



# MNO Network Expansion Mechanisms to Fulfil Connected Vehicle Requirements

5G Automotive Association



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VERSION:	1
DATE OF PUBLICATION:	23.06.2020
DOCUMENT TYPE:	White Paper
CONFIDENTIALITY CLASS:	P (Public use)
REFERENCE 5GAA WORKING GROUP:	Working Group 5
DATE OF APPROVAL BY 5GAA BOARD:	18.06.2020

# Contents

<b>1</b>	<b>Situational overview</b>	<b>5</b>
1.1	Background on government needs	5
1.2	Background on the connected vehicle evolution	5
<b>2</b>	<b>Cost-benefit considerations regarding cellular road coverage</b>	<b>8</b>
2.1	Socio-economic connected vehicle use cases that drive network requirements	8
2.1.1	Key use-case categories	8
2.1.2	Value of V2N use cases	9
2.1.3	Customer behaviours	10
2.2	Connected vehicle requirements that drive network investments	10
2.3	Cost drivers for mobile network setup	11
<b>3</b>	<b>Regulatory framework mechanisms to incentivise network expansion</b>	<b>12</b>
3.1	Road coverage obligations	12
3.1.1	German coverage obligations	13
3.1.2	French coverage obligations	13
3.1.3	Dutch coverage obligations	14
3.2	Reuse of existing public infrastructure	14
3.2.1	Brokering of road operator fibre	14
3.2.2	Concepts of site sharing for base stations	15
3.3	Cross-border coverage improvement	16
3.4	Public co-funding for critical corridors	17
3.5	Expand rural coverage	17
3.5.1	UK measures for rural coverage	18
3.5.2	Black spot programme in Australia	18
3.6	Neutral host infrastructure model	19
3.6.1	Highways England	19
3.7	Spectrum auctions without strict road obligations	20
3.7.1	Japanese best practice	20
3.7.2	Latvian best practice	21
3.8	5G spectrum considerations	21
<b>4</b>	<b>Recommended stepwise approach</b>	<b>22</b>



This paper describes how cellular coverage of roads, to support automotive, road operation and consumer services, can be extended and expedited through cooperation between mobile network operators (MNO), road operators, national and regional governments as well as national road and communications regulators/ authorities. It is primarily a strategy playbook with recommendations on cooperation between mobile network operators and road operators/ governments. The paper should facilitate discussion between road operators, governments and MNO's, to expedite the deployment of mobile networks alongside roads.

# 1 Situational overview

## 1.1 Background on government needs

Governments are facing major societal and political tasks in domains such as climate change and population growth. The EU's ambitious Green Deal clearly demonstrates the magnitude of these tasks and the public debates surrounding them. Debates ranging from energy efficiency and recycling to curbing carbon emissions and new mobility paradigms. Underpinning modern transport are new concepts around connected vehicles, such as vehicle electrification, automation and new mobility services (e.g. mobility as a service). These disruptive concepts have impacts on diverse governmental stakeholders, such as road operators, city management, housing corporations, and stakeholders in both the logistics and energy sectors.

Cellular connectivity has an essential role to support the above-described evolution. Furthermore, the service scope is broadening from telematics towards a wide array of services with high relevance to the transportation sector and society.

The work presented in this White Paper is intended to contribute to the cooperation between mobile network operators, policy makers, road operators and regulatory bodies (representing regional and national governments). One goal for this paper is to identify potential ways to accelerate mobile network coverage of roads to meet the anticipated demand from connected vehicle services while constraining the cost by leveraging existing investments. Another goal is to foster suitable regulatory approaches conducive to rapid, targeted coverage rollout, base station deployment and infrastructure-sharing and scaling for volumes of connected vehicles.

## 1.2 Background on the connected vehicle evolution

The 5GAA has brought together the mobile telecommunications industry and automotive industry for the purpose of developing and delivering concepts that improve the adoption of connected vehicles. The vision of a highly integrated vehicle-mobile network paradigm is embodied in the Cellular Vehicle-to-Everything (C-V2X) technologies supporting advanced services.

As a concept, C-V2X has emerged relatively recently with the delivery of 3GPP standards for C-V2X, comprising short-range (PC5) and wide-area (Uu) communications designed specifically for use by vehicles and associated road infrastructure<sup>1</sup>. Since then, rapid advances have been made in the production of cellular modems and applications to support connected vehicle services by 5GAA members. With the support of 5GAA, 3GPP is currently well into the process of specifying the next evolutionary steps for C-V2X. This will support enhanced connected vehicle services deployed on the earlier standard, to support higher level of autonomy and provide additional environmental benefits via traffic optimisation.

The vision of a highly integrated vehicle with a mobile network approach to V2X clearly requires a widespread, coordinated deployment of mobile network infrastructure providing strong radio coverage of roads to support the wide-area V2X communications mode alongside the short-range, direct mode

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<sup>1</sup> <https://www.3gpp.org/>

for road safety critical services between vehicles and with the road infrastructure.<sup>2</sup> Among the many reasons why such deployments are necessary and desirable are the continuity of telematics services for vehicle support systems, the ability for road operators to provide traffic safety, road monitoring and traffic control, and enabling mobile network operators to provide reliable Quality of Service (QoS), matching the specific requirements of connected vehicle applications.

Clearly, there is an ecosystem of stakeholders in C-V2X that must cooperate in order to enable rapid, efficient and comprehensive road coverage by mobile networks supporting the various societal and business objectives as well as addressing white and grey connectivity areas.

Until recently, the need for active cooperation between government and mobile networks to provide road coverage has not been a major topic for discussion. The first European rollouts of 4G LTE technology, in Germany, were accompanied by clauses around the coverage of rural communities rather than road coverage. But more recent developments, not least the emergence of C-V2X, have put the mobile networks onto centre stage for connected vehicle services.

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*Mobile networks have recently taken a center stage for connected and automated mobility services.*

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As a result, the automotive industry is demanding an improvement in road coverage for its vehicles while the road operators are equally keen to study how their existing and future investment plans can be leveraged that require improved wide-area coverage for their roads.

The automotive industry is well advanced in enabling new vehicles with integrated mobile/cellular communications technologies to support various services including eCall, telematics (e.g. remote diagnostics), road safety related services (e.g. local hazard warning or traffic information), comfort services, and internet access. Soon a significant proportion of new vehicles will be natively connected and there is already a burgeoning industry in after-market devices to enable legacy vehicles (and their occupants) to benefit from such services. Additionally, MNOs intend to expand their service offering beyond the 'connectivity' that dominates today, hence the push to introduce new business-to-business services, leveraging 4G advanced and 5G architecture and capability, including services to automakers and potentially road operators. However, in certain geographical areas, white spots persist where public funding is often required to reduce the risks for private investors.<sup>3</sup>

## 1.3 Road and road infrastructure requirements – on the way to 'digital roads'

The public budgets for constructing and maintaining roads are under pressure. This regularly results in unsuitable road conditions for connected and especially automated mobility (and sometimes even for conventional road usage). We need to emphasise that budget spending for pure road operation already consumes a big portion of the available budgets. In Germany, for example, about two-thirds of the budget is needed to keep roads, bridges, tunnels, lane markings, etc. in good physical condition.

