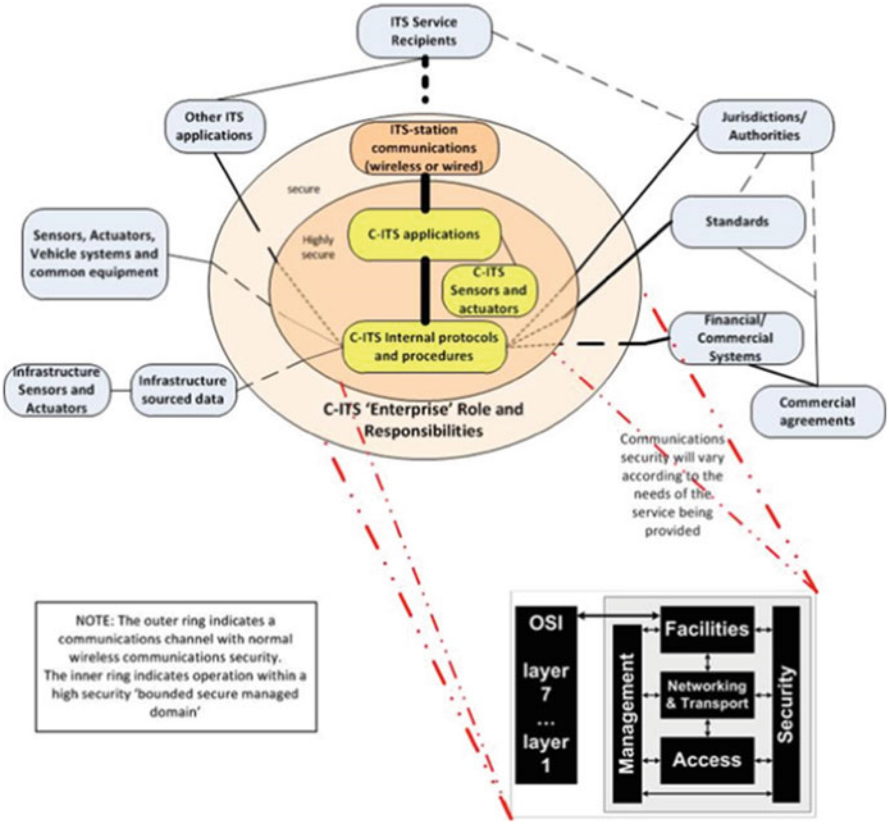


Fig. 1.6 C-ITS Roles and Responsibilities mixed security requirements architecture [11]

- Selection of communication profiles (CEN/ISO TS 17423)
- Path and flow management (ISO 24102-6)
- Service advertisement (ISO 24102-5)
- Management service access points (IS0 24102-3)

Early implementations do not need to implement all of this, and management standards are continuously extended.

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Here, from its first conception around 2000, we have the first true VANET architecture. Each node, be it car or infrastructure, was simply an ITS-station, and it could and would communicate, within its firewalls, with any other compatible node to form an ad-hoc network.

Of course those nodes acting as the infrastructure would perform additional, largely broadcasting to the network, tasks, and provide a link to other non-ITS systems for all vehicles within their range, but this becomes an application level activity, and the basic peer-to-peer network provided the opportunity for vehicles to make and utilize ad-hoc networks.

