What is True 5G? And Why Spectrum is so Important?

Mobile phone services have now been available for over 30 years. During this time, the service has evolved from a luxury providing a simple, voice only service (1G) to a service carrying voice and video at speeds comparable to fixed broadband services and used by everyone (4G). The service is now on the point of taking a quantum leap to 5G. This next generation of mobile services will connect things as well as people. True 5G will be the basic infrastructure of the future, of smart cities and the digital economy. It is not simply a question of faster 4G. It is something radically different which will support a broad array of new, high speed, innovative services and applications.

History of Mobile Technology

Since its first introduction in the mid 1980's, cellular technology has undergone tremendous development over four generations of technology. Each generation represents a substantial technological breakthrough with regard to mobile broadband capability (speed and capacity) as illustrated in Figure 1. The technological advances have enabled the service to evolve from simple voice call and SMS in 2G; to mobile broadband with data speeds of 42Mbps in 3G; and then to support even faster LTE mobile broadband with speeds from 150Mbps up towards 1Gbps in 4G.

The speed and capacity of 4G has enabled high resolution video services for mass users such as YouTube, Facebook, WhatsApp, etc. The evolution into true 5G, is expected to deliver a whole a new paradigm of creative services and applications: Smart cities with smart, green buildings and environmentally-friendly, energy-saving smart grid/meter or water leakage detection; smart transportation with environmentally-friendly autonomous cars; cooperative robotics side-by-side with human for manufacturing or hazard rescue; remote surveillance with 360^{o} video, city discovery with augmented reality, etc[1]

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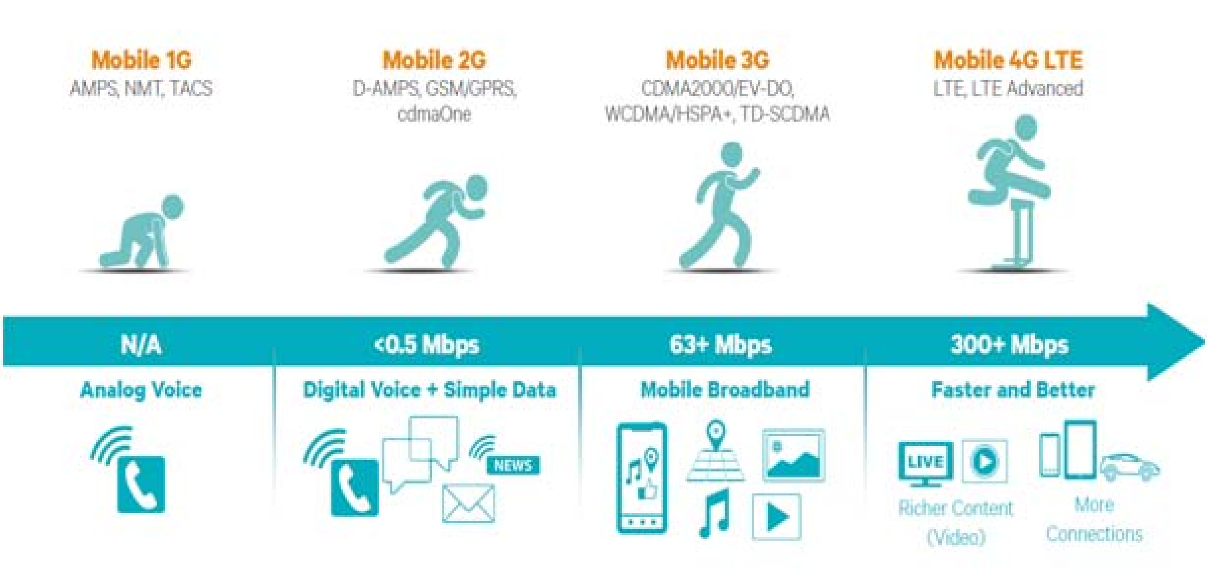
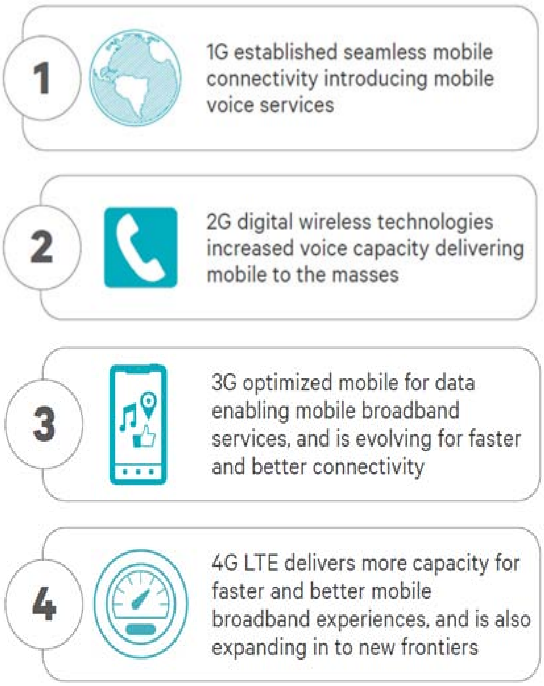
[1] See Figure 2 and Annex 1 for further examples of services and applications that will be possible with true 5G.





