5G DEVELOPMENT IN SINGAPORE

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OVERVIEW OF SINGAPORE MOBILE LANDSCAPE

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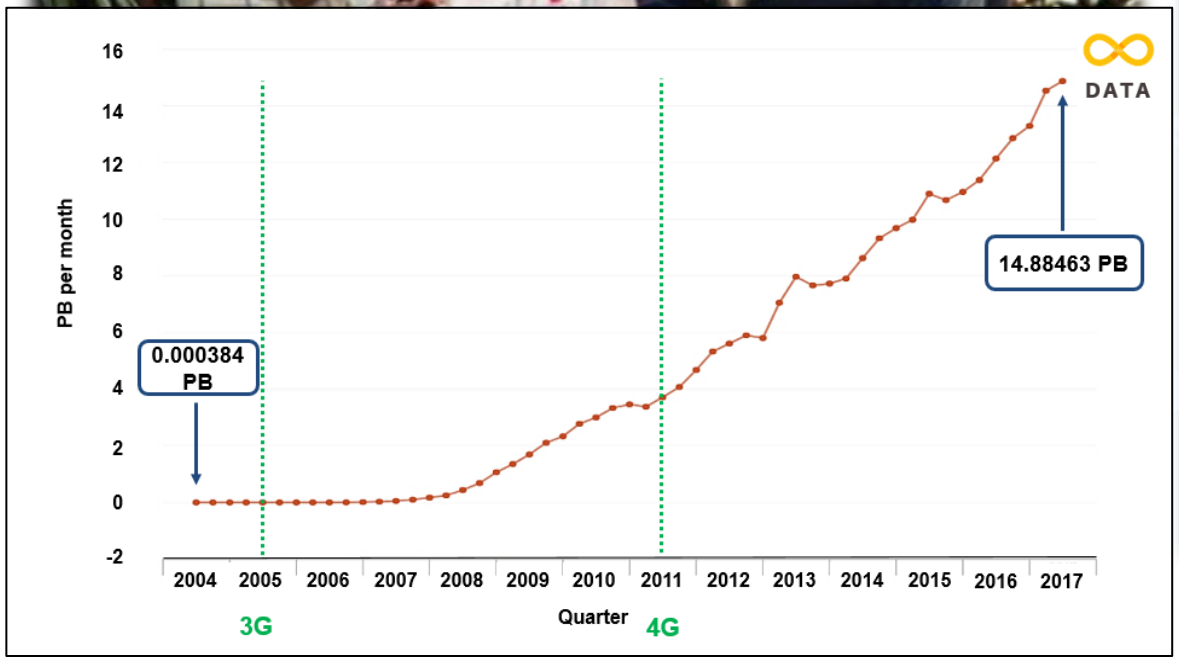
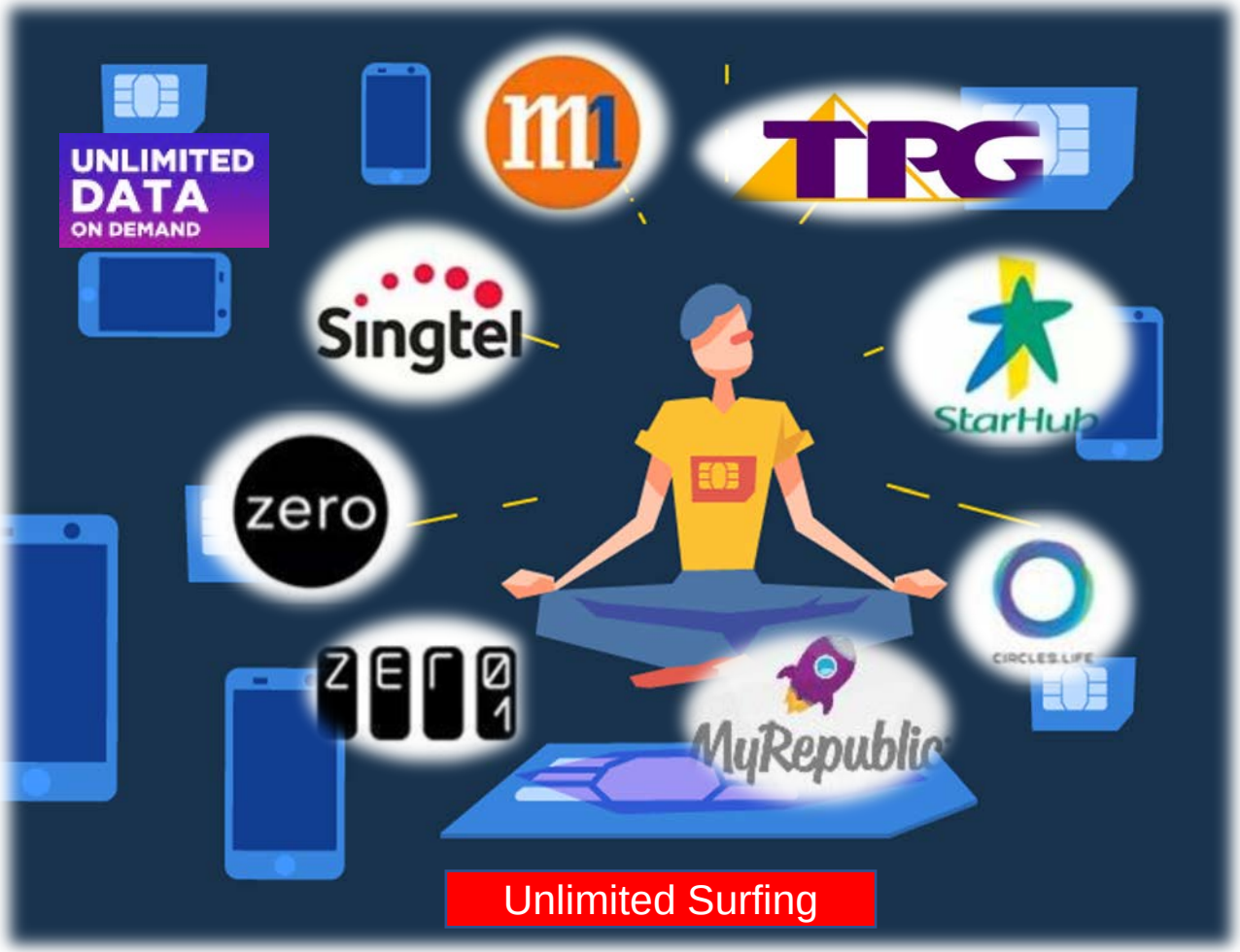
THE DEMAND FOR ∞ DATA AND VIBRANT INDUSTRY