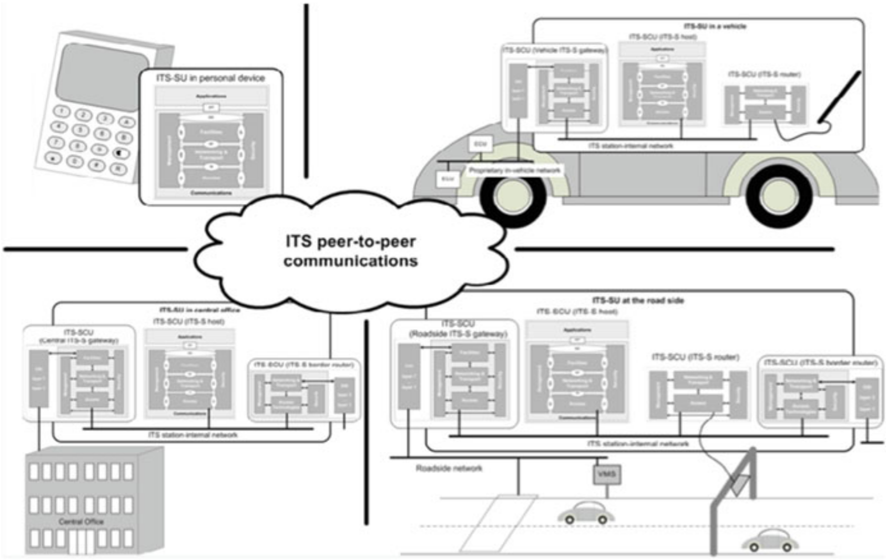

Fig. 1.7 Examples of implementations of ITS-station units [10] and [7]

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But life is not a simple singular and straightforward path, so in parallel, but somewhat separate from these developments, automotive researchers had meanwhile determined that with more bandwidth at 5.9 GHz, they could use the longer range (500 m as opposed to 5 m) system and provide important safety systems, such as collision avoidance, ramp access control, and in the shorter term ice, fog, and obstacle alerts.

Facing the issue of the 5.8 GHz infrastructure cost, considered unfeasible, they thought that due to the extended range provided by the 5.9 Ghz technology a cost reduction factor of 10x would have been achievable. The beacons would not be anymore the source of identification of vehicle location (Global Navigation Satellite System, GNSS, has moved this on) and simple unidirectional antennas would have been used in most cases. In their view, the infrastructure cost would become viable.

But US Department of Transport (DoT), with its crumbling and underfunded road structure, and road authorities in Europe, with the heavy infrastructure costs of the largely non-tolled roads in Europe, combined with heavy adverse budget pressures, soon disabused them that there would be any widescale roll-out of such an infrastructure network.

However, the researchers argued, if the networks were operating in a peer-to-peer fashion, why did they need the infrastructure at all? Particularly as they could, at least for some nodes, connect to previously infrastructure dependent service provision via Wi-Fi from within the vehicle, or via cellular communications? In the places where ITS was needed most, there was usually heavy density of traffic, indeed, always another vehicle within 500 m. Messages and data could not just be simply be "hopped" from one car to the next, but through the network could be "multi-hopped" to another vehicle maybe many kilometres away. Following this logic, there was no need for infrastructure investment! *The world would finally be that of V2V VANETS!*

Throughout the 2000s such systems were developed, demonstrated and evolved to the next level. In 2005 at ITS world congress, BMW demonstrated a VANET based skid alert system between vehicles. Mercedes and GM demonstrated VANET based collision warning, passing car warning and similar systems, proving that VANET technology was feasible in practice. By 2010 the large automotive companies of USA had lobbied and persuaded the US DoT to recommend to introduce these systems mandatorily, at 5.9 GHz. Further US DoT conceded that there would be a business case for infrastructure investment at "hot-spots".

All of the ISO Standards were being developed in an open, Intellectual Property Rights (IPRs)-free environment. However, the automotive companies R&D developments were understandably locked into their IPR, and so inconsistencies between the various Standard Development Organizations (SDO) emerged. The researchers reached near impasse, particularly as the scalability of some of the patent based systems became exposed.

While Europe, i.e., the European Telecommunications Standards Institute (ETSI), has developed a comprehensive *cooperative awareness message* (CAM) and *decentralized environmental notification message* (DENM), IEEE in the USA developed the simpler *basic service message* (BSM), which has formed the basis for the most extensive test and trials that have been enacted.

Further, by this time, an EU-US task force was in place to internationalize ITS and cooperative ITS developments and government strategies. EU/US Harmonization Task Groups (HTG) 1 & 3, in a joint study, advised that some of the choices made were "unfortunate", and that in any event, as US 5.9 GHz trials had been expanded, it had become clear that if all ITS services were to be loaded through this 5.9 GHz channel, even with the "lighter" IEEE BSM, the network would soon become overcrowded, even at relatively low traffic densities, let alone 6 and 12 dual direction lane highways at rush hour!

