5GAA Automotive Association

White Paper on ITS spectrum utilization in the Asia Pacific Region

White Paper

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Executive Summary

With the booming development of intelligent transportation systems (ITS), an increasing number of regulators and governments around the globe pay attention to both technology and spectrum matters around ITS. This white paper summarizes the status of ITS spectrum utilization in the Asia Pacific Region, with focus on Japan, Korea, Singapore, Australia and China. Based on the ITS developments in the region, including business development, spectrum allocation and policy, the white paper provides recommendations on the choice of technology for ITS. The white paper also provides recommendations on the spectrum allocated for ITS applications based on direct vehicle-to-everything (V2X) communications.

5.9 GHz is the most promising band used for ITS applications in Korea, Singapore, Australia and China. 5.9 GHz spectrum has been assigned for ITS deployments or ITS trials. Especially the 5855-5925 MHz band is defined as Band 47 in 3GPP, which is used for V2X operation over the PC5 interface. As it is beneficial to take advantage of the existing ecosystem development, it is highly recommended to consider 5.9 GHz as the target ITS spectrum for regulators and governments planning to allocate spectrum for ITS applications.

Cellular-V2X (C-V2X), including its existing implementation of LTE-V2X as well as future realizations, is considered as the desirable choice of technology for ITS. C-V2X, consisting of the Uu interface and the PC5 interface, provides the required performance for ITS applications both from the communication range and reliability perspectives according to extensive link-level and system-level simulation results. C-V2X has also shown very good performance in trials and tests of ITS applications at 5.9 GHz. For instance, the LTE-V2X trials in China show that the tested C-V2X devices can achieve the requirements according to the relevant 3GPP specifications. It is noted that future commercial ITS deployments in China are also planned to be based on C-V2X. Since it is feasible for C-V2X to coexist with other services or applications in co-channel and/or adjacent channel deployments in the 5.9 GHz band, more regulators and governments around the world pay attention to C-V2X.

In Korea and Australia, even though their ITS trials so far have been based mostly on IEEE 802.11p/ ITS G5 technology, the ITS spectrum is assigned in a technology neutral manner in the sense that C-V2X technology can operate in the assigned ITS spectrum as long as the regulatory requirements are fulfilled. In order to further promote the use of C-V2X for ITS applications in countries where C-V2X has not been considered yet, the principle of technology neutrality is a good start which regulators and governments are encouraged to follow. For countries where the principle of technology neutrality is adopted, trials or tests of C-V2X are encouraged to demonstrate that C-V2X complies with corresponding regulations and should be viewed as the technology of choice for ITS applications.

It is highly recommended to deliver safety related services on dedicated ITS spectrum using the C-V2X PC5 interface complemented by the C-V2X Uu interface on licensed spectrum. For safety related services, for example forward collision warning, control loss warning, emergency vehicle warning, emergency stop, road safety services, pre-crash sensing warning, etc., high performance is desired (low latency, high reliability). Considering the high performance demand of safety related services, dedicated spectrum allocation at 5.9 GHz is suggested for PC5 interface based V2X communications.

Contents

1. Overview

Intelligent transport systems (ITS) bring a new ecosystem with connected vehicles, roadside infrastructure, and mobile infrastructure which is beneficial for the environment, the society and the economy. The vehicle-connected-to-everything mode provides an effective use of the transport infrastructure, reduces the traffic load and environmental pollution, and improves road safety and transport efficiency. The market of connected vehicles is booming. By 2025, there will be more than 526 million cellular-connected vehicles on the roads worldwide, more than 40% of the global stock of vehicles in-use. The data traffic transmitted by connected cars will reach nearly 3.1 exabytes per month globally and each infotainment-enabled vehicle will be downloading more than 2.5 GB of content per month [1].

Cellular-V2X (C-V2X) is one of the technologies to deliver ITS and will enable communication between vehicles, between vehicles and infrastructure, as well as between vehicles and network. C-V2X is standardized by the third Generation Partnership Project (3GPP) and includes two interfaces: The cellular Uu interface and the cellular PC5 interface. For the Uu interface based V2X, cellular network infrastructure is required. An end-user transmits a V2X message to the mobile network and the mobile network transmits it to multiple end-users. For the PC5 interface based V2X, an end-user transmits a V2X message to multiple end-users directly. PC5 based V2X includes three scenarios: V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure) and V2P (vehicle-to-pedestrian). For V2V, either the transmitter UE (user equipment) or the receiver UE(s) are vehicles. For V2I, either the transmitter UE or the receiver UE(s) are road infrastructure, also known as road side units (RSUs). For V2P, either the transmitter UE or the receiver UE(s) are pedestrian UE.

