



Spectrum needs for ITS

Day-1 and advanced use cases

Reza Karimi (Huawei)

Markus Mueck (Intel)

3GPP MRP webinar: 5G Spectrum for Industry Verticals

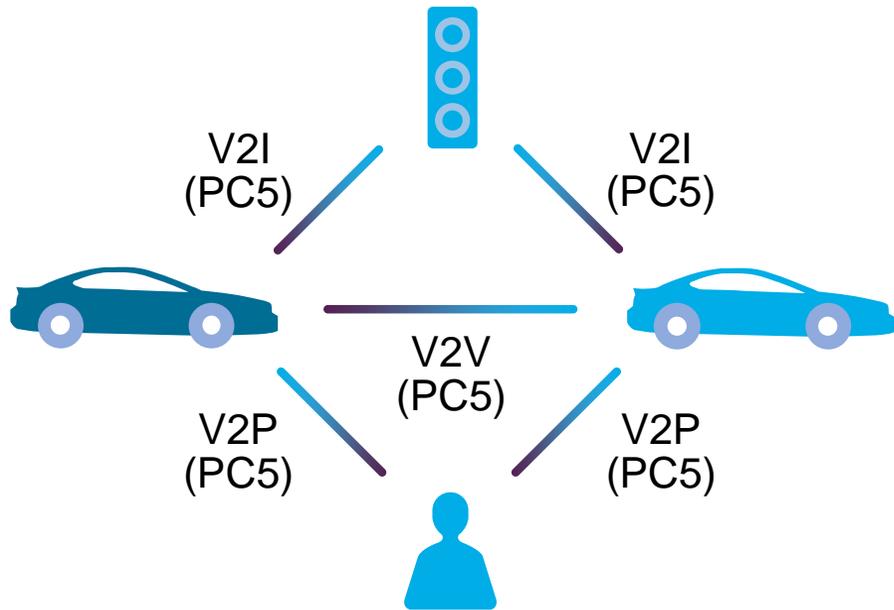
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Introduction

C-V2X: Two complementary modes

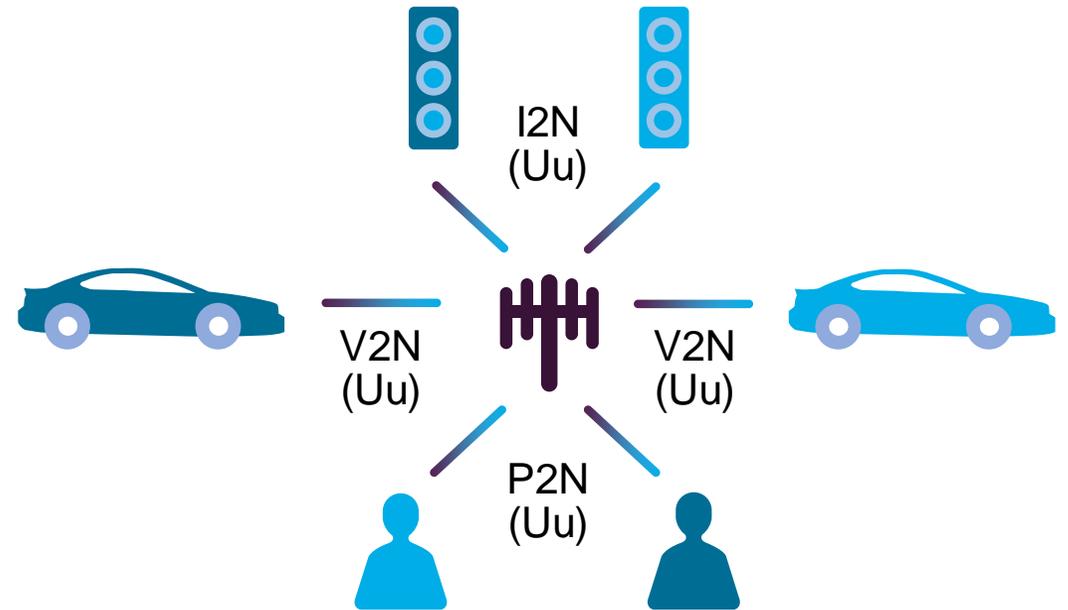
Direct (= Sidelink)

V2V/V2I/V2P in **ITS bands** (e.g. ITS 5.9 GHz)
independent of cellular network



Network (= Up/Downlink)

