IMT 2020 (5G) in Asia-Pacific – Key Insights

ITU - ITTLLDC Seminar
Ulaanbaatar - Mongolia

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To Share

IMT spectrum, case studies in ASP and high-level insights of ITU study

(Study commissioned by ITU and authored by Scott MINEHANE)

Key consideration

(Setting the scene for 5G: Opportunities and Challenges)

P2C pledges

Defining IMT 2020

What and why ?

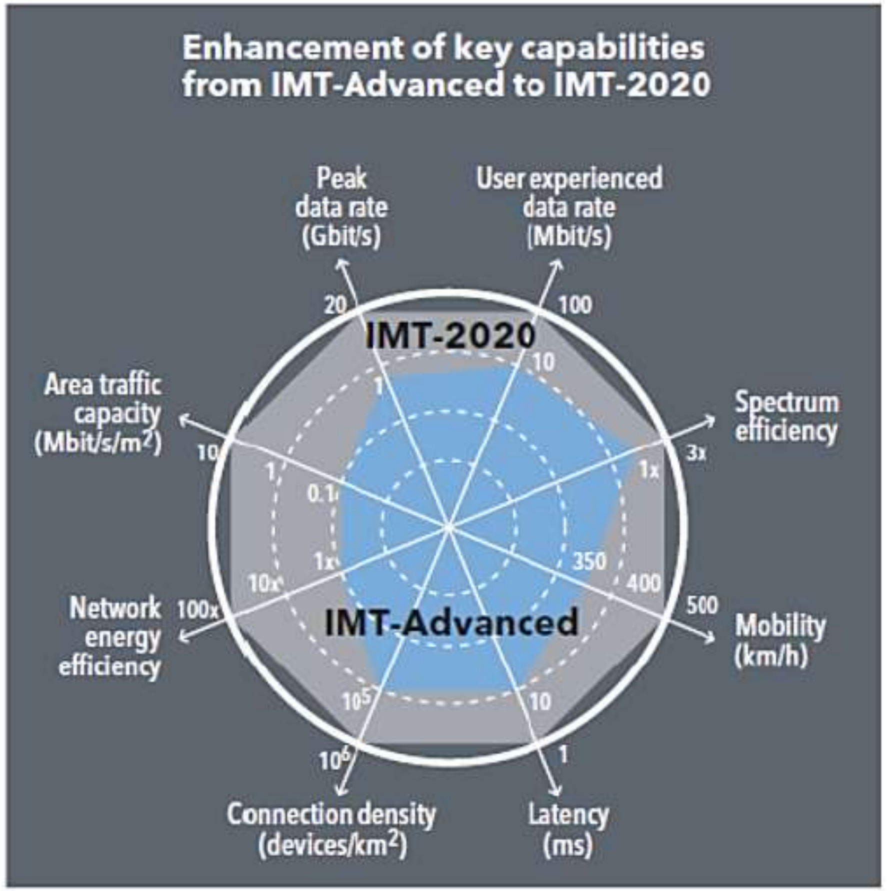
Definition

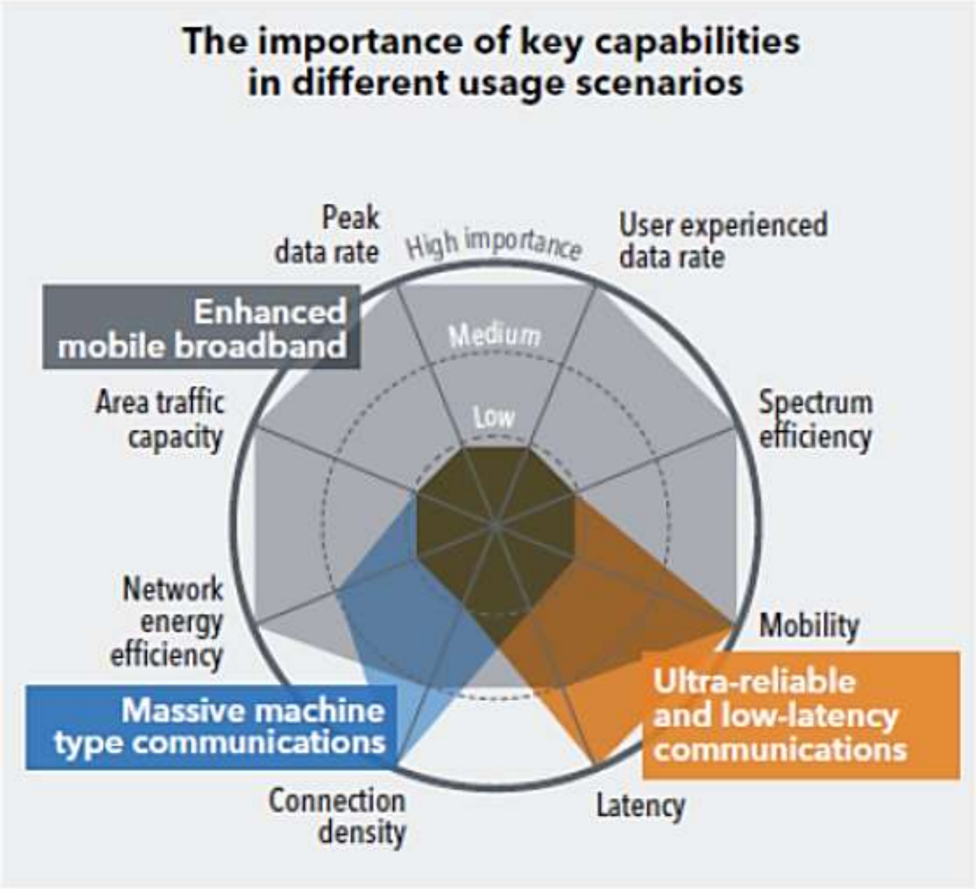
➢ **Res. ITU-R 56-1:** ***Naming for International Mobile Telecommunications***

Since ITU is the internationally recognized entity that has sole responsibility to define and to recommend the standards and frequency arrangements for IMT systems, with the collaboration of other organizations such as standard development organizations, universities, industry organizations and with partnership projects, forums, consortia and research collaborations, therefore the RA-15 debated especially on naming of IMT systems.

- *the existing term* **IMT-2000** *continues to be relevant and should continue to be utilized;*
- *the existing term* **IMT-Advanced** *continues to be relevant and should continue to be utilized;*
- *However for systems, system components, and related aspects that include new radio interface(s) which support the new capabilities of systems beyond IMT-2000 and IMT-Advanced, the term "***IMT-2020***" be applied*
- *In addition it was resolved that the term "IMT" would be considered the root name that encompasses all of IMT-2000, IMT-Advanced and IMT-2020 collectively.*

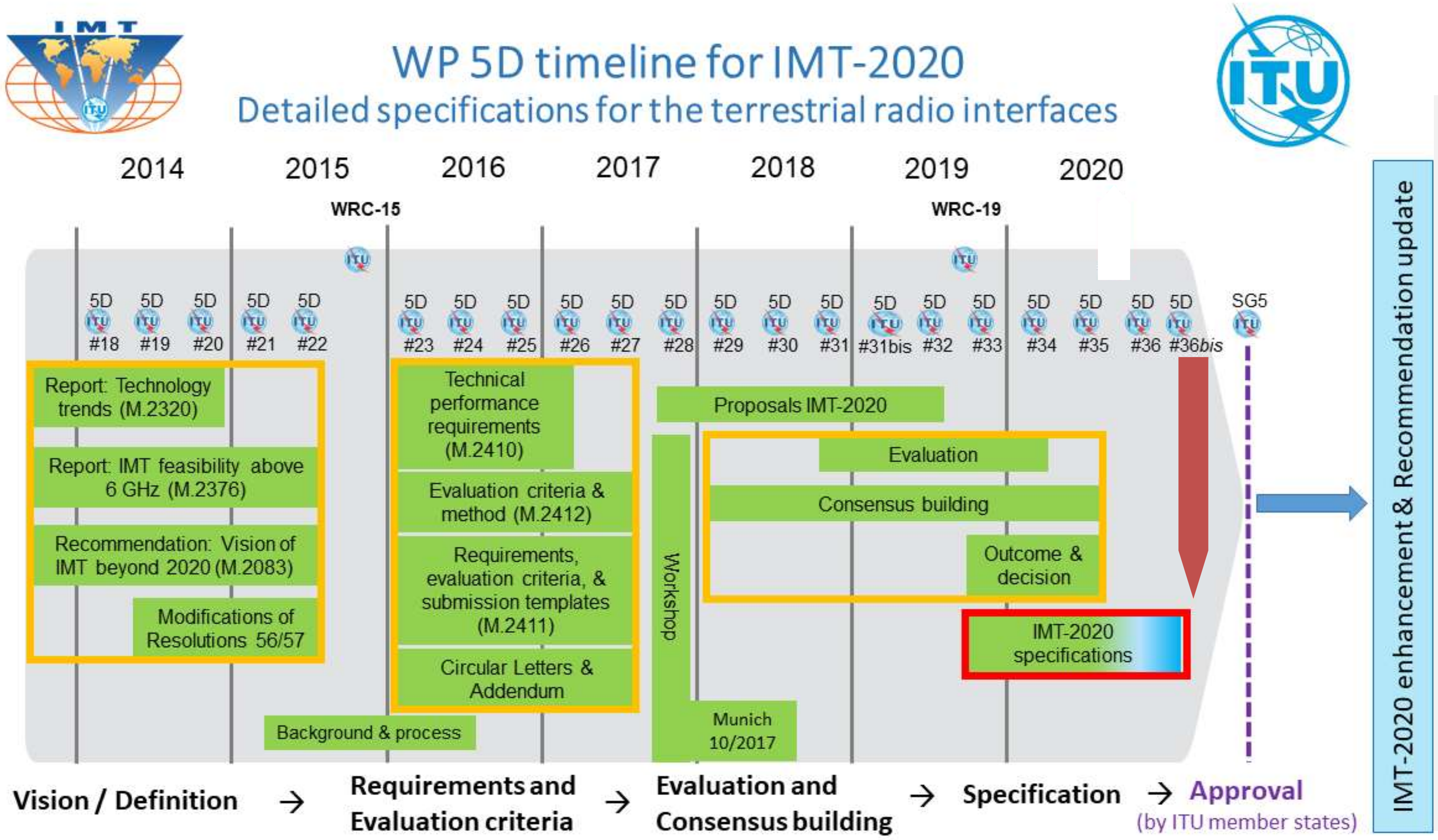
IMT





The values in the figures above are targets for research and investigation for IMT-2020 and may be revised in the light of future studies. Further information is available in the IMT-2020 Vision ***(Recommendation ITU-R M.2083)***

IMT-2020 (5G) – Detailed Timeline and Process in ITU



Status:
Achieved global validation with the successful evaluation by ITU of three new technologies that conform with the IMT-2020 vision and stringent performance requirement.

1. ***3GPP 5G-SRIT***
2. ***3GPP 5G-RIT***
3. ***5Gi*** submitted by Telecommunications Standards Development Society India (TSDSI).