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<sup>2</sup> It should also be noted that the direct short-range communication of C-V2X can benefit of the harmonization and preservation of the 5.9 GHz ITS band on a technology neutral basis and will be able to provide V2X advanced safety services which complement the spectrum bands for cellular networks. The combination of both is beneficial.

<sup>3</sup> "Supporting the implementation of CEF2 Digital" Study: <https://op.europa.eu/s/n7p5>

The remaining funds are needed for such things as appropriate road design, to make roads that are 'readable' both for users and machines as well as for road operation, and to make sure roads are operated efficiently e.g. clearing dangers swiftly (animals, stalled vehicles, debris, etc), taking care of the visibility of traffic signs, etc. These budgets should not be questioned as the number one priority.

Yet it is acknowledged that it is challenging for road operators to make additional investments in digital road infrastructure, comparable to the investments of MNOs in extending coverage and capacity alongside the road networks. However, as indicated in the previous sections, such digital road infrastructure would be invaluable both for meeting government needs and the latest technological developments.

Therefore, 5GAA supports an approach where maximum information can be provided to road users with reasonable needs for public investment in deployment and operating costs, using when possible already existing and continuously spreading public mobile networks, and where needed to expand them. The data to be provided follows concepts already defined by several road operators, laid down in road infrastructure support levels for automated driving (ISA levels<sup>4</sup>). Please note, providing road infrastructure information is NOT only relevant for automated driving modes, but for connected driving in general, as it increases safety and traffic efficiency, and paves the next steps towards "Vision Zero" and climate-neutrality.

It is assumed that a **digital road** consists of:

1. A reliable digital representation (or digital twin) of the static road parameters, such as geometry, speed limits, traffic regulations, etc., and consistent with ISA level D. Using connected vehicles to monitor and report issues on roads, bridges, tunnels, etc.
2. Getting access to information/data from/to roadside infrastructure (e.g. traffic lights, road works warnings, variable speed limit signs, etc.), and dynamic road parameters (such as traffic jams, road hazards, etc.). The latter can be collected via in-car sensors, providing the necessary data, qualified and consolidated by service providers, and consumed as services by traffic participants (ISA level C). This information needs to be provided through highly available and 'low' latency IT interfaces.
3. Providing sufficient mobile network coverage alongside the road network, including sufficient network capacity according to the quality-of-service needs described in use cases, and for distributing traffic-related services, as mentioned above.

Regarding the more advanced ISA levels A and B – cooperative driving and cooperative perception – it is worth investigating sections of the road where additional infrastructure (e.g. road sensors, traffic video camera's and road side units) facilitating cooperative perception and manoeuvring can be justified.

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<sup>4</sup> 25th ITS World Congress, Copenhagen, Denmark, 17-21 September 2018, 'EU-TP1488 Road infrastructure support levels for automated driving', Anna Carreras, Xavier Daura, Jacqueline Erhart and Stefan Ruehrup

## 2 Cost-benefit considerations regarding cellular road coverage

### 2.1 Socio-economic connected vehicle use cases that drive network requirements

It is widely agreed that the combination of 5G connectivity, internet of things (IoT) services and artificial intelligence-based functionalities will re-shape our economies in the coming years. An important share of socio-economic benefits can be derived from use cases that are driven and/or supported by Vehicle-to-Network (V2N) communications along with Vehicle-to-Vehicle and Infrastructure connectivity. In addition to safety and security (reducing road accidents), it will produce more efficient rides, minimising travel times, traffic jams and environmental pollution. At 5GAA, we believe that whenever a use case has an impact on safety, it also has a positive impact on congestion, emissions and, therefore, public expenditure, but also public satisfaction and acceptance, as there are less accidents and traffic flow is more fluid.

#### 2.1.1 Key use-case categories

The global connected car market is growing at a compound annual growth rate (CAGR) of 14.8% from 2018 to 2025. It is forecasted that more than 125 million passenger cars that are sold between 2018-2022 will be equipped with embedded connectivity.<sup>5</sup> These connections are used for a wide variety of valuable services including telematics, connected infotainment, real-time navigation and traffic optimisation, as well as for safety services including automatic crash notification such as eCall.

In addition, so-called Day 1 and Day 1.5 safety use cases are increasingly being trialled and deployed using existing mobile networks. The majority of road accidents are attributable to human error, which makes use cases aimed at informing, alerting or generally helping drivers beneficial.

Several connected vehicle use-case groupings have been defined under 5GAA. Those with the highest socio-economic relevance<sup>6</sup> include:

- **Road safety related**  
This category includes use cases that provide enhanced safety for the vehicle and the driver. Examples of use cases include emergency braking, intersection management assistance, collision warning or lane change.
- **Traffic efficiency and environmental friendliness**  
This category includes use cases that provide enhanced value to infrastructure, road or city providers, where the vehicles will be operating. As examples, green light optimal speed advisory (GLOSA), traffic jam information, maximum speed advice, curve speed warning and temporary restricted area information (also known as geofencing).
- **Society and community**  
This category includes use cases that are of value and interest to society and the public, e.g.

<sup>5</sup> <https://www.marketsandmarkets.com/PressReleases/connected-cars.asp>

<sup>6</sup> <https://5gaa.org/news/5gaa-releases-white-paper-on-c-v2x-use-cases-methodology-examples-and-service-level-requirements/>



vulnerable road user (VRU) protection, emergency vehicle approaching, traffic light priority, patient monitoring, crash report.

## 2.1.2 Value of V2N use cases

The mobile network provides unique advantages for connected vehicle use cases:

- **Improved traffic anticipation**  
Driving is safer and more efficient when you anticipate upcoming events and avoid the need for emergency actions. Therefore, V2N is an excellent addition to V2V and V2I for most of the road safety use cases.
- **Improved reliability/service level of information**  
Here, V2N complements V2V with non-line-of-sight sensing capabilities (curves, beyond intersection, see-through, etc.).
- **Improved (international) ecosystem compatibility**  
In this case, V2N offers high compatibility with cross-border road authorities and across car brands.
- **Reduction of need for widespread road side units**  
Many V2I use cases can be supported by Vehicle to Network to Infrastructure (V2N2I) e.g. using virtual RSU as demonstrated by VicRoads in Australia<sup>7</sup>, or by combining connected intelligent traffic lights and cloud services in a large-scale deployment by Talking Traffic in The Netherlands<sup>8</sup>. Furthermore, 5GAA has concluded that it is ineffective to deploy RSU widely<sup>9</sup>. V2N2I can decrease the need for road-side sensors and actuators and thus governmental expenditure. Lastly, roadside assets can be operated/maintained more efficiently with (cellular) remote asset management.