EVOLUTION FROM 4G TO 5G

4G		5G
25 milliseconds Latency		Latency 5 milliseconds
100 Mb/s Peak Data Rate		Peak Data Rate 10 Gb/s
3GHz Available Spectrum		Available Spectrum 30GHz
99.99% Reliability		Reliability 99.999%
1,000 devices/km² Connection Density		Connection Density 1,000,000 devices/km²

Source: Qorvo

Logistics
Tracking
Smart Meters
Smart Cars
E-Health
Industrial Applications
Enterprise Uses
Smartphones
On-Demand Scalability
4K/8K UHD
AR/VR

DESIRED POLICY OUTCOMES FOR 5G DEPLOYMENT IN SINGAPORE

- ✓ **Infrastructure enabler:** 5G is a key enabler for Singapore's Digital Economy aspirations
- ✓ **Competitiveness**: 5G will provide a competitive edge to enterprises in Singapore; strengthen Singapore's reputation as a telecommunications & connectivity hub
- ✓ **Overall Economic Growth**: Mobile connectivity is already an important driver of growth in Singapore, and this effect will be amplified with 5G

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IMDA'S 5G ROADMAP

2017

- Encourage 5G trials to explore applications and deployment scenarios
- Public consultation to gather feedback on 5G spectrum and regulations

Completed

2018

- Publication of IMDA's recommendations based on the assessment of responses
- Development of a spectrum roadmap and 5G regulatory framework
- Co-existence trials in 3.5GHz and 28 GHz

2019

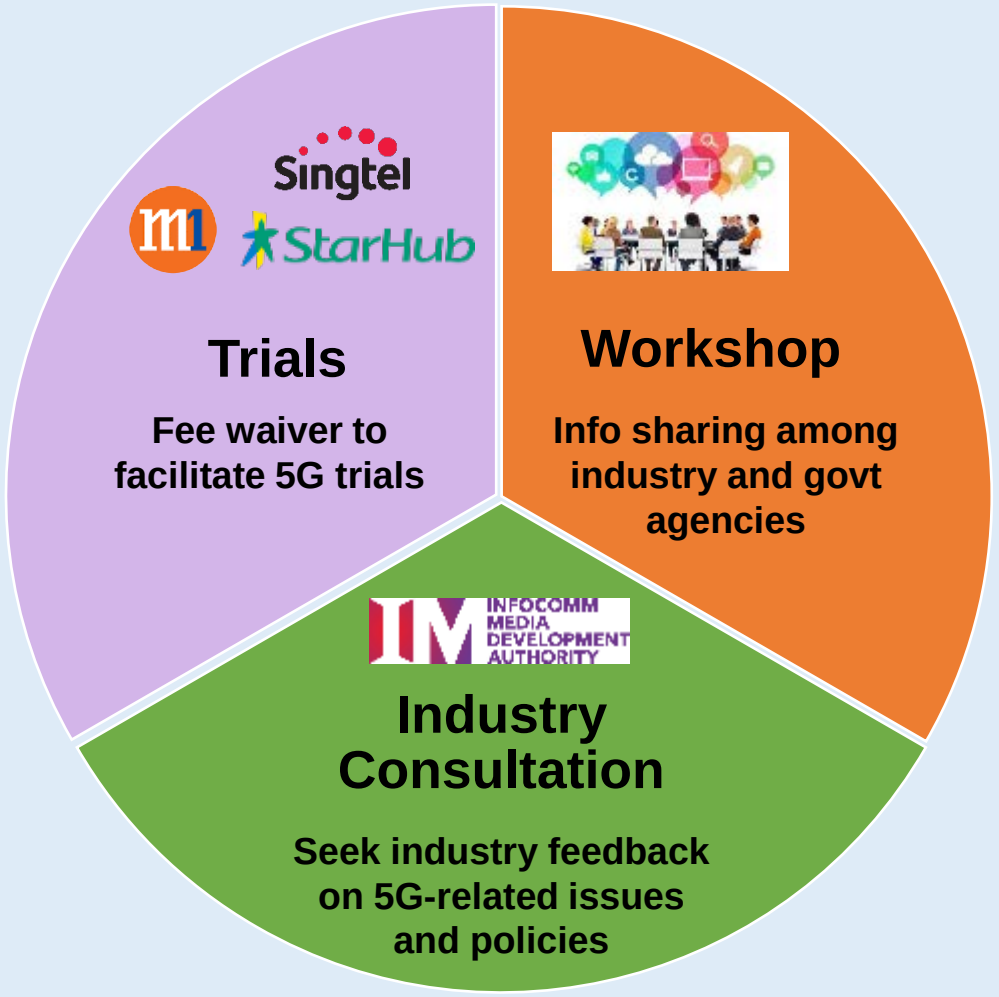
- IMDA will seek to harmonise 5G spectrum at regional and international forums
- Study on 5G Infrastructure Requirements
- Finalise 5G regulations and frameworks