Source https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/Pages/on-road-IMT-2020.aspx

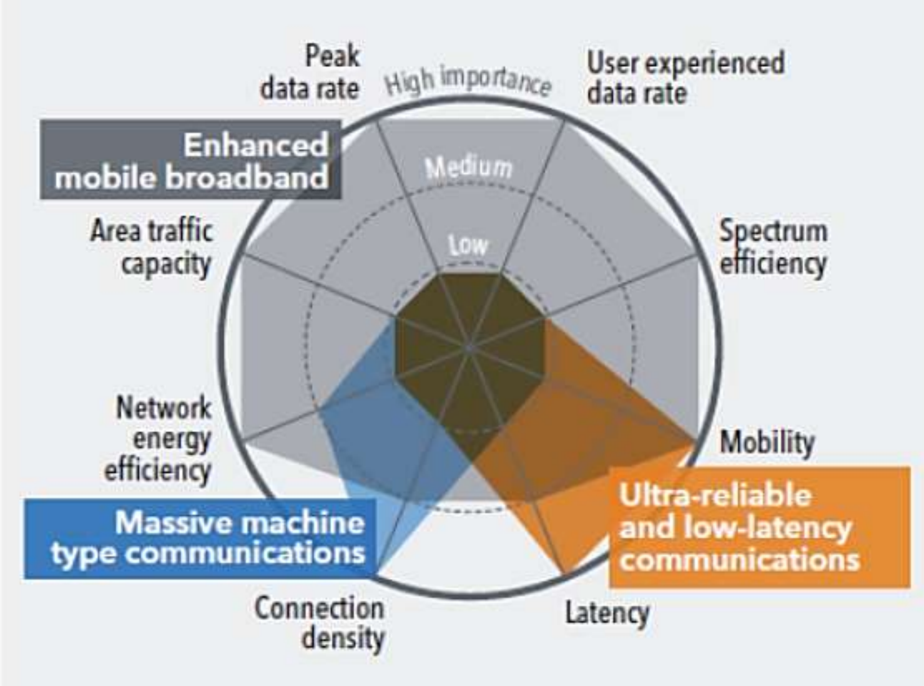
IMT – 2020 Requirements – Data rates

➢ User Experienced Data rate

❖ *This requirement is defined for the purpose of evaluation in the related **eMBB** test environment. The target values for the user experienced data rate are as follows in the **Dense Urban – eMBB** test environment:*

- Downlink user experienced data rate is **100 Mbit/s.**
- Uplink user experienced data rate is **50 Mbit/s.**

These values are defined assuming supportable bandwidth as described in Report ITU-R M.2412-0 for each test environment.



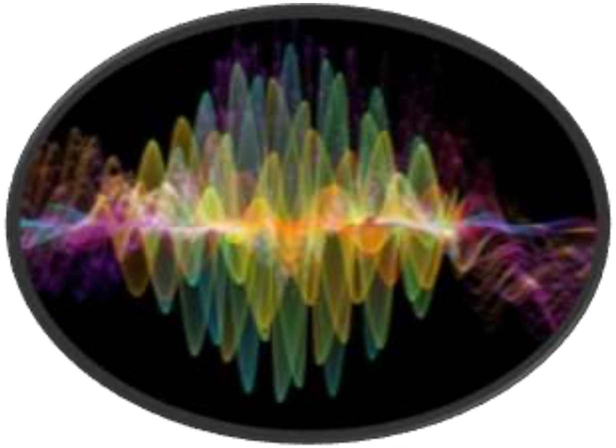
➢ Peak Data rate for eMBB minimum requirements

- Downlink peak data rate is **20 Gbit/s.**
- Uplink peak data rate is **10 Gbit/s.**

IMT – 2020 Requirements – Spectral Efficiency

➢ **Peak Spectral Efficiency for eMBB minimum requirements**

- Downlink peak spectral efficiency is **30 bit/s/Hz**.
- Uplink peak spectral efficiency is **15 bit/s/Hz**.



Average spectral efficiency Minimum requirements

Test environment	Downlink (bit/s/Hz/TRxP)	Uplink (bit/s/Hz/TRxP)
Indoor Hotspot – eMBB	9	6.75
Dense Urban – eMBB (Note 1)	7.8	5.4
Rural – eMBB	3.3	1.6

NOTE 1 – This requirement applies to Macro TRxP layer of the Dense Urban – eMBB test environment as described in Report ITU-R M.2412-0.

Source: https://www.itu.int/pub/R-REP-M.2410-2017

IMT – 2020 Requirements – Latency and connection Density

➢ Connection Density

❖ *This requirement is defined for the purpose of evaluation in the* **mMTC** *usage scenario.*

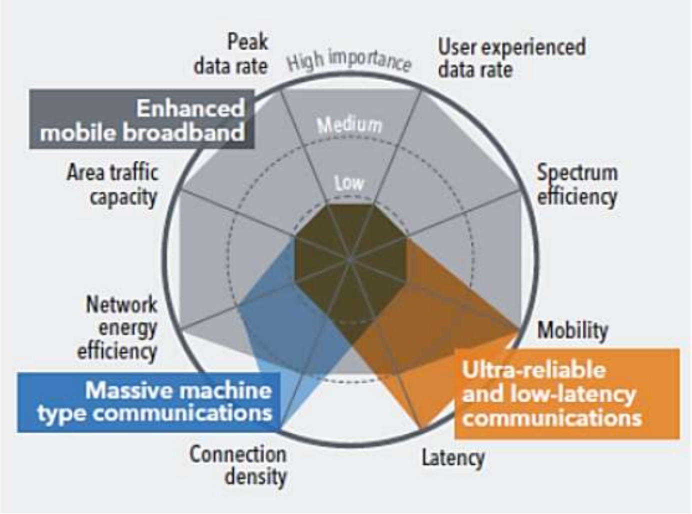
- The minimum requirement for connection density is **1,000,000 devices per km2**

➢ Latency – User Plane

❖ *This requirement is defined for the purpose of evaluation in the* **eMBB** and **URLLC** usage scenarios. *The minimum requirements for user plane latency are:*

- **4 ms** for **eMBB**
- **1 ms** for **URLLC**

assuming unloaded conditions (i.e. a single user) for small IP packets (e.g. 0 byte payload + IP header), for both downlink and uplink.



IMT – 2020 Requirements – Mobility and Reliability

➢ Reliability

❖ *This requirement is defined for the purpose of evaluation in the* **URLLC** *usage scenario.*

- *The minimum requirement for the reliability is* **1-10–5 success probability** *of transmitting a layer 2 PDU (protocol data unit) of 32 bytes within 1 ms in channel quality of coverage edge for the Urban Macro-URLLC test environment, assuming small application data (e.g. 20 bytes application data + protocol overhead).*

➢ Mobility

❖ *This requirement is defined for the purpose of evaluation in the* **eMBB** *usage scenario.*

Traffic channel link data rates normalized by bandwidth

Test environment	Normalized traffic channel link data rate (bit/s/Hz)	Mobility (km/h)
Indoor Hotspot – eMBB	1.5	10
Dense Urban – eMBB	1.12	30
Rural – eMBB	0.8	120
	0.45	500

These values were defined assuming an antenna configuration as described in Report ITU-R M.2412-0.

Source: https://www.itu.int/pub/R-REP-M.2410-2017

Functional Drivers

Functional driver	Description	Added value	Use cases
Enhanced mobile broadband (eMBB)	Faster connections, higher throughput and greater capacity (up to 10 Gbps)	Allows for an extension in cellular coverage into diverse structures (large venues) and the ability to handle a larger number of devices using high amounts of data	Fixed wireless access service, enhanced in-building broadband service, real-time augmented reality service, real-time virtual and mixed reality service, crowded or dense area service, enhanced digital signage, high- definition cloud gaming, public protection and disaster response services, massive content streaming services, remote surgery and examination
Ultra-reliable low latency communication (uRLLC)	Reduced time for data from device to be uploaded and reach its target (1 ms compared to 50 ms for 4G)	Enables time-sensitive connections wirelessly	Autonomous vehicles, drones and robotic applications, health monitoring systems/telehealth, smart grid and metering, intelligent transportation, factory automation, remote operation, self-driving cars, mission-critical services (security and safety), high-definition real-time gaming
Security	Robust security properties, leading to high reliability and availability	Creates an ultra- reliable connection to support applications where failure is not an option	
Massive machine- type communications (mMTC)	Increased spectral efficiency plus small cell deployment	Allows for a large number of connections to support data-intensive applications	Asset tracking and predictive maintenance, smart cities/buildings/agriculture, internet of energy/utility management, industrial automation, smart logistics (advanced telematics), smart grid and metering, smart consumer wearables, environmental management, intelligent surveillance and video analytics, smart retail
Power efficiency	Efficient power requirements for massive multiple- input, multiple-output (MIMO), small cell implementation	Leads to lower costs and enables massive internet of things	

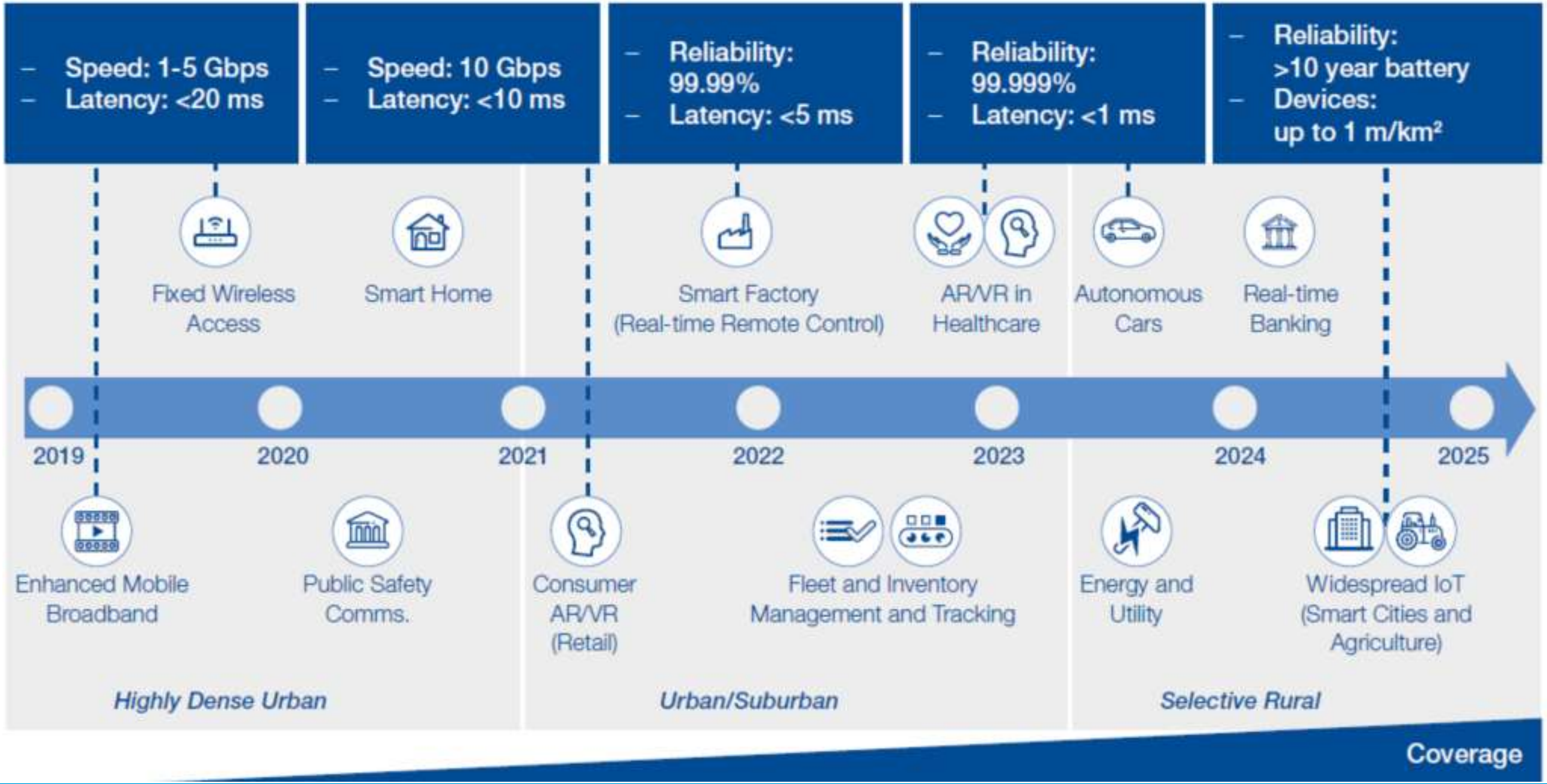
Source: *ITU* , Setting the Scene for 5G: Opportunities & Challenges, 2018, https://www.itu.int/dms_pub/itu-d/opb/pref/D-PREF-BB.5G_01-2018-PDF-E.pdf