Figure 1 below demonstrates use cases that are addressed by Telstra towards different road stakeholders.

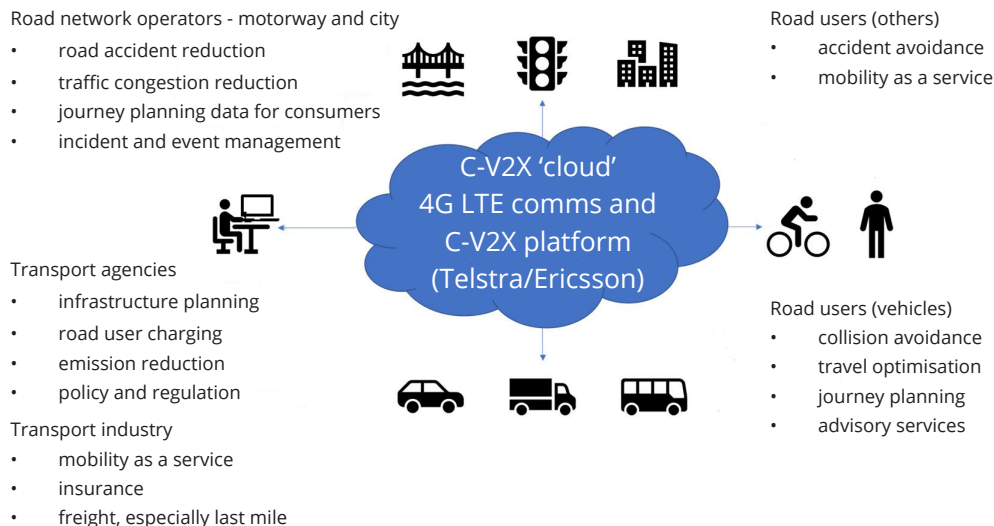


Figure 1: Use cases in relation to their beneficiaries (Telstra)

<sup>7</sup> Virtual RSU Architecture – [https://5gaa.org/wp-content/uploads/2019/05/06.Virtual\\_RSU\\_Architecture.pdf](https://5gaa.org/wp-content/uploads/2019/05/06.Virtual_RSU_Architecture.pdf)

<sup>8</sup> Partnership Talking Traffic – <https://www.talking-traffic.com/en/>

<sup>9</sup> 5GAA White Paper, 'Benefits of using existing cellular networks for the delivery of C-ITS' – <https://5gaa.org/news/5gaa-releases-white-paper-on-the-benefits-of-using-existing-cellular-networks-for-the-delivery-of-c-its/>

### 2.1.3 Customer behaviours

Already today, drivers are using their inbuilt navigation systems, their aftermarket devices, or just their phones to get access to a variety of services. As mentioned above, drivers could benefit significantly from more information about hazards along their route, such as bad weather conditions, slow and stationary vehicles, emergency vehicles, traffic light signal status, and others. This information, if it is delivered near real-time (latency < 1sec), would greatly benefit drivers. A one second latency results in 30 metres distance driven, assuming a vehicle speed of 100km/h.

Examples of successful services using the mobile network as connectivity channel are:

- Increased safety by receiving hazard warnings: BMW, Daimler, Volvo Cars, Waze, etc.
- Warning for approaching emergency vehicles/priority of emergency vehicles: BMW (in Bavaria, Germany), Talking Traffic apps (Flitsmeister, Onderweg)<sup>10</sup>, etc.
- Green light optimal speed advice, using signal phase and time (SPAT) and map data (MAP): Audi, Talking Traffic apps, etc.
- Etc.

## 2.2 Connected vehicle requirements that drive network investments

Mobile network dimensioning is traditionally auctioned and planned using population demographics rather than road traffic. Therefore, coverage along rural/secondary roads can drop significantly in larger countries due to poor business cases for mobile network operators.

It is important to relate cellular network coverage properly to the capabilities of communication technologies. From mobile network operator perspective, connected vehicles make use of the Internet of Things (IoT) that is provided through a few distinct network access technologies (see [Table 1](#)).<sup>11</sup> Connected vehicles on public roads are typically equipped with broadband IoT connectivity.

*Table 1: Distinct IoT segments with respective network coverage, capabilities and access technologies*

	TYPICAL COVERAGE	CAPABILITIES	ACCESS TECHNOLOGY
MASSIVE IOT	Extreme coverage (incl. deep-indoor & rural)	Low-cost devices Small data volumes	NB-IoT CAT-M1
BROADBAND IOT	High coverage (typically population oriented)	High data rates Low latency (best effort) Large data volumes	LTE NR
CRITICAL IOT	Coverage initially in confined areas, but also expanding to public roads	Bounded latencies High reliability Ultra-low latency	NR

<sup>10</sup> Talking Traffic apps – <https://www.talking-traffic.com/en/view-the-apps>

<sup>11</sup> Driving transformation in the automotive and road transport ecosystem with 5G – <https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/transforming-transportation-with-5g>

### Urban areas

Urban areas can be expected to have good coverage due to higher population densities. This already enables the vast majority of use cases already on current 4G networks. Densification and capacity expansions will be needed in urban areas when penetration and usage increases, which requires continued investments by MNOs. The cooperation and partnership models, if supported by a positive regulatory framework, would help to accelerate the network densification while decreasing the costs.

### Regional areas

Roads outside urban areas require special attention to obtain sufficient coverage and quality, in particular for large countries. Traffic intensity and accident statistics can indicate which areas are most critical to complement coverage i.e. in 2018, 9% of EU road fatalities occurred on motorways against 38% in urban areas and 53% on rural roads.<sup>12</sup> Furthermore, even roads with low traffic intensity would require coverage to obtain and share information, but not necessarily high capacity.

Highways and major transport corridors are the roads where capacity needs to be prioritised whereas coverage is the most crucial factor for rural roads.

## 2.3 Cost drivers for mobile network setup

Costs for setting up mobile network infrastructure are mainly based on:

1. Providing (the **right**) location for antenna placement: The processing time and cost of getting building permission are the biggest cost driver.
2. Erecting a mast: Reduced costs for the mast could be a result of the shared use of (public) infrastructure, e.g. lamp poles, traffic lights, noise barriers, advertising screens, public transport information screens, etc.
3. Providing electricity: The connection to already existing electricity, the shared use of ducts, etc. could significantly reduce the costs.
4. Providing fibre connection: The connection to already existing (public) fibre networks, shared use of ducts, etc. could significantly reduce the costs.

