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Foreword

FISITA holds a unique, international position which connects engineering societies, industry and academia in a global network. Leaders from many of the most influential companies within the global automotive mobility industry are represented by FISITA Corporate Membership and use the pre-competitive environment of FISITA to engage collaboratively in support of a shared mission to develop of safe, sustainable and affordable mobility solutions.

FISITA provides a significant platform for its Corporate Member leaders to engage with peers on an annual basis via its technical leadership event, the World Mobility Summit. A unique and exclusive annual meeting that brings together top technical executives from FISITA Corporate Members with invited experts such as scientists, academics, public policy makers and NGOs, in order to consider issues of critical importance to the future of the automobile and mobility.

As the FISITA community continues to lead the rapid advancement of technology, it welcomed many of the world’s mobility systems leaders and strategists to the FISITA World Mobility Summit 2018, held in Shanghai. This significant and popular event was also an important occasion as it marked the first FISITA Summit to be held in China, a relevant location to consider the Summit theme of ‘Vehicle Connectivity’ with an agenda created around the following prioritized areas:

- Policies and Strategies
- Communications and Applications
- Applications and Infrastructure

FISITA’s objective is to provide the international platform for thought leadership, knowledge share, discussion and debate, linking organisations with common challenges and opportunities. Frequent FISITA Summit attendees are attracted to FISITA’s neutral and independent perspective, showing respect of all dialogue progresses.

The pre-competitive engagement that is facilitated by the FISITA World Mobility Summit, is of continued importance as co-operation within and between sectors is instrumental in facilitating future strategies for vehicle connectivity – the FISITA World Mobility Summit provides a high-quality, strategic thought leadership session, within a welcoming and professional environment.

Chris Mason
Chief Executive Officer
FISITA (UK) Ltd
Executive Summary
In recent years, intelligent & connected vehicle technology has seen significant development as this next phase of technology becomes the strategic focus of the automobile industry as it evolves ever further into the area of smart mobility service provision.

FISITA provides a platform for this global community to collaborate at international events, including the technical leadership Summit; a unique and exclusive annual meeting that brings together top technical executives from FISITA Corporate Members with leading scientists, academics, public policy makers and NGOs to consider issues of critical importance to the future of the automobile and mobility.

Automation and connectivity are taken as two of the primary technological pathways in the development roadmap for intelligent & connected vehicles. With vehicle connectivity, based on V2V (Vehicle to Vehicle), V2I (Vehicle to Infrastructure), V2P (Vehicle to Pedestrian) and V2C (Vehicle to Cloud) enabling the functions of automatic control, traffic management and dynamic information services, which are set to become the powerful support mechanisms for high levels of automation in the future.

Once established, these interconnected technologies will greatly reduce road traffic accidents and improve traffic efficiency and comfort, as well as save energy and reduce emissions. For these reasons, vehicle networking is recognised and highly valued by the international technical community as key to the rapid development of intelligent mobility.

Crossing multiple industries such as automobile, general transportation and communication, vehicle connectivity involves the alignment of diverse technologies including cellular and dedicated short-range communication technologies, vehicular communication protocols and communication interfaces, data platforms, cloud computing technologies and information security. In addition, vehicle connectivity also requires the interaction, connect and collaboration with road infrastructure and traffic management, as integral elements of the so called ‘smart grid’ infrastructure support network that will become of vital future importance.

Because of the cross-industry and trans-department characteristics, vehicle connectivity cannot be delivered independently by any one organisation, as it poses unprecedented demands and challenges for collaborative innovation and coordination across multiple technological fields such as automobile, transportation, communication and electronics. Which, in turn provide opportunity for collaborative development in various areas including technology, products, user experience, use cases and business models, thus providing new possibilities for solving the problems of energy, environment, safety and congestion.

The strategic policy at the Chinese government level is the key to the cross-industry collaboration in automobile, transportation and communication, which will affect the development route and direction to some extent. Communication technology and standards are the foundation of vehicle connectivity and application is the key to the industrialisation of vehicle connectivity, which requires the series of specific actions, such as large-scale test and verification, infrastructure construction and deployment, and data platform building, etc.

This Briefing Paper summarises the exploration and experience of technologists from various countries and regions of America, Europe, Japan and China in terms of vehicle connectivity from three aspects: strategy and policy, communication and standard, application and security. It then presents some consideration of forward solutions and suggestions for major issues in future development.

With the maturity of technologies and standards related to vehicle connectivity, a global wave of large-scale deployment will arrive soon. FISITA has supported its community of international industry experts to compile this important Briefing Paper in order to support its community to share knowledge within the pre-competitive environment of FISITA and accelerate the development of vehicle connectivity technology and industrialisation, thus quickening the realisation of automated driving.

Ms. Amelie Gong
Vice Secretary General
China SAE
1. Connectivity and Automation

How Will Connectivity Accelerate the Development of Automation?

Automated vehicles are making a significant ‘headline buzz’ in the media and are expected to dramatically change the paradigm of mobility. As the international engineering community develops the new technologies which will support this evolution, we can consider three main fields of application for automated vehicles:

- For passenger cars, to offer free time to the driver in safe conditions such as at low speed on congested highways or for long distance highway driving

- For goods, platooning of trucks on long haul journeys

- For Mobility-as-a-Service with robot taxis or robot shuttles in urban and peri-urban conditions

In this evaluation the third opportunity looks very promising in early adoption terms, while also the most challenging, in terms of how public transportation will continue to contribute to minimising the CO2 footprint, the congestion and the area dedicated to transportation in the cities (size of the roads and places for parking). However, the most important thing that connectivity will help mobility service with, is a dramatic improvement in safety.

With the first two options, societal and individual consumer acceptance will be a ‘must’ and is a challenge which may turn out to be more significant than the technological challenge.

This societal acceptance will depend largely upon the trust in new mobility concepts and the key condition is to ensure a very high level of safety and ‘usability’, comparable to the level of public and traditional owner driven modes of transportation.

The strategy to ensure high standards of safety will follow the ISO 26262 and the Safety of the Intended Functionality (SOTIF) standards. The concrete targets in term of fatality per billion hours are still in discussion among the industry but will require at least to build systems capable of Automotive Safety Integration Level (ASIL) D in the ISO 26262 (10-9 failures per hour).

To achieve such demanding targets, the systems will use redundant sensors and sources of information such as redundant control and actuators.
For achieving such performance and especially for the redundancy, connectivity will play an ever-important role. Let us consider some examples where connectivity will be a clear enabler for automated vehicles.

- For passenger cars, one big challenge is the control of driving at high speed on highways (130 kph in Europe, or more in Germany), with any loss of control potentially leading to a fatal crash at such speeds. Connectivity can offer a real-time status of the traffic and inform the vehicle ahead of a critical situation such as an obstacle on the highway or weather critical situations like a storm. This information can allow the system to adapt the speed and prepare the right maneuver ahead of the incident. The key performance will be the exhaustivity and the reactivity (or very low latency) of the transmission of this information, which will also need some redundancy in the connectivity. Another benefit of connectivity will be to contribute to the precise location of the vehicle. This will be done by Global Navigation Satellite System (GNSS) and with the addition of ground stations this can offer a better reliability for this localisation.

- For trucks on long haul highway journeys, connectivity will play the same role as proposed above for the passenger cars. In addition, the V2V connection will be mandatory for ensuring effective and efficient platooning and managing the headway clearance between trucks. For which, the performance of connectivity must be fully reliable and will also need some redundant connections. Moreover, based on connectivity, the truck platoon could decrease aerodynamic drag through narrowing the headway gap, resulting in low energy consumption.

- For Mobility-as-a-Service applied to robot taxis or robot shuttles, even if some manufacturers intend to offer systems with all the intelligence embedded in the vehicle, a system combining the intelligence in the vehicle and in the infrastructure, could offer a better performance or at least a better ratio of performance to cost. For instance, in case of cross-roads without visibility (a building at the corner), if the traffic lights are equipped with cameras and radars plus a connectivity to the automated vehicles, this will prevent the cases where a vehicle (car or truck) would not respect the red light on the street crossing the one of the robot taxi.

As these services will start on routes with the most frequent users, this will minimise the investment in the appropriate infrastructure. Another application for connectivity will be necessary for Mobility-as-a-Service: the passengers will need to get in touch immediately in case of trouble on board (malaise, etc.). In addition, the mobility operator will need to have real-time control of the fleet to make sure that every vehicle is operational and can fulfil its mission. Again, an accurate system of connectivity will be a must for this application.

These examples are not exhaustive and additional services will of course grow along with the ramping up of automated fleets. The connectivity “V2X” standing for “vehicle to vehicle and to infrastructure” will play a significant role for enabling the emergence of these automated vehicles.

To sum-up the three cases detailed, connectivity can bring the following benefits:

- Connected services will make the automated vehicle much smarter with a more holistic knowledge of the context, that is weather and traffic conditions, HD-maps, etc. and will enable a much safer driving environment due to the fusion of wider source of information.

- Onboard the vehicle, the driver and the passengers will be able to contribute to this more accurate source of information and will also have the possibility to raise an emergency alert in ‘safe mode’.