With the booming development of ITS and the completion of LTE-V2X standardization in 3GPP Rel-14, an increasing number of regulators and governments pay attention to ITS spectrum planning globally. In Europe, the bands 5855-5875 MHz and 5875-5905 MHz are designated on a non-exclusive and license exempt basis for ITS and safety related ITS, respectively. A future extended ITS designation is reserved for 5905-5925 MHz. Additionally, 63-64 GHz is also planned for ITS in Europe. In the US, 5850-5925 MHz has been available on a non-exclusive basis since 1999, where the RSUs are licensed, but the onboard units (OBUs) are license exempt.

This white paper provides an update on the ITS spectrum utilization and policy in the Asia Pacific Region, with focus on Japan, Korea, Singapore, Australia and China. A summary of the ITS business development efforts in the region is also given for short-range V2X communications.

2. Asia Pacific Region Summary

2.1 ITS Spectrum and Channel arrangement

In Japan, the 755.5 – 764.5 MHz band is available for ITS on an exclusive and licence exempt basis. 5770-5850 MHz is allocated for the ETC (Electronic Toll Collection) and ETC 2.0 system, which is an ARIB STD-T75 based system. In Korea, 5855 – 5925 MHz was assigned for C-ITS (Cooperative ITS) – for V2V and V2I communications – in in 2016. In Singapore, 5875 – 5925 MHz is available for ITS applications since 2017. In Australia, 5855-5925 MHz is available for ITS since 2017. In China, 5905-5925 MHz is assigned for C-V2X trials in 2016. Almost all countries in the Asia Pacific Region assigned 5.9 GHz spectrum for ITS applications. In order to further enlarge the ITS ecosystem, it is recommended that 5.9 GHz spectrum is considered as ITS spectrum for the region or countries where ITS spectrum has not been assigned as of now.

Table 1: Summary of ITS spectrum in Asia Pacific Region

Country	ITS spectrum (MHz)
Japan	755.5-764.5 and 5770 – 5850
Korea	5855 – 5925
Singapore	5875 – 5925
Australia	5855 – 5925
China	5905 - 5925 (trials)

2.2 Spectrum and road authority policy

This white paper also summarizes the ITS business development efforts in the Asia Pacific Region. In Japan, the Ministry of Internet Affairs and Communications (MIC) conducted a research by the “Study Group Focusing on Realization of Connected Car Society” from December 2016 to July 2017. In this research, three trial projects were identified: Connected Network Project, Connected Data Project and Connected Platform Project. In Korea, a C-ITS pilot deployment project by the Ministry of Land, Infrastructure and Transport (MOLIT) was started in July 2014 and completed in December 2017. Under the project, safety applications and security systems were developed using domestic technical standards among which the radio interface (PHY and MAC) standard was based on IEEE 802.11p. In Australia, many states (Queensland, New South Wales, South Australia) are running or have run trial work already with a focus on ITS G5 and Dedicated Short Range Communication (DSRC). Telstra has conducted trials validating the possibility of C-ITS communications over the cellular Uu interface. In China, cellular V2X trials were launched in 2016 based on the allocated experimental spectrum in six cities – Beijing, Shanghai, Chongqing, Changchun, Wuhan, and Hangzhou. Beijing is planning to

build a state-level intelligent driving technologies and mandatory standards test base. Shanghai will build a national intelligent and connected vehicular demonstration area. Wuxi (in Jiangsu Province) will build its C-V2X vehicle networking demonstration area by 2020.

An increasing number of the countries and regulations pay attention to C-V2X. In China, the trial deployment is based on LTE-V2X and future commercial deployment will also focus on C-V2X. In Korea and Australia, even though the trial work is based on the 802.11p / ITS G5 and DSRC, the ITS spectrum is assigned in a technology neutral manner. The amendment to the Korea ITS standards is ongoing in the Telecommunications Technology Association (TTA) to support various radio technologies for ITS applications including C-V2X. In Australia, ACMA (Australian Communications and Media Authority) has indicated its willingness to review the class license subject to international developments.

3. ITS spectrum per country

3.1 Japan

3.1.1 ITS business development

ITS Connect commercial service started in 2015. It provides V2V and V2I safety features. The system complies with ARIB STD-T109 [2]. Table 2 shows the list of applications being supported (or planned to be supported) by ITS Connect.