Capital expenditure (CAPEX) on the radio access part in a 5G mobile network is strongly related to the frequency band used. In city areas, where 3.5 GHz and 26 GHz will be used, base station densities are considerably higher than in rural areas, where 700 MHz is more likely to be used. Therefore, the availability of sufficient spectrum in the right bands is also an important cost driver.

Examples of operating expenditure (OPEX) cost drivers are maintenance, licence costs and operational costs.

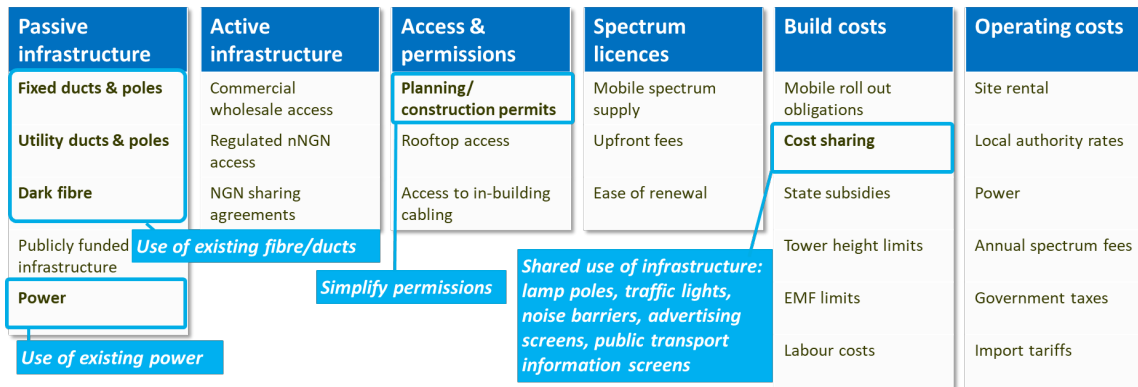
<sup>12</sup> 2019 road safety statistics: what is behind the figures? - [https://ec.europa.eu/commission/presscorner/detail/en/qanda\\_20\\_1004](https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_1004)

An overview of the key cellular network deployment aspects<sup>13</sup> is provided in Figure 2. Clear synergies with road operator deployments are found for aspects such as access to ducts and power, simplified site permits and shared use of roadside infrastructure (lamp poles, traffic signs, etc):

*Road operator deployments provide multiple synergies for mobile network operators, enabling business case improvements for network expansion.*

- **Provide access to passive infrastructure**  
Road operators can provide easy and predictable access to passive infrastructure such as ducts and poles, dark fibre and power to allow cost-effective construction of mobile networks.
- **Simplified site permits**  
Planning authorities can ensure that mobile network operators get quick and easy approvals for planning permission and construction permits, and easy access to rooftops and in-building cabling.
- **Shared use of roadside infrastructure**  
Road operators can provide easy and predictable access to public assets such as lamp poles, traffic signs, etc. to allow cost-effective construction of mobile networks.

Figure 2: Key cellular network deployment aspects, including areas of road operator deployment synergies



### 3 Regulatory framework mechanisms to incentivise network expansion

Governments can incentivise the expansion of mobile networks in several ways. This chapter describes examples to enhance mobile network roll-out along roads, such as sharing of public infrastructure, incentives for improving rural and cross-border connectivity and road coverage obligations.

#### 3.1 Road coverage obligations

Regulatory obligations in 5G spectrum auctions can be a useful tool in obtaining road coverage as part of a series of linked policy measures.<sup>14</sup> Requirements must remain proportionate and provide

<sup>13</sup> Digital Deployment Report – Vodafone Group PLC, <https://gigalife.vodafone.com/deploying-digital-networks/>

<sup>14</sup> Such as moderate spectrum prices and national spectrum licences, as well as a number of specific measures to ensure cost-efficiency in uneconomic areas. This includes state subsidies to finance the construction of passive network elements (towers, roof-top installations, ducts, power supplies etc), to allow installation of active radio equipment at marginal cost and competitive or co-investment laying of ducted fibre for backhaul. It should also include easing of

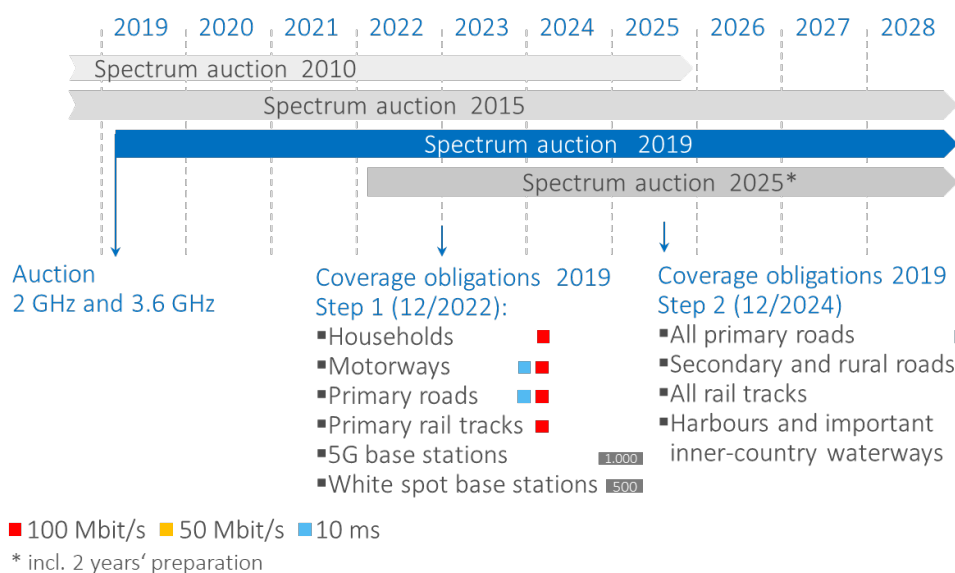
transparent and fair auction conditions to give mobile operator planning and investment security to fulfil their obligations. When designing those obligations, the performance requirements related to connected vehicle services must be properly assessed. The demand for road specific coverage was not formulated in many auctions for previous mobile network deployment (e.g. 2G, 3G, 4G) that were rather population or geographic coverage oriented. This section describes several examples that embraced road specific requirements.