This scenario will need to build reliable and low latent systems of connectivity including some redundancy to ensure the necessary functional safety.
As road transport becomes increasingly shared, connected, intelligent, automated and electrified, it is entering a new age of systems engineering complexity.

This is a seismic shift, the like of which has not been seen in the automotive industry since horses were replaced by cars in the early 1900s. It is such a fundamental shift, that companies completely unrelated to automotive, let alone transport, are now posing a very real threat to the automotive giants of the past in their quest to revolutionise the future of mobility. This level of disruption was last observed with the advent of the World Wide Web which also created a hotbed of opportunity and has since enabled and accelerated the world of ‘information technology’ that we know today.

The speed at which vehicle startups (market disrupters) are bringing new technologies and features to market is sending shock waves through an industry that has historically been highly conservative with respect to the integration of new technologies into vehicles.

Unencumbered by traditional methods, and positively embracing risk, market disrupters are making rapid progress when it comes to developing products for future mobility. The sheer scale of the technical and commercial opportunities associated with next-generation mobility are huge.

The traditional automotive industry has a global market of 80 million vehicles per annum and with an average sale value of circa $19,000 providing an estimated value of $1.5 trillion representing some 2% of global GDP: we can see why this industry is an attractive proposition.

However, market disrupters have a very different view, with an estimated annual global market of 10 trillion vehicle miles at an average value of $1 per mile. This provides an estimated value of $10 trillion representing some 13% of global GDP and a very different opportunity.

The next $100 billion market has been somewhat elusive for investors over the last decade, and we are now seeing the emergence of an opportunity 100 times bigger. This is big business, gathering major momentum, and attracting huge investment.

Thought provoking advertising tells us about the safety benefits of Advanced Driver-Assistance Systems and autonomy, the connectivity benefits of vehicle-to-everything communications, and the environmental benefits of electromobility; but as engineers we have to see through the glossy benefits and get to the details of what is realistically required to realise the change and bring these features to the masses with safety, security and functionality in mind.

It is acknowledged that embracing risk has paid dividends in the progress of human kind throughout the course of history, but we have also learnt that unknown risks can be catastrophic. It is through sacrifice and a great deal of research that we have learnt that risk-based systems engineering is currently the best-known approach to understanding and mitigating the risks associated with safety related systems.

As the role of the driver is progressively removed from vehicle control and off-board information relating to the vehicles current environment and position becomes key, the electronic systems that replace human input will need to provide extremely high levels of dependability to ensure public acceptability of these technologies. Potential threats to dependability range from changing environmental conditions through to malicious human misuse.

Resilience has been defined as the persistence of dependability in the face of change. Thus, the electronic systems of future vehicles, as well as the intelligent transport systems that they interact with, will need to be designed to ensure a high degree of resilience to a wide range of threats.

So, the technology is close, and we are on the brink of a revolution, but is the industry ready for such a leap? For example, can some semblance of order be implemented on the non-deterministic nature of machine learning for such a complex application as automated driving?
As the automotive industry goes through this period of unprecedented change, requirements are emerging for the evolution of advanced systems engineering methods and tools for the integration and verification of new technologies, which will transform the way the automotive industry engineers vehicles in the future. This transformation towards 'Resilience Engineering' is being driven by a number of key factors that directly impact the cost of developing vehicles and the threat of brand deterioration in the event of liability or quality related issues:

- Modern vehicle complexity is growing faster than our ability to manage it using traditional and current methods and tools. This is increasing the possibility of performance shortfalls due to inadequate or missing specifications and incomplete verification coverage, highlighting the need for risk-based systems engineering and a robust Design Verification Process (DVP).

- System design has historically emerged from pieces, with component engineering performed in isolation from the complete vehicle architecture. However, with increasing complexity and an incomplete understanding of the total system, the potential capability (and cost) requirement for developing systems that are brittle, difficult to test, complex and expensive increases significantly. This highlights the need for the system integrator to assess and pass information to suppliers to ensure that the correct design targets and verification methods are employed.

- Technical and programmatic sides of projects can be inefficient, or poorly aligned, significantly increasing the risk of ineffective decision making. This severely hampers both technical and programmatic risk evaluation and management throughout the vehicle development life-cycle, highlighting the need for the technical and programmatic risks to be fully understood and dealt with accordingly.

- Rising vehicle connectivity will inevitably be accompanied by increasing cyber security threats, which will constantly evolve and develop as attackers strive to overcome existing and evolving defenses and exploit unidentified vulnerabilities. This highlights the need to consider mis-use and unintended use, as well as intended use cases.

- Most major engineering failures result from a failure to map, manage and mitigate risks appropriately. Following the Space Shuttle disasters, the Columbia Accident Investigation Board determined that the preferred approach is review by an “independent technical authority” highlighting the need for stronger technical risk-based decision making.

The main issue facing this revolution, however, is product resilience. Safety, security, and functionality aspects all contribute to resilience. But can these aspects be measured, assessed and verified for such complex systems? Currently ISO 26262 for functional safety and SAE J3061 for cybersecurity offer the best chance of achieving the high levels of confidence required to engineer vehicles that are safer and more secure.

Whilst changes are being implemented to tackle the issues surrounding automated driving, significant work is still required to align the standards. Even ISO 26262 Edition 2, published in December 2018, is unlikely to fully cover the requirements for automated driving functions. This is a reflection of the complexity of verifying the safe and secure operation of automated vehicles rather than any inadequacy in the standards generation process.

It is the risk-based systems engineering processes within these standards, defining rigorous recommendations and regulations throughout the product lifecycle (from concept to decommissioning) that must be built upon to achieve the necessary resilience for shared, connected, intelligent, automated and electrified vehicles. In this way vehicle resilience services support a unified risk-based system engineering approach to boost the development of future vehicles that are highly resilient to environmental and criminal threats, thus ensuring acceptable levels of functional safety, safety of the intended functionality, cyber security, connectivity and mission-critical functionality.

With the growing and evolving risks to vehicle safety, security and functionality, it is suggested that risk-based systems engineering delivers the highest standards of vehicle resilience through an agile, rigorous and uniquely unified approach to the integration of complex technology for the protection of brand, consumers and user experience.
2. Policies and Strategies

EU (C-ITS) Initiatives and Standardisation for V2X in EU

At the end of 2016, the European Commission decided to adopt a European Strategy on Cooperative Intelligent Transportation Systems (C-ITS). C-ITS is the key initiative for cooperative, connected and automated mobility in Europe, driving the goal to see deployment of mature C-ITS services in 2019 and beyond.

The regulatory basis for EU-wide C-ITS services is described in the EU-delegated act. This approach ensures the compatibility, interoperability and continuity for the deployment in all member states. It defines vehicle-to-vehicle, vehicle-to-infrastructure and infrastructure-to-infrastructure communications for all kind of C-ITS deployments, to enable the provision of C-ITS services to end users. As examples, these services will cover the following use cases: traffic jams, stationary vehicle warnings, dangerous situations, adverse weather conditions, road works warning and signalised intersections.

To achieve its goal, the EU Commission is supported by several industry groups, for example the Amsterdam Group, an umbrella group consisting of representatives from C-ITS driving industry organisations. The Amsterdam Group exchanges information, discusses and creates solutions between the involved stakeholders in the context of C-ITS.

Other key industry consortia are the CAR2CAR Communication Consortium focusing on C-ITS deployments on ITS-G5 derived from the standard IEEE 802.11, or the 5G Automotive Association (5GAA) a global, cross-industry organization, working together to develop end-to-end solutions for C-ITS based solutions on cellular technology (LTE, 5G).

The C-Roads Platform is the joint initiative of European Member States and road operators for testing and implementing C-ITS services in light of cross-border harmonisation between member states. Its goal is to achieve the deployment of interoperable cross-border C-ITS services, as listed in the delegated act, for road users. Different working groups shall ensure proper common decisions towards interoperable deployments. Examples for deployments of cross-country C-ITS corridors based on the C-Road Platform are SCOOP in France & Luxembourg, Nordic Way in Sweden & Norway and Finland, the ITS-Clusters in Netherlands, Germany and Austria as well as Compass 4D City project and others.

Currently, C-ITS services are currently verified by academia and industry partners within several publicly funded projects sponsored by the European Commission.
Radiocommunication systems required for the Connected Car

In Japan, as shown in Figure 1, a variety of radiocommunication technologies or systems are employed to enable the connected car such as, cellular system for wide area and continuous connection, DSRC (WAVE, G5, ITS Connect) and Beacon (Radio, Infrared).

In order to establish various services of connected cars, the appropriate communication system should be chosen, taking into account advantages and disadvantages of each system.

Advantages and Disadvantages

Table 1: Ranges of Radiocommunications Systems
While considering the role-sharing of each radiocommunication systems, the type of communication will be classified as below:

- **Spot area communication:** Server-Client (Vehicle) Communications at specific spot such as ETC
- **Short range communication:** Short range area Communications such as V2V or V2I
- **Wide area communication:** Server-Client (Vehicle) Communications in wide area

Moreover, applications for connected car represented by communication type as Figure 2.