Table 2: ITS Connect Applications

Category	Applications
V2I	Collision Avoidance Assistance during Right Turns
	Assistance in Avoiding the Overlooking of Pedestrian Crossings
V2V	Collision Avoidance Assistance
	Assistance in Confirmation of Nearby Vehicles
	Information Support on Status of Nearby Vehicles
	Information Support on Status of Passengers
	C-ACC (Cooperative Adaptive Cruise Control)
	Information Support Regarding Incoming Trams

ETC service has been widely installed in many vehicles in Japan. There were incentive programs for OBU installation and large toll fee discount to expedite the ETC adoption in the market. Currently, more than 60 million cars have installed ETC. ETC 2.0 service was recently started to enhance ETC service by providing various types of information such as traffic information with broadband communication using Car Navigation devices and OBUs. It is also used to collect Car Probe data. ETC and ETC 2.0 comply with ARIB STD-T75 [3].

VICS (Vehicle Information and Communication System) also provides real-time road traffic information about congestion and regulation. This information is displayed on the navigation screen. VICS uses

FM radio, ETC 2.0 system (5.8 GHz), and Infrared beacon. For more details on VICS, the interested reader is referred to the following link: http://www.vics.or.jp/en/vics/index.html.

3.1.2 ITS Spectrum and Channel arrangement

Japan allocated two bands for ITS communication applications. As described in Figure 1, 755.5 – 764.5 MHz is used for ITS Connect and 5770 – 5850 MHz is used for ETC/ETC 2.0. Only one channel is available in ITS Connect band. It is used for V2V, V2I and I2I communications.

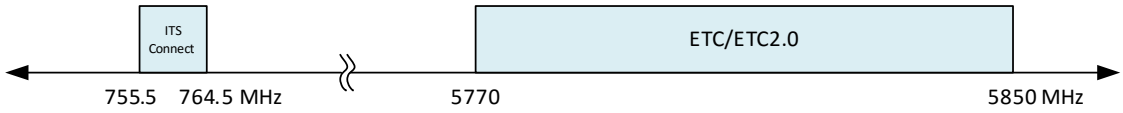

Figure 1 Japan ITS Spectrum Allocation for Communication

In the ETC/ETC 2.0 band, seven FDD channels are defined as specified in Figure 2.

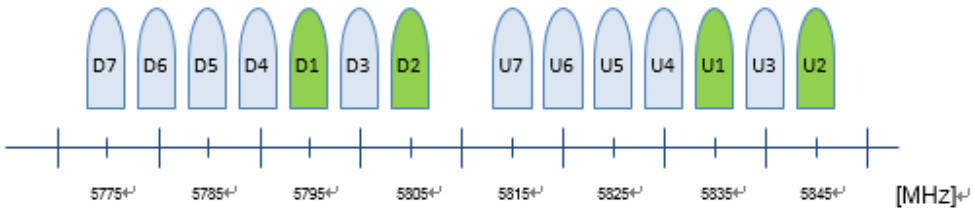

Figure 2 ETC Channel Assignment

Channel combinations for D1/U1 and D2/U2 channels are used for ETC at the toll booths on the toll highways, while all channels including D1/U1 and D2/U2 are used for ETC 2.0. Table 3 shows the ETC/ETC 2.0 regulatory technical conditions.

Table 3: ETC/ETC 2.0 regulatory technical conditions

Parameter	**Regulatory Technical Conditions**
Frequency band	5.8 GHz (5770 – 5850 MHz)
Modulation	ASK, QPSK
Modulation symbol bit rate	1.024 Mbps (ASK), 4.096 Mbps (QPSK)
Occupied bandwidth	4.4 MHz/channel
Centre frequency separation	5 MHz
Maximum Transmit power	RSU: 300 mW (coverage of 30 m or more), 10 mW (coverage less than 30 m) OBU: 10 mW

3.1.3 Spectrum Policy

MIC held a series of meetings to discuss the Realization of Connected Car Society in 2017. The study group identified the following three projects Japan should work on:

- Connected Network Project
  - Edge Computing Model for Driving Assistance
  - Cooperating with Infrastructure for Driving Assistance using LTE, etc.
  - V2V Information Sharing Model
- Connected Data Project
  - Efficient Data Collection
  - Cloud Utilization
- Connected Platform Project
  - System Architecture
  - Cooperative Platform

A testbed will be launched for technical/social evaluation of these projects as well as for security and privacy issues.

