Future networks – Connected cars

It is entirely likely that the emergence of new mobility services will drive a growing need for connectivity. Different technologies exist that are capable of meeting this demand, using different networks. This brief will focus on Intelligent Transport Systems (ITS) for roads, and specifically on connected cars, as a way to better understanding existing connectivity strategies and what impact they are expected to have, on both networks and the automotive sector.

Synopsis

The process of connecting road infrastructures to vehicles, and vehicles to each other, opens the way to a host of applications. Messages can be generated automatically by vehicles' on-board sensors (slippery road, emergency braking…) or sent by road infrastructure managers (roadwork, winter maintenance, traffic conditions…). They can be exchanged "directly" via short-range communications using the 5.9 GHz band, or over mobile operators' cellular network over longer distances, using the frequency bands allocated to those operators. One of the main challenges lies in creating an amalgamated ecosystem between vehicles, telecommunications networks and road networks, which would pave the way for a variety of uses in the areas of road safety, traffic efficiency, environmental protection and driver comfort.

Despite the promises surrounding connected cars, there are currently several obstacles hampering their deployment:

- the communication technologies that will outfit these vehicles have yet to be fully defined, and a fierce battle is currently underway between the sector's players – notably between carmakers working to impose their standard amongst the two rival technologies: ITS-G5 and C-V2X;
- the associated business models have not been clearly identified, especially with regards to the deployment of the roadside units that infrastructure managers use to communicate with vehicles;
- the difficulty of guaranteeing truly reliable communications over a large portion of road networks, with is vital for road safety-related use cases.

Lastly, it should be pointed out that, in addition to technologies based on built-in connectivity in cars, other models based on providing connectivity through the user's smartphone are likely to emerge, and rapidly usher in innovative applications.

1. Intelligent Transport Systems

1. Connected and autonomous vehicles

Intelligent Transport Systems (ITS) are designed as an ecosystem capable of collecting, processing and transmitting transport-related information, using digital technologies. They thereby create a communication link between the different layers of driving, namely the infrastructures, the vehicle(s) and the user. These systems have a range of uses, including driver assistance, connected and autonomous vehicles.

The term “**connected** vehicle” covers not only multiple connections but also a range of applications and services. A connected vehicle is connected not only to a network (Vehicle to Network, or V2N), making it possible to provide in-car services such as real time traffic updates, but also to exchange information with other vehicles (V2V), with infrastructures (V2I), and with pedestrians (V2P).

In addition to their connectivity, some vehicles can be outfitted with more or less advanced driver assistance systems. Those with the most advanced systems are called **autonomous** vehicles, capable of driving themselves, in some configurations.

2. Different use cases

Both connected and autonomous vehicles are already operational, and one of the selling points and sources of differentiation being pushed today is their steady progression towards increased connectivity and autonomy. Vehicles can already be partially connected: real-time traffic information, Bluetooth, etc. By the same token, some vehicles have an optional driver assistance solution, for performing manoeuvres such as parallel parking or emergency braking without requiring driver intervention.

There are many potential areas of application and use cases: road safety, traffic efficiency, environmental protection and driver comfort are the key driving forces behind connected vehicles’ design. And even more advanced goals are being explored for trucks and vehicle fleets.

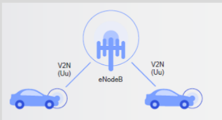
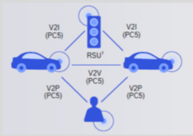
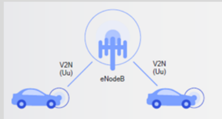
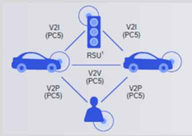
2. Existing technological solutions

The fact of vehicles’ growing connectivity raises the question of which technologies will be used to supply this connectivity, and what impact they might have on communication networks and their infrastructure. To be able to assess these implications, we first need to draw a distinction between the two main types of communication that enable connected vehicles to exchange information:

- direct, short-range communications that use the 5.9 GHz frequency band;
- long-range communications that use mobile operators’ cellular networks, in the frequency bands allocated to them.

A vehicle may be capable of employing communication methods using the 5.9 GHz band or mobile operators’ networks, separately or simultaneously. As a result, several connectivity strategies may exist:

Table 1: Connectivity strategies

	Mobile operators' bands	5,9 GHz band	Mobile operators' bands + 5,9 GHz band
Technologies	2G, 3G, 4G, soon 5G	ITS-G5 (Wi-Fi)	C-V2X (Cellular Vehicle-to-Everything)
Communication system	Vehicle-to-Network 	Vehicle-to-Vehicle Vehicle-to-Pedestrian Vehicle-to-Infrastructure 	Vehicle-to-Network Vehicle-to-Vehicle Vehicle-to-Pedestrian Vehicle-to-Infrastructure  

Source: Qualcomm

It should also be mentioned that network rollouts in mobile operators' frequency bands and in the 5.9 GHz band are not necessarily performed by the same players.