**Figure 2: Application and Communication Type for Connected Car**

The choice of radiocommunication system depends on the communication type of the application, as well as the place of communication.

For example, in the case of ETC (Electronic Toll Collection) application, the spot area communication is considered to be appropriate.

For applications such as internet access, the wide area (cellular) communication, and for the V2X communication in autonomous driving, the short-range communication (DSRC), is considered to be appropriate, respectively.
The Korean government is currently focused on the subject of communication technology for vehicle connectivity, i.e., V2X that is represented as vehicle to any device communication for cooperative intelligent transport systems (C-ITS) and cooperated automated driving. The key consideration continues to be whether V2X technology, based on Wireless Access in Vehicular Environment (WAVE), which has been invested in for several years by the public sector, or V2X technology based on cellular communication networks (C-V2X) by private sectors will become the preferred mechanism.

Many related stakeholders including telecommunication companies, equipment manufacturers, small and medium enterprises, mobility service providers, academia and research organizations focused on this important question and ultimate decision of either WAVE-V2X or C-V2X. Recently, it is clear that similar situations and considerations exist within Europe, the US and the other developed countries.

At the time of writing it is not clear whether one of these will be progressing a prompt decision in order to open V2X markets and enable confident infrastructure investments. Nobody knows what the ultimate direction will be, and therefore there remains uncertainty regarding the effective and sustainable future market preference, whether one technology will become dominate, or both technologies will find a place in the technological landscape.

Wireless access in the vehicular environment (WAVE) is defined as dedicated short-range communication (DSRC) by the Federal Communication Commission (FCC) in United States in 2003. The Institute of Electrical and Electronics Engineers (IEEE), one of the standard development organizations (SDO) has established a standard ‘802.11p’, which was revised by DSRC based on Wi-Fi technology. Since then, many countries in the EU and others including Korea have begun to develop vehicular connectivity technologies according to this standard.

In 2007, Korea started to develop WAVE technology for cooperative vehicle to infrastructure connectivity as a part of the Smart Highway Project funded by the Ministry of Land, Infrastructure and Transport (MoIT). Since then, WAVE has been designated to be a core and exclusive communication infrastructure not only for conventional ITS services but also for cooperative ITS (C-ITS) providing V2X connectivity. WAVE technology has been applied as a key technology providing V2X connectivity in the C-ITS pilot project in Daejon-Sejong City funded by MoIT during 2013 to 2017, which has been directed by Korea Expressway Corporation (KEC), The Korea Transport Institute (KOTI), and ITS Korea.

The status of V2X connectivity changed from 2016 due to the application of 4G/LTE communication technology being adopted into telematics and vehicle connectivity in ITS services. Importantly, the introduction of 5G technology, which will become potentially feasible for V2X connectivity and mobility services within a few years will also have an effect. But the question becomes one of whether technically the spectrum of 5.9GHz band with 7 channels or 70MHz width designated as C-ITS exclusive and neutralized can be shared dually with WAVE and C-V2X.

As proposed from 3GPP, C-V2X might have technical advantages over 802.11p-based WAVE-V2X. C-V2X has a higher spectral efficiency, enabling it to serve more road users within a given spectrum so that C-V2X might be able to provide higher levels of safety to more road users than WAVE. However, this is not yet proven in real traffic situations compared with WAVE that has been already approved in the C-ITS project (and others) to be ready for manufacturing sooner, rather than later.

In 2017, a special committee for V2X promotion was established by the Ministry of Science and ICT (MSIT) and Ministry of Land, Infrastructure and Transport (MoIT), to develop a cooperative harmonization of V2X technology as a core communication infrastructure providing vehicle connectivity in C-ITS services and automated driving systems. Many related stakeholders including research organizations such as Korea Electronics Technology Institute (KETI), Korea Expressway Corporation (KEC), ITS Korea, 5G Forum, etc. have participated as a member in this committee. A few key issues upon V2X technology itself and co-existence with WAVE and Cellular within 5.9 GHz band have been discussed during a series of meetings, but no conclusions have been precisely identified to date.

Instead, a consensus has been reached where the decision of what and how is to be made with respect to keeping a balance between users’ and providers’ point of view based on comparison of WAVE-V2X and C-V2X with benefits and costs, reliability and security, data ownership, use cases and business models, etc.

The recent decision by the European Commission (EC) in April 2019 implemented new rules stepping up the deployment of C-ITS on Europe’s roads and supporting DSRC technology might, in turn, influence Korea to positively to take a decision to WAVE-V2X for vehicle connectivity and C-ITS services in the near future.
China

The Chinese government actively promotes the technical and industrial development of intelligent, connected vehicles, which it also considers as a breakthrough point for the transformation and upgrading of the manufacturing industry. While elevating the development of intelligent connected vehicles to the level of a national development strategy, China has also formulated and issued the technological development roadmap for intelligent connected vehicles, setting out its technical framework and development ideas.

Vehicle connectivity is one of the technological paths for intelligent connected vehicles and an important technical support for intelligent vehicles. The Ministry of Industry and Information Technology of China (MIIT), National Development and Reform Commission (NDRC), the Ministry of Transport of China (MOT), the Ministry of Public Security of China (MPS), the Ministry of Science and Technology (MOST) and other supervision departments concerning vehicle connectivity have actively promoted the application of vehicle connectivity according to their own responsibilities.

Vehicle connectivity has always been considered as a key area that may have a leading position in the development of China’s intelligent connected vehicles, and it is worth stating that China also has a leading communication industry and unified planning and deployment of infrastructures.

(I) Strategic planning guidance

China has regarded the development of intelligent connected vehicles as a national strategy. The policy deployment of the country’s vehicle connectivity is covered by the strategic planning for intelligent connected vehicles, which is an important part of the strategic deployment for intelligent connected vehicles.

MIIT, NDRC and MOST jointly released, on April 25, 2017 the Medium and Long-term Development Planning of the Chinese Automobile Industry and it took intelligent connected vehicles as one of the breakthrough points to lead the transformation and upgrading of the whole industry. Meanwhile, intensified efforts are being made to focus on key technologies of intelligent connected vehicles, standards and regulations, network infrastructure construction, basic big data platforms, vehicle information security and other major tasks. NDRC is taking the lead in formulation of the Strategy for Innovative Development of Intelligent Vehicles, which was released on January 5, 2018. This defines the strategic direction, development goals, main paths, key tasks and supporting measures for the development of intelligent vehicles. In addition, recent action plans are proposed in the strategy to ensure early start-up and orderly implementation. It also clearly points out that vehicle connectivity is an important path for the development of intelligent vehicles.

(II) Promotion of technology and industry development

In terms of the technical path of vehicle connectivity, China has clearly defined C-V2X as a national strategic path, which is different from America, Japan and Europe and other countries that are going through the selection period of technological paths of DSRC and C-V2X. The clear path has earned China valuable time for the technology development and promotion of vehicle connectivity. Under the guidance of this clear technical strategic path, original equipment manufacturers (OEM) in the country, such as SAIC, Chang’an and FAW are actively developing typical LTE V2X applications; Datang and Huawei become the first batch to unveil LTE-V2X communication chips and several communication terminal equipment vendors have emerged, such as Neusoft, Nebula Link and Gervict.

Recently, Baidu, Alibaba, and Tencent (BAT) have successively made a foray into the field of vehicle-road coordination, which will expedite the implementation of industrialisation of vehicle-road coordination.

Meanwhile, relevant ministries and commissions of China have taken measures such as demonstration and pilot projects to actively promote the development of vehicle-road coordination according to their lines of business, to support the technical progress and industrial implementation of vehicle connectivity in a better manner.

MIIT has promoted the demonstration of intelligent transportation applications based on the broadband mobile internet, establishing “5+2” vehicle connectivity demonstration areas in Beijing, Changchun, Wuhan, Chongqing, Zhejiang, Shanghai and Wuxi. The demonstration area involves the application, experimental verification, test and evaluation of new technologies and products such as vehicle-road coordination, advanced driver assistance, autonomous driving and big data on traffic, which strongly promotes the test and demonstration of vehicle-road coordination. MOT has transformed the Tongzhou Test Site in Beijing to enable it to be suitable for the transformation in intelligent transportation detection (such as on-board intelligent terminal and vehicle-road coordination equipment) and carried out pilot projects of intelligent highways and national traffic control networks across the country.

It is worth pointing out that MOT has promoted the Zhejiang Expressway to launch the pilot project of intelligent highways, build the vehicle-road coordination traffic system and realize the functions of freight train formation and free flow charge, which has taken a key step in the infrastructure upgrading and transformation of vehicle-road coordination. MPS, relying on the Traffic Management Research Institute of the MPS, is building a national comprehensive intelligent traffic test base and carrying out China’s first large-scale urban demonstration pilot project for vehicle-road coordination in Wuxi.
At the World Internet of Things Convention in September 2018, a vehicle-road coordination demonstration was made available, which covered 226 intersections and 5 elevated highways, 100,000 social vehicles and multiple functional applications. Since the tenth “Five-year Plan”, MOST has launched national technological plans such as “key special projects of new energy vehicles” to support the development direction of intelligent vehicles. Each year, the key special funds for intelligent connected vehicles exceed RMB 100 million, which mainly support technological progress in on-board environment perception, test and verification, demonstration and construction.