1st Generation Mobile
- Analogue systems with limited capacity
- Provide basic mobile voice communications
- Limited roaming is supported

2nd Generation Mobile
- Digital systems with higher voice capacity
- Supports two-way texting (SMS) and low speed data (CSD, GPRS, EDGE) at around 100Kbps (max)
- True international roaming is achieved

3rd Generation Mobile
- Offering even higher voice capacity
- Supports video-call
- Improve data speed, starting from 384Kbps all the way up to broadband speed at 42Mbps

4th Generation Mobile
- Data centric system, all services delivered by IP data
- Voice and Video calls carried over data (VoLTE/ViLTE)
- Boosting data speed from 150Mbps and above toward 1Gbps, comparable to fixed broadband

Figure 1: Capability Improvement over Generations[2]

cont'd …

[2] Qualcomm, "The Evolution of Mobile Technologies: 1G -> 2G -> 3G -> 4G LTE", June 2014 *https://www.qualcomm.com/media/documents/files/the-evolution-of-mobile-technologies-1g-to-2g-to-3g-to-4g-lte.pdf*

Implications for Spectrum

With each generation of technology, the demand for spectrum has grown significantly. The spectrum requirement of 2G is 8 times that of 1G; for 3G it is 25 times that of 2G, and for 4G, 4 times that of 3G. Table 1 summarizes the increase in demand of spectrum and number of spectrum bands for each mobile generation. True 5G is no different in requiring more spectrum. It will also require huge bandwidths and low latencies (delay).

Mobile Generation	Technology	3GPP Release	User Speed		Carrier Bandwidth	Number of Bands	Amount of Spectrum
			Download	Upload			
1G	TACS / AMPS		voice only	voice only	25/30kHz	2	140 MHz
2G	GSM		14.4 Kbps	14.4 Kbps	200kHz		
	GPRS		53.6 Kbps	26.8 Kbps			
	EDGE		217.6 Kbps	108.8 Kbps			
3G	UMTS	Rel 99	384 Kbps	128 Kbps	5MHz		
	HSPA	Rel 5	7.2 Mbps	3.6 Mbps			
	HSPA+	Rel 6	14.4 Mbps	5.76 Mbps			
	HSPA+	Rel 7	21.1 Mbps or 28 Mbps	11.5 Mbps			
	HSPA+	Rel 8	42.2 Mbps	11.5 Mbps			
	HSPA+	Rel 9	84.4 Mbps	11.5 Mbps			
	HSPA+	Rel 10	168.8 Mbps	23.0 Mbps			
4G	LTE	Rel 8	100 Mbps	50 Mbps	**20MHz**	**68**	**2350 MHz**
	LTE-A	Rel 12	1 Gbps	500 Mbps			

Table 1: Increasing demand of Spectrum and number of Spectrum Band by Generation[3]

cont'd …

[3] *AMPS specifications; TACS specifications; 3GPP TS25.331; 3GPP TS36.306; 3GPP TS36.104*

What is True 5G and Why is Spectrum so Important?