MIC also updated the Japan Frequency Action Plan in 2017. The priority of ITS enhancement in 5.8 GHz has been increased significantly. Specific technologies are not identified. However, the plan states that global trends towards new V2X technologies will be taken into account.

3.2 Korea

3.2.1 ITS business development

In Korea, the 'C-ITS master plan' was established in year 2012, includes C-ITS infrastructure implementation, OBU distribution, etc. and targets 'zero traffic accidents in 30 years' [4]. Based on the master plan, the C-ITS pilot deployment project was initiated in July 2014 and completed in December 2017. The C-ITS pilot deployment project was developed as a national task by MOLIT to verify C-ITS technologies and services and to prepare full-scale deployment of C-ITS. The target scenarios for the C-ITS pilot deployment project were the expressway, national and urban roads in Daejeon city and Sejong city (total 87.8 Km). Under the project, safety applications and security systems were developed using domestic technical standards where the radio interface (PHY and MAC) standard was based on IEEE 802.11p.

The 15 C-ITS applications listed in Table 4 were developed and tested in the C-ITS pilot deployment project.

Table 4: C-ITS applications developed and tested in the pilot deployment project of Korea

	Application name	**V2V/V2I type**
1	Location Based Vehicle Data Collection	V2I
2	Location Based Traffic Information Provision	V2I
3	Wave Communication	V2I
4	Hazardous Location Notification	V2I
5	Road Feature and Weather Notification	V2I
6	Road Work Zone Warning	V2I, V2V
7	Signalized Intersection Violation Warning	V2I, V2V
8	Intersection Right Turn Conflict Warning	V2V
9	Transit Vehicle Operation Management	V2I, V2V
10	School Bus Warning System	V2I, V2V
11	School and Silver Zone Warning Data Collection	V2I
12	Pedestrian Collision Warning	V2I
13	Forward Collision Warning	V2V
14	Emergency Vehicle Approaching Alert	V2V
15	Vehicle SOS Service	V2I, V2V

As the next phase, the C-ITS implementation project is initiated in 2018. Target locations of this project include expressways (total 128 km of the Seoul metropolitan ring road and the Kyungbu express road), Seoul city and Jeju island. More advanced applications and service scenarios specified for each target location will be developed and deployed under the C-ITS implementation project. The base technical standards for the project are not determined yet.

3.2.2 Situation of ITS Spectrum and Channel arrangement

In the Republic of Korea, the 5855 – 5925 GHz band has already been assigned for C-ITS (V2V and V2I communications) by the Ministry of Science and ICT (MSIT) in 2016. In this spectrum, it is determined to use seven radio frequency channels with 10 MHz channel bandwidth each, where the defined channels are shown in Table 5 [5][6]. Specifically, channel 5 (5895 -5905 MHz) should be used as a control channel, while the other six channels can be used as service channels.

Table 5: Channel arrangement and channel types for 5855 – 5925 GHz

Channel No.	1	2	3	4	5	6	7
Centre frequency (MHz)	5860	5870	5880	5890	5900	5910	5920
Channel type	Service channel	Service channel	Service channel	Service channel	Control channel	Service channel	Service channel

In addition, the following regulations must be met to use the 5855 – 5925 GHz frequency band for ITS applications [6]:

- Maximum occupied bandwidth should be limited to 10 MHz.
- Transmit power and E.I.R.P are limited to 100 mW and 2 W, respectively.
- Frequency tolerance should be less than 20 ppm.
- (Unwanted) Spurious emissions should not exceed the reference power levels given in Table 6.
- The reference power level and resolution bandwidth are related to the frequency range, as shown in the Table 6.

Table 6: Frequency range, reference power level and resolution bandwidth

Frequency range	Reference power level	Resolution Bandwidth
Below 1 GHz	-36 dBm	100 kHz
Above 1 GHz	-30 dBm	1 MHz

3.2.3 Spectrum Policy

In Korean regulations, the 5855 – 5925 GHz band is assigned for the purpose of ITS applications without specifying any particular radio technology to be operated in this spectrum. Thus, from the regulatory perspective, it is understood that frequency band 5855 – 5925 GHz is assigned for ITS applications in a technology neutral manner, i.e., any radio technology can be used in this spectrum as far as the technology complies with the corresponding regulations. It is noted that an amendment to the Korean ITS standards is ongoing in TTA, and one of its goals is to support various radio technologies for ITS applications, including C-V2X, in addition to the technologies based on IEEE 802.11p.