But technology once again moved faster than ITS research and development. For while the ITS community has spent one and a half decades developing these future systems, and had still not made any significant commercial implementations, the world of mobile communications had sprinted forward. The humble analogue cellphone had been ditched in the mid 1990s and the now all-digital, cellphones had moved to Global System for Mobile Communication (GSM) and most to Universal Mobile Telecommunication Systems (UMTS). Both modes supported digital data as well as voice, moving from General Packet Radio Service (GPRS), with theoretical transfer speed of max. 50 kbit/s (40 kbit/s in practice) to Enhanced Data Rates for GSM Evolution (EDGE), with a theoretical transfer speed of max. 250 kbit/s (150 kbit/s in practice), and over the cell ranges achieved for all wireless mobile telecommunications.

Meanwhile, commercial vehicle fleet management systems and some interactive sat-nav systems had long ago ditched the idea of expensive 5.9 GHz unproven

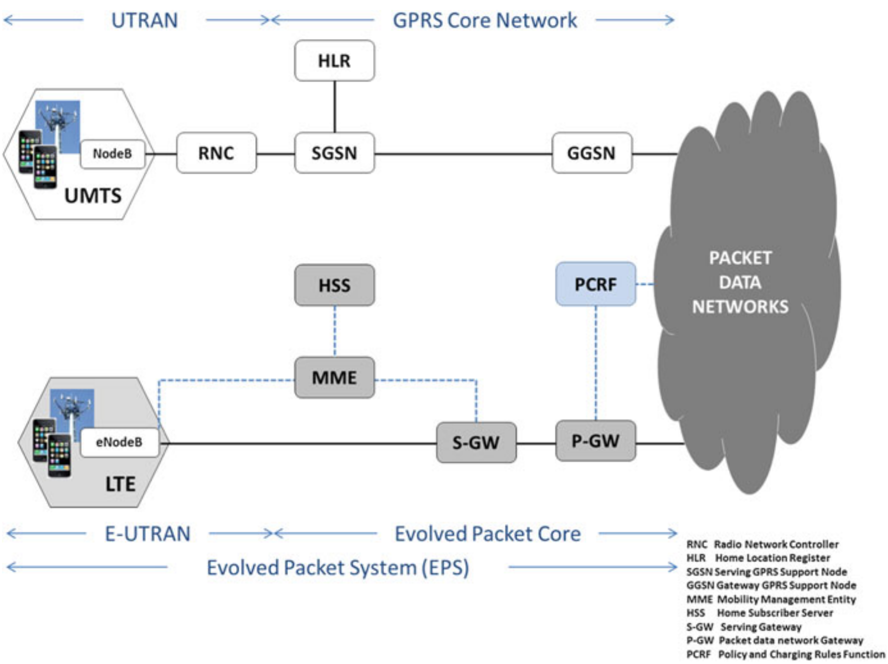

Fig. 1.8 Evolution of the public mobile networks for packet services

technologies, to satisfactorily using GRPS/EDGE. Then in 2012, so-called 3.9G or 4G networks started to be introduced (a variant having already been used in Japan for several years).

These Evolved-Universal Terrestrial Radio Access Network (E-UTRAN), also known in Europe and by the Third Generation Partnership Project (3GPP) as "Long Term Evolution" (LTE) are fundamentally different in that whereas previous generations are "circuit switched networks", these systems are "packet switched networks", totally digital and capable of rapid and fast evolving data rates, offering peak download rates up to 299.6 Mbit/s and upload rates up to 75.4 Mbit/s depending on the user equipment category, and continuing to improve. Figure 1.8 shows the differences among the 2.5G and the LTE networks.

Now a schism developed between the marketing departments of automotive manufacturers and their Research departments.

Nearly everyone now carries a smartphone. In any car there is now likely to be at least as many smartphones as occupants. Nearly all of these smartphones support Bluetooth, a Ultra-High Frequency (UHF) wireless radio system in the Industrial, Scientific and Medical (ISM) band from 2.4 to 2.485 GHz, from fixed and mobile devices, which builds personal area networks (PANs). Invented by telecom vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS-232 data cables. Bluetooth can connect several devices, overcoming problems of synchronization and making phone calls is just one of their functions. They have become the entertainment and communication centres of their owners.