### 3.1.1 German coverage obligations

In 2018, the German Bundesnetzagentur provided clear obligations on network demands along the roads<sup>15</sup>, see Figure 3. For example:

- Coverage with a transmission rate of at least 100 Mbit/s and a maximum latency of 10 milliseconds for all German motorways and all federal roads.
- Coverage with a transmission rate of at least 50 Mbit/s for all state roads.

Figure 3: Cellular obligations for German cellular auction (source: Bundesnetzagentur, Germany)



### 3.1.2 French coverage obligations

The French regulator, Arcep, and mobile network operators announced a historical agreement to accelerate mobile coverage in the French regions.<sup>16</sup> Mobile operators have committed to improving reception quality across the country, particularly in rural areas and, more importantly for connected vehicles, the MNOs have expressed their commitment to accelerate the coverage of transportation routes, so that all the major roads (i.e. motorways, roads connecting main urban conurbations and

planning restrictions (e.g. increases in maximum permitted tower heights, simpler approval procedures).

15 Bundesnetzagentur – 5G award decisions III & IV of 26 November 2018 – [www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/ElectronicCommunicationsServices/FrequencyAward2018/20181214\\_Decision\\_III\\_IV.pdf](http://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/ElectronicCommunicationsServices/FrequencyAward2018/20181214_Decision_III_IV.pdf)

16 ARCEP document: 'Results of the work done on achieving ubiquitous, high standard mobile coverage for every person in France', 22 January 2018 – [https://www.arcep.fr/uploads/tx\\_gspublication/description-dispositif-couverture-mobile-ENG-220118.pdf](https://www.arcep.fr/uploads/tx_gspublication/description-dispositif-couverture-mobile-ENG-220118.pdf)

roads with an average daily traffic volume of 5,000 vehicles – calculated on an annual basis<sup>17</sup>) and railways have at least 4G coverage.

### 3.1.3 Dutch coverage obligations

Cellular coverage is typically compared with population coverage, where the Netherlands ranks #6 globally<sup>18</sup>. When comparing coverage on secondary roads based on coverage maps, the Netherlands tops rankings.

Arguments can be found in the IMT-2000 auction where licensees were required to fulfil coverage obligation by January 2007. This includes a minimal outdoor service level of 144 kbit/s and realisation at any time in 95% of the cases:

- In the urban area of all municipalities that have at least 25,000 inhabitants.
- On all main connections between those municipalities (road, rail, inland waterways).
- On all highways passing through neighbouring countries Germany and Belgium.
- In the vicinity of the main airports (Amsterdam Schiphol Airport, Maastricht Aachen Airport and Rotterdam Airport).

This meant that roads between 219 out of 388 villages needed to be covered by 3G. Considering the small country size and dense population, this resulted in most roads between smaller villages (i.e. <25,000 inhabitants) being covered.

## 3.2 Reuse of existing public infrastructure

### 3.2.1 Brokering of road operator fibre

The introduction of 5G new radio equipment in the RAN is expected to require more dense radio sites when the 3.5 GHz and 26 GHz frequency bands are to be used. For roadside deployment this site densification will require significant CAPEX investments.

Providing optical fibre connectivity to the new sites is expected to be one of the key cost drivers. Therefore, the idea of allowing mobile network operators to make use of road operators' unused optical fibres to lower the CAPEX costs for roadside 5G coverage has become a popular one in the 5G community.

However, although simple in its concept, it is unknown today what complexities may need to be overcome when deploying 5G new radio equipment using this paradigm. More research is needed to establish whether this is a feasible approach, how it should be organised, and what the main challenges are when doing this in practice. For example, the fibre may not belong to the road operators but to the state and is sometimes reserved for state services like defence, national intelligence or the police.

An approach currently under investigation by the Dutch government is to take a broker role between the road authorities and the mobile network operators. This way, access to the road operator's infrastructure can be given under the same conditions to all mobile network operators, while minimising the burden

<sup>17</sup> <https://www.arcep.fr/cartes-et-donnees/new-deal-mobile.html#4GEnVoiture>

<sup>18</sup> Opensignal – The state of mobile network experience, page 9 – [https://www.opensignal.com/sites/opensignal-com/files/data/reports/global/data-2019-05/the\\_state\\_of\\_mobile\\_experience\\_may\\_2019\\_0.pdf](https://www.opensignal.com/sites/opensignal-com/files/data/reports/global/data-2019-05/the_state_of_mobile_experience_may_2019_0.pdf)

on the road operator. This also makes it easier to explore the reverse approach: can the road operator use MNO's fibre-optic infrastructure in locations where the road operator has insufficient low capacity today?

This research is being organised in a stepped approach: first, identify if there is overcapacity that could be shared by the road operator and explore if it is actually suitable for usage by a mobile network operator, then investigate how this could be organised technically and define how the broker role could facilitate the execution of that technical integration process, and only then execute it in real life on a specific test location.

During these steps the deployment requirements of all involved parties (road operator, broker, MNO) will be considered, and the corresponding set of agreed processes and monitoring methodology will be described.

In parallel, other elements such as legal implications, financial models, the future scalability of the model, etc. must be investigated, and corresponding recommendations will be delivered.

Note that insights will be gathered and delivered within these activities, but no decision about the eventual 'adoption model' is expected during the course of this research. This action hence defines how the adoption of this paradigm could be organised if valuable and feasible, but not if and when it will be adopted.

### 3.2.2 Concepts of site sharing for base stations

Two types of site sharing can be distinguished: usage of public infrastructure by private mobile network operators and sharing of (privately owned) mast sites between MNOs. Sharing of infrastructure owned by private companies (e.g. private road operators) is also an option, however that is done on commercial terms between the involved parties.

The first aspect concerns the **sharing of public infrastructure**. For this, the new European Electronic Communications Code<sup>19</sup> is very relevant. According to article 57, member 4, MNOs should have the right to make use of public buildings and other infrastructure for the deployment of small cells:

"Member States shall, by applying, where relevant, the procedures adopted in accordance with Directive 2014/61/EU, ensure that operators have the right to access any physical infrastructure controlled by national, regional or local public authorities, which is technically suitable to host small-area wireless access points or which is necessary to connect such access points to a backbone network, including street furniture, such as light poles, street signs, traffic lights, billboards, bus and tramway stops and metro stations. Public authorities shall meet all reasonable requests for access on fair, reasonable, transparent and non-discriminatory terms and conditions, which shall be made public at a single information point."

The new rules must be applied by Member States before 21 December 2020. Member states of the European Economic Area (EEA, EU countries and Iceland, Liechtenstein and Norway) are now implementing this EU Directive in national law. The 5GAA recommends that such mandates should not be limited to small cells only, but also comprise wide-area cells.