2020

- Get Singapore ready for 5G commercial deployment

OVERVIEW OF REGULATORY ROADMAP

Three-Pronged Approach



Targeted Policy Areas

- Timely Availability of Spectrum Resource
- Facilitate Access to New Mobile Sites
- Enhance Backhaul Infrastructure
- Review Spectrum Pricing Framework
- Review the Possibility of Infrastructure Sharing
- Review of Quality of Service Frameworks

5G TRIALS IN SINGAPORE

IMDA's 5G Trial Framework to Facilitate 5G Regulatory Sandbox

Industry Technical / Market Trials

To encourage more 5G trials, IMDA has waived the frequency fees associated with 5G technical and market trials from May 2017 to December 2019.

- Live demo of 360-degree VR content broadcast
- One-North Trials to test drone and AVs

3.5 GHz

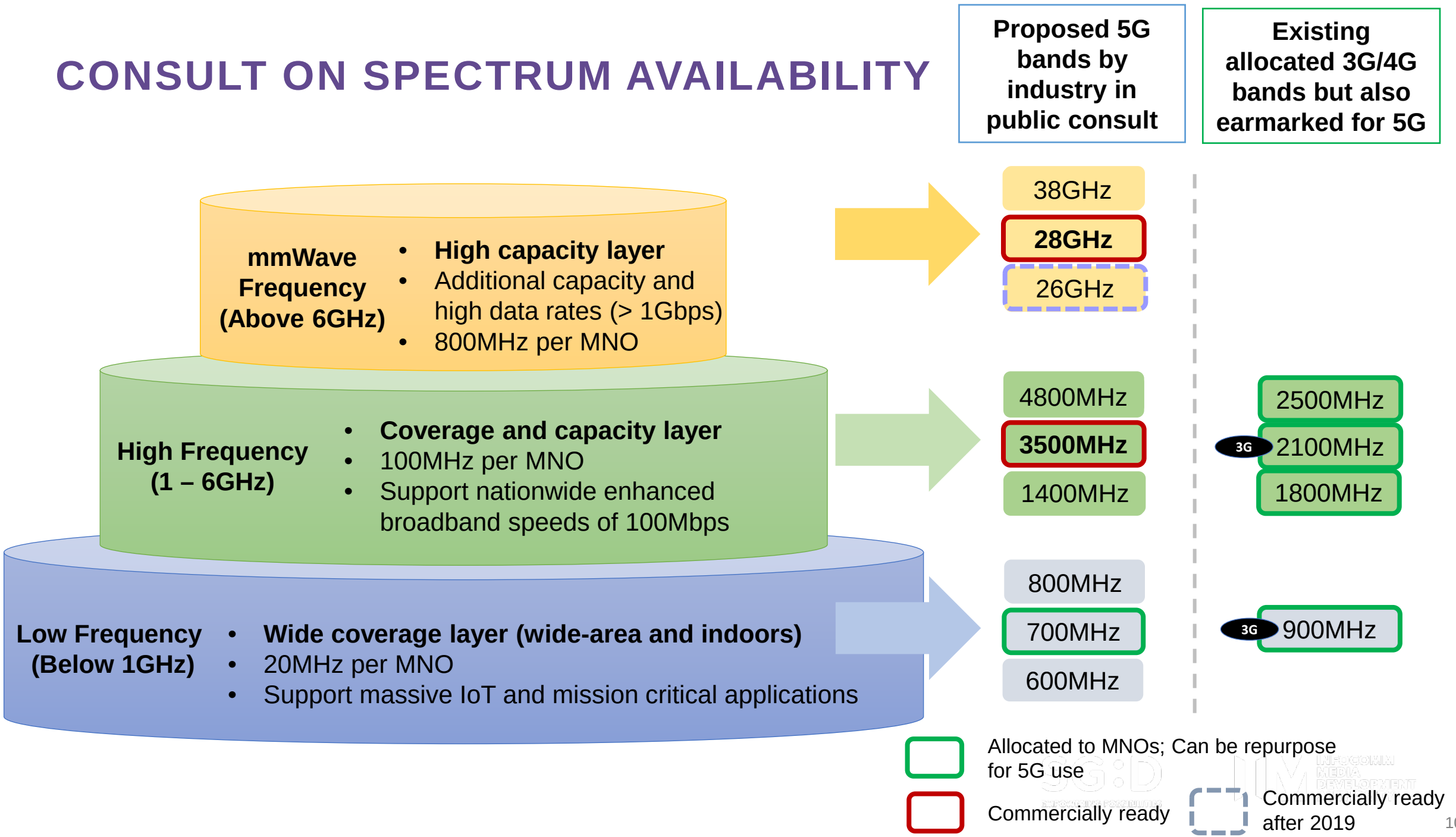
- Outdoor Trials on throughput & latency; evaluate potential interference to FSS and conditions for co-existence

28 GHz

- Indoor Trials on throughput & latency
- Outdoor trials on co-existence with satellite operation on maritime vessels and aircrafts