5 use case analysis

Primary industry sector (10)	Secondary industry sector (10)	Technology specialty area (11)
Manufacturing	Machinery and equipment	Internet of things
Transportation	Automotive	Mixed reality
Public services	Logistics	Autonomous driving
Health and social work	Railways	Drones
Agriculture	Education	Robotics
Energy	Info and communications	Advanced communication systems
Logistics	Semiconductors	Artificial intelligence
Media and entertainment	Urban infrastructure	Cloud
Mining and quarrying	Consumer goods	Digital twin
Professional services	Sports	Gamification
		Simulation/imaging

Source: World Economic Forum (WEF) and PWC - *The Impact of 5G: Creating New Value across Industries and Society*

Maturity of use cases: *enabled across industry sectors by evolving features of 5G*



Source: World Economic Forum (WEF) and PWC - *The Impact of 5G: Creating New Value across Industries and Society*

5G Opportunities for Mobile Operators

FWA

High-speed, reliable Internet to the rural areas, at a fraction of the cost of laying fiber to each households

Virtualization & Cost

Telco transformation – virtualize and cloudify networks (RAN & core)

Infrastructure sharing using MORAN and MOCN – especially in rural areas

Industry Transformation

Multi-access Edge Computing

Private 5G Network (dedicated)

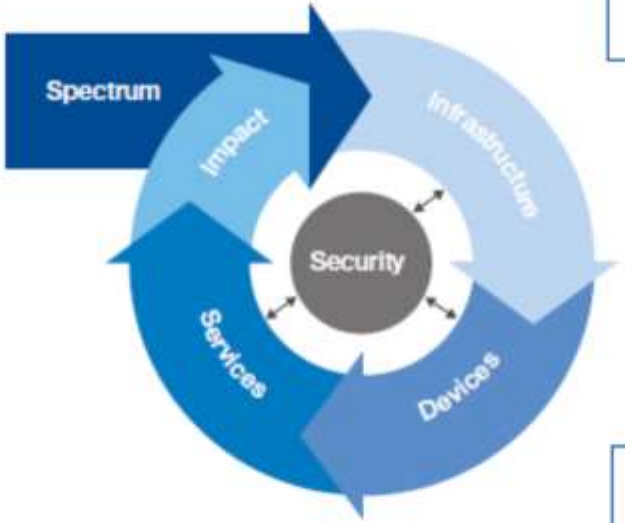
Network Slicing (virtualized)

Ecosystem

The 5G Ecosystem Cycle represent the need for stakeholder collaboration and alignment throughout the ecosystem, including coordinated decision-making that will have repercussions on the ecosystem's subsequent components

SPECTRUM is the oil of the 5G ecosystem, without which no 5G network infrastructure or devices can operate. The future networks will rely on a combination of mainstream and alternative technologies and will use both licensed and unlicensed spectrum across different spectrum bands together (low = long range, indoor penetration but low capacity density; high = short range, no indoor penetration, high capacity density).

IMPACT can be achieved in two dimensions:
- Economic impact: employment (payroll), economic output, profits, investment
- Social impact: health, education, livelihood, air quality, greenhouse gas levels, land use and biodiversity, waste management, water consumption, water quality.



INFRASTRUCTURE comprises the elements of the 5G network that provide coverage, bandwidth, latency and reliability for 5G devices such as base stations, mobile backhaul, edge clouds and core networks, as well as the end devices on which the 5G network will be used.

The actual and perceived end-to-end **SECURITY** of 5G infrastructure, devices and uses will be a key factor for end users, enterprises and public institutions when deciding to move their activities to 5G.

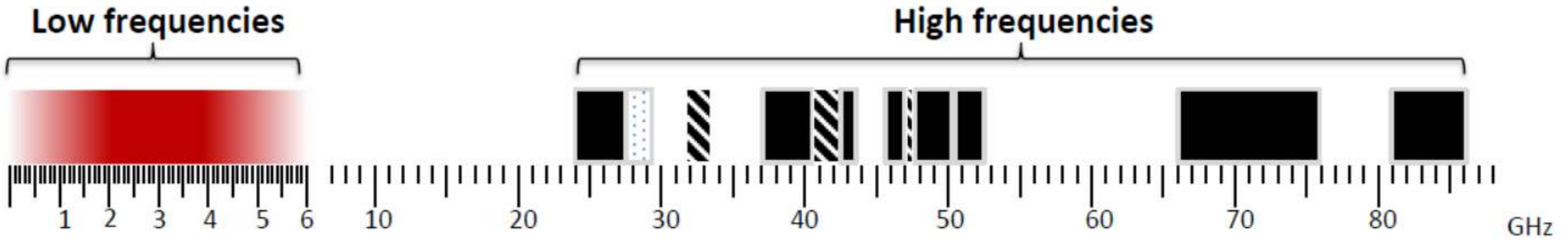
According to Gartner, the number of connected **DEVICES** (sensors, smartphones) in use will increase to 25 billion by 2021, from 14.2 billion in 2019, creating stronger sectorial dependencies on the networks. The devices must be able to support much greater performances and need to exist in a variety of form factors to support the new 5G-enabled use cases and business models.

5G represents an opportunity for connectivity providers to improve network leadership by being the first movers and competitively positioning themselves to deliver key **SERVICES** across diverse geographies. However, subscriber-based business models need to be transformed to enable digital services that support the roadmaps of enterprises across sectors. Involving non-traditional stakeholders across industries would be required to create partnership-based ecosystems and achieve the deployment of 5G networks more quickly.

5G ecosystem

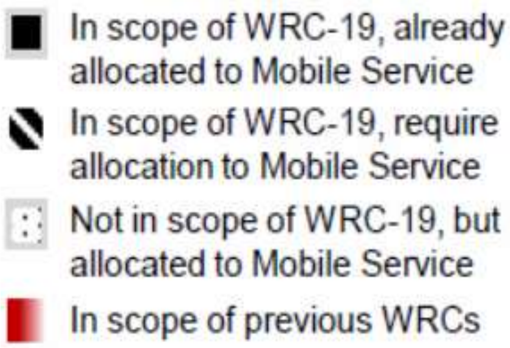
Source: World Economic Forum (WEF) and PWC - *The Impact of 5G: Creating New Value across Industries and Society*

IMT spectrum and WRC-19



Band (MHz)	Bandwidth
450-470	20
470-698	228
694/698-960	262
1 427-1 518	91
1 710-2 025	315
2 110-2 200	90
2 300-2 400	100
2 500-2 690	190
3 300-3 400	100
3 400-3 600	200
3 600-3 700	100
4 800-4 990	190
Total Bandwidth *(Regional allocations vary and therefore totals can be different for a specific region)*	**1,886**

Identified for IMT, GHz (BW)	Region 1	Region 2	Region 3
24.25-27.5 (3.25)	All	All	All
37-43.5 (6.5)	All	All	All
45.5-47 (1.5)	50	1	2
47.2-48.2 (1.0)	62	All	7
66-71 (5.0)	All	All	All



A look at our ASP region

How it has been adopted?

Case Examples - Australia

Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners	Length of Licence	Price Paid
November – December 2018	3.4-3.7 GHz allocated and 5G has been commercially deployed	Auction	3575–3700 MHz band: All lots were sold to Dense Air Australia (29 x 5 MHz), Mobile JV (131 x 5 MHz), Optus Mobile (47 x 5 MHz) and Telstra (143 x 5 MHz)	3.4-3.7 GHz: 10 years (30 March 2020 – 13 December 2030)	Dense: AUD $18,492,000 Mobile JV: AUD 263,283,800 Optus: AUD 185,069,100 Telstra: AUD 386,008,400
April 2021	26 GHz	Auction (ESMRA)	2,400 MHz in total in regional licences. Winners were Telstra – 1,000 MHz, Singtel Optus 800 MHz and TPG-Vodafone 600 MHz	15 year term ending in 2036	$0.0127/MHz/Pop Dense Air: AUD28,689,900, Mobile Jv: AUD108,186,700, Optus Mobile AUD226,203,100, Pentanet Limted AUD7,986,200 and Telstra AUD276,576,2000
December 2021	850 MHz band (814–825 MHz, 859–870 MHz) 900 MHz band (890–915 MHz, 935–960 MHz)	Auction	All 16 lots available were allocated. Optus won 8 lots of spectrum at auction for $1,119,183,000, and acquired a total of 12 lots of spectrum for $1,475,958,000. Two set-aside lots were allocated to Optus for a pre-determined price, and two lots of 1 MHz were automatically allocated also to Optus as the winner of the 900 MHz lower products. Telstra won 4 lots of spectrum for $615,660,000.	20 years commencing 1 July 2024, expiring 30 June 2044.	The total revenue raised was $2,091,618,000. This was equivalent to almost $1.21/MHz/pop.

Case Examples – Bangladesh

Country	Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners	Length of Licence	Price Paid	Other Conditions
Bangladesh	31 March 2022	The auction featured 10 lots of 10 MHz in the 2.3 GHz band (100 MHz in total) and 12 lots of 10 MHz (120 MHz in total) in the 2.6 GHz band.	Auction	In the first phase, • Teletalk and the third largest mobile operator Banglalink secured 30 MHz for BDT1,680 crore (USD195 million) and 40 MHz for BDT2,241 crore (USD 260 million) from the 2.3 GHz band respectively. • Market leader Grameenphone and second largest MNO Robi Axiata acquired 60 MHz (the maximum cap on spectrum in this auction) in 2.6 GHz band for BDT3,360 crore (USD389 million) each. At the end of the first phase of the auction, 30 MHz spectrum remained unsold from the 2.3 GHz band, which was then re-auctioned in the second phase with no interest from the operators. Refer to https://www.tbsnews.net/bangladesh/telecom/btrc-holds-spectrum-allocation-auction-394478	15 Years	Out of 220MHz offered, 190 MHz of spectrum was successful sold to Grameenphone, Robi Axiata, Banglalink and state-owned operator Teletalk for a total of nearly **USD1.24 billion.** The base price for each MHz on the spectrum was set at USD6.5 million for a unit . 30 MHz of 2.3 GHz band remained unsold after the auction.	MNOs are required to pay 10 percent of the total purchase price within 60 days of the announcement of the final auction results, while the remaining 90 percent will be paid off in equal instalments over 9 years. BTRC instructed all telecom operators to begin test runs for the 5G spectrum within six months of the auction. Currently, 4G services are operational in Bangladesh. Once 5G services are introduced, mobile internet speed is expected to increase severalfold in the country.