<sup>19</sup> <https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1547633333762&uri=CELEX:32018L1972>



Use of local public assets like location, fibre/backhaul and power by parties such as mobile network operators depends of bilateral agreements between the parties. Experience in Spain showed that there needs to be clearly communicated benefits to society (e.g. improved emergency services, road safety, traffic efficiency, environment) to create acceptance for use of public infrastructure by private companies. Information campaigns are needed to convince citizens that the services made possible by 5G networks will make their lives easier and safer.

The second aspect of site sharing is the **sharing of (privately owned) network elements and associated facilities between MNOs**. This was required by the European Directive (2002/21/EC)<sup>20</sup> and has already been implemented by several countries in Europe. For instance, national Dutch law has required for some time that providers of electronic communication services and mast sites must comply to reasonable requests for shared use of their sites, antenna systems or antennas. On the other hand, there are also restrictions on how MNO's can collaborate, such as competition law. Note that in 2010 an 'Antenna covenant' has been established between the Dutch government (both national and municipalities) and MNOs regarding the deployment of antennas which do not require environmental licences. This covenant been prolonged and is scheduled to be updated to capture the new aspects of deploying 5G antennas.

### 3.3 Cross-border coverage improvement

Cellular spectrum licences are auctioned at the national level, and hence cross-border behaviour is typically not included in auction obligations. As an exception, the Netherlands has had licence requirements since 2000 on all highways passing through its neighbours Germany and Belgium, as indicated in paragraph 3.1.3.

The Digital Baltic Road is a good initiative where 5G deployment is aligned cross-border for the main corridor between Latvia, Estonia and Lithuania.<sup>21</sup> The EU is also supporting other cross-border initiatives through programmes like 5GCroCo<sup>22</sup>, 5G-MOBIX<sup>23</sup> and 5G-CARMEN<sup>24</sup>.

Coverage alone is not enough; connected vehicle use cases benefit from a fast network reselection (roaming) when entering another country. Technical capabilities to enable this - as described are available in standards - are not widely deployed yet. Several proofs of concept have already been successfully executed.<sup>25</sup> The 5GAA also works on 'network reselection improvements' with aim of providing clarity on approaches to achieve fast network reselection.

Though cross-border network reselection is already technically feasible, the incentives are still lacking to get it implemented in networks. Therefore, it is essential to find the right incentives for mobile network operators to embed this functionality, for example through public-private cross-border programmes or as requirement in auction obligations, but supported by bi-national agreements.

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20 (2002/21/EC), article 12 on 'Co-location and sharing of network elements and associated facilities for providers of electronic communications networks'  
<https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32002L0021>

21 Digital Baltic Road - <https://www.5gtechritory.com/2018news/the-digital-baltic-road-memorandum-will-accelerate-the-deployment-of-5g-mobile-communications-network-in-the-baltics>

22 <https://5gcroco.eu/>

23 <https://www.5g-mobix.com/>

24 <https://5gcarmen.eu/>

25 Keeping vehicles connected when they cross borders - <https://www.ericsson.com/en/blog/2019/5/connected-vehicle-cross-border-service-coverage>



## 3.4 Public co-funding for critical corridors

The European Commission has proposed, in the context of the preparation of the next Connecting Europe Facility Digital (CEF2 Digital), a major public financing support action for accelerating private investments in 5G infrastructure along highways, railways and waterways known as '5G corridors', intended to enable connected and automated mobility solutions.<sup>26</sup> The CEF2 Digital programme has been agreed at the highest political levels and is subject to budget negotiations with Member States. It is expected that public funding for major pan-European roads, including the 5G corridors will amount to a significant part of the €3 billion requested by the Commission for CEF2 Digital. However, a recent study funded by the European Commission found that investment for backhaul, 5G networks and vehicle to network infrastructure for a fully future-proof scenario alongside the 26,000 km of highways covered by CEF Digital could cost a maximum of around 210 000 Eur per km and 5.46 billion Eur in total.<sup>27</sup> To achieve the best results and share ('mutualise') the additional cost of extended services and sector coverage, a logical next step would be to coordinate the programme with other CEF, EU and national funding instruments.

This supportive public policy context creates a favourable environment to encourage private investments in large-scale deployment of 5G infrastructures, paving the way toward future autonomous mobility. In the next five years a large share of new vehicles and other mobility devices will be exchanging data with external sources, bringing new services and public-private business models to automotive and transportation markets. However, white areas for connectivity will persist and must also be appropriately be addressed.<sup>28</sup>

The 5G-PPP board, co-led by the European Commission and industry, has tasked the **5G-PPP Automotive Working Group** to develop a common **Strategic Deployment Agenda for Connected and Automated Mobility in Europe**, of which the initial proposal was published in October 2019.<sup>29</sup>

## 3.5 Expand rural coverage

Access to 21st century communications is essential for people living and working in regional and remote locations. Reliable telecommunications services can make the difference between being able to use quality tele-health services locally and having to drive hundreds of kilometres to a capital city for treatment. In emergency situations, strong communication links can be lifesaving. Reliable mobile coverage is vital in making sure citizens can contact the services they need in times of emergency. It will also accelerate the market penetration and seamless deployment of existing and future safety services (e.g. local hazard warning or traffic information) preventing accidents on rural roads where the majority of fatal collisions occur (55% of EU road fatalities in 2018). In addition, digital connectivity can improve productivity for farmers and regional tourism operators can reach new markets, realising the potential of their businesses.

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26 Cross-border corridors for Connected and Automated Mobility (CAM) - <https://ec.europa.eu/digital-single-market/en/cross-border-corridors-connected-and-automated-mobility-cam>

27 Supporting the implementation of CEF2 Digital - <https://op.europa.eu/s/n7pS>

28 In practice, official EU guidance is that such EU projects must involve connectivity and service provision that goes beyond any legally binding national 5G coverage obligations. Therefore, it would be preferable if Member State and EU policy was more closely aligned as national coverage obligations may act as a de-facto barrier to innovative cross-border EU Projects.

29 <https://5g-ppp.eu/wp-content/uploads/2019/10/20191031-Initial-Proposal-5G-SDA-for-CAM-in-Europe.pdf>

### 3.5.1 UK measures for rural coverage

In 2018, Ofcom published advice to the UK government on further options beyond new coverage requirements.<sup>30</sup> The following four main levers were identified (which could be used in combination with each other):

- Planning reform and other measures to reduce the cost of building and operating mobile masts, which UK and devolved governments might take.
- Agreements between operators to share their mobile infrastructure
- Roaming arrangements in rural areas.
- Public subsidies to pay for new coverage.

The UK government recently accepted a united proposal from mobile operators that combines these levers. The proposal to pool resources to address 4G coverage gaps in rural areas, in a deal worth more than £1 billion, is designed to deliver access to 95% of the country by 2025. That could mean 280,000 additional premises and 16,000 km of roads in the countryside.