1. Direct communications in the 5.9 GHz band

On the matter of frequencies, for direct communications, connected vehicles can use the 5875 – 5905 MHz band (aka "5.9 GHz band") which was harmonised for ITS in the European Union through Decision 2008/671/EC.

The regime governing the use of the 5.9 GHz band is one of general authorisation, or licence-free use, reserved for ITS applications. Any Intelligent Transport System can therefore use this frequency band for free, without having to make a prior declaration or requesting an authorisation, provided it complies with the technical conditions for using the band defined by European authorities.

Performance and use cases

Direct communications in the 5.9 GHz band have the following properties:

- a range of around one kilometre for V2I communications, and around 500 metres for V2V communications;
- relatively low latency of around 10 milliseconds;
- relatively low speeds due to the narrowness of the available bandwidth;
- no guarantee against interference.

These performance levels can nevertheless vary considerably, depending on whether or not there are obstacles along the wave's path (notably in urban settings) and the density of vehicles using the band at the same time.

Direct communications in the 5.9 GHz band are not confined to only vehicle-to-vehicle (V2V) communications, but can extend to communication with the road infrastructure (V2I) via roadside units (RU)[1]. These RU can be installed in precise locations along the road, notably locations that are known to be dangerous, to warn connected vehicles and so reduce the risk of accidents.

Direct communications in the 5.9 GHz band are used to provide drivers with additional information on other vehicles, on the state of traffic and the driving environment. This information serves to complete information detected by the vehicle thanks to its own sensors (radars, cameras, lidars) and can be used by the car's algorithms to improve road safety, optimise driver assistance services and, ultimately, provide greater autonomy.

Technologies used in the band

Because the conditions of use for the 5.9 GHz band are technologically neutral, any technology can be employed provided it complies with the harmonised technical conditions of use.

In practice, there are currently two main technologies capable of using the 5.9 GHz band:

- ITS-G5 (Intelligent Transport System – G5)
- C-V2X (Cellular Vehicle-to-Everything).

ITS-G5 is a mature technology, derived from Wi-Fi. Several large-scale pilot projects have been conducted using this technology, notably the SCOOP pilot that aims to deploy 3,000 vehicles over 2,000 km of road in five locations in France: Ile-de-France, the A4 motorway, Isère, the main ring road in Bordeaux and Brittany. This technology is designed to work only in the 5.9 GHz band. We nevertheless need to be careful when assigning the notion of maturity, as few trials with a significant density of vehicles have been conducted and documented to date.

C-V2X is a more recent technology, defined by 3GPP (3rd Generation Partnership Project). This technology can use the 5.9 GHz band for direct communications, as well as mobile operators' cellular networks to communicate for with vehicles – notably low-band frequencies to enable broader coverage than the 5.9 GHz band (see below). C-V2X today is based on LTE technology, for both direct communications in the 5.9 GHz band and for cellular communications (referred to as "LTE-V2X"). In time, C-V2X is expected to evolve to incorporate 5G ("5G-V2X"), and thereby benefit from the resulting improvement in performance (speed, latency, reliability).

These technologies are not currently interoperable, in other words a vehicle equipped with one technology would not be able to communicate with a vehicle equipped with the other. But work is being done on making ITS-G5 and C-V2X interoperable, and on addressing the issue of their radio coexistence in the same frequency band.

Work in progress and announced rollouts

In Europe, the 2010/40/EU Directive (Article 7) stipulates that the European Commission must define the specifications needed to ensure compatibility, interoperability and continuity with a view to the deployment and operational use of ITS in the European Union. The Commission is in the process of preparing a draft delegated act that defines these specifications. In its current iteration (as of 14 January 2019), the delegated act authorises the deployment of ITS-G5 technology, which is the most mature, and lays out a process for enabling the rapid introduction of other technologies, such as C-

[1] E.g. to enable road infrastructure managers to transmit information to vehicles (on road work, etc.).

V2X, as soon as they are technically mature and capable of guaranteeing compatibility and interoperability with existing technologies (or defining a suitable migration path). Work is also being done by CEPT (European Conference of Postal and Telecommunications Administration) and ETSI (European Telecommunications Standards Institute) on the issue of ITS-G5 and C-V2X technologies' coexistence in the same frequency band.