Case Examples - China

Country	Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners	Length of Licence	Price Paid
China	December 2018	2.3 GHz (indoor) 2.6 GHz 3.3 GHz (indoor) 3.5 GHz 4.9 GHz	Spectrum Allocation through bidding	China Mobile approved to use spectrum in the 2.515-2.675 GHz and the 4.8-4.9 GHz ranges nationwide 5G trials. China Telecom allowed to use 3.4-3.5 GHz frequency range to carry out 5G trials in mainland China. China Telecom will return its 2.635-2.655 GHz spectrum over the same timeframe. China Unicom said it has been approved to use the 3.5-3.6 GHz frequency band for a nationwide 5G trial rollout until June 2020. CBN awarded a 5G commercial license in the 4.9-4.96 GHz range. In January 2020, CBN received a 5G test license in the 4.9 GHz band. China Telecom, China Unicom and CBN will share the 3.3GHz to 3.4GHz band for indoor coverage.	Not applicable (?)	China decided to reduce spectrum fees with no 5G spectrum auction fee, no license fee for 5G spectrum in the first 3 years and to charge only 25%, 50%, 75% for the 4th to 6th year.

Case Examples - Indonesia

Country	Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners	Length of Licence	Price Paid
Indonesia	2016	1800 MHz and 2100 MHz	1800 MHz was refarmed	The 1800 MHz band was reorganised to make eight allocations to four operators in contiguous blocks to transition to LTE and facilitate carrier aggregation. Four mobile operators — Telkomsel, XL Axiata, Indosat and Tri — had spectrum reallocated.		
	April 2021	2300 MHz	Auction	PT Telekomunikasi Selular won 2 Blocks: Blocks A and C PT Smart Telecom won one block, block B Each block size was 10MHz each.	10 years	PT Telekomunikasi Selular paid IDR 176.9 billion (USD 12.1 million) for each block PT Smart Telecom paid IDR 176.5 billion for its block

- Palapa Ring project and HTS
- A2D Terrestrial TV

Case Examples - Japan

Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners	Other conditions
April 2019	400 MHz of 28GHz, 200 MHz of 3.7 GHz, 100 MHz of 4.5GHz bands. 4.9 GHz.	Beauty contest – allocations determined by commitments	NTT DoCoMo, KDDI, Softbank, Rakuten: awarded 400 MHz spectrum on the 28 GHz frequency, NTT DoCoMo, KDDI, Softbank were awarded 200 MHz on 3.7 GHz. Rakuten requested 100 MHz. NTT DoCoMo were assigned 100 MHz on 4.5 GHz bands. 4.6-4.9 GHz and 28.2-29.1 GHz bands are scheduled to be assigned for local 5G (private 5G) by the end of 2020, subject to technical and other conditions.	5G licences applied for come with coverage obligations and security commitment. The minimum coverage requirement from the government is serving every prefecture within two years, and at least 50% of the whole country within five years. Tax incentives for companies investing in Japan's 5G wireless network.
April 2021	1.7 GHz		Rakuten Inc received approved to deploy base stations using the 1.7 GHz band in areas that exclude Tokyo, Nagoya and Osaka.	

Case Examples – Korea (Republic of)

Country	Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners	Length of Licence	Price Paid	Other Conditions
Republic of Korea	June 2018	280MHz of 3.5GHz spectrum and 2,400MHz of airwaves in the 28GHz band.	Auction	Sk telecom and KT both acquired 100 Mhz of mid-band spectrum while LG U+ acquired 80Mhz. All three operators acquired 800Mhz of 28Ghz mmWave spectrum.	The 3.5 GHz band licences are valid for ten years. The 28GHz band licences are valid for five years.	South Korea raised $3.3 billion from the 5G spectrum auction. SKT paid KRW1.22 trillion, KT KRW968 billion and LG Uplus KRW809.5 billion. The final price per 10MHz block was just 13 per cent higher than the reserve price of KRW94.8 billion.	Telecom companies, LG Uplus, SK Telecom and KT, can use the sub-6 GHz frequencies for the next 10 years and mmWave frequencies for the next 5 years.

Case Examples – Malaysia

Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners	Length of Licence	Price Paid	Other conditions
2016	900 MHz and 1800 MHz	Refarming/ Administration decision	Celcom and Maxis saw their 900 MHz holdings (2x17 MHz and 2x16 MHz, respectively) reduced to 2x10 MHz, while Digi's holdings were increased from 2x2 MHz to 2x5 MHz and U Mobile was awarded 2x5 MHz. In the 1800 MHz band, Celcom, Digi, and Maxis each had their 2x25 MHz holdings reduced to 2x20 MHz, making 2x15 MHz available for award to U Mobile	15 years (1 July 2017 to 30 June 2032)	RM499.72 million for a 2x5 MHz block in the 900 MHz band, and RM217.77 million for a 2x5 MHz block in the 1800 MHz band	Coverage targets: DNB aims to cover Putrajaya, Cyberjaya and some parts of Kuala Lumpur with 5G by end of 2021. Coverage expansion for 17 major cities in Peninsular, Sabah and Sarawak will take place in 2022 and 2023.
June 2021	900 MHz	Direct Award	2 x 5 MHz was allocated to Altel Communications	5 years		
July 2021	700 MHz, 3.5 GHz and mmWave	Direct Award	Digital Nasional Berhad, the Government owned entity who is the 5G single wireless network provider. 2 x 40 MHz of 700 MHz and 200 MHz of 3.5 GHz unknown amount of mmWave spectrum	Annual Apparatus Licence	**Reference Access Offer, 5G wholesale to cost telcos RM30K per Gbps monthly**	

Case Examples -Maldives

Country	Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners
Maldives	2018	3.5 GHz band	Auction	Ooredoo Maldives won 5G spectrum licence in February 2018. Dhiraagu trialled 5G services in November 2018.

EMF

Case Examples – New Zealand

Country	Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners	Length of Licence	Price Paid	Other Conditions
New Zealand	May 2020	3.5 GHz	Direct offer	Spark and 2degrees Mobile allocated 60 MHz, Dense Air was offered 40 MHz and a further 50 MHz went to the Maori Spectrum Working Group which can onsell its spectrum to MNOs if it wishes to do so. Vodafone New Zealand was not allocated any spectrum as it already had 60 MHz in the 3.5 GHz band.	The spectrum was only offered for two years, until 31 October 2022. Usually spectrum licences are for 20 years in New Zealand.	Spectrum offered at a low fixed cos of NZ$250,000 per 10 MHz of bandwidth	Spectrum licence is until 31 October 2022 It appears Government will proceed with a auction in November 2022 as planned

Case Examples – Philippines

Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners	Length of Licence	Price Paid	Other Conditions
2018	700, 2100 and 2600 MHz and 3.3 and 3.4 GHz spectrum	Beauty contest for new third market player based on national population coverage, minimum average broadband speeds and capital and operational expenditure	DITO was successful and awarded 70-90 MHz of 700, 2100 and 2600 MHz plus 140 MHz of spectrum allocated in the 3.3 – 3.4 GHz band. Including 2 x 10 MHz of 700 MHz, at least 20 MHz of 2100 MHz and 20 MHz of 2600 MHz spectrum.	Length of franchise period	Not applicable	Extensive nationwide rollout commitments

Case Examples – Thailand

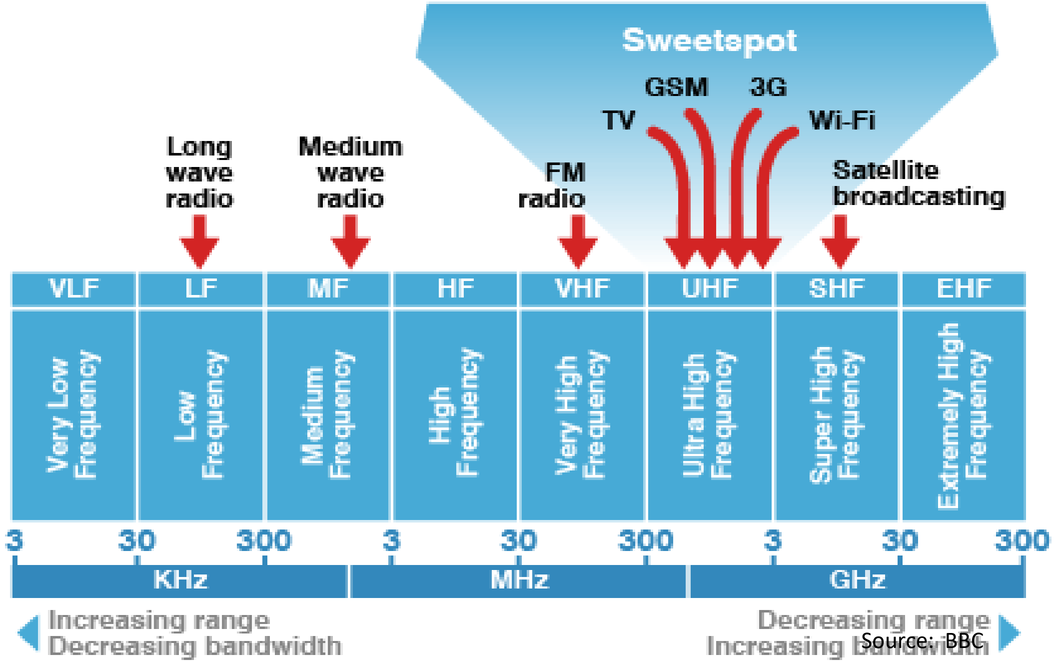
Country	Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners	Length of Licence	Price Paid	Other Conditions
Thailand	February 2020	700 MHz, 2.6 GHz and mmWave 26 GHz	Auction	Advanced Info Service (AIS) acquired the most licenses: 23 across all three spectrum bands (one license for the 700 MHz range, 10 for the 2600 MHz band and 12 for the 26 GHz band). True Corporation (True) obtained 17 licenses (nine from 2600 MHz range and the rest from 26 GHz band). Total Access Communication away with two (26 GHz range). CAT Telecom and TOT, which are to be merged to become National Telecom company (NT), won six licenses, with TOT getting four (26 GHz) and CAT getting two (700 MHz). DTAC only took part in the 26 GHz auction, winning two out of the possible 26 licenses for 100 MHz blocks.	Licences are for 15 years	6 GHz: 37,164 Million THB (USD1.2 billion) 700 MHz: 51,462 Million THB (USD1.6 billion) (three operators paid equivalent of \$0.36/MHz/POP for 2 x 10 MHz block) 26 GHz: 11,570 Million THB (USD373 Million) Total: 100,196 Million THB (USD3.23 billion)	Those who won 2600-megahertz spectra to provide 5G network coverage for at least 50% of the Eastern Economic Corridor (EEC) one year after the auction, by February 2021.