True 5G applications enable a fully mobile and connected society supporting countless emerging uses as shown in Figure 2 below:

- **Pervasive Video :** Augmented Reality, Virtual Reality, Three-dimensional (3D) Services
- **High Speed Mobility :** up to 1000 passengers at a speed of 500 km/h
- **Extreme Real-Time Communications :** user throughput (1Gbps) and latency (< 1ms)
- **Ultra-reliable Communications :** Autonomous Driving, Collaborative Robots, Public Safety

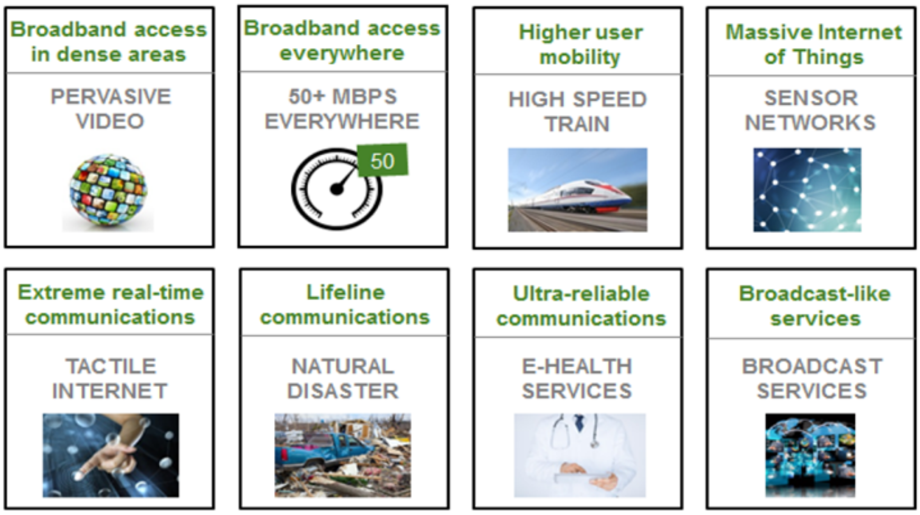


Figure 2: True 5G Use Cases[4]

These true 5G uses require ultra-fast data speeds (up to 1Gbps at home or office and at least 50Mbps everywhere else) and ultra-short latency (as low as 1ms latency for uses such as autonomous driving, remote robotics (surgery), tactile Internet, etc.) to ensure the highest quality and fastest transmission.

Ultra-fast data speeds require very wide bandwidth; spectrum bands of more than 100MHz are required. This is at least 5 times the bandwidth used for 4G and represents a huge increase simply not available in the spectrum bands allocated to earlier generations of mobile services. Despite all the hype around 4.5G and 5G the reality is that the requirements of true 5G cannot be served by just uplifting the existing 4G network solely with higher speeds or by simply re-farming the existing 582MHz spectrum currently used for 2G/3G/4G in Hong Kong.

cont'd …

[4] NGMN, "5G White Paper", Feb 2015

True 5G is a system of systems. The architecture of true 5G will be radically different from that of 4G to enable it to support the new and emerging services and applications. The ITU has defined a clear roadmap for 5G development. This is not an evolution; the changes for the new generation of technology mark a step change in standards. The true 5G architecture will be revolutionized with:

- Cloud RAN / Edge Computing: to allow low latency (from 10ms all the way down to 1ms) to support low latency applications (autonomous driving etc)
- Network Slicing: allows network to partition "slices of resources" at every portion from RAN to Core to allow the realization of the highly diversified uses in a "single" 5G network