At the national level in France, the autonomous vehicle development strategy[2], published by the Ministry of Transport in May 2018, provides for the draft of an infrastructure connectivity deployment plan. At the same time, a working group whose members include several institutional (Ministry of Transport, Ministry of the Economy, Arcep) and industrial (automakers, mobile operators, motorway manager…) stakeholders met in 2018 and produced a report comparing available technological solutions, and the socio-economic value of covering different, typical sections of the country's road system. The Government's follow-up to this report is not yet known.

Some automakers have decided not to wait for the regulatory framework to be stabilised, and have already announced plans to launch their connected vehicles onto the market, outfitted with one of these technologies, including:

- with ITS-G5: Volkswagen[3] (installation in new vehicles starting in 2019), Renault;
- with C-V2X: PSA[4] (starting in 2020), Ford[5] (for its vehicles in the United States, starting in 2022), BMW.

A few points of international comparison can be provided here:

- Japan began deploying roadside units in 2011 to enable I2V services using DSRC (Dedicated Short-Range Communications, equivalent to ITS-G5) technology, operating in the 5.8 GHz band. Another system is currently being trialled for V2V services, using the 760 MHz band.
- In China, the 5905 – 5925 MHz band has been reserved for C-V2X technology since October 2018.
- In the United States, the 5850 – 5925 MHz band is dedicated to DSRC. C-V2X systems can, however, access it to conduct trials in well-defined geographical areas.
- In late 2017, South Korea completed a pilot project on I2V, V2I and V2V services on an 88 km stretch of motorway, based on DSRC technology using the 5855 – 5925 MHz band.
- Lastly, in September 2018 Austria and its national motorway company, ASFINAG, issued a call to tender for equipping the motorway network with ITS-G5 capabilities.

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[2] https://www.ecologique-solidaire.gouv.fr/quelle-strategie-developpement-du-vehicule-autonome-en-france

[3] Press release: https://www.volkswagen-newsroom.com/en/press-releases/volkswagen-group-assumes-pioneering-role-in-rapid-road-safety-improvement-541

[4] Press release: https://www.groupe-psa.com/fr/actualites/corporate/le-groupe-psa-accelere-dans-le-deploiement-des-vehicules-connectes/

[5] Press release: https://www.qualcomm.com/news/releases/2018/01/09/qualcomm-and-ford-collaborate-c-v2x-global-initiative-improve-vehicle

Finally, it must be mentioned that the availability of the chips used for C-V2X technology could constitute a sovereignty issue, as only a small number of companies today supply these chips, although their numbers should grow as the connected vehicle market develops.

Queried stakeholders' positions on the choice between these two technologies

As their various announcements reveal, automakers are not unanimous in their technological preferences. Among those queried, some are in favour of ITS-G5 and believe it is crucial that the deployed technologies be interoperable, to ensure a high enough penetration rate in the vehicles on the road. These players therefore consider it imperative that C-V2X be backwards-compatible with ITS-G5, which will be deployed first.

Other carmakers, which are backing C-V2X, cite the economies of scale enabled by the technology: because their vehicles are manufactured on a global scale, these automakers prefer to align themselves with China, which has chosen C-V2X. These players also believe that C-V2X is an intrinsically better technology than ITS-G5, and attribute their competitors' choice of ITS-G5 to a technological lock-in (i.e. their initial investments now tie them to ITS-G5). These companies find the technological debate unfortunate as it creates a host of uncertainties that are hampering the deployment of technologies and of roadside infrastructures.

On the mobile operator side of the equation, one telco believes that C-V2X will probably emerge as the more powerful technology over time: its ability to call on a server in the network makes it possible to optimise the use of 5.9 GHz band spectrum in a centralised fashion. The same is not true of ITS-G5. This player nevertheless underscores the fact that C-V2X is not yet mature enough, which makes it impossible to verify performances claims. According to a second telco, cellular communications and V2V direct communications both serve a purpose and will be complementary, with direct communications able to be used as a relay solution in cellular networks' white areas. On the whole, the mobile operators who were queried stated that they did not want to come out in favour of one technology or the other, and believe that both should be available as options.

Lastly, one of the equipment suppliers queried expressed their support for ITS-G5. This player believes it is vital to be able to establish direct communications with users without having to rely on mobile operators' networks: C-V2X technology's ability to use mobile networks is, according to this player, of little interest. This equipment supplier also points to the considerable hindsight available on ITS-G5, which makes it possible to accurately assess the technology's performance, contrary to C-V2X.