3.3 Singapore

3.3.1 ITS business development

Existing ITS deployments have played an important role in enhancing commuters' travelling experience in Singapore. The increasing vehicle population in the land-scarce city-state, coupled with the changing social, economic and technological landscapes have brought about new transportation challenges. At the same time, they have also brought forth new opportunities for growth and breakthrough in transportation technology applications and solutions. In 2014 Singapore's Land Transport Authority and Intelligent Transport Society published Smart Mobility 2030: ITS Strategic Plan for Singapore [7].

Smart Mobility 2030 consolidates the perspectives from the Land Transport Authority and the industry, paving the way for a more comprehensive and sustainable ITS ecosystem in Singapore in the coming years till 2030.

Smart Mobility 2030 outlines the vision broad strategies that are essential for the successful implementation of ITS initiatives and charts the key focal areas to meet transport challenges in a systematic and coordinated manner for a smarter future urban mobility.

Singapore's ITS vision is "Moving towards a more connected and interactive land transport community". This ITS vision aims to shape Singapore into a highly-integrated, lively and more inclusive community where people enjoy high quality of life.

The three Key Strategies are:

- Implement innovative and sustainable smart mobility solutions
- Develop and adopt ITS standards
- Establish close partnerships and co-creation

3.3.2 Situation of ITS Spectrum and Channel arrangement

In February 2017, Singapore spectrum management regulator Infocomm Media Development Authority (IMDA) published the decision for Framework and Standards for ITS in the 5.9 GHz (5875 MHz - 5925 MHz) frequency band [8].

In the decision, IMDA decided to open the 5875 – 5925 MHz band for ITS applications. IMDA also decided to allow ITS usage within 5855- 5875 MHz, where the operation should comply with the SRD (Short Range Devices) technical specification and the emission power limit to 100 mW. ITS technology operating in this band should be in accordance to the TSAC (Telecommunications Standards Advisory Committee) recommended standard [6]. This standard is established based on IEEE 802.11p with modifications to the PHY and MAC layers to provide reliable and low latency communications between vehicles, and to IEEE 1609 wireless access vehicular environment (WAVE) for security and network management. DSRC devices shall comply with the maximum field strength or radio frequency output power illustrated in Figure 3 [9].

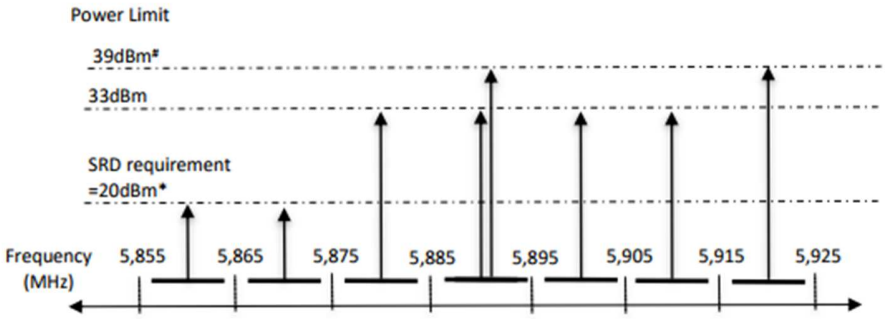

Figure 3 DSRC spectrum power limit and channel arrangement in Singapore

The available spectrum is divided into seven 10 MHz channels, see Table 7. 5875-5885 is dedicated to V2V Safety applications, whereas 5885-5895 is used for WAVE Short Message Protocol (WSMP) messages and management messages. 5905-5915 is assigned to Road Pricing Service and 5915-5925 to Long Range Channel; these two channels are public channels that only government agencies and their designated entities are allowed to install and operate using ITS devices. 5895-5905 MHz and 5855-5875 MHz are service channels that can be used by both government agencies and private entities.