Because of regulations forbidding manual use of cellphones while driving, almost all vehicles now provide Bluetooth or plugged capability to support hands-free use of the cell phone. Car owners now pressured automotive manufacturers to use this link to also provide infotainment linked to their smartphone. The marketing departments have pressurized the automotive product designers to provide these facilities.

It is now only one step further to use this technology, whether linked by Bluetooth to the car owners phone, or embedded in the vehicle, for ITS service provision.

Additionally, in Europe, regulation for eCall, a post incident “silo” system to link affected vehicles to the emergency services, will legally require a cellphone Universal Subscriber Identity Module (USIM) in every light vehicle, so the basic infrastructure will already be in place.

On another front, Wi-Fi is now supported on all smartphones, and Wi-Fi operators want the 5.9 GHz band for shared use. They argue that while the ITS sector has implemented just a few hundred research units at 5.9 GHz, in the past 15 years, they have implemented several billion active users, including for safety applications. They are currently arguing for shared use of the bandwidth, if granted this will fundamentally affect the current approaches to provision of critical safety services dependent on using 5.9 GHz.

But it is clear that, for advanced ITS safety systems, a preselected 5.9 GHz or similar “fast” ITS dedicated communication system will still be required.

1.2 V2X Communication Scenarios and Requirements

V2X communication is a very general term that includes all possible forms of communications involving a vehicle and the external environment. It is the natural extension of the VANET concept, where the vehicle it is not anymore the only communication node involved, but the vehicle becomes part of a larger system where many elements are involved together. It belongs to the family of the Cooperative Intelligent Transport Systems (C-ITS) communications.

Automotive researchers have developed a number of application and service scenarios, which have been considered and specified based on this concept, and can be considered as tightly related to the VANET technology.

In order to be actually deployed in the operational environment, most of the application scenarios require the adoption of some standardized solution (e.g. the vehicles need to speak some “common language”) and a high level of adoption by the vehicles on the roads. Even if it is agreed that an increasing number of vehicles will be equipped with V2V communication capability in the coming years, the level of market penetration of these technologies will have to increase gradually with rate that will be proportional to the vehicle replace rate. As a matter of fact, several decades will be needed before an adequate level of V2V technology penetration in the market will be reached able to guarantee a reasonable operational service availability for those services, such as collision avoidance and ramp management, that require a high population penetration to enable them to operate safely or effectively.

For this reason, it was soon realized that the V2V communication technology alone was not enough to enable a fast and effective deployment of most of the application scenarios proposed by the ITS community and pushed by the policy makers. Therefore, the extension of the same communications principles and technology was considered by realizing that the vehicle should not restrict its capability to communicate to other vehicles only, but should become able to connect with many different communication nodes that can be deployed or used in the road-side infrastructure, remote service centres, pedestrians, bikers, smart devices, etc. (the ITS-station concept). So the concept of V2I and V2V evolves to a more general extension to the vehicle-to-anything (V2X).

Nowadays, in the ITS community, it is taken for granted that the vehicle communication capabilities will enable the future vehicles to become one of the many co-operative communication nodes of a distributed ITS ecosystem supporting an increasing variety of services and applications by means of the use of the most appropriate communication media.

This vision is not restricted to vehicular transportation only, but it will also include other transportation modes that will equally benefit from a gradual adoption of ICT in order to make the mobility of people and freight safer, more efficient, environmentally and economically sustainable. This vision is represented by Fig. 1.9 showing the vehicle as one of the elements of a fully integrated multi-modal ITS communication ecosystem.

The only way to make possible the establishment of such extended integrated communication environment is to develop and adopt a standardization approach. At the beginning many proprietary technological solutions have been developed able to quickly answer to specific market or operational requirements. These solutions, even if sometimes elegant from a technical standpoint, often miss to fulfill objectives for scalability, massive deployment and interoperability. The result has been the creation of a very fragmented market for ITS solutions which are often very difficult to integrate or anti-economical to deploy and operate.

ITS is a very global market involving a large number of private and public stakeholders. Different specific geographic constraints apply from both regulatory and policy standpoints (e.g., regional frequency bands regulations, communication licensing rules, regulated services, strategic industrial priorities, etc.). A global standardization process is the fundamental tool needed to convert these general constraints into technically usable requirements.