True 5G implications for mobile operators and Government policy

True 5G is not about eMBB (enhanced Mobile Broadband) (which is the focus of 4G). True 5G is about mMTC (massive Machine-Type Communications) and URLLC (Ultra-Reliable and Low Latency Communications). Each of these uses requires certain performance metrics in terms of high data speeds, low latency, indoor coverage penetration, massive numbers of connectivity and reliability. Different spectrum frequency bands will service different purposes. High frequency bands can provide ultra-fast data speed, but are not good for extensive coverage; low frequency bands can penetrate buildings for indoor coverage but do not have sufficient bandwidth for high data speeds. Hence, spectrum allocation can no longer be generic as in the past when the focus was on mobile broadband alone. Spectrum allocation for true 5G needs a thorough understanding and consideration of these different requirements and how to meet them. This is a sea change and requires forward thinking and careful planning taking into consideration each scenario (eMBB, mMTC and URLLC).[5]

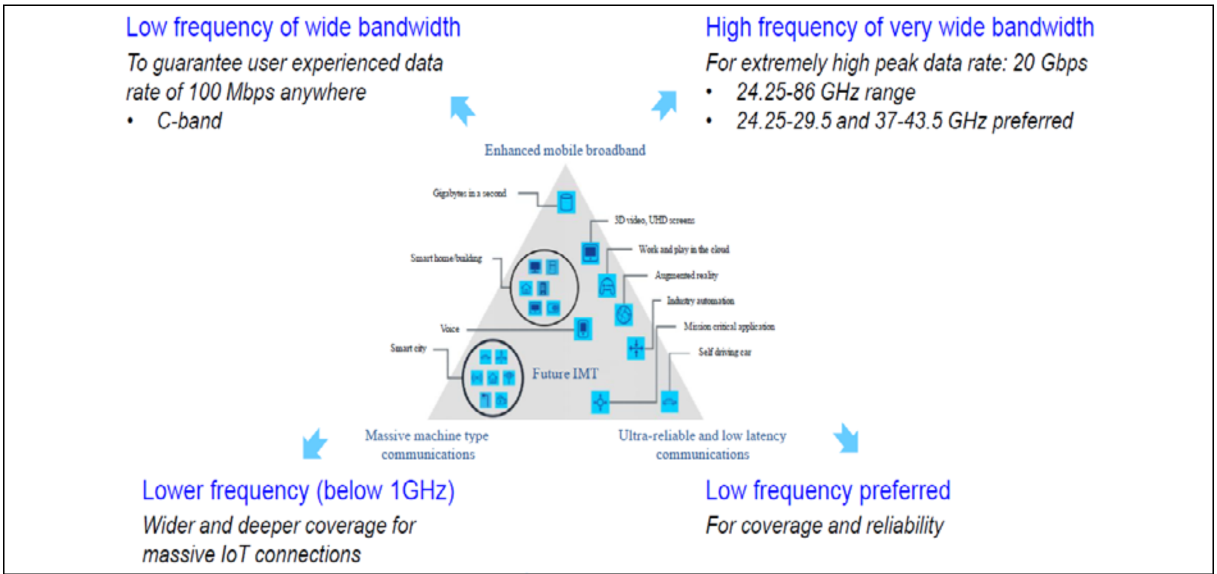


Figure 4: ITU – 5G Vision[6]

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[5] For more examples and further detail regarding the considerations for each scenario, please see Annex 1.

[6] ITU-R, "IMT Vision – Framework and Overall Objectives of the future development of IMT for 2020 and beyond", Sep 2015 https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

Based on these requirements, the ITU has looked into spectrum bands in low frequency ranges below 6GHz for re-farming from broadcast into mobile service as well as new spectrum bands at very high frequencies above 6 GHz (mmWaves from 24GHz and above) to provide sufficient spectrum bandwidth for 5G.

The use of new spectrum bands at very high frequencies will impose significant new challenges for the mobile industry. Further, a huge number of small cells will be required (perhaps 10 times the number of existing base stations) all over Hong Kong. Consequently, implementation of true 5G requires some time.

What is the Government doing to facilitate true 5G?