Stated as a world-first in the industry, the deal would result in all four operators investing in a shared network of new and existing masts to “close almost all partial not-spots, areas where there is currently only coverage from at least one, but not all, operators”.<sup>31</sup>

### 3.5.2 Black spot programme in Australia

In a country the size of Australia (the world’s sixth-largest country with an area of nearly 7.7 million square kilometres) with the majority of the population concentrated in capital cities and large towns along the coastline, delivering and maintaining cost-effective mobile network connectivity comes with unique challenges.

The Australian Federal Government’s Mobile Black Spot Programme is one of the largest-ever expansions of mobile network coverage for regional and remote communities. Commencing in 2014, the first four phases of the programme (Round 1, Round 2, Priority Locations Round and Round 4) saw the Federal Government’s commitment to fund a total of A\$380 million (circa € 234 million). Australia’s three MNOs – Optus, Telstra and Vodafone – have all contributed by matching their own investment funds with grants awarded by the Federal Government. This has generated an overall investment of more than A\$836 million delivering a total of 1,229 new base stations across Australia. The award of a further Round 5 funding of A\$80 million was scheduled to be announced in early 2020 with a further Round 6 fund of A\$80 million to follow. The Federal Government has also allocated another A\$60 million to the Regional Connectivity Programme from 2020 onwards, which allocates further Black Spot Grants as well as developing a digital technology hub and exploring alternate voice service trials in remote areas.<sup>32</sup>

In addition to legacy fixed telecommunications network services and 3G/4G mobile network coverage, regional and remote areas also have access to Australia’s National Broadband Network Company (NBN Co) Sky Muster satellite service. The NBN Sky Muster programme comprises two Ka band geo-

<sup>30</sup> Improving mobile coverage – Ofcom, <https://www.ofcom.org.uk/phones-telecoms-and-internet/coverage/improving-mobile-coverage>

<sup>31</sup> <https://www.mobileworldlive.com/latest-stories/uk-operators-forge-1b-rural-coverage-deal/>

<sup>32</sup> Australian Government: Mobile Black Spot Programme – <https://www.communications.gov.au/what-we-do/phone/mobile-services-and-coverage/mobile-black-spot-program>

stationary satellites capable of delivering 25Mb/sec download and 5Mb/sec upload speed, and aims to provide high-speed internet to over 400,000 Australians living in regional and remote areas.

Australian telecom operators are actively pursuing work programmes to deploy new 5G mobile networks with the focus on locations where consumer demand is greatest in populated areas and where industrial applications will generate revenue from the unique functionality offered by 5G. While existing 4G networks provide good coverage over the major Australian national road network today, it is likely to be some time before this 4G road network coverage is matched by 5G technology.

## 3.6 Neutral host infrastructure model

Neutral host infrastructure comprises a single, shared network infrastructure for certain key subsystems. These assets can be provided on an open access basis to all MNOs seeking space, power and connectivity. Assets are usually deployed, maintained and operated by an independent, third-party provider like a 'tower company' such as American Tower. All interested mobile network operators get access to sites, owned by the third party, to host their base stations. Neutral host infrastructure enables CAPEX and/or OPEX efficiencies to help identify and enable new funding models.

Unlike vertically integrated networks that accommodate one technology solution, neutral host infrastructure is a shared platform, capable of supporting all MNOs and technologies, giving their customers what they are looking for – seamless coverage and high capacity.<sup>33</sup> This approach allows operators to focus on service delivery and infrastructure companies to focus on real-estate development and capital investment. By shifting investment from an upfront, CAPEX-heavy model where MNOs shoulder all deployment costs to a neutral host model where sharing helps to spread costs across multiple parties and converts a CAPEX burden to an easier to manage OPEX.

### 3.6.1 Highways England

Highways England, a major UK highways operator, has outlined an approach to improve mobile network road coverage. The road operator completed a feasibility study, working with the UK Department for Digital, Communications, Media and Sport (DCMS) to examine approaches towards providing improved/expedited LTE/5G coverage of roads in the UK. The initial stages of this feasibility study included a consultation meeting with all UK MNOs, to gather their views on potential ways forward.

The result of the feasibility study was the selection by Highways England of the 'Neutral Host Infrastructure' model as their preferred next step (for trial) in the approach to improving mobile coverage of UK roads.<sup>34</sup> The next stage of the Highways England's study is to establish an on-the-road trial of the Neutral Host Infrastructure solution.

This solution appears to align most closely with Highways England's current investment model, which is based around a set of objectives relating to improving road safety and functionality. In the neutral host infrastructure approach, the physical means of providing mobile network base stations is provided by the road operator, leveraging existing and future investments in roadside utilities (land, power, fibre backhaul). The selection of the neutral hosting partner brings in additional investment, de-risking the

<sup>33</sup> 'Is neutral host infrastructure the way forward?', Tech UK, July 2018 –<https://www.techuk.org/insights/opinions/item/13533-is-neutral-host-infrastructure-the-way-forward>

<sup>34</sup> This section is the summary from a discussion between Vodafone and Highways England

project by providing the opportunity and incentive for the partner to recover their investment with profit by attracting MNO 'residents' onto the infrastructure. The neutral host approach also ensures that the road operator maintains an even hand in how it cooperates with individual MNOs, and at the same time reduces its workload dealing with multiple customers of the neutral host network.

## 3.7 Spectrum auctions without strict road obligations

There are several countries primarily outside Europe where very good coverage has been achieved even without strict obligations utilizing 'beauty contests'.<sup>35</sup> Despite a large share of beauty contests concluded in unfavourable results, there are circumstances when they can generate good outcomes, when conducted in a constructive manner, which drives the market to deliver the output policy makers desire (e.g. in terms of coverage, capacity and competition).

Neither China nor Japan charge upfront fees for spectrum but instead judge whether the deployment commitments of firms match the country's policy objectives and assign spectrum accordingly. Both countries enjoy more expansive connectivity than their global peers.<sup>36</sup> Very high customer demands on coverage anywhere, anytime in combination with fierce competition between MNOs are important success factors for good coverage, as proven in Japan and Latvia.