Table 7: Description of channel types in the 5855-5925 MHz band in Singapore

Frequency range (MHz)	Centre frequency (MHz)	Usage
5855-5865	5860	ISM Band Public/Private Channel
5865-5875	5870	ISM Band Public/Private Channel
5875-5885	5880	V2V Safety Channel
5885-5895	5890	Control Channel
5895-5905	5900	Public/Private Channel
5905-5915	5910	Public Channel
5915-5925	5920	Long Range Channel

3.3.3 Spectrum Policy

In the decision for Framework and Standards for ITS in the 5.9 GHz (5875 - 5925 GHz) Frequency Band [5], IMDA also decided spectrum management for using this band for ITS applications. Regarding the licensing approach, vehicular OBUs are operated in a license exempt manner, while localised radio-communication station license or wide area private network license is necessary to operate an RSU/non-vehicular installation. IMDA has decided to charge RSUs and non-vehicular installations only for the spectrum used for the ITS application service channel and not for the common control channel. There are two types of spectrum fees: For the shared-use case, the annual frequency management fee is $2500 (based on per 10MHz usage); for the exclusive-use case, the annual frequency management fee is $9200 (based on per 10MHz usage). The licensing framework is summarized in Table 8 and the details can be found in [8].

Table 8: Summary of the licensing framework at 5.9 GHz in Singapore

Description	Vehicular OBU	RSU /Non-Vehicular Installation
Spectrum	5875 – 5925 GHz (“5.9 GHz band")	
Technical Requirement	Compliance with the IMDA adopted TSAC recommended standards	
Equipment Registration Scheme	General Equipment Registration	
Licence Approach	Licence exempt	Localised Radio-Communication Station Licence/ Wide Area Private Network Licence
Spectrum Fees	NA	Yes
Shared Use		Chargeable shared-use annual frequency management fee of $2,500* (based on per 10 MHz usage)
Exclusive Use (where applicable)		Chargeable exclusive-use annual frequency management fee of $9,200* (based on per 10 MHz usage)

*Includes chargeable one-time application and processing fee of $300. The use of control channel (5885 – 5895 GHz) by RSU or non-vehicular installation will not be charged.

3.4 Australia

3.4.1 ITS business development

The Australian road authorities in each state or territory are responsible for setting rules that apply to road users in that area. Many states (Queensland, New South Wales, South Australia) are running or have run trials already with focus on ITS/G5 and DSRC. Additional work has been taking place independently from government funded initiatives; for instance, Telstra conducted trials validating the possibility of C-ITS communication over the LTE Uu interface. No PC5 based LTE-V2X testing has taken place to date.

For V2X safety applications, there is no mandate being discussed at this stage. Two key bodies are responsible for the V2X safety standards: Austroads and the Australian Road Research Board (ARRB).

- Austroads is a government body with members from all states (including the New Zealand transport agency) that provides technical guidance and frameworks for the states to implement, creating some level of national alignment.
- ARRB is an independent group that supports and delivers applied research for AU and NZ state road agencies. For example, in 2015 ARRB commenced work on 54 projects for Austroads, spread across the Assets, Freight, Network, Registration & Licensing, Safety and Technology programs.

3.4.2 Situation of ITS Spectrum and Channel arrangement

In Australia, ACMA published its Radiocommunications (Intelligent Transport System) Class Licence 2017 [9]. 5855-5925 MHz is available for ITS and the available spectrum is divided into seven 10 MHz channels, see Table 9, with ITS stations required to comply with ETSI Standard EN 302 571. 5855 – 5875 MHz is assigned for non-safety related ITS. 5875 – 5895 MHz is assigned for safety related ITS. 5905 – 5925 MHz is reserved for future applications. According to the ACMA Class Licence 2017, transmission is allowed when stations are operated:

- On a frequency, or within a range of frequencies, greater than 5855 MHz and not greater than 5925 MHz; and
- at a radiated power that does not exceed a maximum EIRP of 23 dBm/MHz; and
- provided the ITS station complies with ETSI Standard EN 302 571, with some minor modifications.

Table 9: Description of channel types in the 5855-5925 MHz band in Australia

Frequency range (MHz)	Centre frequency (MHz)	Usage
5855-5865	5860	Non-safety
5865-5875	5870	Non-safety
5875-5885	5880	Safety
5885-5895	5890	Safety
5895-5905	5900	Control
5905-5915	5910	Future applications
5915-5925	5920	Future applications

3.4.3 Spectrum Policy

There are no restrictions on specific operators of ITS stations, other than compliance with the class license, see Section 3.4.2 above. It was proposed during consultation that operation is restricted to road authorities as one of the conditions of the license, but this has not been adopted in the final text.

The ACMA has a history of technology neutrality and has indicated a willingness to review the class license subject to international developments. Essentially, if there is a technical standard based on LTE-V2X that can be referenced from another jurisdiction, then this can be assessed for inclusion in a review of the class license. The timeline for this review would be no sooner than late 2019.