Unfortunately the answer is "nothing". It is not clear if the Government understands all the implications of true 5G. The Government is not making spectrum available. It has not made any new spectrum available since 2013 and will not be making any new spectrum available until 2020 at the earliest. As explained in HKT's previous paper *"Spectrum Supply in Hong Kong"* (released on 10 January 2017)[7], subsequent to the decision of WRC-15 in Nov 2015, the EU and UK authorities swiftly and publicly committed the assignment of both 700MHz and 3.5GHz bands for true 5G launch by 2020. Japan, Korea and China are also all paving the way for the launch of true 5G by 2020 by making more spectrum available. Meanwhile, in Hong Kong, OFCA has stated that there is no new spectrum available for at least the next 3 years.

Conclusion

True 5G is not just going to happen by itself. True 5G is a step-change advance in mobile communications and promises to unleash a whole range of intelligent, high speed, bandwidth-hungry services. To make Hong Kong the world-leading telecommunication hub once again by rolling out true 5G by 2020, the Government needs to make spectrum available and facilitate access to a whole new range of sites that the Government controls for the installation of small cells.

It appears that OFCA is only focused on re-auctioning 900MHz/1800MHz spectrum to (a) maximise the financial "wind-fall" to Government; and (b) allow operators to re-farm this spectrum to 4G (which they are doing already); this is extremely short-sighted policy-making.

OFCA should be preparing the ground today for the emergence of true 5G services which will be available when we step into the next decade - disappointingly it is not doing so; and, worse, it is on the record as not wanting to do anything because it says "zero" new spectrum will be available.

- # -

Hong Kong Telecommunications (HKT) Limited
February 8, 2017

[7] HKT, " Spectrum Supply in Hong Kong", 10 Jan 2017
https://www.hkt.com/staticfiles/PCCWCorpsite/Press%20Release/2017/Jan/20170110e%20Spectrum%20Supply%20Paper.pdf

ANNEX 1 – True 5G Usage Scenarios and Spectrum Requirements

1. Enhanced Mobile Broadband (eMBB)

eMBB concerns human-centric use cases for access to multimedia content, services and data. Following the growing demand of spectrum for mobile broadband services, WRC-15 identified new frequency bands for true 5G at below 6GHz band: (a) in the 700MHz band (694-790MHz) of the digital dividend, and (b) in the lower part of the C-band (3.4-3.6GHz). This spectrum allocation has all but ensured that the first set of 5G equipment for commercial deployment will operate on a globally harmonized 700MHz or lower part of C-band. Detail explanation of these two bands can be found in our previous Paper[7] on Spectrum Supply in Hong Kong.

In addition to 700MHz and the lower part of C-band, WRC-15 decided to identify even more new bands for the next WRC in 2019 that will allow true 5G technology to meet demand for greater capacity. The leading countries have been forward-looking in their spectrum planning for proposed frequency candidates below 6GHz band.