### 3.7.1 Japanese best practice

Japan is referenced for its high 4G cellular availability rate; it is ranked second on global population coverage. Arguments for this result are:

- Japan has sufficient optical fibre penetration for its nationwide backhaul network, see Figure 4.<sup>37</sup> This enables MNOs to deploy broadband mobile communication services easily.
- Strong demand from Japanese customers on coverage, quality and price, since second- or third-generation mobile communication systems entered the market. Also, competition amongst mobile operators has been tough; demanding customers select MNOs not only on price but also considering the value of coverage and quality.
- The Ministry of Internal Affairs and Communication (MIC) in Japan has been pressing MNOs to boost coverage and quality as a part of

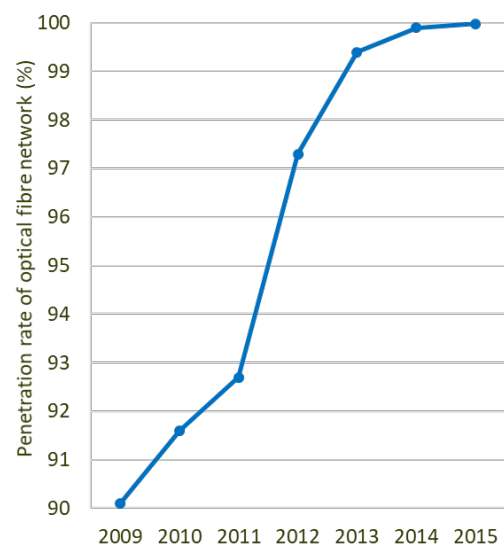


Figure 4: Penetration of optical fibre in Japan

<sup>35</sup> 'beauty contest': Auction in which the winning bid is the one which gets recognized highest ratings based on a predetermined set of KPI's, such as spectrum efficiency, deployment timelines, encouraging competition, public benefits, etc.'

<sup>36</sup> Optimising spectrum assignments to deliver expansive 5G connectivity - <https://www.ericsson.com/en/public-policy-and-government-affairs/optimizing-spectrum>

<sup>37</sup> <https://www.soumu.go.jp/johotsusintokei/whitepaper/ja/h28/html/nc252210.html>

requirements in frequency assignment decisions (the so-called 'beauty contest'). On a quarterly basis, MIC also evaluates area-coverage rate, number of base stations, total throughput and technology introduction status.

The Ministry also announced its plans to utilise traffic signal assets for 5G network deployment.<sup>38</sup>

### 3.7.2 Latvian best practice

The Latvian mobile operator LMT has achieved very strong coverage results without serious coverage obligations:

- 99.93% population coverage
- 99.8% geographical coverage
- 14ms average E2E latency
- >30Mbps average speed

Competition between MNOs and demanding customers in Latvia have been instrumental in achieving these strong results.

## 3.8 5G spectrum considerations

A number of spectrum aspects need to be considered for successful deployment of 5G. This paragraph provides insights on the specific situation and actions that may be necessary in Europe, however other regions likely have similar issues.

A successful and timely 5G launch will benefit from the availability of large contiguous blocks of spectrum in all or part of the 3400-3800 MHz 5G pioneer band. The market demands a possible introduction of mobile communications networks requiring very large contiguous bandwidths (80-100 MHz). It may be necessary for the administrations to reorganise the 3400-3800 MHz band on the basis of nationwide coverage in order to provide wide contiguous spectrum. The exact contiguous bandwidth per licensee is to be determined by national award processes.

Due to the current fragmentation of the band, this may not be reached in some countries within the Conference of Postal and Telecommunications Administration (CEPT) by 2020. Therefore, CEPT administrations should assess the necessary actions to make large contiguous blocks of spectrum available for high throughput 5G services in a timely manner:<sup>39</sup>

- National actions are required to consider how to reorganise the entire band, to make it available for 5G to maximise social/economic benefits. It is up to each national administration to introduce 5G according to national policy objectives.
- Administrations should not preclude award outcomes with smaller bandwidths, and existing mobile communications networks should not be excluded from obtaining spectrum rights to continue providing services.

Timely availability of the 3400-3800 MHz band for 5G deployments is crucial for the success of 5G

<sup>38</sup> <https://asia.nikkei.com/Spotlight/5G-networks/Japan-to-greenlight-5G-base-stations-on-200-000-traffic-signals>

<sup>39</sup> CEPT - ECC Report 287, "Guidance on defragmentation of the frequency band 3400-3800 MHz", <https://www.ecodocdb.dk/download/3a143dbe-7cbc/ECCRep287.pdf>

in Europe. National administrations are expected to apply appropriate measures to defragment this band for authorising large spectrum blocks.

It should be noted that 3400-3800 MHz is not the only band relevant for 5G deployment. In particular, the low-band spectrum (<1 GHz) is considered essential to accomplish rural road coverage. Action has been taken in Europe to update regulations for existing frequency bands in low- and mid-band spectrum to enable deployment of 5G NR, including advanced antenna system use. In other regions, spectrum is made available in similar frequency bands, for example in 3 GHz but also below and above that frequency range. The mmWave spectrum is also becoming available, and will provide very high bitrates in certain areas, but is not expected to provide total coverage of roads.

## 4 Recommended stepwise approach

Public-private cooperation on the country-level is highly encouraged to achieve the required road coverage quality as there are strong dependencies between different types of stakeholders.

The previous chapters have indicated that cellular network demands for connected vehicles can vary a lot between countries, within countries and depending on respective use cases. Furthermore, the ways to complement cellular network coverage and network performance along the road vary a lot per country and per specific geographical area within countries. Hence, there is no single recommendation that serves all needs.

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*Dialogue between road authorities and mobile network operators is essential in order to achieve sufficient coverage quality along roads.*

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The 5GAA rather recommends a stepwise process to road authorities, public/private road operators and municipalities in order to identify their specific situation and suited mechanisms:

1. What drives the need for road coverage for the specific stakeholders?
  - a. What are the governmental priorities (safety, efficiency, CO2 emissions, operational cost savings, economic stimuli, etc.)?
  - b. What are the key stakeholders and use cases for these priorities?
2. What is the current road coverage situation?
  - a. Identify/measure road coverage across the complete road network and broken down by:
    - i. Motorways
    - ii. Federal roads
    - iii. Secondary road network (state roads/local roads/municipal roads)
  - b. Who are the relevant stakeholders (regions, municipalities, countries in border areas, owners of public infrastructure, etc.)?
3. Which of the suggested mechanisms in chapter 3 can improve the situation?
  - a. Road coverage obligations (as part of a series of linked policy measures)
  - b. Provision of public roadside infrastructure
  - c. Cross-border coverage improvement
  - d. Public co-funding for critical corridors
  - e. Incentives to expand rural coverage
  - f. Neutral host model for infrastructure sharing
  - g. Spectrum auctions without strict road obligations for competitive MNO markets with high

- customer demands
  - h. Ensure sufficient 5G spectrum
4. What steps need to be taken and which key stakeholders need to support this?

This stepwise approach will provide clear markings for stakeholders to define a forward-looking action plan and requirements underpinning the connected vehicle future.