Alternatively, if it can be shown that LTE-V2X is compliant with the class license (essentially EN 302 571), then there would be no restriction on operating LTE-V2X devices in the available ITS spectrum in Australia.

3.5 China

3.5.1 ITS business development

In China, several C-V2X related demonstrations/pilots have been conducted since 2016, where both the Uu and PC5 interfaces were demoed in these trials. In November 2016, Chinese regulator Ministry of Industry and Information Technology (MIIT) assigned 5905-5925 MHz as experimental spectrum for C-V2X pilot development in six major cities – Beijing, Shanghai, Chongqing, Changchun, Wuhan, and Hangzhou. Both laboratory and field tests were included in the pilot projects of C-V2X direct-link communication on 5.9 GHz band. The tests included communication performance tests (e.g., latency, reliability, coverage), RF performance tests (e.g., emission, spurious), and coexistence tests (e.g., coexistence with fixed links, fixed satellite service, RLAN). The tests were performed under more than ten working environments, include crossroads, bridges, straight roads, and turns in urban and highway scenarios. The test results show that the C-V2X testing devices can achieve the requirements according to 3GPP specification, and it is feasible that new C-V2X devicse can coexist with other incumbent services or applications either in co-channel and in adjacent channel manner.

Moreover, Beijing is planning to build a state-level intelligent driving technology and mandatory standards test base. More specifically, this test base is responsible for the validation and testing of intelligent driving technologies including C-V2X under various road scenarios such as urban roads, urban expressways and rural expressways. It fully supports the main function and scenario testing and certification of the Uu interface (dynamic speed limit, brake reminder, remote automotive driving, etc.) and the PC5 interface (including crossroads warning, brake assist, lane change assistance, etc.).

The Shanghai National Intelligent Connected Vehicle Pilot Zone (A NICE CITY) is the first pilot zone in China approved by MIIT in June 2015, which is undertaken by Shanghai International Automobile City (Group) Co., Ltd. The pilot zone aims to test and demonstrate two key technologies: intelligent vehicle and V2X communication. During the first stage of the pilot zone, the closed test area was formally put into operation since June 2016. At present, the pilot zone has moved to its second stage, the open road test area, which is now under construction.

From June 2018 to June 2019, the pilot zone plans to carry out the construction of large-scale C-V2X demonstration projects on urban open roads. There will be no less than 3000 vehicles participating in this demonstration project, including cars, passenger cars, buses and wagons. Based on these, C-V2X functional and performance testing, interconnected testing and validity verification will be conducted; meanwhile, pre-commercial evaluation will be carried out with the result of user/driver feedback and a sharing data base. All of these activities aim to speed up the formulation of C-V2X standards, explore the new format and business model of C-V2X, and comprehensively promote the industrialization of C-V2X in China.

By 2020, Wuxi (in Jiangsu Province) will build the C-V2X vehicle networking demonstration area, where the C-V2X network will cover the whole city to provide real-time information exchange. Both Uu and PC5 interfaces are targeted to be supported, where almost all business scenarios of C-V2X should be demostrated/tested.

i-VISTA (Intelligent Vehicle Integrated Systems Test Area), undertaken by China Automotive Engineering Research Institute and supported by MIIT and Chongqing municipal government, is a demonstration project of intelligent vehicle, intelligent traffic application and a public service platform for product engineering. i-VISTA aims to serve the testing and demonstration of advanced driving assistance systems, V2X, autonomous driving, intelligent traffic, etc. i-VISTA provides virtual simulation test, lab test, closed, semi-closed and open road test environment for environmental detection sensors and vehicles, which will cover over 90% of complicated road conditions in the west area and over 85% of road and communication environments around the country. i-VISTA is devoted to provide comprehensive, neutral, impartial, professional and respected tests, R&D and consultation service of intelligent connected vehicle and intelligent traffic. All of this work aims to support standards research, experimental verification, test certification, application demonstration and product engineering of intelligent connected vehicle and intelligent traffic technology in China.

3.5.2 Situation of ITS Spectrum and Channel arrangement

In November 2016, the Bureau of Radio Regulation (BRR) of MIIT assigned 5905-5925 MHz for C-V2X trials in six major cities – Beijing, Shanghai, Chongqing, Changchun, Wuhan, and Hangzhou.

BRR is determined to complete its ITS spectrum planning activities within 2018. BRR assigned State Radio Regulation of China (SRRC) and Telematics Industry Application Aliance (TIAA) to lead the study for 1) spectrum needs for ITS service in China, 2) coexistence study, and 3) ITS spectrum management methodology.