A number of SDO have been involved in the process and one result has been the formalization and publication of standards based optimizing aspects of specific communication stacks. When trying to integrate the different standards into a global ITS scenario, some inconsistencies and gaps have evolved and the following phase, currently in progress, is devoted to the creation and increasing involvement of the different SDOs and ad-hoc task forces into a joint harmonization process which today is achieving a worldwide footprint.

Fig. 1.9 The extended ITS scenario (*source* ETSI ITS)

As it becomes clear that the future world of ITS will be multi-media, in order for VANETs to function efficiently and usefully, we need first to ensure that whenever applicable/possible the service should be provided with a “media-independent” approach, this means that the application standardization groups, largely ISO and CEN, need to better ensure the provision of applications should be media independent. This also means that the providers of communications standards, largely IEEE and ETSI, should ensure that their standards provide usable application-unaware communications and not application biased nor application-centric communications standards. Here the evolution of smartphone “apps” provides a model that can be followed. Temptation to add “features” into heartbeats and awareness messages, because the developers can see its usefulness in specific applications, loads and burdens the communications standards with overhead that is not used by most, and clutters up the network, largely uselessly.

Also, while the focus of interest of course lies with the most safety critical systems (collision avoidance, ramp access management for example), those systems require a high population penetration to work, and has already been observed, with a car park replenishment rate of about 5 % per annum, may not be fully workable for 20 years. Designing such systems to operate using only the current 5.9 GHz band, with current radio technology, is therefore fraught with danger. Put yourself back 25 years in your mind to the world of analogue mobile communications, with handsets the size of bricks and struggling to make even a reliable phone call most of the time. Could you have imagined then the state of the art today for mobile communications? Can you therefore realistically imagine today the radio environment in which VANETS will operate 20 years time from today? Perhaps researchers should focus more on what can be achieved in the very near future with low population penetration services, than struggle with the more difficult long-term challenges, albeit that such applications are intellectually and technically far more interesting. And of course, it is these high profile services which attract the attention and sympathy of regulators and Departments of Transport. A conundrum indeed.

The concepts of the BSMD is critical for many of the safety critical applications, but it too can be an unnecessary overhead where security is a lesser threat. Developers of application standards need to be more selective in their propositions for when it is appropriate. Perhaps the answer may be quite simple. It is clear that for most safety critical applications, time is of the essence. Taking the examples of collision avoidance and ramp access management (managing ingress and egress onto/from busy highways), these are time critical, and position critical, applications. They carry far more risk than, for example, an ice alert or a pothole warning. A fog alert has a loose location sensitivity, whilst a pothole alert is very location specific. Neither, in the context of life saving communications, are very time or security critical. Neither have a downside in the event of malicious hacking. Neither need a BSDM. But the collision avoidance and ramp access systems both need rapid communication and security. The malicious hacking of a ramp entry system or collision avoidance system is potentially devastating, and, once in place, highly likely to be the target of terrorists.

All of the more recent developments in ITS wireless communications recognize the desirability of using an IPv4/IPv6 approach for interoperability, but the need, with current radio technology, for more rapid communications for these safety critical systems, is also well understood.

Perhaps the simple solution that we alluded to above would be to limit use of the 5.9 GHz band to safety critical "fast" applications and require all other systems, for example safety systems such as fog and pothole alerts, even cooperative traffic efficiency and active road safety, to use a different wireless medium. Technology developers and regulators need to sit together, perhaps in the framework of the EU/US HTGs, to develop a practicable, workable and politically acceptable solution.

1.3 The Architecture of ITS-Station (ISO, CEN, ETSI)

The reference architecture of what is now referred by most of the standards as the *ITS-Station* (ITS-s) is the result of a long evolution and joint harmonization effort among the many organizations involved in the process.

The initial approach was necessarily to study and develop independent specialized communication stacks able to allow a peer-to-peer communication between two peers.

In most of the cases, the original concept of the proposed communication architecture was based on the adoption of specialized units (e.g. vehicle unit, road-side unit, etc.) conceived for specific implementation.

Multiple SDOs have been and are active in standardizing the specific communication stacks. But most of the physical R&D activity was actually prototyping, testing and further developing proprietary applications and then trying to get their proprietary solutions adopted by the standardization process. This has not been productive nor helpful.