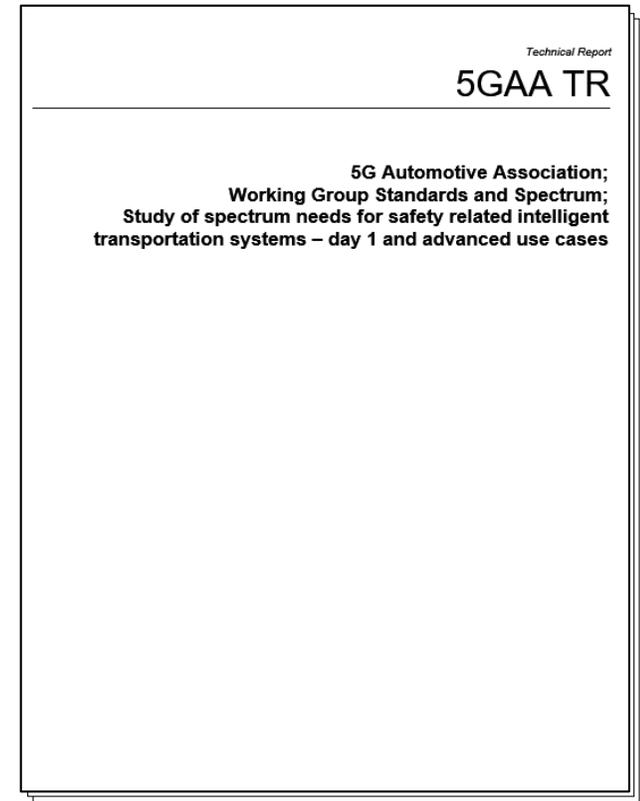
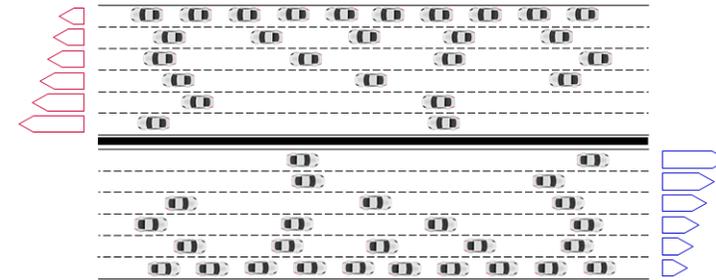
V2N in **bands** designated for
mobile communication networks



Spectrum studies

- ❑ 5GAA considers that **LTE-V2X** and **NR-V2X** are the most suitable technologies for the support of **day-1** ITS and **advanced** driving use cases, respectively¹.
- ❑ We have recently undertaken a study of the spectrum needs of such use cases.
- ❑ In our analysis, we have accounted for
 - relevant road geometries,
 - geographic density of road users,
 - message size, repetition rate, latency,
 - effective spectral efficiency of C-V2X.

¹ LTE-V2X relates to 3GPP Rel. 14 or 15 specifications, whereas NR-V2X relates to 3GPP Rel. 16 and beyond specifications (NR based). 5G-V2X relates to the combination of LTE-V2X and NR-V2X, whereas C-V2X is an umbrella term which encapsulates all 3GPP V2X technologies. Unless explicitly stated otherwise, the term C-V2X encompasses both direct (PC5) and network-based (Uu) modes of communication. If only PC5 or only Uu are addressed, then the terms C-V2X PC5 and C-V2X Uu are used, respectively.



Direct communications C-V2X PC5

Day-1/basic safety use cases

- ❑ Day-1 use cases typically employ **continual/repetitive** messages (CAM/BSM) of 300 Bytes at a repetition rate of ≤ 10 Hz.
- ❑ These include Cross-Traffic Left-Turn Assist, Intersection Movement Assist, Emergency Brake Warning, Traffic Jam Warning, Real-Time Situational Awareness, Lane Change Warning, and Automated Intersection Crossing.
- ❑ We have examined **urban intersection** and **freeway** scenarios, accounting for a range of vehicle speeds, and the impact of congestion control on repetition rate.
- ❑ Spectrum needs for continual repetitive messages in **day-1 basic safety** use cases are **at least 10 MHz** under nominal traffic dynamics. Additional spectrum may be needed in abnormal traffic dynamics; e.g., shockwaves.