3.5.3 Spectrum Policy

Assigned by BRR, TIAA and SRRC are leading the study of ITS spectrum policy. This study will cover the license or license-exemption for OBUs and RSUs, as well as the legal entity for licensing if a license is needed. Related to spectrum policy, it is also proposed to study whether a license for roadside information service providers is needed to avoid misusing I2V message.

4. Recommendations

4.1 Recommendations on ITS spectrum

5.9 GHz is the most promising band used for ITS. In Korea, Singapore, Australia and China, 5.9 GHz is assigned for ITS deployments or ITS trials. A summary of ITS spectrum in the Asia Pacific Region is given in Table 10. Note that 5855-5925 MHz is defined as Band 47 in 3GPP, which is used for V2X applications. As it is beneficial to take advantage of the existing ecosystem development, **it is highly recommended to consider 5.9 GHz as the candidate ITS spectrum for the regulators and governments where ITS spectrum has not been assigned yet.**

Table 10: Summary of ITS spectrum in the Asia Pacific Region

Country	ITS spectrum (MHz)
Japan	755.5-764.5; 5770 - 5850
Korea	5855 - 5925
Singapore	5875 - 5925
Australia	5855 - 5925
China	5905 - 5925 (trial)

4.2 Policy considerations

C-V2X, which consists of both the Uu interface and the PC5 interface, is considered as the desirable choice of technology for ITS. The study of C-V2X was started in 2015 in 3GPP, while the V2V related standard was released in June 2016 and the V2X part was finalized in March 2017. C-V2X meets the requirements of ITS use cases, including forward collision warning, control loss warning, emergency vehicle warning, emergency stop, co-operative adaptive cruise control, queue warning, road safety services, automated parking system, wrong way driving warning, pre-crash sensing warning, traffic flow optimisation, etc. [11]. Compared with DSRC, given that the technology development of C-V2X was started in recent years, C-V2X provides better performance both from the communication range and reliability perspectives. According to link-level and system-level simulation results [12], to enjoy the same link performance (BLER=0.1) for both LOS and NLOS transmission scenarios, lower SNRs are achievable by the LTE-V2X PC5 interface compared to IEEE 802.11p. For example, the required SNR of IEEE 802.11p is about 4.2 dB to 5.2 dB higher than LTE-V2X PC5 in LOS scenarios with relative speed of 30km/h to 280km/h, respectively. Regarding the communication range, LTE-V2X PC5 outperforms IEEE 802.11p by a range between 20% and 80% [12]. In addition to the performance benefits, C-V2X also offers a clear evolution path to 5G. 5G V2X provides advanced V2X services including vehicle platooning, extended sensors, advanced driving, and remote driving [13].

LTE-V2X has shown very good performance in conducted trials and tests. In China, C-V2X trials in six cities were started in 2016 after the C-V2X standard was released by 3GPP. The testing results show that C-V2X testing devices can achieve the requirements according to 3GPP specification. Also, it is shown that it is feasible for C-V2X to coexist with other services or applications in a co-channel and/or adjacent channel manner in the 5.9 GHz band. With the development of C-V2X, an increasing number of regulators and governments pay attentaion to C-V2X in the Asia Pacific Region. In Korea, the amendment to the Korea ITS standards is ongoing in TTA to support various radio technologies for ITS applications including C-V2X. In Australia, ACMA has indicated its willingness to review the class license subject to international developments. In order to more efficiently promote ITS applications in regions or countries where C-V2X is not considered as of now, geovernment agencies and regulators are encouraged to take C-V2X into consideration for future developments by, for example, being technology neutral as a starting point. For regions or countries where technology neutrality is adopted, trials or tests of C-V2X are encouraged to verify that C-V2X complies with corresponding regulations. If it is compliant with regulations, there should be no restriction in operating C-V2X devices in the allocated ITS spectrum.

Dedicated ITS spectrum at 5.9 GHz is proposed to deliver safety related services using PC5 interface based V2X communications. For safety related services, e.g., forward collision warning, control loss warning, emergency vehicle warning, emergency stop, road safety services, pre-crash sensing warning, etc., high performance is desired (low latency, high relaibility). Considering the high performance demand of safety related services, dedicated spectrum allocation is suggested. For non-safety related services, e.g., automated parking system, traffic flow optimisation, etc., allocation of spectrum in a shared manner can be considered to improve the spectrum utilization.

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