Due to the international nature of the ITS standardization effort, an increasing co-operation has developed among the international standardization organizations involved in the process, such as ISO, ETSI, CEN, IEEE, SAE, Association of Radio Industries and Businesses (ARIB) Japan, Telecommunications Technology Association (TTA) Korea, IETF and International Telecommunications Union (ITU) with the aim of achieving internationally deployed and harmonized standards and worldwide interoperability.

The starting point for harmonization has been the reference architecture of the generic ITS-station.

ISO/TC204 [9]—ITS was established in 1993 and is responsible for the overall system aspects, infrastructure aspects and application aspects of ITS. In particular, its working group "WG18—Cooperative Systems" is focused on C-ITS and, in the frame of its activity started developing the concept of a general architecture for a generic node of the C-ITS network able to accommodate different communication stacks. ISO TC204's communication stacks are developed by its working group 16 "Wide Area Communications", but, with the exception of millimetre wave (60 GHz) and infrared communications, are largely based on adapting other available wireless network technologies to support ITS. In respect of 5.9 GHz, ISO started out to develop its own protocols, but transferred its efforts to collaboration with IEEE to ensure that its IEEE 802.11p and IEEE 1609 standards met its requirements, and have developed its 5.9 GHz communications around these. The basic idea is that this architecture is able to include many different options (i.e., stacks) that can be selected and adopted, whenever applicable, in specific implementations.

CEN/TC278 [1] was established in 1991, predating ISO 204 by a little less than 2 years, and operates, at European level, in tight synergy with ISO/TC204 which manages the corresponding standardization at global level. These days its works jointly with ISO TC204, and works under its lead in global aspects of ITS standardization, and concentrates TC278's remaining efforts on European-specific requirements, largely associated with the EU and the single market.

ETSI/TC-ITS [7] was established with the approval of its Term of Reference by the ETSI Board#64 in 2007 and the related Technical Committee started its activity in January 2008 with the objective to carry out the development and maintenance of Standards, Specifications and other deliverables to support the development and implementation of ITS Communications provision across the network, for transport networks, vehicles and transport users, including interface aspects and multiple modes of transport and interoperability between systems. In general, ETSI produces globally-applicable standards for ICT.

The European Commission in order to speed up the process of deployment of the ITS solutions in the European Market and to steer the standard harmonization process in the domain took a number of actions. The European Commission published an Action plan for the deployment of ITS in Europe in 2008 [3, 4]. This was followed in 2009 by a request to the European standardization organizations to develop harmonized standards for ITS implementation, in particular regarding cooperative systems. This request was formalized in the standardization Mandate M/453 [2]. ETSI and CEN jointly accepted the mandate that was then carried out by ETSI/TC- ITS and CEN/TC278 and finalized in 2013 with the finalization of the "Release1" of the ITS standards.

1.4 Regional Regulation

In respect of regulatory aspects on the use of VANETs, and indeed ITS services in general, approaches have differed throughout the globe.

In Europe, the ITS Directive, the ICT Rolling Plan and the current and subsequent year "Annual Program for Standardisation" encompass the EU aims for regulation and standardization of ITS. VANETs are not specifically mentioned in any of these documents, but of course many of the applications promoted will or may use VANETS.

So far regulation and regulation proposals in Europe that affect ITS are restricted to four areas: Electronic Fee Collection (EFC), eCall, HGV Tachographs and HGV Weigh in motion. Within the car, there has been far more action, for example requiring electronic traction control systems, but ITS is, by its nature, between a vehicle and other parties outside of the vehicle, so in-vehicle systems are not included here.

In respect of EFC there are regulations determining that in the situation you employ EFC toll collection in Europe, the manner that it shall be done. However, take-up/compliance in this area is poor.