For a number of stakeholders, however, the main criterion for choosing between the two technologies is not so much performance as the existence of an ecosystem. One of the automakers queried believes that the 5G – and so the C-V2X – ecosystem will be more active and more dynamic than the ITS-G5 ecosystem. Conversely, one telco points out that the C-V2X ecosystem is still only fledgling, and that the technology lacks maturity.

While more of the pioneer rollouts adopted ITS-G5 technology, recent announcements would seem to indicate that more and more manufacturers are leaning towards C-V2X, which raises the question of how firmly entrenched current positions really are. Under these circumstances, the challenge for the regulator is to shed light on a complex technological debate, and to help define a regulatory framework that is capable of eradicating those uncertainties that are currently weighing on automotive industry players, while also being sure to avoid any risks of technological lock-in.

Roadside infrastructure deployment schemes

There is a great deal of uncertainty today surrounding the procedures for deploying roadside units. With a cost estimated at around €3,000 per unit (providing 2 km of coverage), rollouts would be very expensive, even when only covering motorway networks, and even if their linear density is optimised to cover only the most hazard-prone areas[6]:

- first, there is uncertainty over whether this type of deployment makes socio-economic sense for the community at large: the first results of the cost-benefit analysis on the matter performed by the Ministry of Transport could prove positive under certain hypotheses;
- second, there is uncertainty over the business models that would enable private sector players to invest in roadside units, as the ensuing revenue streams have yet to be clearly identified.

All in all, it is hard to predict who would be in charge of their deployment: the State, local authorities, motorway managers, private sector players…

2. Cellular communications over mobile operators' networks

Connected vehicles can also use mobile operators' networks (aka cellular networks) to connect to the Internet and exchange information. This requires vehicles to be outfitted with a SIM card, to have a contract with mobile operators to use their network, and for there to be mobile coverage of the roadways.

Contrary to the 5.9 GHz band, mobile networks use different frequency bands allocated by Arcep, under an individual licensing system.

Compared to the possibilities offered by the 5.9 GHz band, having vehicles connected to the cellular networks enables:

- access to faster connections, and so opening the way to a broader array of services[7];
- communications over longer distances between vehicles;
- a guarantee of non-interference which, in practice, means that when interference is detected, a procedure is triggered to eliminate the source.

Vehicles' access to the cellular network also allows them to reap the benefits of technological progress on mobile operators' networks, and notably the advent of 5G (fifth generation mobile networks), provided the vehicles' connectivity capabilities evolve apace with those of mobile networks.

Lastly, cellular connectivity can be delivered either through SIM cards built into the vehicle or through the user's smartphone.

3. How will this affect the car sector?

1. A change in the relationship between automakers and mobile operators

[6] To which must be added the operating costs for these infrastructures, whose estimates vary considerably.

[7] Accessing the Internet for entertainment purposes, pointing out places of interest, remote engine start, locating a stolen vehicle…

Reliability: a key source of concern

For automakers, providing vehicles with connectivity helps to increase the appeal of their products in several respects. First, it enables them to offer new “under the hood” services, such as maintenance and safety[8]. Second, it opens the door to a wider array of in-car features and entertainment products for drivers[9].

These developments are driving automakers to demand greater levels of reliability and coverage. However, existing contractual relations tend to commit mobile operators to obligations of means which, in automakers’ view, only partially satisfy their requirements. According to one operator, it would be impossible to guarantee the actual reliability of communications along a large portion of road systems, which means that vehicles need to be developed that provide a high enough degree of safety, including when there is a no connectivity.

Moreover, some operators report having to contract roaming solutions with foreign operators to ensure a continuity of service when the connected vehicles are being driven abroad. According to some operators, this use of roaming could make accountability between the different players more complex, and so reduce operators’ ability to commit to a certain degree of reliability of communication. Some operators are predicting the emergence of a new market for providing dedicated cross-border plans for ITS, and expect to see new international players appear in this segment.

It is also not inconceivable that some automakers will opt to become MVNOs[10] – to take it upon themselves to provide their vehicles with connectivity. On the one hand, this strategy would allow them to take advantage of the size of their customer base to obtain the best trading conditions, notably with respect to roaming and quality of service and, on the other, automakers could thereby tier their quality of service by vehicle range.

On the mobile operator side of things, some recognise that very high levels of reliability can be achieved in a controlled environment, where the set-up is fully controlled and managed by a single entity (railway lines, specific industrial sites, or motorways). They nevertheless stipulate that the degrees of reliability that automakers want do seem unattainable on a national scale, and this because of the multiple sources of communication failure that can exist outside the bounds of the radio communications themselves – which are under the control of telecoms operators. A lack of mobile coverage could be offset by V2V communications, or by downloading the data needed ahead of time, to be able to drive in mobile networks’ white areas if they are anticipated accurately enough.