MIIT, MPS and MOT jointly issued state-level Management Standards for Road Test of Intelligent Connected Vehicles, regulating the application of road test, audit and management of intelligent connected vehicles, as well as the requirements for the test subject, test driver and test vehicle. Relevant provincial and municipal authorities have formulated detailed implementation rules according to local, actual situations and specifically organised the implementation of road test of intelligent connected vehicles. At present, more than 10 provinces, including Beijing, Shanghai and Chongqing, have accepted the application for opening road test.

(III) Organisation and standard guarantee

Through technological innovation drive, scientific research projects and financial support, China strengthens the construction of standard systems and supports the construction of innovation alliances and other institutions to promote the technical development and industrial implementation of vehicle connectivity in various aspects.

MOST has launched national technological plans such as “key special projects of new energy vehicles” and technological project approval of intelligent connected vehicles under the special project of new-energy vehicles. Each year, the key special funds for intelligent connected vehicles exceed RMB 100 million, which are mainly used to support on-board environment perception, test and verification, demonstration and construction, etc. In addition, China has intensified standardisation work to promote the sustainable development of intelligent connected vehicles. MIIT and the Standardization Administration have released the National Guidelines for Developing the Standards System of the Telematics Industry, covering a wide range of areas including automobiles, communications and electronics.

China encourages and supports the construction of innovation alliances and other organisations to deliver transparency to their innovation and collaboration in their organisational role in scientific research, industry development and academic exchanges. So far, various alliances of intelligent connected vehicles in three fields (i.e., automobile, traffic and communication), including CAICV, China ITS Industry Alliance (traffic) and C-V2X Working Team (communication) of IMT-2020 (5G) Promotion Team have conducted technical promotion and industry transformation in their respective fields and at different levels.

Aside from that, China, in combination with the innovation needs and actual national conditions, has already established an innovation centre of intelligent connected vehicles named China (Beijing) Intelligent and Connected Vehicle Research Institute Co., Ltd. and is focused on the research and development of basic cutting-edge technologies and generic crossover technologies of intelligent connected vehicles. In addition, China has also built the technical framework system of core architecture, setting up the transformation rules of generic crossover technologies and promoting the application and transformation of intelligent connected vehicles and the industry development.
3. Communication and Regulations

**DSRC vs LTE-V2X: Fundamentals, V2X Upper Layer Standards and Comparison**

**Fundamentals**

At the current time there are two standardised short-range vehicle safety communications technologies suited for broadcast kinematic and other vehicle state information to other vehicles and to infrastructure field elements. Vehicle safety communications that send these standardised messages are normally classified by link, vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I). Generally, V2I also refers to the broadcast of short infrastructure-generated messages such as traffic signal phase and timing (SPaT) to vehicles, although vehicle state information sent to infrastructure field elements such as traffic signals comprise an important class of applications.

The two underlying radio technologies to instantiate these safety services are, respectively:

- **802.11p** is a Wi-Fi (IEEE 802.11)-based protocol, initially dubbed 802.11p and referred to as Dedicated Short-Range Communication (DSRC) in various regions of the world to include the United States but called ITS-G5 in Europe. In this section, we refrain from “DSRC” and “ITS-G5” labels of this technology but instead refer to it as 802.11p, especially since DSRC has a meaning specific to tolling in Europe and much of Asia.

Explain simply, 802.11p describes a “listen before talk” protocol, and it differs from other Wi-Fi flavors because it is standardised to work outside the Internet Protocol (IP) conventions of those Wi-Fi flavors. The radio access is “glued” to applications in the US with a series of standards produced by the IEEE 1609 Working Group. These standards collectively enable what is known as Wireless Access for Vehicular Environments (WAVE). There are a different set of specifications and norms in Europe under the aegis of European Telecommunications Standards Institute (ETSI) ITS Technical Committee, commonly called ETSI TC ITS. This specific ETSI stack is known in industry as ITS-G5. Emerging standards in other global regions use variants of the WAVE or ITS-G5.

- **LTE-V2X** is a 3rd Generation Partnership Project (3GPP)-specified radio access technology based on LTE, operating in broadcast mode without network assistance and called PCS. This is at various times called LTE-V2X or Cellular V2X (C-V2X). This communications link is direct, and its only relationship to cellular networks is that it uses the same waveform and time division concept of LTE. That is, operation in the PCS mode need not make use of a SIM card. To be clear, LTE-V2X includes the wide area access via the core network, and this is often called vehicle-to-network (V2N). This wide area network mode of C-V2X does require network infrastructure and a SIM card, and can be simply regarded a natural evolution of cellular networks with some vehicle-specific features such as Quality of Service (QoS) required for V2N. To cover all bases, there is also a direct communication mode of C-V2X that requires local infrastructure to “referee” the time slots. This is called Mode 3.

Finally, Mode 4 which includes a specification for distributed algorithms implemented between vehicles without network assistance. PCS Mode 4 uses Global Navigation Satellite System (GNSS) receivers for synchronisation instead of relying on cellular network coverage. This section focuses on Mode 4, and specifically 3GPP-specified LTE-V2X beginning with Release 14 (Rel-14). This set 3GPP specification was completed in 2017. The automotive industry is specifically interested in Rel-14 and its very close variant, Rel-15 PCS Mode 4 because given availability of a common spectrum, operation in this mode does not require user subscription with the mobile network operators, and from a safety proposition the common spectrum, combined with well-defined and therefore standardised interfaces and minimum performance specifications, enables vehicle safety communication at scale.

**V2X upper layer standards**

As stated, LTE-V2X and 802.11p interoperate based on radio access and service layer specifications and standards. These specifications are defined and profiled in the US by SAE International. Within SAE, both the DSRC and C-V2X Technical Committees and other nascent committees do this work under a newly-formed SAE Communications Steering Committee.

In Europe, the aforementioned ETSI TC ITS defines upper layer standards; moreover, there exists vehicle-based application profiles developed and recently refined by the Car-to-Car Communications Consortium (C2C-CC) and roadside-based profiles developed by the C-ROADS Platform ([https://www.c-roads.eu/platform.html](https://www.c-roads.eu/platform.html)). A potential pan-European Delegated Act may in fact define a normative profile which is drawn from C2C-CC and C-ROADS.
In China, China SAE has defined initial upper layer standards which are similar to the SAE International standards, and C-ITS is developing a companion set of national standards, again similar to SAE International standards. It is worth noting that Japan’s Association of Radio Industry Broadcasters (ARIB) has developed an “ITS Connect” standard which has some similarities to the WAVE stack; however, ARIB standards and ITS Connect are uniquely applied to Japan.

Additionally, the ISO TC204 (Intelligent Transport Systems or ITS) WG16 has developed a base set of Cooperative-ITS (C-ITS) standards which are in principle media independent, on top of which there are a series of medium-specific adaptation standards. However, there have been only a few implementations of vehicular safety communications using ISO standards to date.

Finally, because all these standards require trust and therefore authentication of the source of the vehicle safety messages, there are largely globally harmonised security service standards that describe how certificates (and the ‘digest’ or a subset of certificates) are transmitted. These certificates are bootstrapped, replenished and revoked via still-under-development Public Key Infrastructure (PKI) institutions that are being separately developed in the US, Europe, China and elsewhere.

While there are some aspects of these standards that are dependent on particular radio access technologies, the V2V and V2I safety service profiles – and the dozen or so years of research and trial deployments – can be for the most part used with almost any radio access technology as shown in the visual below. In this example, the air interface in green is LTE-V2X, and the blue upper layers are reused. It could be suggested that this layered approach is in principle part and parcel of ETSI and SAE specifications and standards, but that is not really the case. There are still a significant number of cross-layer references, requiring some rework of the standards. This rework is currently underway in both ETSI and the SAE.

Figure 3: Air Interface Layers
Comparison
The IEEE 802.11p-based V2X technologies were developed over a decade ago. Improvements in modulation, coding and transmission time as well as better receivers and overall advances in technology driven in 3GPP enable LTE-V2X to offer increased communication range (~2X). Alternately expressed, this yields higher reliability (lower packet error rate) over the same communications range. This improvement translates to better non-line-of-sight (NLOS) performance compared to IEEE 802.11p-based radio technology. Hence, in real world situations, LTE-V2X can more reliably deliver V2V and V2I safety services.


From that work it is clear that LTE-V2X shows superior performance to 802.11p in parameters that matter for vehicle safety communications: reliability (measured in packet reception rate), end-to-end latency (sec), and resiliency to interference.

Additionally, in that report LTE-V2X is shown to perform as well as 802.11p under channel congestion. (Such channel congestion can subsequently be addressed by adapting congestion control mechanism defined by ETSI and SAE.) LTE-V2X is shown to not be adversely affected by the hidden node scenario. In such a scenario, two transmitters reach the same receiver, but they are out of communication range of each other. Because the two transmitters are unaware of each other, the concern, mitigated by data, is that the scheduling algorithm would not be able to effectively avoid mutual collision.