Case Examples – Singapore

Country	Year/Date	Spectrum Bands	Method of Allocation	Spectrum Allocated and winners	Length of Licence	Price Paid	Other Conditions
Singapore	June 2020	100 MHz of 3.5 GHz band Plans to make available up to 100 MHz spectrum within 3.4–3.5 GHz band, on a "restricted" use basis (limited to indoors and underground) mmWave spectrum	Call for Proposal: 3.5 GHz awarded through a beauty contest 800 MHz of mmWave band allocated to each MNO	Singtel Mobile Singapore and the JVCo (Antina) operators were awarded the 3.5 GHz Spectrum Rights. All MNOs applied for and were assigned two 400 lots in the mmWave band (800 MHz each) for nominal amounts.	15 years (from 1 January 2021 until 31 December 2035)	IMDA required each operator to pay a base price of SGD55 million (USD40 million) for one 100 MHz lot of 3.5 GHz band spectrum (for a standalone 5G network) plus annual fees of SGD150,000. Singtel submitted the winning assignment bid of SGD2,100,128 to be assigned its preferred 100 MHz lot.	Each operator was required to submit proposals for their 5G deployment meeting IMDA's key obligations and requirements including providing 5G SA networks with at least 50% coverage within 24 months from the commencement of the 3.5 GHz spectrum right. IMDA committed to not impose 5G QoS obligations, but reserved the right to do so in the future.
	November 2021	2.1 GHz	Auction	2.1 GHz (non-FROR): $15,500,000 per paired lot • Consortium (M1 Limited and StarHub Mobile Pte Ltd) - 15 MHz (3 paired lots) • Singtel Mobile - 20 MHz (4 paired lots) • TPG Telecom - 10 MHz (2 paired lots) 2.1 GHz (FROR): $3,000,000 per paired lot • Consortium - 10 MHz (2 paired lots – 1 each for M1 Limited and StarHub Mobile Pte Ltd) Singtel Mobile - 5 MHz (1 paired lot)		• Consortium: $52,500,000 for 25 MHz • Singtel: $65,000,000 for 25 MHz • TPG: $31,000,000 for 10 MHz	Winning bidders will have rights to the 2.1GHz spectrum for deployment of 5G network and services from Jan 1, 2022, and will be required to establish two nationwide networks with full-fledged 5G standalone capabilities with at least 50 per cent coverage by end-2022, and nationwide coverage by end-2025.

Key Observations – Bands Allocated

- Most ASP countries covered by the ITU study have allocated spectrum (34 out of 37) over the past 5 years, (note we were unable to access data from some Pacific countries)
- The top ***three most popular IMT spectrum bands allocated*** were: 1) ***700 MHz band*** for 4G and 5G services, 2) ***1800 MHz*** typically used for 4G services & 3) ***3.5 GHz*** band for 5G services
- ***5G spectrum allocations in the pioneer band (3.5 GHz/ n77/78 band) took off from 2018***. The 3.5 GHz band allocations continued throughout 2019 and started to increase significantly after 2020.

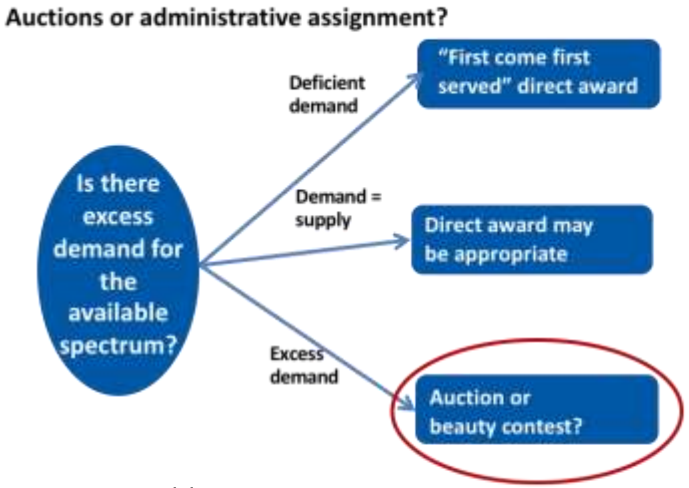


Source: BBC

Key Observations – Grant method and terms

- Overwhelming preference in the region for ***spectrum allocation through spectrum auctions.*** Other methods of spectrum assignment included assignment, administrative allocations, beauty contests, hybrid (assignment and auction), direct offers and call for proposals.

- Due to COVID-19 **different payment terms** have occasionally been negotiated between MNOs and regulators including discounts and annual payment terms, or waiving of fees (eg in China).



Source: NERA Economic Consulting + WPC additions, 2021

Why Governments, regulators and MNOs typically prefer auctions	
Allocative efficiency	**Transparency of outcomes** eg don't favour publicly owned incumbent
Consistency of rules	Robustness to legal challenge
Anti-corruption laws require auction	Revenue Raising (MNOs willing to pay reasonable price)

Key Observations – License conditions

- ***Length of licence varies between Asia-Pacific countries***. The most common licence length in the region over the past five years is 15 years *(e.g., China (Hong Kong), Malaysia, Mongolia, Myanmar, Singapore, Thailand)*

- **Conditions have imposed to encourage the rollout of a 5G networks and/or ensure nation-wide coverage,** *For example, In Thailand, NBTC motivated 5G investment in Thailand by giving 3 years grace period for any repayment if 5G is deployed in 50 percent of Eastern Economic Corridor (ECC) Area within 1 year and 50 percent of smart city within 4 years.*

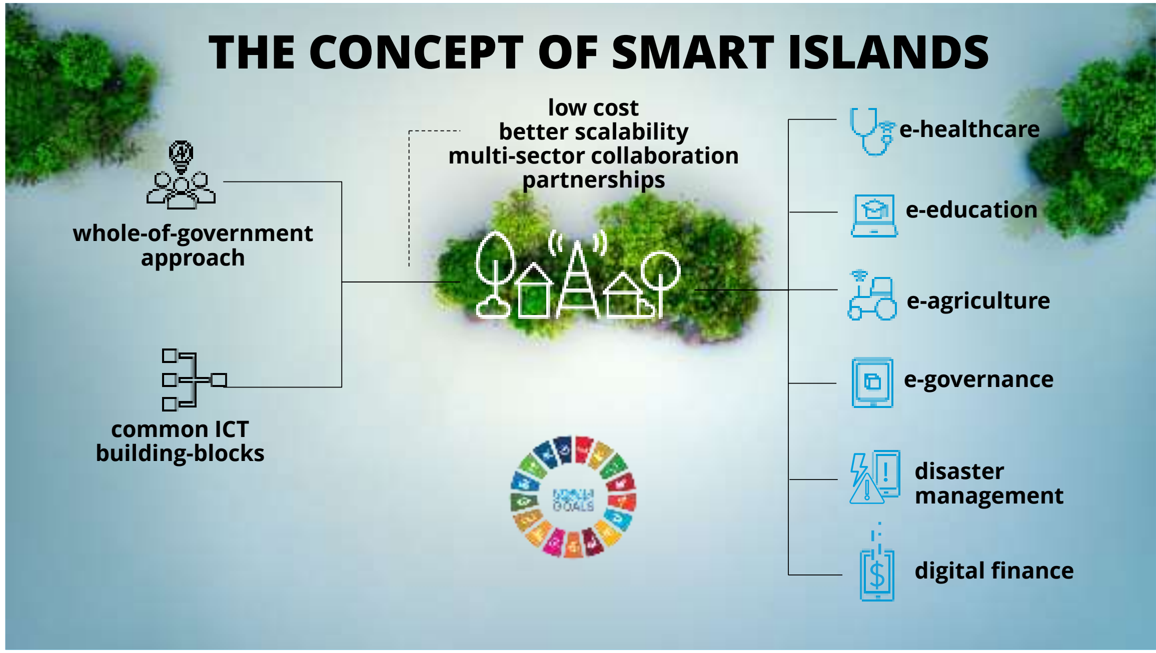
- **Single Wholesale Networks (SWN) as an alternative approach to allocating IMT Spectrum to MNOs.** *(Malaysia) SWNs are considered one possible solution to address urban access and rural coverage challenges. SWNs can provide better coverage, particularly in rural areas, than would otherwise occur in a competitive market. Issues like competition, using public funds for commercial services, traffic management and network planning etc. need attention.*

Key Observations – Enabling new services

- Several examples of **refarming spectrum** in the Asia-Pacific region *(eg Australia, Indonesia, Malaysia, Pakistan)*

- It is mostly developed markets prioritising 5G that have **already allocated mmWave spectrum**, although there are exceptions.

- **Allocations have been to facilitate/promote competition, and regulators have imposed spectrum limits on MNOs:** *there have been many instances of spectrum caps being utilised to avoid creating an uneven market, such as in Thailand and Australia.*



Key Observations – others

2021/22 onwards

- More focus on releasing **capacity mid-band spectrum**, namely the 2.6 GHz and 3.5 GHz bands.
- spectrum access provided by regulators as a **precursor to 5G launches** (eg Vietnam,) **and/or additional spectrum for 5G**
- Some IMT spectrum releases are **paired with scheduled 2G/3G service shutdowns** (eg Vietnam).
- Some IMT spectrum releases are an attempt to **facilitate industry competition** (eg, Iran).
- **Refarm low band spectrum into 5G NR compatible blocks (**eg 2 x 5 MHz blocks) (eg Australia).

Going Forward - Points to consider

Spectrum Management Roadmaps

Roadmap is important as it is an agreed plan for both government and all stakeholders setting out the steps and timing in making available unused spectrum and in better utilising existing spectrum allocations.

Refarming relevant bands for efficient RF utilization

Refarming of certain IMT bands may be required to make the existing band allocations into larger contiguous blocks and preferably to be licensed in 5 MHz blocks.

Preparing to release upper mid-level bands

Future IMT bands should be made available, including the 6 GHz band. Additional mid-band spectrum will be needed by 2025–30 to address the IMT-2020 user experience requirements in the most populated cities in Asia-Pacific.

Synchronization for TDD based networks

With TDD systems (including systems in the 3.5 GHz band) there are two levels of synchronisation which are, namely inter-operator synchronisation within a country and synchronisation across borders. Putting in place synchronisation and agreed frame structure ensures efficient spectrum usage – no additional guard band is required – and network equipment costs can be reduced. This will assist in making 5G services more affordable. This has been the approach adopted in the region including in Australia, China, Japan, the Republic of Korea and Singapore.

Embedded security

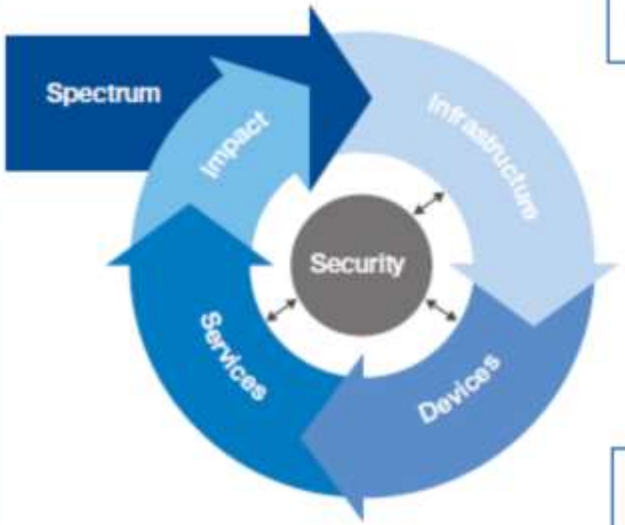
Considerations in 5G ecosystem

Ecosystem

The 5G Ecosystem Cycle represent the need for stakeholder collaboration and alignment throughout the ecosystem, including coordinated decision-making that will have repercussions on the ecosystem's subsequent components

SPECTRUM is the oil of the 5G ecosystem, without which no 5G network infrastructure or devices can operate. The future networks will rely on a combination of mainstream and alternative technologies and will use both licensed and unlicensed spectrum across different spectrum bands together (low = long range, indoor penetration but low capacity density; high = short range, no indoor penetration, high capacity density).

INFRASTRUCTURE comprises the elements of the 5G network that provide coverage, bandwidth, latency and reliability for 5G devices such as base stations, mobile backhaul, edge clouds and core networks, as well as the end devices on which the 5G network will be used.