2017 H1 | **2017 H2** | **2018 H1** | **2018 H2** | **2019 H1**

CONSULT ON SPECTRUM AVAILABILITY



SPECTRUM PLANS

	Reallocation and Cross Border Coordination	Harmonisation & Coexistence Studies	Further Study and Consultation
Next Steps	• Bilateral agreements and cross-border coordination to enhance coexistence • Re-farming of existing services to reallocate this band for mobile services • Assess and develop channelling arrangements for Singapore	• Formulate national position for submission to regional and international fora • Monitor developments from the coexistence studies undertaken by various ITU study groups	• Monitor regional and international developments • Consultation to seek views on the allocation of affected spectrum bands for mobile services
Spectrum Bands	• 700MHz • 1400MHz • 3500MHz • 4800MHz	• 26GHz • 28GHz • 38GHz	• 800MHz

Expected Timeline for Spectrum Release

2020
26/28GHz (Above 6GHz)

2021
700MHz (Below 1GHz)

2022
3.5GHz (1 – 6GHz)

SPECTRUM ALLOCATION POLICY

28GHz

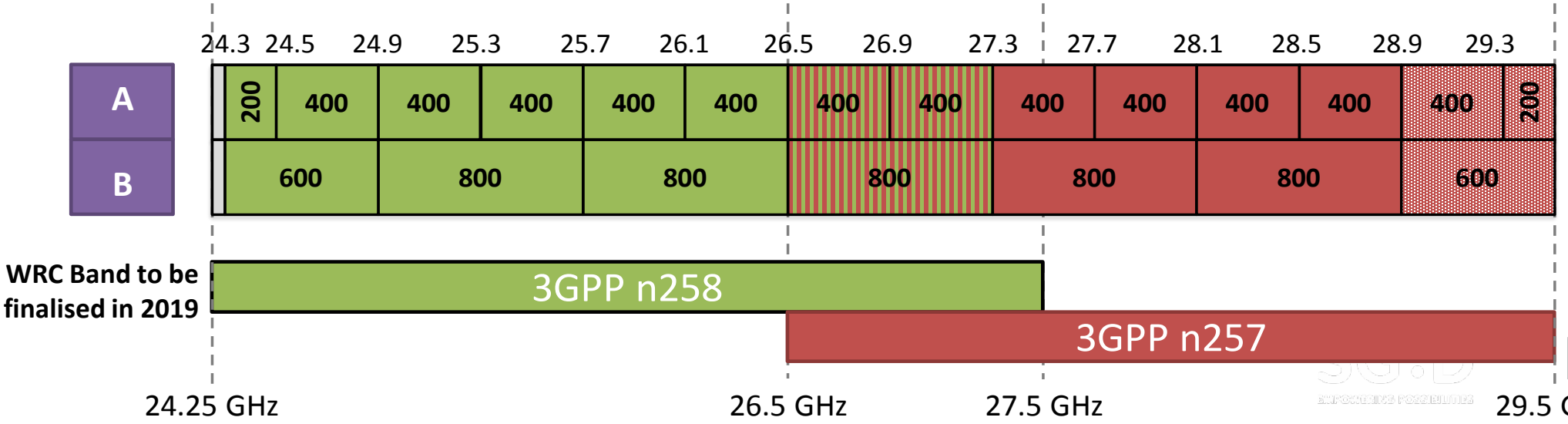
- mmWave used for localised deployments
- Minimum 5G block size: 50MHz
- Optimal block size for technical efficiency:
  - 400 MHz (if deployed in combination with 4G)
  - 800 MHz (technically preferred, maximum and most ideal size for 5G)
- Unclear if more than 800MHz would be of any immediate value for now
- Operators may have a preference for placement of blocks, given that the ecosystem for band 28 is more developed at the moment

3.5GHz

- Minimum 5G block size: 10 MHz
- Need at least 20 MHz of bandwidth to match 4G speeds and capacity
- Optimal block size for technical efficiency: 100 MHz (max)
- Assumes only 100 MHz in total can be freed up (e.g. 3400 – 3500 MHz / 3500 – 3600 MHz)
- Assess situation which would benefit from a market-based allocation approach (e.g. auction)

SPECTRUM PLANS FOR 26 / 28GHZ BANDS

- Continue to encourage and facilitate 5G trials in the 26 / 28GHz band
- Support prioritisation of 24.25 – 27.5GHz and 37 – 43.5GHz bands
- Conduct 5G coexistence studies in the 28GHz band
- 28GHz band currently under-utilised in Singapore with uplink transmission confined to air platforms/vessels, restricted to certain technical parameters and operating on a non-interference and non-protected basis
- If necessary, IMDA will put in place operational guidelines within the licensing condition for satellite services to mitigate interference issues (i.e. min. distance away from shore, stage of flight before transiting from terrestrial to satellite services)



Sufficient spectrum in the 26/28GHz band

'Mainstream' 5G band today but not in WRC studies today

MNOs' CONCERNS & POSSIBLE IMPLICATIONS

MNOs' Feedback

- Limited proven use cases for enterprises
  - Not keen to provide 5G to consumers due to perceived lack of willingness to pay for incremental benefits
- High CAPEX required for roll-out, especially mmWave equipment (due to cell densification and use of street-level furniture)
  - However, not keen to share infrastructure due to legacy hardware compatibility
- Spectrum cost needs to be kept low for 5G roll-out to be economically viable

Implications

- Initial roll-out of 5G networks are likely to be on a localised basis (as opposed to nationwide) aimed at specific applications/use cases
- As significant investments have been sunk into the 4G networks, MNOs are likely to continue to 'milk' the network in the next few years
- 5G services will likely be available in Singapore only after 2020