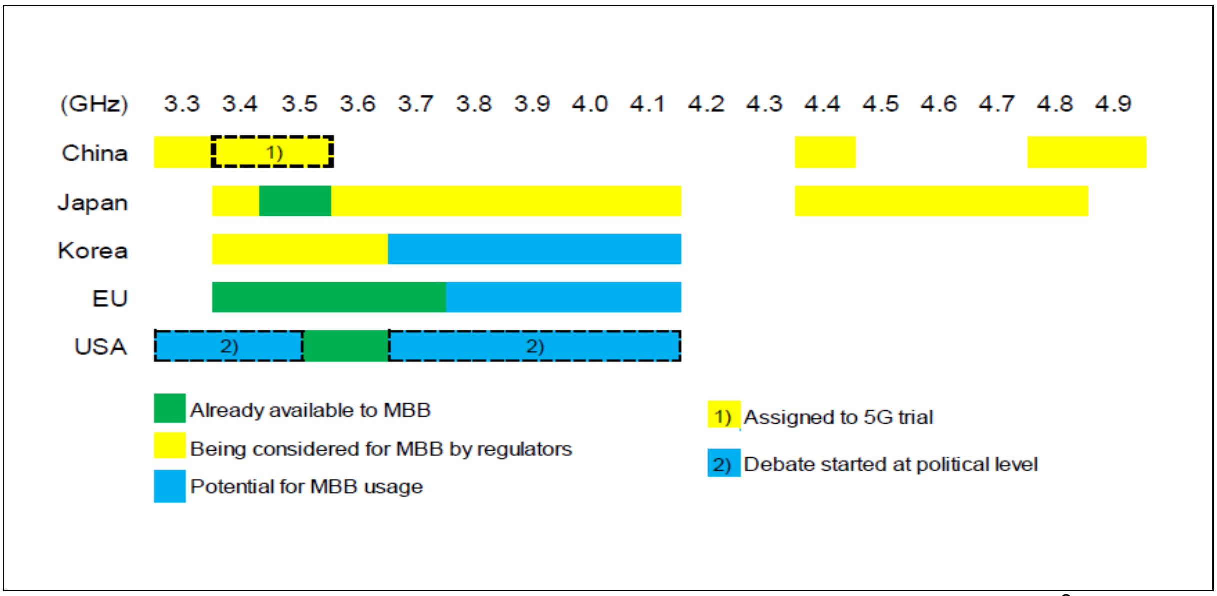

Figure A: Frequency Candidates considered by leading countries for WRC-19[8]

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[8] GSA, "5G Vision, Characteristics and Requirements", Jun 2016 http://www.gsma.com/spectrum/wp-content/uploads/2016/08/GSA-5G-Spectrum-update.pdf

As of the mmWave bands above 24GHz, many candidate frequencies are being studied by different countries.

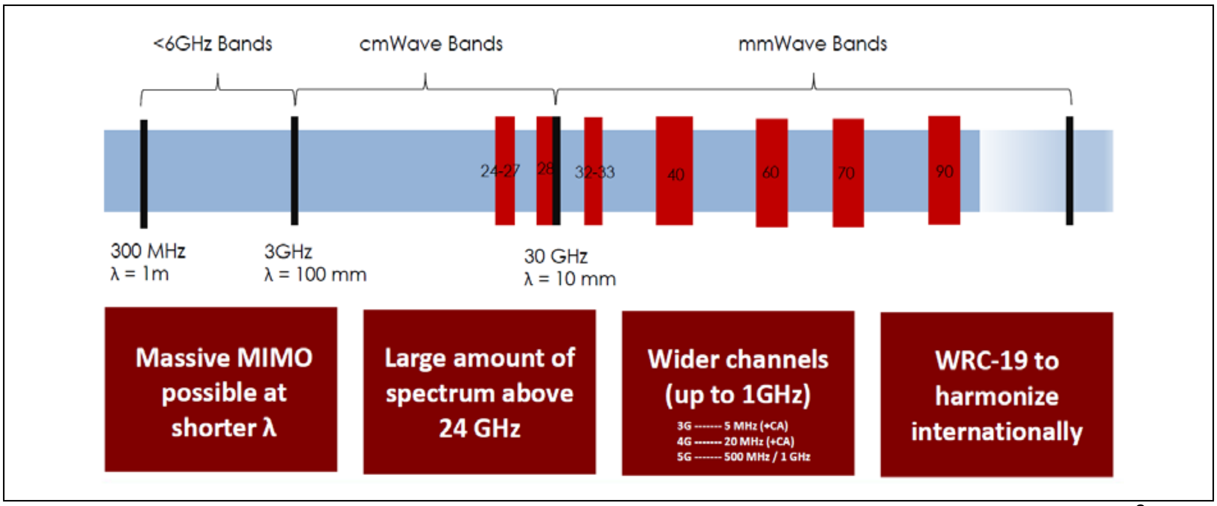

Figure B: mmWave Frequency Candidates being studied by leading countries for WRC-19[9]

- EU RSPG[10] is focusing their study in the bands 24.25-27.5GHz, 31.8-33.4GHz and 40.5-43.5GHz.
- UK OFCOM[11] is examining whether either 24.5-27.5GHz or 31.8-33.4GHz could be utilised for early 5G deployment.
- US FCC[12] adopted new rules for mobile and fixed use wireless broadband in frequencies of 28 GHz (27.5-28.35GHz), 37GHz (37-38.6 GHz), and 39GHz (38.6-40 GHz) bands.