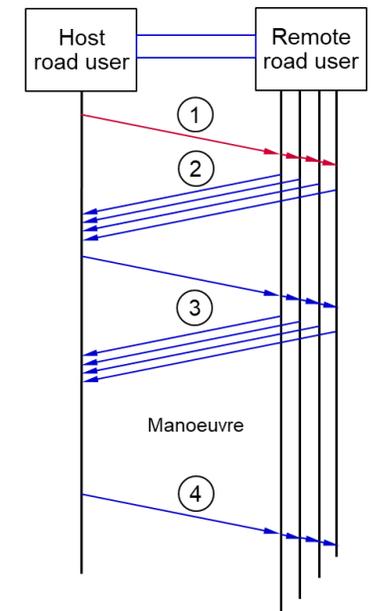
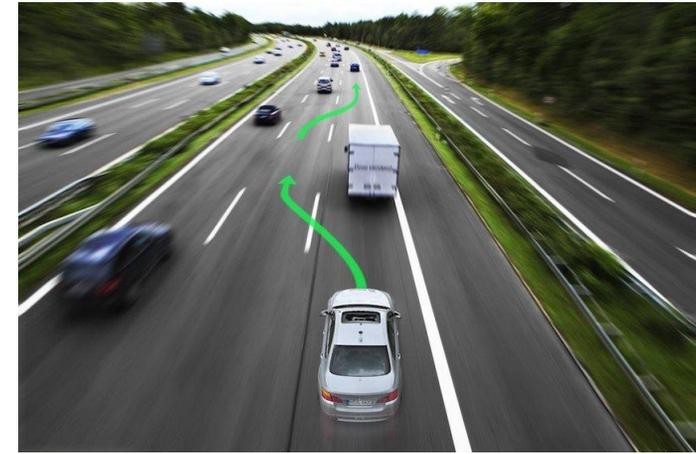
Advanced use cases (1)

- ❑ Some advanced driving use cases, e.g. **High Definition Sensor Sharing**, involve the ability of road users to share their processed sensor data with other road users on a **continual basis** to provide advanced driver assistance and to facilitate autonomous driving.
- ❑ We have examined **freeway** scenarios, accounting for a range of vehicle densities, speeds, and **sensor data**.
- ❑ The appropriate **amount** of **sensor data** which should be shared is an open question for the industry, and directly impacts the required spectrum. We have considered four different sensor sharing solutions in published literature.
- ❑ Our estimate of spectrum needs for these use cases is **40 MHz or more** depending on the extent of information sharing.



Advanced use cases (2)

- ❑ Many other advanced driving use cases are **event-triggered**, where messages are exchanged in response to a desire by a road user to undertake a specific **manoeuvre** (e.g., cooperative manoeuvres).
- ❑ 5GAA has studied a number of such use cases, and the preferred methodology for the calculation of their spectrum needs is under discussion.
- ❑ Our initial assessment is that the spectrum needs for each of the event triggered use cases considered are **unlikely to exceed several MHz** at most, and certainly much less than for advanced use cases such as cooperative perception.
- ❑ Note that the contribution of event triggered use cases to the overall ITS spectrum needs is stochastic, in the sense that such use cases may or may not **occur at the same time**, and this can result in a highly **time varying** demand for spectrum at any given location...



- (1) Notification and trajectory information
- (2) Feedback (confirmation/rejection)
- (3) Decision and feedback
- (4) Termination

Advanced use cases (3)

- ❑ ... As a result, the evaluation of the spectrum needs for advanced use cases is not a trivial task.
- ❑ Nevertheless, it is clear from our studies that the **70-75 MHz** of ITS spectrum in the **5.9 GHz band** (allocated in many regions and under consideration in other regions) is needed to support the **basic safety** and **advanced** use cases under consideration today.
- ❑ Like any emerging sector, there could be unforeseen ITS use cases that would require even more spectrum as the market evolves.
- ❑ As the ITS industry develops further, and we begin to better understand the demands of advanced driver assistance and autonomous driving, we will assess the extent to which the **5.9 GHz band** (**globally harmonised** for **ITS** by the ITU-R) is sufficient to meet the spectrum needs of the road users, and whether additional spectrum designated for ITS will be required.



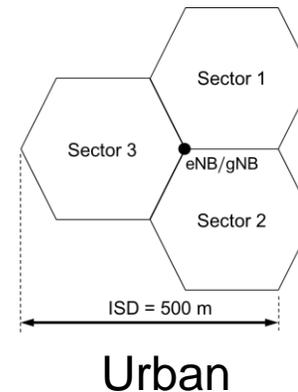
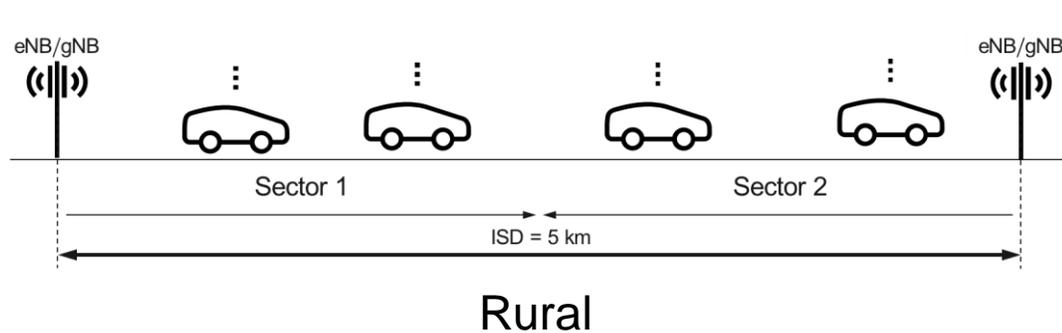
recommends