Lastly, some players do plan on eventually outfitting vehicles with both technologies, to be able to take advantage of the resulting increased reliability.

Varying views on how to provide 5G coverage

According to the operators that were queried, 5G coverage will come up against not only infrastructure rollout costs, but also the cost of accessing the towers along the motorways, billed by motorway managers. The managers of motorways may also be tempted to deploy their own infrastructures, to be able to then market new services designed to make travelling by car more attractive, and sold directly to drivers without having to go through mobile operators. Asked about the relevance of a model being planned in Germany (providing shared coverage along certain

[8] For instance via alert mechanisms
[9] Unlocking the car remotely, access to online content, etc.
[10] Mobile Virtual Network Operator

transport corridors) at least one operator voiced their opposition to such a policy[11]. In any event, operators point out that providing URLLC[12] coverage along the roads would only make economic sense if users are willing to pay for services, which has yet to be proven.

Mobile competition in connected car markets?

As it stands today, it is carmakers that choose the operator in charge of the vehicle's connectivity. According to carmakers, this unique contractual relationship enables infrastructure deployments that more closely match their needs. However,the fact that the mobile operator in charge of the vehicle's connectivity is chosen by the manufacturer, and not the end users, may stem more from sales considerations than technical ones, as automakers want to keep a direct relationship with drivers.

If operators and automakers maintain that technical communications between the vehicle and its manufacturer must take place through a mobile operator chosen by the automaker, they also agree that connectivity for users' own personal purposes can be supplied over the mobile network of user's choice. Vehicles could, for instance, be outfitted with a dual SIM card, one built-in by the automaker and dedicated to the vehicle's technical aspects, and the other chosen by the user and employed for entertainment purposes. Leaving it up to users would allow them to choose the level of connectivity that matches their needs, and to enjoy (at least in part) the familiarity of their mobile operator's environment in the car (the in-car environment does not depend solely on the mobile operator, but also on the car's operating system). Regardless of the access system chosen, as long as it provides access to the Internet as a whole, users benefit from an open Internet, in keeping with net neutrality regulation.

2. Mobility as a service: from the car as an object to the car as a service

Alongside models based on one of the on-board connectivity technologies in cars, some players are predicting the emergence of a model where connectivity is provided by the user's smartphone. It is likely that the two models will coexist, as their suitability will depend on the use case.

Cellular 5G: the smartphone as hub of the car-as-a-service model?

On-board connectivity technologies deliver a higher level of reliability because they are integrated into the vehicle's entire chain of command, and provide stronger anti-break-in guarantees than with smartphones. They therefore seem better suited to critical use cases, notably those tied to passenger safety.

Smartphone-based solutions make more sense for those use cases that are less or not critical (i.e. not tied to safety). It is worth mentioning that the first driver assistance apps to be released were designed and deployed by players from outside the automotive industry, as natural adjuncts to the opening of GPS networks and later superfast mobile networks. The increasing power of mobile networks and devices, which makes it easier to deliver traffic updates and additional information, have, for instance, led to a steady decline in the use of built-in GPS systems in cars – as drivers opt for the app versions available on their smartphones. From a broader perspective, highly innovative applications are more likely to develop on smartphones, because of the faster adoption and deployment they enable, as it is much cheaper to change smartphones or update an app than it is to buy a car. Added to which, drivers are not the only ones who own smartphones, but more vulnerable

[11] It should nonetheless be underscored that the reason the operator gave was not technical or financial, but pertained rather to the administrative burden that could potentially be associated with such a measure.

[12] Ultra Reliable Low Latency Communications.

people such as pedestrians and cyclists do as well, which facilitates the development of more wide-reaching solutions. Lastly, the mobile app market is synonymous with a breakneck pace of innovation, likely to facilitate large-scale deployment and a rapid cycle of multi-platform app-based solutions. Besides, 5G will become compatible with smartphones faster than it will with on-board solutions which could bolster smartphones' central role in use cases not tied to safety. Conversely, it may take longer for automakers to deploy on-board solutions in vehicles and for consumers to adopt them. Among other things, the update procedures for these solutions are far more cumbersome.

The rise of a hybrid model?

One expert who was queried believes that the emergence of a hybrid model is also possible, based on roadside units, when they exist, and users' smartphones, with services complementing one another naturally, according to their quality, relevance and reliability.

Moreover, given the number of sensors they already have, today's vehicles can be seen as a mobile sensor. By and large, their data can be accessed using a standard on-board device (OBD) capable of transmitting the data to a smartphone, to then be used in a range of applications, and this without having to deploy dedicated infrastructure.