Finally, LTE-V2X was shown to not be susceptible to the near-far effect, where there could be signals from two or more transmitters with different power levels in adjacent subchannels. Such a power difference can occur even for two nearby transmitters when one of them is obstructed and be perceived as two sources at different ranges.

The table below summarises key C-V2X technology attributes:

| Key attributes       |  |
|----------------------|  |
| **Range**            | Around twice the range of 802.11p |
| **Reliability**      | More reliable than 802.11p at the same range |
| **Latency**          | ~ 4ms transmission latency (with end-to-end latency determined by configurable Packet Delay Budget) |
| **High speed support** | Up to 500km/h relative speeds |
| **Spectrum**         | ITS 5.9GHz |
| **Channel Size**     | 10/20MHz |
| **Waveform**         | SC-FDM |
| **Modulation support** | Up to 64 QAM (Rel-14) |
| **Channel Coding**   | Turbo coding |
| **Synchronization**  | Synchronous |
| **Resource Selection** | Semi-persistent transmission with frequency domain listen-before-talk |
| **Security and Privacy** | Reuse of security services defined by ETSI, SAE and IEEE 1609 |
Many countries/global regions have allocated spectrum for ITS near 5.9 GHz. (Japan is the exception, as there is 9 MHz allocated at 755.5-764.5 MHz for their ITS Connect safety services). From a global perspective, the International Telecommunications Union (ITU) has an agenda item to address harmonisation of ITS spectrum at 5.9 GHz at their next meeting, World Radio Conference 2019 is to be held in Sharm el-Sheikh, Egypt, 28 October to 22 November 2019.

In the USA, beginning in 1999, 75 MHz (5850 – 5925 MHz) with a 5 MHz guard band (from 5850 – 5855 MHz) and nominally six 10 MHz service channels and one control channel are allocated for 802.11p, and no other radio technology is allowed in that band, except under experimental license. The V2V channel is designated to be CH172, the 10 MHz at the lowest end of the ITS spectrum. There is a concept of multi-channel operations with an always-on safety channel (CH172) and a second 802.11p transceiver which rendezvous with other vehicle or infrastructure 802.11p transceivers at the control channel half time, listens for a service advertisement, then spends the remaining time in a pre-defined message exchange. This scheme is defined in IEEE 1609.4.

In early 2017, the National Highway Traffic Safety Administration (NHTSA) issued a V2V Notice of Proposed Rulemaking (NPRM) to mandate V2V. This NPRM focused on CH172 only. At the time of writing, the V2V NPRM is no longer active, as there has been a change of NHTSA philosophy, but the present situation is that the US Department of Transportation will not pick “technology winners or losers”.

The early and small scale 802.11p deployments in the US are therefore voluntary and not mandatory, with various road infrastructure owner operators installing roadside units. On the vehicular side, General Motors has installed a CH172 802.11p radio on Cadillac CTS models beginning in model year 2017. Toyota has announced they will deploy 802.11p across different Toyota and Lexus models beginning in 2021, claiming to use the entire 70 MHz; however, it is uncertain whether they will implement multi-channel operation to fulfil that claim.

Of significant interest is that unlicensed Wi-Fi proponents have long coveted the spectrum from 5850 to 5925 MHz, as their consensus view is that it has lay fallow for nearly 20 years. In 2013, there was a Federal Communications Commission (FCC) Notice of Proposed Rule Making (NPRM) on how to share some of this spectrum, which would allow unlicensed Wi-Fi to operate within it, given that “harmful interference” of safety-of-life communications has been shown to not be the case. The FCC has recently released a test report (https://www.fcc.gov/document/fcc-requests-comment-59-ghz-phase-i-testing-data) for the laboratory “Phase 1” assessment of sharing techniques, but there has been no definitive ruling, at the time of writing. Of additional significance, in 2014 the FCC relaxed the emission limits for Wi-Fi which affects the lower end of the ITS spectrum adding another interference source to CH172 operations.

In late 2018, the 5G Automotive Association (5GAA) introduced a waiver petition to FCC to access the ITS spectrum and the particulars. This includes a what is the channel plan that would allow C-V2X to use the upper 20 MHz of ITS spectrum while accommodating 802.11p operation in CH172. Subsequently, SGAA introduced a motion, that asked for 40 MHz for use in 5G side-link. It is expected that there will be continued discourse in the US, given that proponents of unlicensed Wi-Fi also want spectrum in this regime.

The unanswered question is when will the LTE-V2X/C-V2X supporters introduce a petition and/or waiver to access the ITS spectrum and the particulars: what is the channel plan, and will it be compatible with 802.11p operation in CH172?
Europe

In 2008, the European Commission has allocated 70 MHz to ITS, with 30 MHz available for safety services but on a technology-neutral basis. The C-ITS community in Europe has focused on the 30 MHz for safety services. A complicating factor is that until 3GPP Rel-14 LTE-V2X was undergoing standardisation ETSI and to some extent CEN C-ITS standards, mandated under M/453 in 2010, have assumed that 802.11p would be the underlying air interface to deliver these services. The assumption was that so-called Day 1 and Day 1.5 services would only need 10 MHz, and most of the standardisation and field trials focused on using the control channel. Multi-channel operations were assumed to be necessary much later.

With the advent of LTE-V2X, 5GAA has proposed a band plan that allocates priority to the lower 10 MHz for LTE-V2X and the upper 10 MHz for 802.11p, with the middle 10 MHz as a guard band. The 5GAA proposal is predicated on the belief that the market can decide the prevailing technology, and eventually that technology would encompass the spectrum. European Conference of Postal and Telecommunications Administrators has mandated ETSI to study sharing schemes, and that work is underway. The Wi-Fi encroachment into the spectrum is not an issue in Europe, but CEN DSRC (tolling) as an existing and therefore ‘victim’ technology which has a poor out of band emission mask and leaks into the lower end and urban rail / communication-based train control, which wishes to use ITS spectrum at the higher end complicates matters.

Recently, the European Commission and Member States updated the aforementioned 5.9 GHz ITS spectrum mandate to CEPT/ETSI. Key changes included adding an ITS spectrum band extension to 5935 MHz, which provides an additional 10 MHz for a total of 80 MHz and spectrum priority settings with 40 MHz for road ITS (5875-5915 MHz) and 20 MHz for urban rail ITS (5915-5935 MHz). This mandate will result in a CEPT Report and a follow-on update of the EC Decision 2008/671/EC on 5.9 GHz based on CEPT findings.

The recent Delegated Act that prescribed ITS-G5 to deliver specified C-ITS services has evoked the technology debate in Europe, with C-V2X proponents considering approaches to revise the Delegated Act within months of its potential date to be put in force.

China

China has no legacy of ITS safety communication; therefore, by and large Chinese institutions have embraced LTE-V2X, this includes spectrum regulators. In July 2018, the Bureau of Radio Regulation (BRR) released for public comment use of 5905-5925 MHz for vehicle direct communication. This would appear to be the first time globally that a regulator has assigned dedicated spectrum for 3GPP Rel-14 C-V2X. Consolidating comments received during the public consultation, in October 2018 BRR formally announced the allocation of 5905-5925 MHz for LTE-V2X in China and recommended one 20 MHz channel. BRR also announced that Flight Service Station use of 5905-5925 MHz will not be approved beginning in 2022, clearing this band for LTE-V2X.
Tomorrow’s 5G networks will address a host of verticals in three technology pillars: enhanced mobile broadband, massive Internet of Things (IoT) with many small short-range communications, and mission critical control. For an overview of these please see https://www.qualcomm.com/invention/5g/what-is-5g among other widely available references.

It is important to point out that while the automotive industry is an important vertical in the development of 5G, other industry verticals are pushing many 5G innovations, and the automotive community can benefit from those. One such potential benefit would be the advent of network slicing – from the vehicle to the core network and back on a reservation basis – to provide potentially low latency services with predictive quality of service but over mobile network operator-control spectrum.

However, the evolution of direct communication for low latency, high mobility applications is mostly in the automotive domain. Autonomous vehicles will require continued technology evolution to accommodate ever-expanding safety requirements and use cases. The path to 5G is expected to deliver this direct communication evolution.

Building upon C-V2X, 5G PC5 is expected to bring even more possibilities for the connected vehicle with extreme throughput, low latency, and enhanced reliability. Some of these use cases are illustrated in the following visual.

**Figure 4: Evolving C-V2X Direct Communications Towards 5G NR – While Maintaining Backward Capabilities**

- **Evolution to 5G NR, while being backward compatible**
  - C-V2X Rel-14 is necessary and operates with Rel-16
- **Autonomous driving use cases**
  - 5G NR C-V2X Rel-16
  - Backward compatible with Rel-14/Rel-15 enabled vehicles
  - Higher throughput
  - Higher reliability
  - Wideband carrier support
  - Lower latency
- **Basic and enhanced safety**
  - C-V2X Rel-14/Rel-15 with enhanced range and reliability
- **Basic safety**
  - IEEE 802.11p

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**5G V2X**

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In 3GPP the radio access network design for 5G “new radio” is being developed, with considerations for backward compatibility. This evolution will include some significant performance parameters to enable some of these envisioned applications.