5G ecosystem

The actual and perceived end-to-end **SECURITY** of 5G infrastructure, devices and uses will be a key factor for end users, enterprises and public institutions when deciding to move their activities to 5G.

IMPACT can be achieved in two dimensions:

- Economic impact: employment (payroll), economic output, profits, investment
- Social impact: health, education, livelihood, air quality, greenhouse gas levels, land use and biodiversity, waste management, water consumption, water quality.

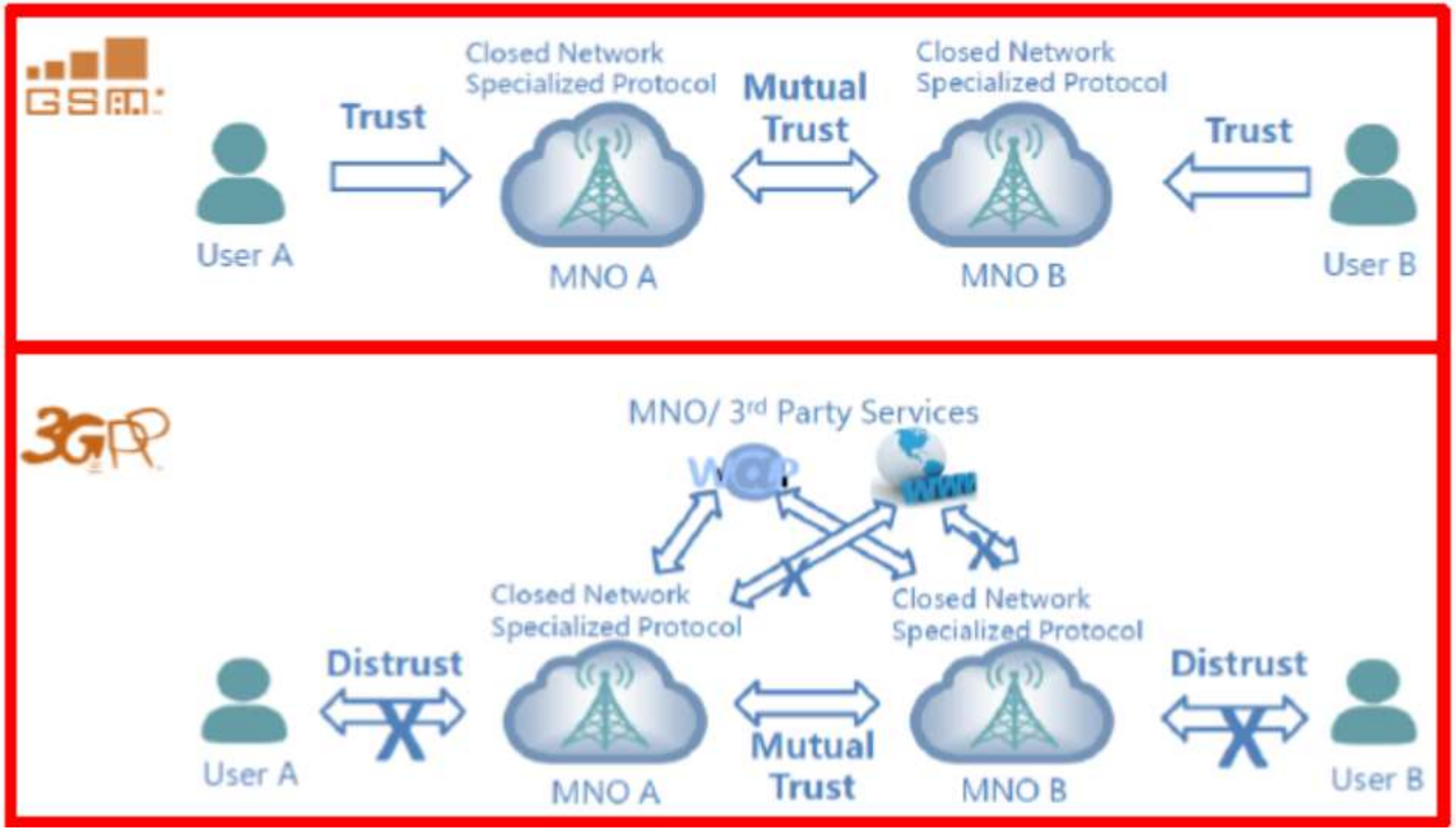
According to Gartner, the number of connected **DEVICES** (sensors, smartphones) in use will increase to 25 billion by 2021, from 14.2 billion in 2019, creating stronger sectorial dependencies on the networks. The devices must be able to support much greater performances and need to exist in a variety of form factors to support the new 5G-enabled use cases and business models.

5G represents an opportunity for connectivity providers to improve network leadership by being the first movers and competitively positioning themselves to deliver key **SERVICES** across diverse geographies. However, subscriber-based business models need to be transformed to enable digital services that support the roadmaps of enterprises across sectors. Involving non-traditional stakeholders across industries would be required to create partnership-based ecosystems and achieve the deployment of 5G networks more quickly.

Source: World Economic Forum (WEF) and PWC - *The Impact of 5G: Creating New Value across Industries and Society*

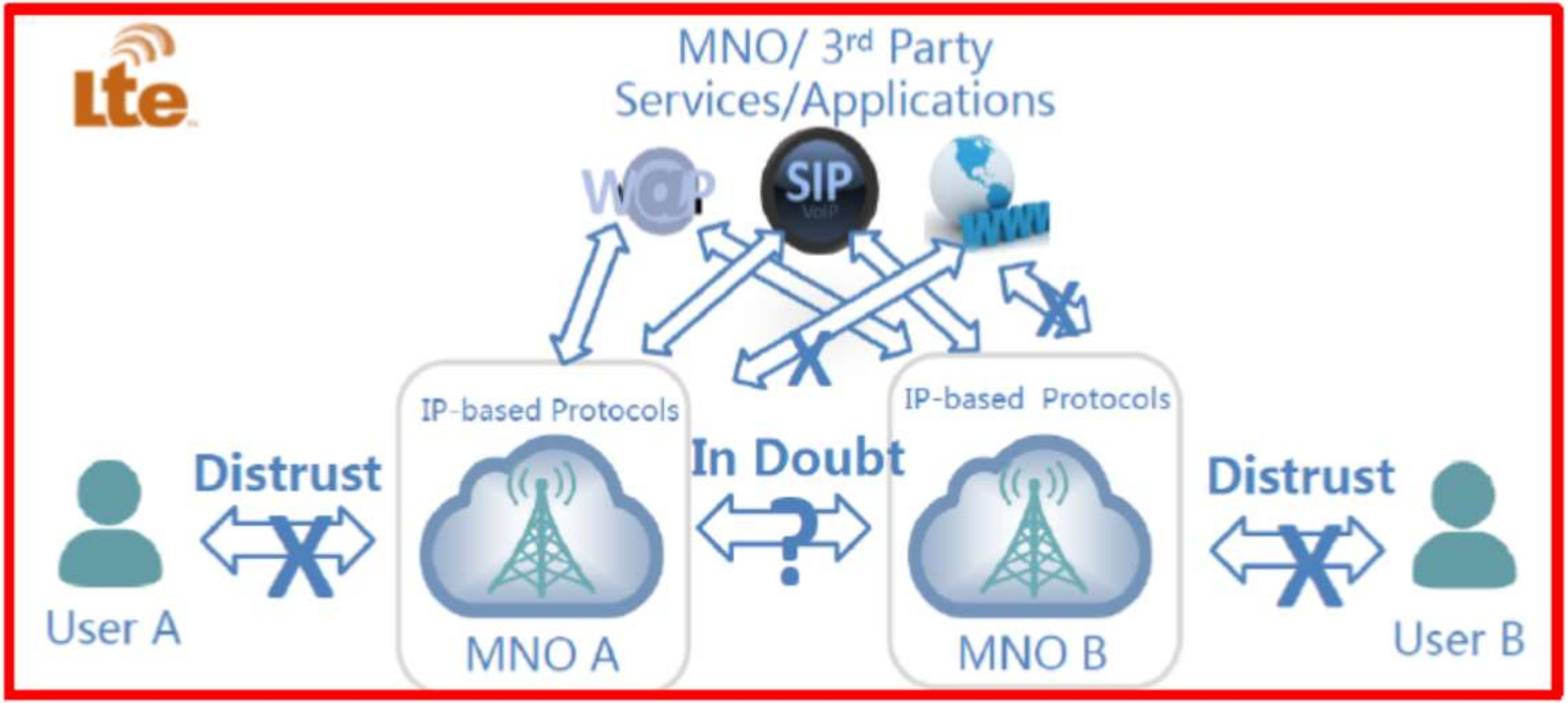
Evolution of security/challenges in telecommunication networks

Trust of a party **A** to a party **B** for a given task **S** is a measurable belief of **A** in that **B** accomplishes **S** dependably for a specified period **P** within a particular trust context **T** (in relation to task **S**)



Source [ITU Workshop on "Security for 5G and beyond“,](#) (China Mobile and KDDI)

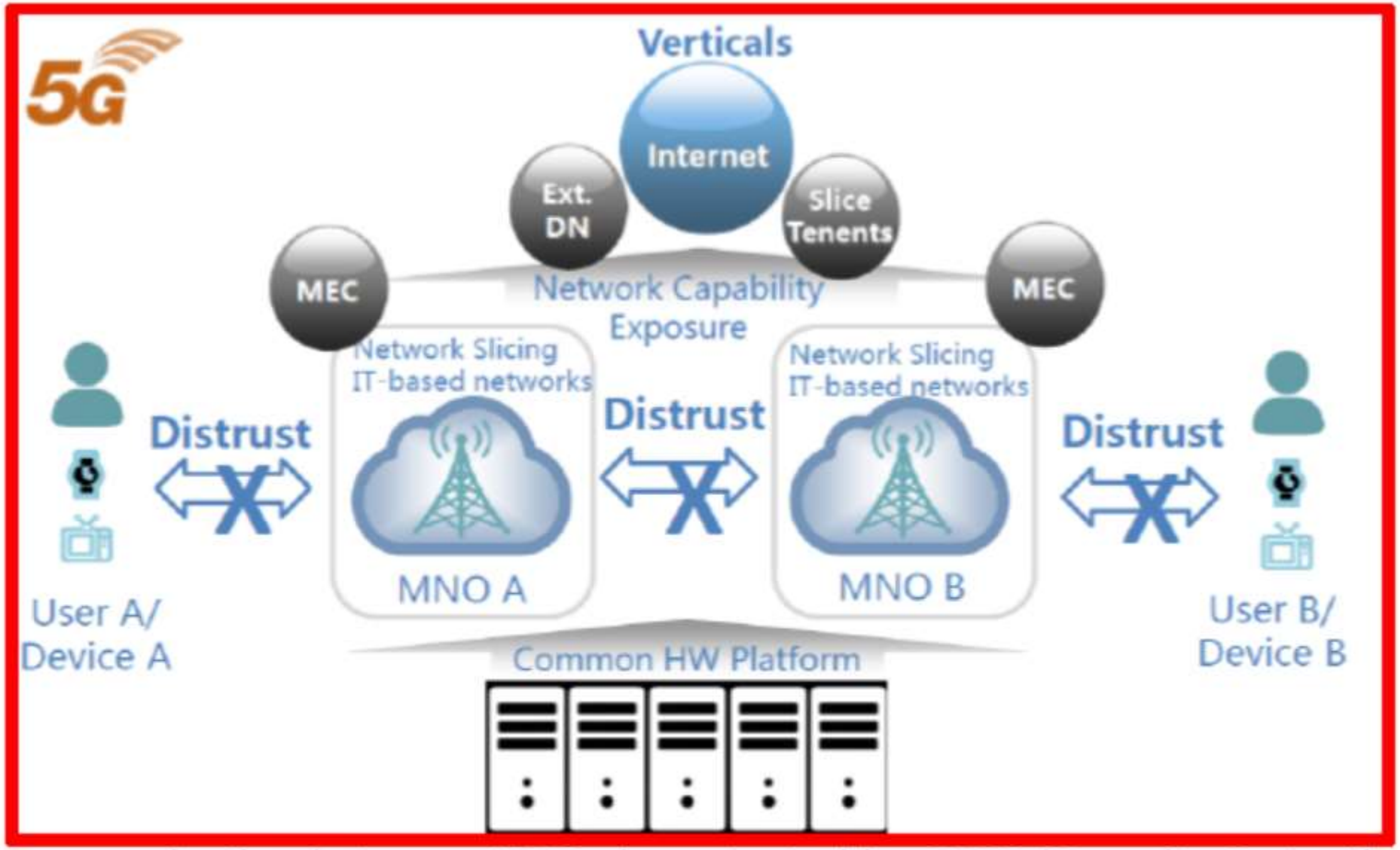
Evolution of security/challenges in telecommunication networks



- Monitoring and filtering mechanism are required for communication between MNOs.
- IMSI information may be leaked by using IMSI catcher.