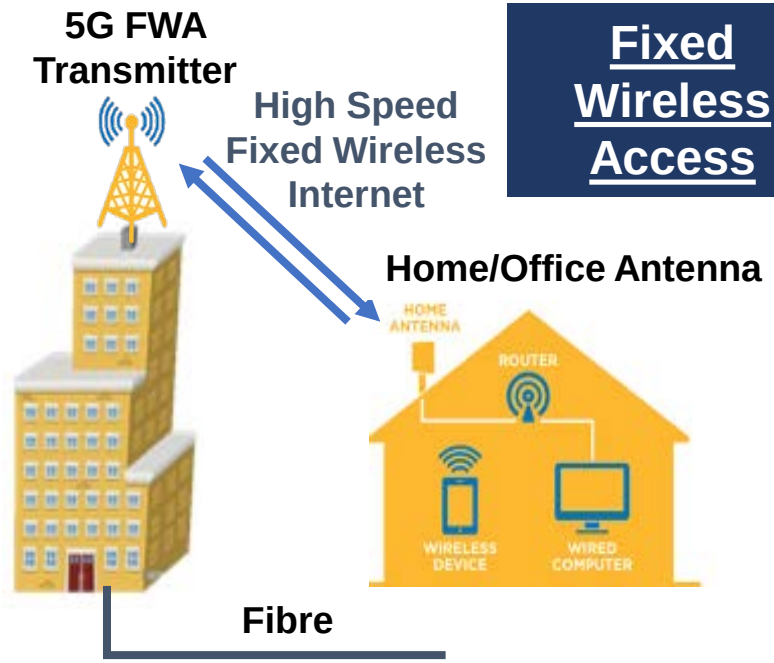
Balanced pricing policy for licensed

High spectrum fees means less funds for deployment and innovation

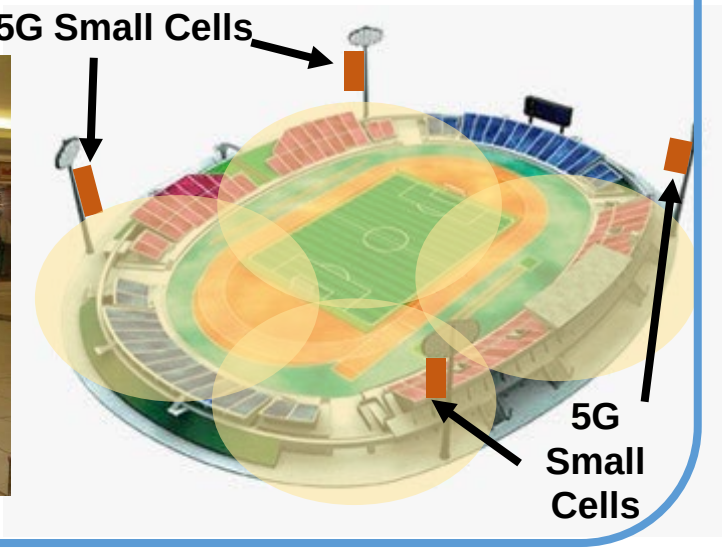
Reduction in cost to facilitate deployment of new technology