3GPP Rel-14 LTE-V2X addresses the basic safety applications envisioned in the early days of V2X deployment. Those applications are depicted at the left in the above diagram, whereas 5G NR V2X addresses advanced applications and those under the aegis of autonomous or automated driving depicted at the right side of the diagram. These applications are complementary. Hence, 5G NR V2X does not replace R14 LTE-V2X for basic safety. Instead, 5GAA extends the capability V2X communication to enable these advanced use cases on new spectrum.

There is a long-standing supply base for 802.11p, starting with the Qualcomm-Atheros 802.11p chipset, upon which the original trials and standardisation through to the current day where chipset suppliers include Qualcomm, Autotalks and NXP. On top of that supply base is a global stack supplier industry that includes Cohda Wireless, Commsignia, Genvict, Marben, Nebula, Neusoft, and Savari. These companies, amongst others, provide standards-based 802.11p implementations in Europe and the US, and they are also tracking and supplying to emerging Chinese standards. On the vehicle side, there are Tier 2 module makers and Tier 1 integrators. On the Remote Switching Unit (RSU) side, there are stack suppliers which can provide units, either by themselves or with partners in the traffic signal control industry.

This base gives LTE-V2X, generally marketed as C-V2X as a global solution for V2X communications, a starting point. Many suppliers and system integrators have expressed their support for the deployment of C-V2X technology in upcoming production vehicles and RSU starting as early as 2019.

As examples, Qualcomm Technologies and others are currently conducting C-V2X field validations working with car manufacturers and automotive ecosystem participants in Germany, France, Korea, China, Japan, the U.S. and elsewhere. Chipsets supporting C-V2X were first announced in late August 2017 by Qualcomm, then by Datang in November 2017, and in February 2018 by HiSilicon. These are 3GPP Rel-14 direct communication chipsets. Automotive ecosystem participants interested in delivering next generation products incorporating C-V2X technology using Qualcomm Technologies’ solutions include Tier-1 suppliers LG Electronics, Continental, Ficosa-Panasonic, Lear and Valeo, as well as cellular module manufacturers Gemalto, LG Innotek, Quectel, Sierra Wireless, Telit, WNC and ZTE.

Qualcomm Technologies is also working with the very same software stack and application providers listed in the prior paragraph as 802.11p suppliers: Cohda Wireless, Commsignia, Genvict, Marben, Nebula, Neusoft, and Savari. Traditional LTE module system integrators such as Sasken and Thundersoft are part of this LTE-V2X commercialisation ecosystem. Other chipset makers are taking different paths: Datang announced the development of their own module and software stack, and HiSilicon is working with their parent company, Huawei, to produce a full stack and module.

A mixture of radio, software stack providers and automakers gathered at the annual meeting of China SAE in early November 2018 to showcase multi-levels of interoperability, in an exhibition of technology maturity of C-V2X technology.

In conclusion, commercial solutions are becoming available now in the form of modules, and products including RSUs and aftermarket onboard units are expected to enter the global market from 2019, with some automakers expected to launch commercially in vehicles in late 2019/early 2020. Global markets are embracing C-V2X technology, with significant activity throughout Asia, especially in China, and with interest in Europe, and in the US.

In summary, it is expected that 3GPP Rel-16 will deliver a direct communications radio that will enable some of these use cases. The challenge will be to find the usable ITS (and therefore common) spectrum for automotive applications. Ideally, that spectrum would be sub-6 GHz, as higher frequencies and particularly the millimetre wave spectrum are difficult to work with in the vehicle (with cabling and antennae) and with high mobility applications.
Securing computers and networks is challenging, as evidenced by frequent reports of data breaches and vulnerabilities. Until now computer and information security has generally focused on the need to protect data, with the greatest impacts of compromised security tending to be financial in nature or related to data privacy. The advent of increasingly connected and automated vehicles is an important example of how computing devices are now being placed in control of physical processes, as well as being connected to other networks such as the internet and critical infrastructure. These so-called cyber-physical systems now mean that life and health can potentially be impacted by security failures.

In a similar way to IT cybersecurity, defending against attacks in connected vehicle systems requires a combination of measures providing a defense in depth approach. This should include both proactive measures that are 'designed-in' during vehicle development, and reactive measures that can cope with unknown new attacks and enable the vehicle to recover or survive with an appropriate level of availability.

A broad landscape of security standards for connected vehicles is emerging, with a range of process and technical standards either recently published or under development. The following overview describes some of the key standards development activities in this area.

Although no international standard yet exists for automotive cybersecurity engineering, the SAE recommended practice J3061 was published in January 2016. This describes a framework which organisations can use to integrate cybersecurity engineering activities into an overall engineering process. In common with ISO 26262 for functional safety, SAE J3061 recommends a product development lifecycle based on the systems engineering V-model, incorporating appropriate security activities throughout the vehicle lifecycle, from concept through product development, production, operations and decommissioning.

More recently, ISO and SAE agreed to collaborate on the development of future joint standards and formed a joint working group in October 2016, which is currently developing ISO/SAE 21434 Road Vehicles – Cybersecurity Engineering. This international standard will build on the foundation of J3061 and incorporate existing cybersecurity best practices. ISO/SAE 21434 will provide a framework that includes requirements for a cybersecurity process, and a common language for communicating and managing cybersecurity risk amongst stakeholders, addressing the challenges of risk management across the complex automotive supply chain. The standard will focus on process requirements and will not prescribe specific technology or solutions related to cybersecurity.

Cybersecurity is also the subject of ongoing regulatory activity, with a United Nations Economic Commission for Europe (UN ECE) task force for cybersecurity and over-the-air updates recently submitting recommendations to the parent UN committee for future vehicle type approval regulations on these topics.

Further best practices and guidelines on a range of cybersecurity topics are under development by SAE. SAE J3061-2 is a work-in-progress recommended practice which will provide examples of methods for cybersecurity testing and assurance. Another work in progress is SAE J3101, which will cover hardware security. It will contain a set of common requirements and use cases for hardware protected security environments suitable for automotive applications.

SAE J3138 is a recently published recommended practice providing security guidance related to the diagnostic link connector (OBD-II), to ensure safe vehicle operation if a compromised external device is connected to this port.

A number of existing ISO standards for data communications in road vehicles are currently being updated to address cybersecurity, such as ISO 14229 for Unified Diagnostic Services and ISO 20777 covering the Extended Vehicle (ExVe).

Technical security standards related to V2X communications are also available and under development. In Europe, ETSI publishes standards for Cooperative Intelligent Transport Systems (C-ITS) based on the wireless standard IEEE 802.11p. The key security related ETSI C-ITS standards include TS 102 731 Security Services, TS 103 097 Security Headers and Certificates, and TS 102 940 ITS Security Architecture and Security Management. The IEEE also publishes the IEEE 1609 series of standards for V2X communications which are also based on IEEE 802.11p. IEEE 1609.2 covers the security aspects, including secure message formats and security management.

It is important to recognise that conformance to standards alone does not automatically lead to a secure vehicle. However, security standards based on expert industry consensus do provide important building blocks for organizations to develop sufficiently rigorous engineering processes and robust security measures. Appropriate application of these processes and measures provides greater assurance that a connected vehicle can remain adequately secure over its lifetime.
4. Applications and Commercialisation

In-Vehicle Services and Backend Data Platform and Infrastructure

Connectivity is one of the current mega trends, which not only has a huge impact on lifestyle for us all but will lead to radical transformations in the automotive industry.

Emission-free, accident-free and stress-free mobility are the main objectives for connected mobility solutions. However, the main benefit should always be with the end-user whose future mobility needs have to be simplified. Consequently, an integration of the mobility user ecosystem (personal preferences, user accounts) with the numerous mobility ecosystems offering “Mobility-as-a-Service” is required. Data fusion between these ecosystems will be a main objective of a data platform. The basis of these requirements are the exchange of data with vehicles and backend to backend integrations to exchange data between ecosystems. Already today, end-users gain from new connectivity opportunities such as intelligent infotainment systems. It should also be considered that the more traditional vehicle domains like powertrain will be positively affected and will benefit from the advantages of connectivity.

Today powertrain software functions are located in Electronic Control Units (ECUs) inside the vehicle. By implementing the infrastructure for connectivity into the vehicles, it will be possible to execute parts of the software functions in the backend. Complex, but less-time-critical tasks with high demands on computational power and memory will be switched to cloud computing networks. High-level calculations like optimising speed profiles, context dependent control calibrations and diagnostics will be outsourced. The results are then transferred to the local in-vehicle network and the connected ECUs for further processing. It is obvious that simpler but time and safety critical tasks remain in the vehicle ECUs.

Autonomous driving would not be possible without offloading computation to the backend. Safety critical functions will always have an in-vehicle fall back. For crowd sourced services which utilize a cross OEM fleet the data platform will be the interface to several OEM backends to receive data and provide value-added information. A digital twin (digital representation of processes, systems and devices) of individual components, subsystems as well as a holistic system will allow for further data analytics and to combine digital twins for end user relevant services. Such interoperability can only be achieved with compatibility of data models and data formats.