Source [ITU Workshop on "Security for 5G and beyond“,]() **(China Mobile and KDDI)**

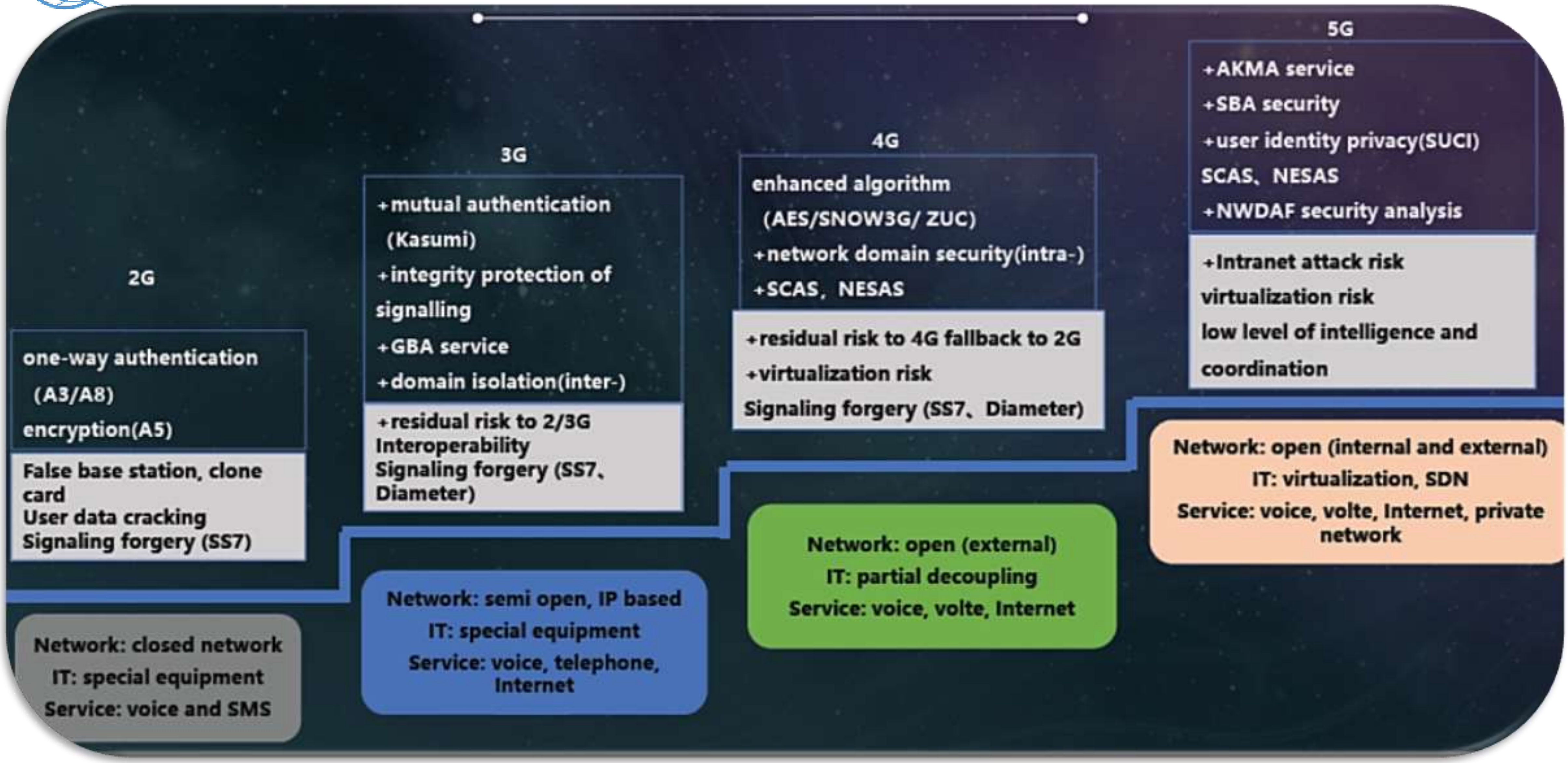
Evolution of security/challenges in telecommunication networks



- Communication between MNOs is protected by SEPP (Security Protection Proxy).
- Protected from IMSI catcher.

Source ITU Workshop on "Security for 5G and beyond", **(China Mobile and KDDI)**

Evolution of security/challenges in telecommunication networks



Source ITU Workshop on "Security for 5G and beyond", (China Mobile)

Convergence of computation and communication

Computing and communication is distributed (everywhere) in 5G network

IaaS: Infrastructure as a service
PaaS: Platform as a service
SaaS: Software as a service
MEC: Multi-access Edge Computing
SR: Segment Route
SDN: software-defined network

Source ITU Workshop on "Security for 5G and beyond", **(China Unicom)**

Changes in 5G environment

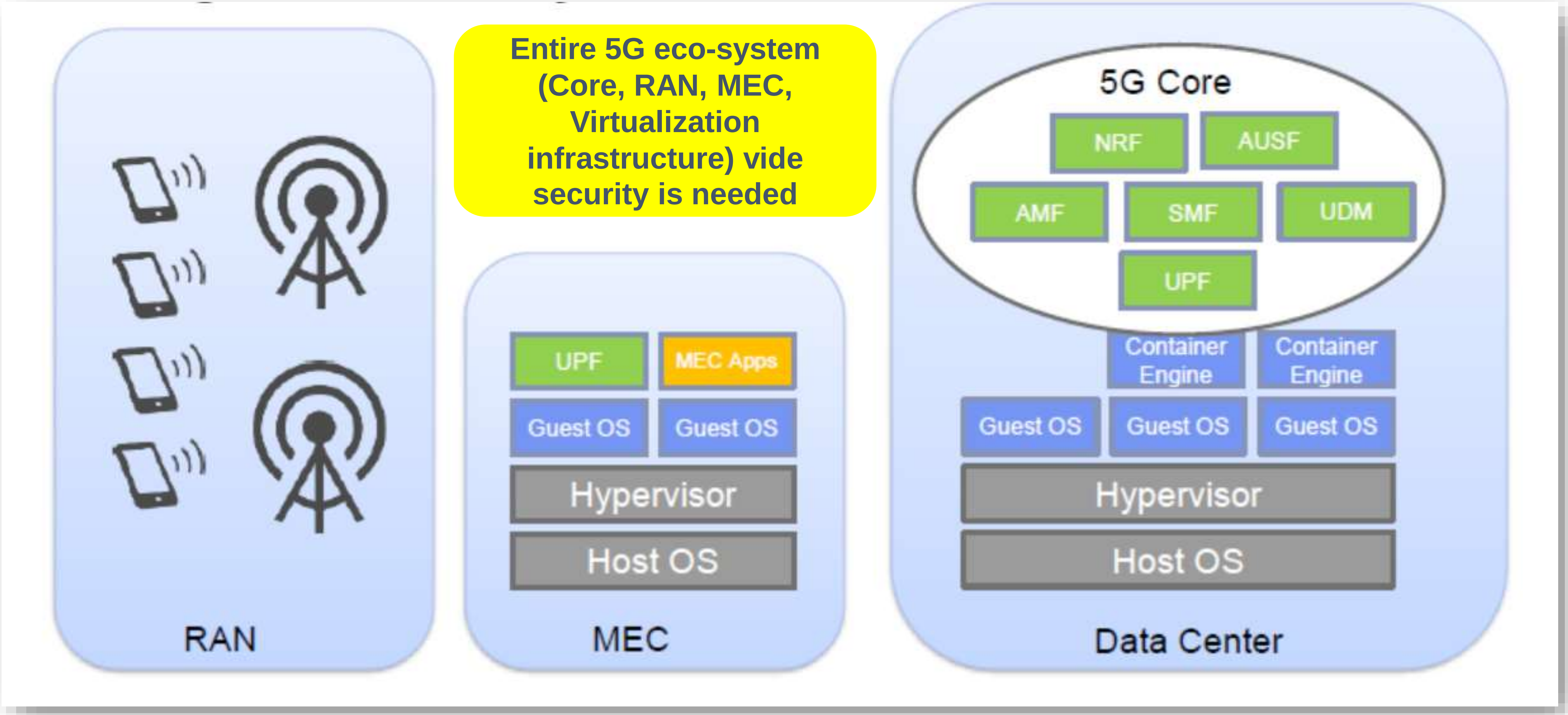
Changes	Items
Network Infrastructures	• Virtual machine technologies for communication platform • Use of open-source software • Exposures of network interfaces • Supply chain risks • Complexity of systems and networks
New Functions, New Technologies	• MEC (Multi-access Edge Computing) • Slicing • NFV (Network Function Virtualization) • SDN (Software Defined Networking)
Enhanced Mobile Core	• Adaptation of SBA (Service Based Architectures) • Use of Internet Protocols (JSON, HTTP/2, TLS, TCP)
New Services using 5G	• IoT • Connected Car • Smart City, Smart Agriculture, …

5G core uses internet-based protocols, such as RESTful, JSON on HTTP.

Internet experts including malicious attackers are familiar with these protocols.

Source ITU Workshop on "Security for 5G and beyond", **(KDDI)**

5G network Architecture and security



Source [ITU Workshop on "Security for 5G and beyond“,](#) (KDDI)

What to consider at national level?

- **Enhanced and Systematized built-in security** to form an immune ability against internal and external attacks
  - *Security control for organization, people, operation, physical situation to operate 5G network system*
- Dynamic and flexible **security capability deployed on demand** with Integrated response and recovery capabilities **to improve network resilience**
- Risk/threat analysis and countermeasures **for new use cases**
- **Special Security for 5G non-public network e.g. PPDR requirements**

Standardization work at ITU on IMT2020

ITU-T Study Group 17 (SG17) coordinates security-related work across all ITU-T Study Groups, often working in cooperation with other standards development organizations (SDOs) and various ICT industry consortia.