POTENTIAL 26/28GHZ INFRASTRUCTURE DEPLOYMENT

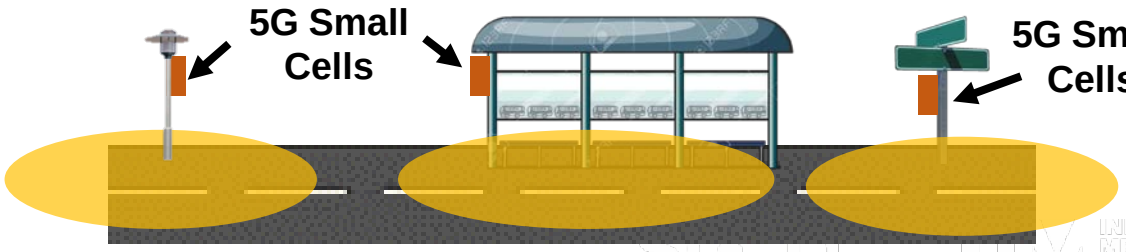
Fixed Wireless Access



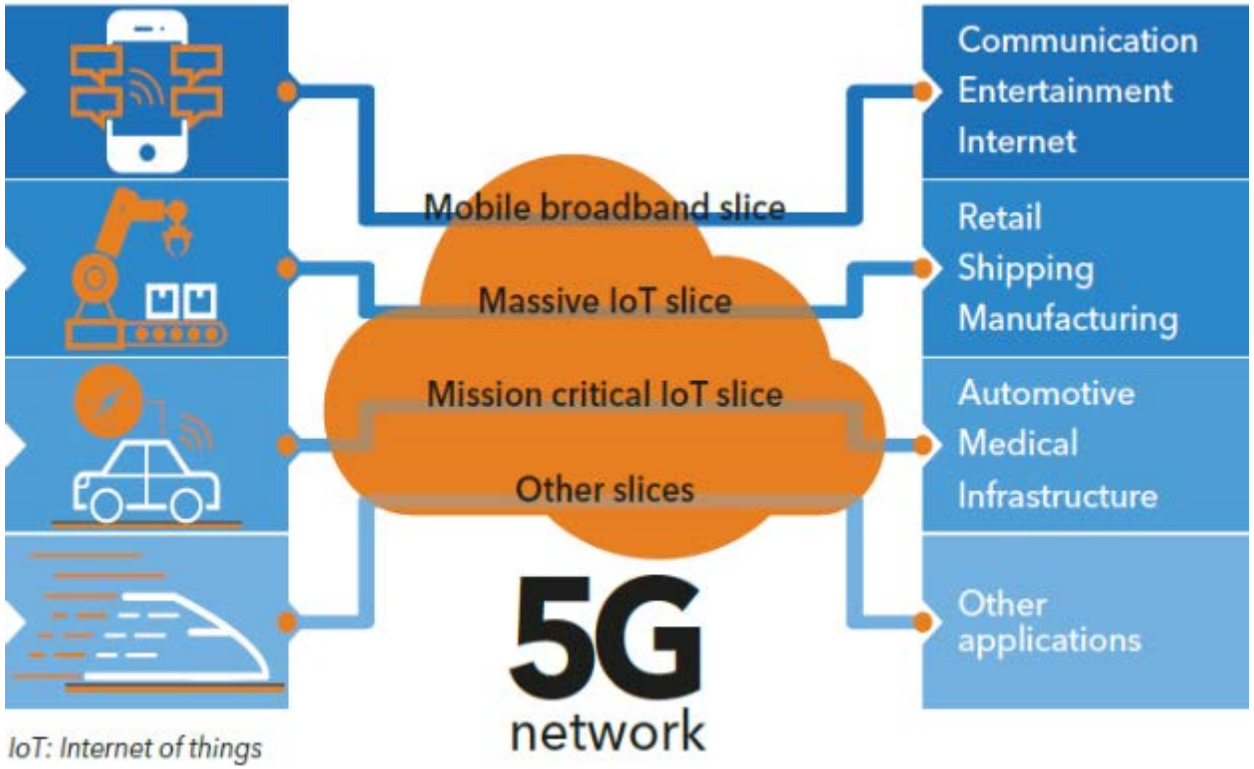
Hotspots (i.e. stadiums, shopping malls)



Street-level infrastructure (i.e. street signs, traffic lights, lamp posts, bus stops)



QUALITY OF SERVICE



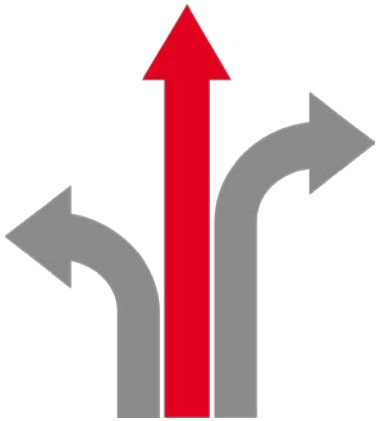
- Initial cell deployment – hotspot and indoor

- Industry's Proposal:
  - Customise QoS framework for 5G networks
  - Exempt 5G from QoS obligations for the initial phase of 5G deployment

- Network slicing capabilities – catered for different applications and needs
  - Performance of industry 5G network can be maintained by Service Level Agreements between MNOs and their customers

- Next Steps:
  - Assess the need to introduce QoS/QoE framework for 5G services, in order to protect consumer interest and critical services (e.g. autonomous cars, healthcare)

SUMMARY



More facilitative regulatory and industry development frameworks

Regulatory Framework

Allow developments and innovations

Create opportunities

Infrastructure Framework

Open to identify and tackle unnecessary barriers to infrastructure sharing

Accelerates investment in infrastructure

Explore further ways to reduce the cost of deployment and operation of network and other related infrastructure