New services will be created to improve existing features like “Predictive Diagnostics”. Today the scope of diagnostic capability is related to the individual vehicle. Connected vehicles make it possible to extend this scope to whole fleets and to collect all relevant information in the backend data platform.

Highly sophisticated algorithms based on artificial intelligence are able to analyse large amounts of fleet data to identify non-obvious correlations between different signals. The gathered information will be used for health and condition monitoring, refurbishment and even value assessment of components of the vehicle. Improved telematic services can provide smart maintenance services. This becomes all the more important as the car sharing market continues to grow with a challenge of cost control for fleet operators.

Another example for a new service inside the powertrain domain is the connected horizon. Already today, engine and transmission control systems adapt to the information of the topography and geometry of the road network. In the future, this information will be combined with the current traffic situation as well as the road condition sensed by other vehicles and provided to cloud services. This will help to equalize traffic, improve safety and reduces CO2 emissions.

The backend data platform offers fully operated solutions, which are ready to integrate as well as services that can be used as building blocks for developers to build white-labelled customer specific solutions, which can be offered to their users in a B2C context with integration and operation also delivered by the service provider. Since OEMs have made their choice of cloud providers and connectivity devices the data platform should be cloud agnostic (use of different IaaS provider) and device agnostic (connectivity device independent). Integrations between OEM backend and solution provider backend will become more relevant for global, large-scale applications.

As a basis for all services involving connected cars a typical data platform consists of the following layers:

1. The device itself with a Connectivity Control Unit (CCU) connecting the device to a backend.
2. The backend manages the connectivity on layer.
3. Further generic functions to manage devices and log activity.
4. First layer with mobility relevant services, which are hosted in a micro-services architecture for compatibility and interoperability. Platform service Application Programming Interfaces (APIs) are available for use of partners and customers.
5. Fully integrated and operated solutions such as “Predictive Diagnostics” or “Connected Horizon” are hosted on this layer.
6. Integration between solutions (vendor agnostic) of layer 4 with adjacent data fusion and holistic system approach.
From the idea to the rollout, developers can use the modular building blocks to develop connected solutions by using already existing platform services. Platform services can provide functions, which can be integrated in the connected solution architecture. To give an example, connected horizon requires a map reference to provide accurate information attributed with geo coordinates matched on a map. A map matching platform service helps to bring geo attributes and information about road topography, geometry and in the future road condition together and make it consumable. To combine cyber security with functional safety security services, data encryption and anomaly detection have to be integrated as well.

Integrating and operating connected mobility solutions can become quite a challenge if in-vehicle, cloud and big data expertise need to be combined. Only a few providers can offer this combination of expertise. IT companies are working on gaining relevance but show white-spots for in-vehicle system expertise.

Connectivity Needed for OTA Software Updates

Connectivity is also likely to be required for Over-The-Air (OTA) software updates - ironically, the need for connectivity increases cybersecurity risks which drives a need for OTA updates. Increasingly, even conventional automobiles are becoming software platforms on wheels and it is expected that all new automobiles sold in 2025 will have embedded cellular connectivity (as well as Wi-Fi). The increased complexity of electrical architectures and vehicle software, together with competitive pressures to introduce vehicles as quickly as possible, are leading to vehicle recalls that are software-related. Traditionally, customers have had to go to automobile dealerships to attend to recalls but this is inconvenient, a more convenient and less expensive approach is to re-flash the software over-the-air, an approach which will also lead to high levels of recall completion.

Another benefit of OTA software updates, is that new capabilities can be enabled in the vehicle post-sale, perhaps creating additional revenue streams for the automaker. Software can continuously be developed throughout the vehicle’s lifecycle to increase the functionality of the vehicle’s embedded hardware (e.g. new Advanced Driver Assistance Systems (ADAS) or self-driving features). Or the vehicle might be tuned differently because actual customer usage may turn out to be different or less demanding than was assumed during the development process (e.g. extending the Electric Vehicle (EV) battery’s state of charge and range of operation).

OTA updates bring with them two types of challenges, however. The first involves the practical matter of how to reliably execute the update. A safety-related OTA update needs to occur as soon as possible, but the vehicle may not be in an area where there is cellular or Wi-Fi connectivity at that time.

With a data platform new business models can be managed and consumption of platform services on layer (3) can be billed depending on use-case (integration vs. direct go-to-market) as a subscription or a licensing model. A network of partners can be used to quickly scale solutions worldwide. In this environment it is typical to partner with companies which might be in competition on another layer/field.

In addition to new functions, the business model for software begins to change: Software will be more and more independent from the used hardware. Standards such as AUTomotive Open System ARCHitecture (AUTOSAR) enable software that is independent of chosen microcontrollers and microprocessors. This is supported by hardware virtualization, means software will be executed on virtual machines, separated from the underlying hardware resources. In consequence, Software as a Product (SaaP) as well as Software as a Service (SaaS) will become a major business model for suppliers and OEM.

Even if there is connectivity, the update may take a long time and create inconvenience for the vehicle’s owner (this may be less of an issue with an AV fleet owner), especially if the update is interrupted and has to be restarted from scratch. Moreover, the update may also require that the (electric) vehicle is not charging at the same time and the delayed charging time may mean reduced vehicle range and the associated inconvenience.

These issues, though troubling, are less worrying than the second type of challenge which is related to ensuring the security of the vehicle and its associated cloud system service while the update occurs. Cybersecurity risks can harm the vehicle systems and render vehicle operation unsafe with loss of control and vulnerable to theft. Although non-connected vehicles are susceptible to hacking (via the On-board Diagnostics (OBD)-II port, keyless entry, Bluetooth pairing with personal devices, etc.), the probability and severity of hacking will be significantly increased with connected vehicles in the future, especially connected automated vehicles. Future vehicles will have many more attack surfaces and since fundamental vehicle systems for braking, steering and acceleration will be increasingly connected to the cloud it is possible that a virus can not only infect the cloud service but can then put at risk other vehicles in the fleet. Non-infected vehicles on the road could also be at risk due to the unsafe operation of the infected vehicles. Personal and financial information can, of course, also be stolen or compromised.
Fortunately, help is on its way as many automotive and technology companies are developing holistic approaches to end-to-end security. This includes, for example, protecting critical vehicle systems from more vulnerable infotainment interfaces during the design of the electrical architecture, and developing electronic control unit processors that have secure boot mechanisms, cryptographic techniques and embedded hypervisors. Artificial Intelligence also has a role to play as it can infer malevolent intrusions and alert other systems of suspicious behavior. OTA software updates for critical vehicle functionality may need to be delivered from an OEM-controlled gateway to a dedicated modem on the vehicle, separate from the customer-facing one needed for delivering internet content to the vehicle’s infotainment system. OTA solutions are necessary for securing the vehicle throughout its lifecycle because even secure embedded vehicle electrical and electronic systems can become vulnerable over time to increasingly sophisticated cyberattacks if there is no updating of the security protections. Such updates should have end-to-end security between the vehicle and cloud and can provide analytics and prognostics to monitor all vehicle systems to ensure best performance and security.

Connectivity Needed for Tele-Operation

Recent events in 2019 have illustrated the potential benefits that may be realised if Tele-Operation is used to complement AV deployment. One incident involved a driver sleeping while in Auto-pilot mode and another involves some complaints from the general public that robotaxis can stop unexpectedly and hesitate to advance, necessitating a switchover to manual mode. In both cases, a Tele-Operator could conceivably take over control of the vehicle and drive it to safety or enable it to proceed forward without holding up traffic.

It can be argued, in fact, that Tele-Operation may be necessary in the near-term for a fleet operator because it not only improves passenger satisfaction if the vehicle is not overly cautious, but it can also reduce the manpower required to rebalance stranded vehicles. Corner-cases that can confuse AVs and cause hesitation may hurt customer acceptance, but tele-operation might alleviate the problem and allow a viable robotaxi service to be implemented sooner. Since passengers in the robotaxi may need to contact a remote service centre operator for other reasons (e.g. for safety, security or comfort) this connection may already exist between the vehicle and a remote operator.

Tele-Operation solutions require that the:

- Vehicle senses its environment
- Vehicle communicates to a remote Tele-Operator its 360° awareness of the situation
- Tele-Operator sends commands to vehicle to control braking, steering, acceleration.

Stereoscopic images or 3D sensor data (e.g. lidar, radar and camera) representing what the vehicle sees is probably necessary because it is more difficult to determine depth visualisation with monoscopic images. Colour images are easier for humans to process than black and white images (shadows, in particular, make it harder to see with monochrome images). Virtual Reality Head-Mounted Displays (HMDs) tend to provide a more compelling immersion experience for the Tele-Operator than traditional large simulator screens. HMD security authentication will be necessary in order to permit secure access to the vehicle in order to take over control.