So far, there has been no agreement on a globally harmonized band above 24GHz. Until any decision at WRC-19, network equipment currently used on mmWave technology will be mainly for the purpose of trials only.

2. *Massive Machine Type Communications (mMTC)*

mMTC is designed for a very large number of connected devices and typically transmitting a relatively low volume of non-delay-sensitive information. mMTC is important to the true 5G vision to connect with things. It is generally described as Internet of Things (IoT) with connected devices including sensors and actuators. The usage scenarios include smart grids, smart farming, smart cities and intelligent transportation.

cont'd…

[9] Qualcomm, "The Promise of 5G mmWave", 22 Jun 2016

[10] EU Radio Spectrum Policy Group, "Strategic Roadmap towards 5G for Europe", 9 Nov 2016 http://rspg-spectrum.eu/wp-content/uploads/2013/05/RPSG16-032-Opinion_5G.pdf

[11] OFCOM. "Mobile Data Strategy", 30 Jun 2016 https://www.ofcom.org.uk/__data/assets/pdf_file/0033/79584/update-strategy-mobile-spectrum.pdf

[12] FCC, "FCC takes steps to facilitate Mobile Broadband and Next Generation Wireless Technologies in Spectrum above 24GHz", 14 Jul 2016, https://apps.fcc.gov/edocs_public/attachmatch/DOC-340301A1.pdf

2a. NB-IoT or LTE-M Network

The nature of smart grids, smart farming and smart cities imposes specific network requirements with (a) massive number of connectivity (say 10,000 connections per cell), (b) 10 years battery life; and (c) extensive coverage to rural areas or deep in-building penetration with 10-20dB gain. For the benefit of extensive coverage, low frequency of sub-1GHz such as 700MHz and 850/900MHz are usually used.

In the UK OFCOM[13] is even considering the use of VHF band in the 55-68MHz, 70.5-71.5MHz and 80.0-81.5MHz for IoT services and M2M applications in remote and rural areas for smart farming.

2b. V2X Network

Intelligent Transport System (ITS) is one of the key drivers of Smart Cities. ITS is vital to make transport safer, more efficient and more sustainable in cities. Figure C illustrates the ITS network infrastructure with Vehicle-to-Everything (V2X) connectivity which constitutes of Vehicle-to-Infrastructure (V2I), Vehicle-to-Network (V2N), Vehicle-to-Pedestrian (V2P), and Vehicle-to-Vehicle (V2V).

Figure C: Vehicle-to-Everything Infrastructure[14]

The direct connectivity V2V is about sharing of car information for the purposes of road safety. A dedicated 5.9GHz band has been allocated solely for ITS to protect against any unnecessary interference.

- US: 75MHz @ 5.850-5.925GHz
- Europe: 70MHz @ 5.855-5.925GHz
- China: 20MHz @ 5.905-5.925GHz

In Hong Kong, the 5.850-5.925GHz band is currently assigned as an unlicensed band. A forward-looking spectrum plan of re-farming this 5.9GHz band for ITS use in Hong Kong is necessary.

cont'd…

[13] OFCOM, "VHF Radio Spectrum for the Internet of Things", 2 Mar 2016 https://www.ofcom.org.uk/__data/assets/pdf_file/0029/78563/vhf-iot-statement.pdf

[14] Qualcomm, " Leading the world to 5G: Cellular Vehicle-to-Everything (C-V2X) Technologies", Jun 2016

Ultra-Reliable and Low Latency Communications (URLLC)

URLLC is designed for networks with very strict requirements in terms of latency and reliability. LTE/5G technology is capable of delivering these latency and reliability requirements which are particularly suitable for Public Safety services. There is a golden opportunity to replace the current Tetra network, which is about to be obsolete, with LTE/5G technologies.

Re-farming the UHF band for LTE deployment of Public Safety is extremely challenging. As such, a new spectrum band is needed to build a green field LTE based Public Safety network for the migration of Tetra.

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