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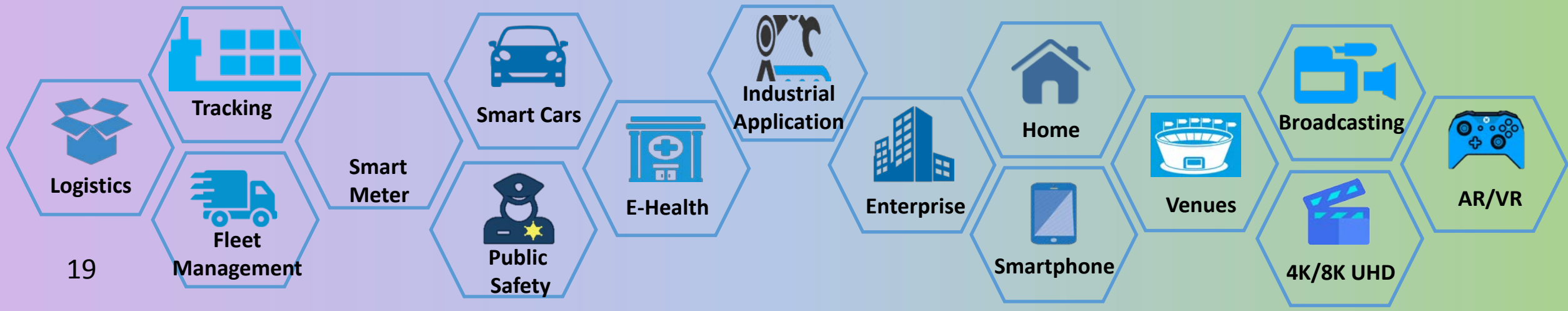
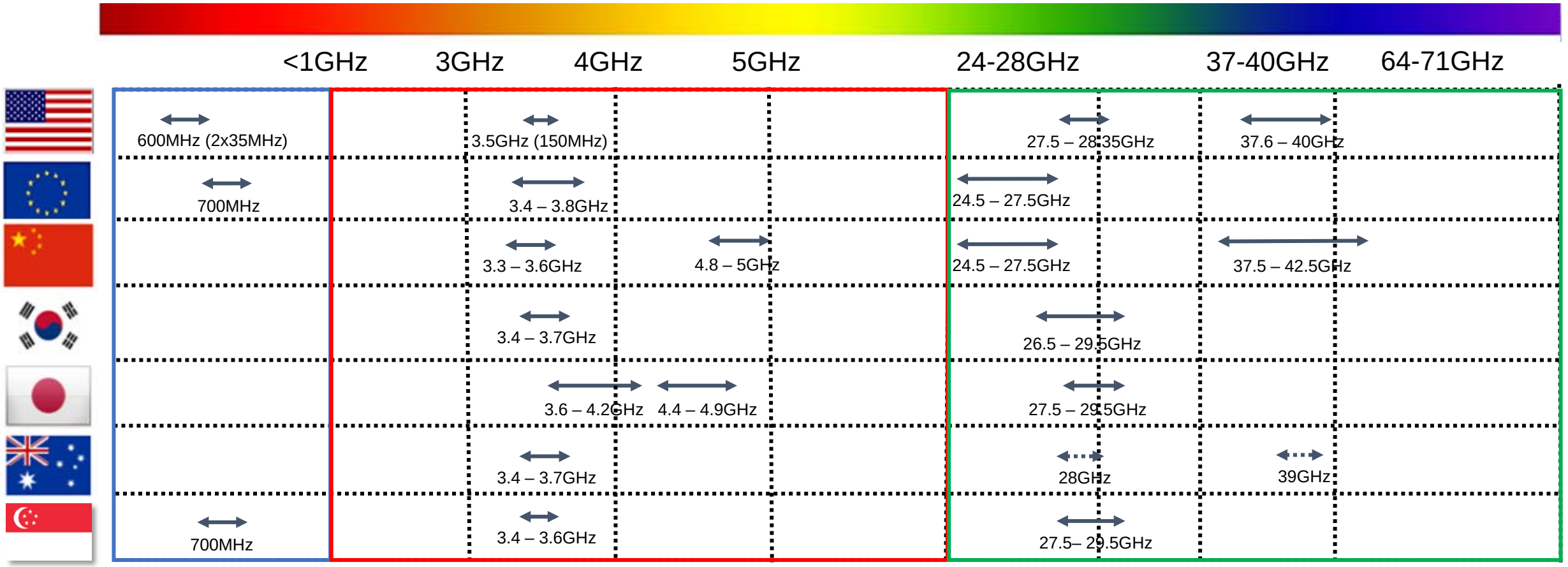
5G – BROAD RANGE OF SPECTRUM REQUIREMENTS

Diverse set of 5G services will require a diverse set of spectrum bands, with different characteristics addressing unique requirements

Low Frequency Cell	High Frequency Cell	Millimeter Wave Cell
Below 1 GHz	1 – 6 GHz	Above 6 GHz
For Coverage	For Coverage and Capacity	For Capacity
20 MHz bandwidth per MNO	100 MHz bandwidth per MNO	800 MHz bandwidth per MNO
Low data rate to support massive IoT	Support nationwide enhanced broadband speeds of 100Mbps	Additional capacity to achieve up to 1000Mbps



GLOBAL SNAPSHOT OF 5G SPECTRUM



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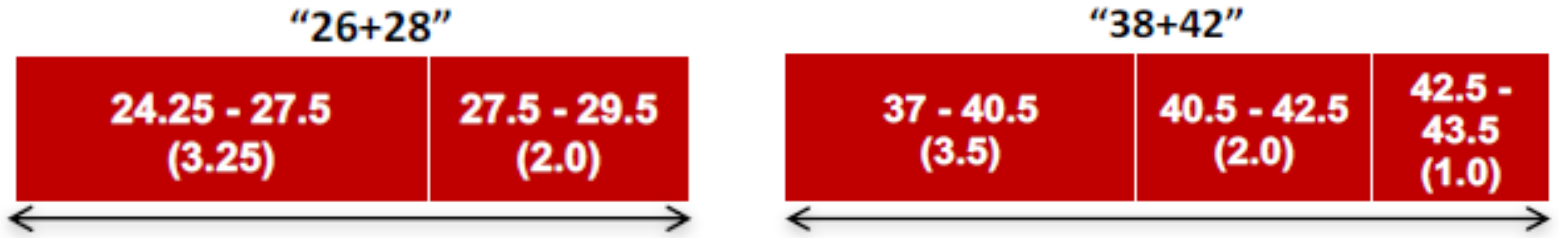
INDUSTRY INTEREST IN 28GHZ BAND

- The 28GHz band is currently under-utilised in Singapore, and uplink transmission will mostly be confined to air platforms or vessels, restricted to certain technical parameters.

- At WRC-15, Singapore had supported the decision to include the 28GHz band into the WRC-19 agenda item to invite ITU to conduct technical studies to explore the possibility of coexistence.