Low wireless communications latency is obviously critical between the vehicle and Tele-Operator and should be a least 10 times faster than the vehicle’s mechanical latency. Therefore, the time for both uploading high-quality sensed information, remote processing and downloading commands will need to be <<100 ms. This is particularly challenging for highway speed operation and may justify initial deployment with robotaxis operating in a city centre where vehicle speeds are typically <50 kph. Bandwidth requirements can be reduced with smart data compression protocols and by sending only the “delta” image to the Cloud (and perhaps with only the edges of the object rather than the entire object). A high bandwidth connection will be needed in case of decreased performance (multiple users, obstructions, etc.). It may also be appropriate to select routes for where the signal strength is known to be high if it does not affect vehicle safety or trip duration negatively.
The vehicle needs to have, at all times, a planned emergency stop function in case connectivity fails. The Tele-Operator, ideally, has approximately 10 seconds to adjust to seeing a new environment when they are required to engage. Actuator control is relatively straightforward for by-wire vehicles, so this should not be an issue.

Although Wi-Fi can be faster than 3G or even LTE, the latter should be adequate and may enable large area coverage more affordably. Future 5G systems with pico-cells can further improve Quality of Service (coverage, bandwidth, latency). Rather than sharing with other road users, a dedicated cellular connection might improve service reliability. Moreover, each fleet operator may decide to have its own Tele-Operation center since knowing what causes the Tele-Operation system to engage could be confidential information to the company and tied in with its proprietary software development.

The cost of the hardware to enable tele-operation can be modest, especially for low speed robotaxi operation, and it should be possible for one Tele-Operator to manage many vehicles since robotaxis typically do not fail at the same time and/or can be scheduled to move at different times. Robotaxi development can learn from each “remote control” engagement and this should lead to improved algorithms for all the vehicles in the fleet.

Tele-Operation could become a more active area for development because corner-cases can delay robotaxi deployment and business model monetization. Some of these applications could include:

- Failure for the driver to respond to take over, as requested, in L2+ operation
- Taking over if the AV systems degrades below a certain level (either due to system failure or environmental conditions) and manual control is impossible
- Augmenting the robotaxi in rebalancing the shared vehicle fleet.

Other types of examples might include moving autonomous, electric vehicles at night to charging stations and returning them to the customer’s parking spot in the morning prior to being used by the customer; this may be particularly attractive in regions, such as China, where homes may not have a charge port and where a remote charging infrastructure can be less expensive to install and have greater utilization to reduce costs. Another example might be driving the passenger(s) in autonomous mode to a local hospital or care-giver or even, in some cases, locking the vehicle and driving the vehicle to a local police station. It is true that these corner-cases can be achieved without Tele-Operation, but the use of Tele-Operation can make the performance more reliable and improve the perceived safety of the robotaxi fleets.
5. Closing Remarks

V2X Landscape

There is much progress being made as the international technology community develops the V2X landscape, uncertainty has been referenced a number of times from contributors to this FISITA Briefing Paper, which therefore means opportunity lies ahead, especially with regard to technology preference, safety, spectrum, the regulatory landscape and progress towards 5G.

It seems likely that LTE-V2X will transition to 5G under the more generic umbrella of C-V2X. The reasoning for this statement is straightforward and based on market forces: most new vehicles are expected to feature embedded cellular connectivity in 2021, with some automakers set on enabling virtually all of their vehicles with cellular modems in the near future.

Integrating LTE-V2X into cellular modems allows for LTE-V2X implementation to become extremely cost-effective at a time when the auto industry is moving toward 100% wireless connectivity. Also, by leveraging the existing cellular infrastructure for network communications (V2N), LTE-V2X can combine the capabilities of roadside units (RSUs) and the cellular network to help improve safety and support autonomy (e.g. providing local and wide-area road condition information and real-time map updates).

Combined RSU and cellular infrastructure can reduce deployment cost, resulting in important economic benefits. Cellular players’ extensive experience in deploying, managing, and maintaining complex communication systems will not only provide cost savings, but can also support new business models and service opportunities.

In addition, the following questions will need to be answered in the future:

- With the deployment of 5G, the coverage will need to be available across all types of roads. Without a clear business model, C-ITS in the short to medium term does not look economically viable, especially in low density areas. Cross boundary roaming will also need to be considered and will be key for mobility, particularly for the automotive industry.
- The C-V2X business models – how should these be framed with different stakeholders, such as OEMs, Telcos, etc.
- Who will operate the 5G co-operating driving services and the Mobile Virtual Network Operator (MVNO)?

Amelie Gong
Vice Secretary General, China SAE
Proposal for the development of vehicle connectivity

Contributors to this FISITA Briefing Paper have created an extremely relevant study on the development and strategic layout of the global vehicle connectivity industry, which is comprehensively presented.

The paper objectively analyses the development degree of relevant, current automotive technology R&D and the potential pathways of the future through contributions from North America, Europe and Asia, delivering a broad mix of opinion from a diverse international community, covering many areas of technological relevance - as well as presenting thoughtful consideration of other relevant and associated areas, such as: policy formulation, laws and regulations improvement, infrastructure construction progress, technical support and future planning.

The Paper delivers oversight, opinion, support and reference from within the international FISITA community, delivering a current perspective and consideration of the potential near and long-term development of the future. All from a moment in time when our industry is evolving rapidly, and embarking upon an exciting transformation, as reflected by the title of the 2018 FISITA World Mobility Summit – ‘Vehicle Connectivity’.

As an output from the 2018 Summit, this Paper is intended to be a reference document that enables our technical leaders to share knowledge, as a key contribution to the pre-competitive technical community of FISITA. It will also enable others to draw from their expertise and thought leadership in support of the continued development of vehicle connectivity.

As we consider the present position and future challenges and opportunities, it is clear that the acceleration of international cooperation and collaboration, by making use of regional expertise, can be a key component in the development cycle of existing and new technologies.

A key role in support of the world’s technologists is being delivered through FISITA’s promotion of communications between the relevant practitioners via various activities such as the annual technical leadership event, the World Mobility Summit.

Conclusion

The role of FISITA in this context

As the world’s technology community continues to progress the vehicle connectivity agenda, FISITA continues to provide the pre-competitive environment which supports engineers to collaborate, share knowledge and learn from each other in equal measure; this is in pursuit of their quest to develop and deliver next stage technology, contributing to the creation of safe, sustainable and affordable mobility for today and tomorrow.

The key contributors to this FISITA Briefing Paper summarise the importance of FISITA as the bond which builds connection, promotes international cooperation and facilitates international communication between its mix of Society and Corporate Members, academia and relevant stakeholders. Stating that FISITA is an excellent learning and networking platform enables individual engineers and researchers in the global automotive and mobility systems industry to communicate seamlessly, facilitating the development and application of emerging technologies.

FISITA has enabled an effective, high-level, thought-leadership culture to gather and consider the relevant technological developments of the moment and harvested opinion and take out actions which will now be shared and progressed via working groups and membership forums.

Mike Ma
VP Technical, FISITA
6. Contributors and Acknowledgements

References


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7. About FISITA

FISITA is the international membership organisation that supports the automotive and mobility systems sector in its quest to advance technological development. Having delivered against this mission for every generation of engineers since 1948, we are uniquely placed to promote excellence in mobility engineering and the development of safe, sustainable and affordable mobility solutions.

Since creation, FISITA has seen significant growth in influence and relevance. Today our network of Member Societies and Corporate Members extend a reach to over 210,000 engineers in 37 countries, placing us at the heart of the industry and enabling members to connect with each other, network, share technological advancements and collaborate in a pre-competitive environment.

FISITA facilitates dialogue between engineers and industry, governments, academia, and environmental and standards organisations, across all areas of automotive and mobility systems technology. Achieved through organising and delivering internationally-acclaimed technical events, including the World Congress, World Mobility Summit, FISITA PLUS conference and EuroBrake, the world’s largest braking technology conference; as well as endorsing the significant events run by our Member Societies.

The FISITA Roadmap to 2020 strategic engagement plans see our organisation’s continued investment in the next generation of engineers through the ‘Your Future in Automotive’ initiative, and the long-term ‘Engineer 2030’ project, while our Industry Committee is pioneering our strategic tracking of the evolving mobility sector through the FISITA Eco-System mapping project – ensuring that our organisation continues to deliver leadership and a relevant community to this and future generations of engineers.

Engineers create solutions, FISITA continues to support them to do so.

Vision

Promoting excellence in mobility engineering
Join FIEC today
The exclusive international community for mobility systems engineers

Collaborate, engage, share, learn

- Showcase your unique professional profile and network within the global community
- Search and apply for the latest industry jobs, internships and work experience placements
- Engage in peer-to-peer creative collaboration in the International Discussion Forum
- Hold direct conversations with others via the Private Messaging function
- Utilise the FISITA Travel Bursary for exclusive funding opportunities
- Gain unlimited access to FISITA content and resources
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Promoting excellence in mobility engineering

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Mobility Engineer 2030 is a collaborative initiative, utilising FISITA’s unique, international status and relationships between our key industry and academic stakeholders to consider how mobility engineers of the future can be best educated and prepared to deliver the skills-sets that the fast-evolving ‘mobility services’ industry will require.

What’s inside...

- How automotive is changing
- The demands of industry
- Examples of current best practice
- A new educational concept

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