HGV tachograph remote read and weigh in motion are still future regulations, but the EC is minded to use the 1990s 5.8 GHz DSRC technology to do this. Now that there are more capable alternatives, the logic behind this decision may be questioned, but if it is the will of the EC, no doubt will and resource will be found, to provide the work required.

eCall remains a special case. It can in no way be described as a VANET—in its current inception it is better described as a "silo" system. However there were good reasons for this as it was originally conceived as an extension of the public E112 pan-European system already deployed by the European mobile operators in their network and is based on the use of a circuit-switched voice channel to deliver both the data (provided within the "Minimum Set of Data"—MSD) coming from the vehicle involved in a road accident and the actual voice call. Regrettably, the time elapsed since the completion of the standardization work and the decision about the actual operational deployment has been postponed several times and, in the meanwhile the mobile network technology has evolved introducing different technologies which will gradually replace 2G. Therefore, the EC is looking for the means to migrate to packet switched data at an appropriate time and has already mandated to the involved standardization organizations (namely CEN and 3GPP) the related analysis for the future migration.

Anyway, eCall does bring a USIM into a vehicle which could be used to also support C-ITS functionality—if the network operators and application designers can use this opportunity. However the current eCall modem is a very limited and constrained beast, and it may well be that eCall migrates to support over an ITS-station over a period of time.

Another important aspect to enable the deployment of ITS at global level is related to the spectrum allocation and to the relevant regulations. In Europe, the EU Decision 2008/671/EC [3] established the use of the 5,855–5,925 MHz band for ITS safety related applications [5]. The deployment in this initial ITS band is in progress with the channel 176 used as control channel. The European ITS channels are compatible with the US-DRSC channelization (see Fig. 1.10) and are close to the radio band used by Wi-Fi devices. This radio band is referred to as the Unlicensed National Information Infrastructure (U-NII) and, in particular, the 5,850–5,925 MHz spectrum is called U-NII-4 and is being studied by the FCC and the NTIA for possible extensions of the spectrum available for Wi-Fi connectivity. In general, all devices operating in any U-NII band must ensure to be able to prevent harmful interference.

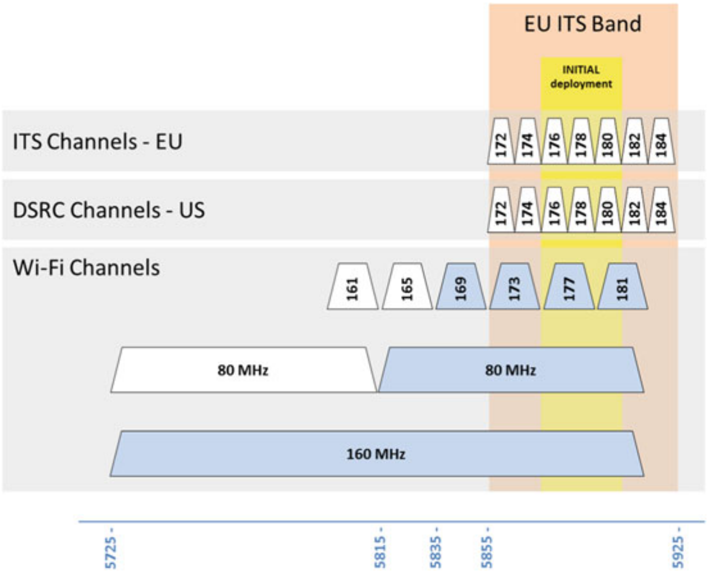

Fig. 1.10 5.9 GHz spectrum allocation

The current proposal coming from some radio local area network (RLAN) stakeholders for sharing spectrum and ensuring coexistence with ITS services consists of migrating the ITS control channel beyond the boundary of U-NII-4, from channel 176 to channel 180. This would not be possible in Europe where the 176–180 channels can be used without restrictions. Therefore, rearranging spectrum as proposed by some parties in the US is not feasible in Europe due to the different spectrum allocations. This is just an example of the issues to be addressed when considering spectrum regulation at global level. In general, some global harmonized spectrum sharing solution would be needed as it will become difficult to control movements of equipment across regions.

In terms of policy, in order to speed up and support the EU goals for the achievement of a competitive and resource-efficient transport system, the European Commission issues specific standardization mandates requests to the European standardization organizations (ESOs) to finalize coherent set of guidelines, specifications and standards to support the different aspects ITS deployment. For example, the Mandate M/453 [2], successfully created the conditions for a joint standardization activity among ETSI ITS and CEN TC278. New mandates are expected soon on strategic areas such as the ITS deployment in urban areas.

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