- A majority of vendors see the 28GHz as an important band and this band is supported by Japan, Korea and the US.
  - GSA is looking at “26+28”GHz tuning range and “38+42”GHz tuning range to encourage economies of scale

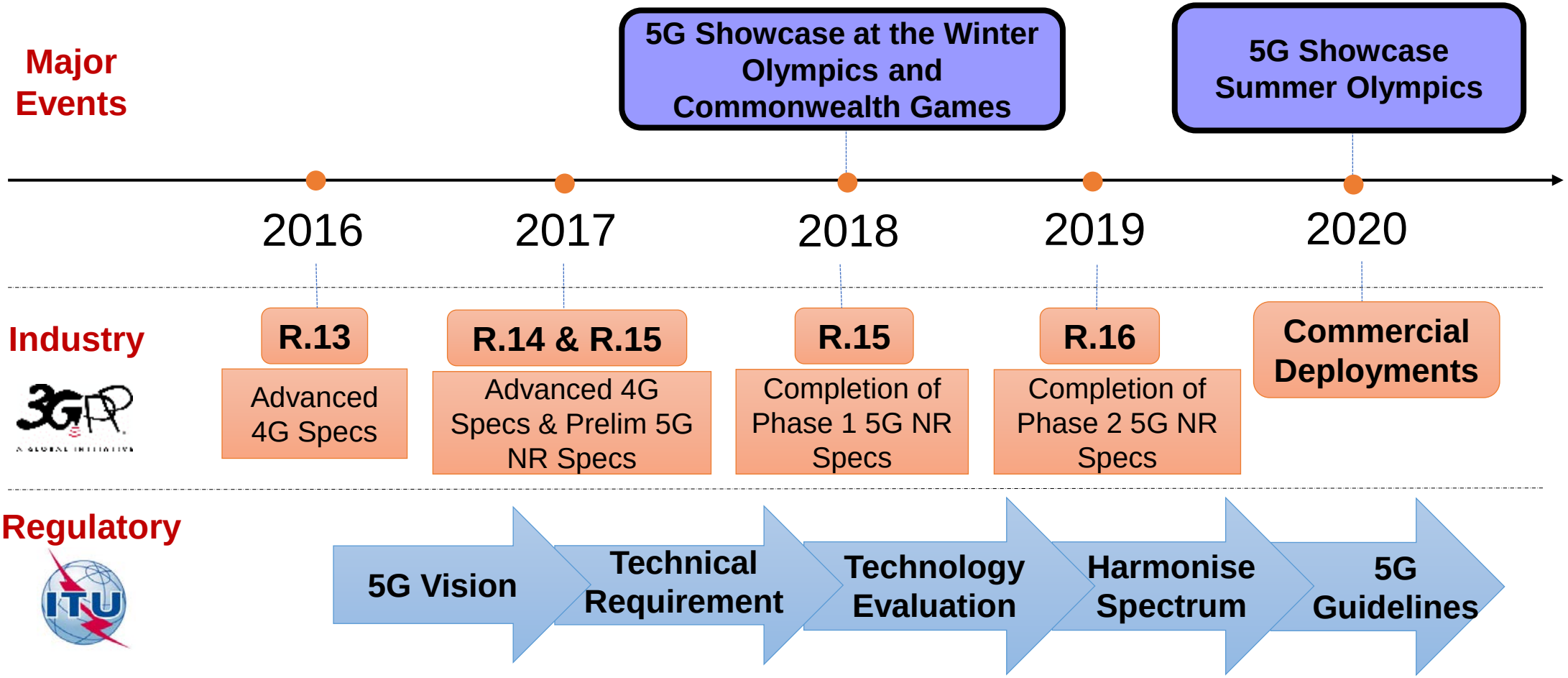


INDUSTRY RESPONSES ON 28GHZ BAND

- Apart from the bands identified for WRC-19, the industry has highlighted for the 28GHz to be considered as a 5G band in Singapore.
  - Ecosystem, use cases and business models developed in the 28GHz can accelerate the development of the other mmWave bands (i.e. 24.25 – 27.5GHz band)
  - Benefits from wide tuning range spanning from 24.25 – 29.5GHz in commercial equipment
  - Wide contiguous bandwidth (i.e. 24.25 – 29.5GHz) can support high throughput to augment the existing wide-area 3G and 4G networks.

- However, the satellite industry has highlighted that the 28GHz band is heavily used worldwide for various satellite services and is also seen as a critical band for the continued innovation and deployment of the HTS and VHTS systems.
  - Co-channel coexistence between satellite services and 5G networks is generally difficult
  - FS / FSS in neighbouring countries may interfere with the 28GHz IMT services in Singapore.

INTERNATIONAL DEVELOPMENTS



Note: NR relates to the New Radio being developed by the 3rd Generation Partnership Project ("3GPP") for 5G systems

FACILITATING 5G TRIALS IN SINGAPORE

- To encourage more 5G trials, IMDA has waived the frequency fees associated with 5G technical and market trials from May 2017 to December 2019.

FREQUENCY BANDS ELIGIBLE FOR FREQUENCY FEE WAIVER FOR 5G TRIALS

Category	Frequency Bands
1 - 6GHz	1427 – 1518MHz 3400 – 3600MHz
Above 6GHz	24.25 – 27.5 GHz 27.5 – 29.5GHz 31.8 – 33.4 GHz 37 – 40.5 GHz 40.5 – 42.5 GHz 42.5 – 43.5 GHz 45.5 – 47 GHz 47 – 47.2 GHz 47.2 – 50.2 GHz 50.4 – 52.6 GHz 66 – 76 GHz 81 – 86 GHz

Trial use cases must fall under one of the 3 categories defined by ITU-R for 5G networks:

- ✓ Enhanced Mobile Broadband (“eMBB”)
- ✓ Massive Machine-Type Communications (“mMTC”)
- ✓ Ultra-Reliable and Low-Latency Communications (“uRLLC”)

Technical performance parameters will be viewed as recommended guidelines

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