- 1 that, taking into account *considering h*), Administrations should consider using the frequency band 5 850-5 925 MHz, or parts thereof, for current and future ITS applications;

Network-based communications C-V2X Uu

Advanced use cases (1)

- ❑ Many **V2N** use cases have already been introduced for some time, and are accommodated in spectrum designated for **mobile communication networks**.
- ❑ We have therefore focused on the spectrum needs of a number of future **advanced V2N** use cases, such as Tele-Operated Driving, Obstructed View Assist, Infrastructure Assisted Environment Perception, and High Definition Map Collection and Sharing.
- ❑ We have examined mobile network deployments in **rural, urban,** and **dense urban** environments in this context.



Advanced use cases (2)

	Spectrum needs (MHz)		
	Rural	Urban	Dense urban
Software Update of Reconfigurable Radio System (DL)	12	2	3
Autonomous Vehicle Disengagement Report (UL)	13	4*	4*
Patient Transport Monitoring (UL)	25	8*	8*
Tele-Operated Driving (UL)	100	30*	30*
Obstructed View Assist (DL)	**	45	90
Infrastructure Assisted Environment Perception (UL)	**	92 – 184	
In-vehicle entertainment (DL)	**	450	900
High Definition Map Collection and Sharing (UL)	**	360	720

* The urban and dense urban sectors must both support at least one user.

** To meet the use case requirements, an increased spectrum availability is not sufficient in itself, but needs to be complemented with improved network and device capabilities, and is under consideration by 5GAA.

- ❑ Spectrum needs could be much higher in **rural** environments due to **large inter-site** distances, and – given limited bandwidths available in **low-bands** – it is unlikely that the use case could be implemented with the same performance in very rural environments. Spectrum needs along highways can be reduced through network densification.
- ❑ The spectrum needs for some advanced use cases **cannot be met** by the **existing** spectrum **holdings** of MNOs and would require **10s to 100s of MHz** of additional **mid-band** spectrum.
- ❑ Some of this demand could be offloaded to mm-Waves in low mobility conditions and where coverage is available.

Conclusions

Conclusions: direct communications

- ❑ Based on our studies of C-V2X direct communications (V2V/I/P):
 - We expect that the delivery of **day-1** use cases via **LTE-V2X** for the support of **basic safety** ITS services will require between **10 and 20 MHz** of spectrum at **5.9 GHz** for V2V/I communications.
 - We expect that the delivery of **advanced** use cases via **LTE-V2X** and **NR-V2X** for the support of **advanced driving** services will require an additional **40 MHz or more** of spectrum at **5.9 GHz** for V2V/I/P communications.
- ❑ Detailed analysis of spectrum needs of **advanced event triggered** use cases is in progress.
- ❑ Nevertheless, it is clear that the **70-75 MHz** of ITS spectrum in the **5.9 GHz band** (as presently allocated in many regions and under consideration in other regions) is needed to support the basic safety and advance use cases under consideration today.
- ❑ Like any emerging sector, there could be unforeseen ITS use cases that would require even more spectrum as the market evolves.

Conclusions: network based communications

- ❑ Based on our studies of C-V2X network-based (V2N) communications:
 - At least **50 MHz** of additional¹ service-agnostic **low-band (< 1 GHz)** spectrum would be required for **mobile operators** to provide advanced automotive V2N services in **rural** environments with affordable deployment costs.
 - At least **500 MHz** of additional¹ service-agnostic **mid-band (1 to 7 GHz)** spectrum would be required for **mobile operators** to provide high capacity **city wide** advanced automotive V2N services.
- ❑ 5GAA places great value on the importance of V2N communications in enabling future advanced driving use cases, as supported by the Uu interface of C-V2X.
- ❑ Accordingly, the 5GAA recommends that national and regional **administrations** ensure the **availability** of sufficient spectrum for mobile communication networks in the so-called **low-bands** and **mid-bands** for the support of services, including ITS, in the coming decade.

¹ In the above, the term “additional” means availability of spectrum in addition to the bands that are currently identified for IMT use by mobile communication networks.