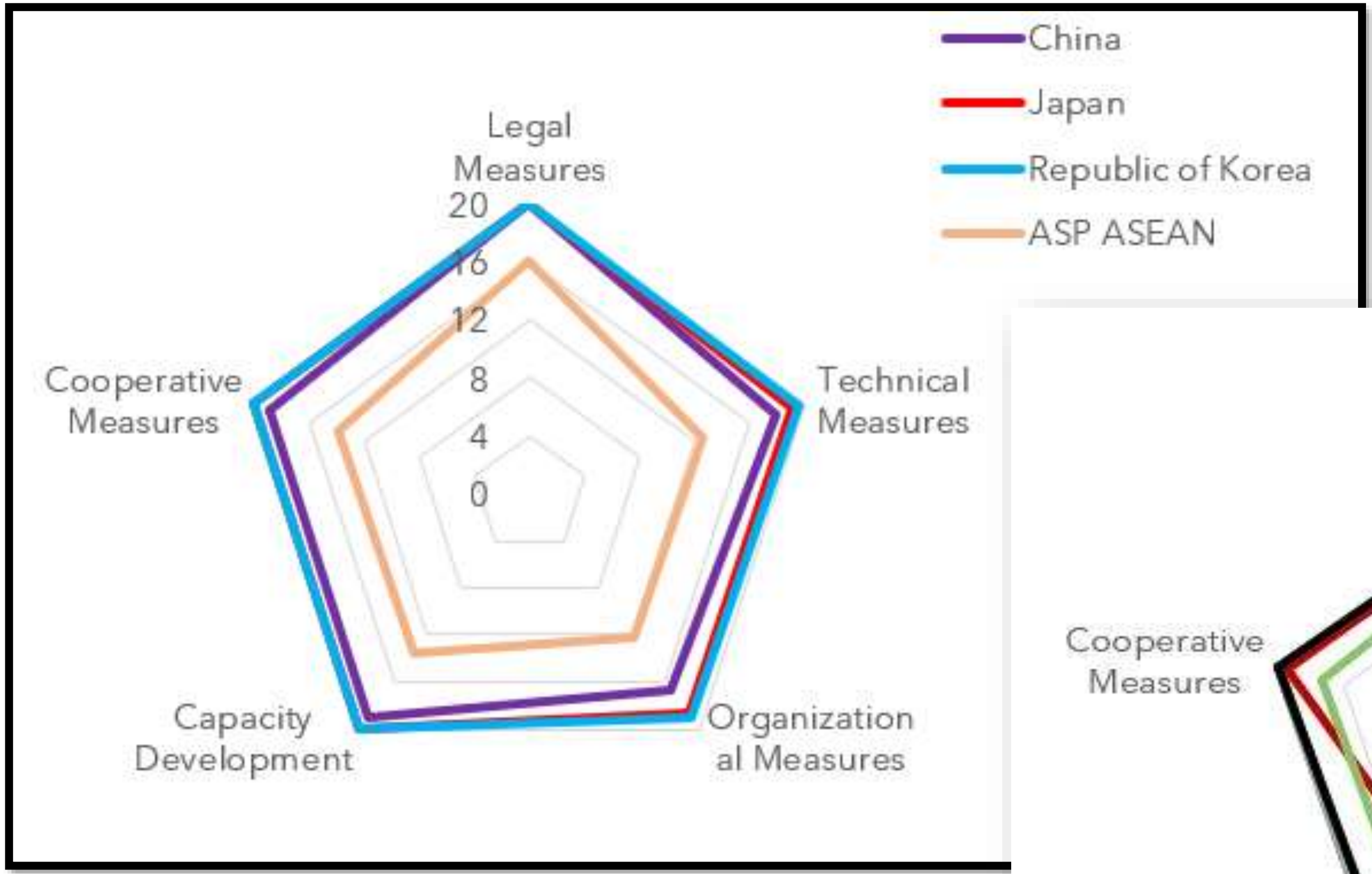
ITU-T Study Group 2 (SG2) Operational aspects of service provision and telecommunications management

Aspects	Recommendation Number (Title)
Security for Management plan	M.3016.0 Security for the management plane: **Overview** M.3016.1 Security for the management plane: Security **requirements** M.3016.2 Security for the management plane: Security **services** M.3016.3 Security for the management plane: Security **mechanism** M.3016.4 Security for the management plane: **Profile proforma**
Security mgmt. services	M.3210.1 **TMN management services** for IMT-2000 **security** management
Security management systems	M.3410 Guidelines and requirements for **security management systems** to support telecommunications management

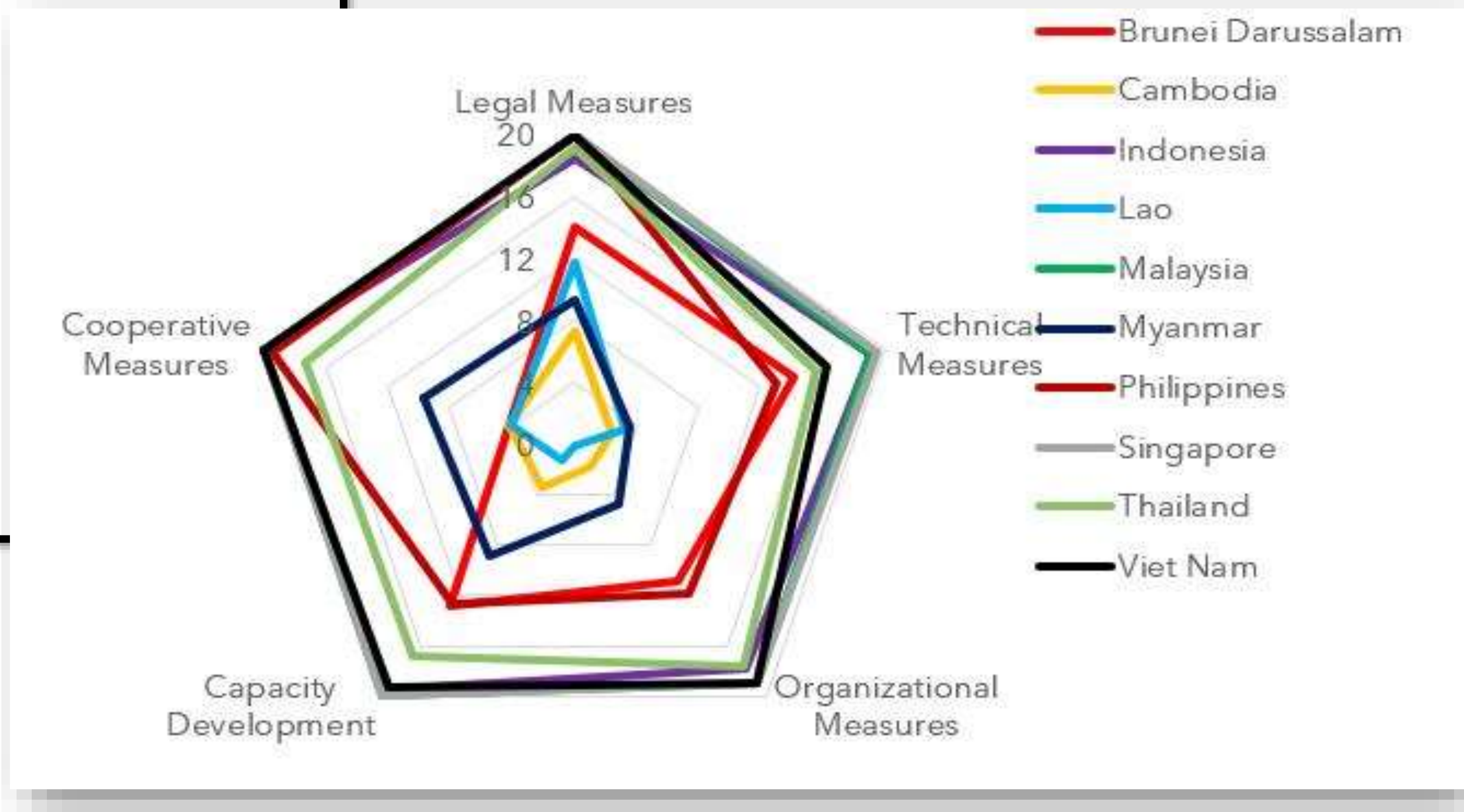
SG2 does **not** create new security services or mechanisms, only reuses those that are defined by SG17 or the industry.

Source ITU Workshop on "Security for 5G and beyond“, **(ITU)**

Development work at ITU on cybersecurity

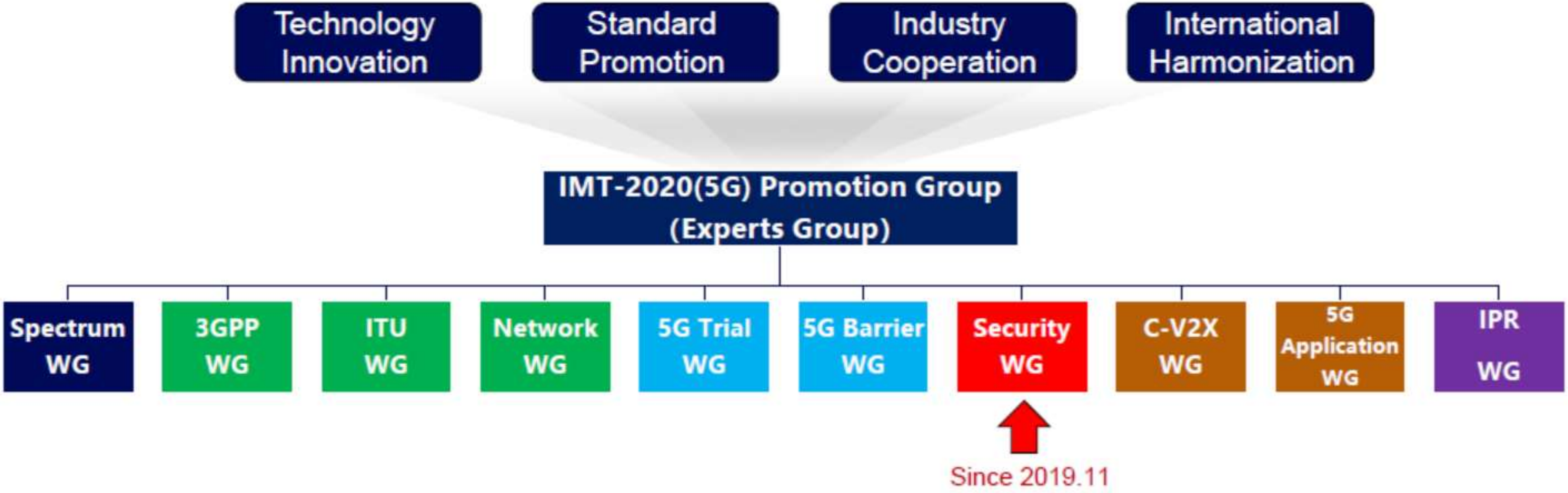


A look at general national cybersecurity posture in selected ASP administrations



Source ITU

Work in China on 5G security:
WG within IMT2020 (5G) promotion Group



- Network Equipment Security Assurance Scheme (NESAS) has been approved as the basic standard for 5G security assessment and has been implemented by China's IMT-2020(5G) Promotion Group.
- All 5G equipment suppliers in the Chinese market comply with the NESAS standard system.

Source ITU Workshop on "Security for 5G and beyond", **(CAICT)**

Japan’s 5G security guidelines

- The guidelines **present** security threats to the 5G system and relevant security controls in a structured manner.
- Provide readers with practical advice on identifying and addressing common security challenges.
- Rather than specifying each security control in full detail, the document assumes that readers adapt control prioritization and implementation to their individual scenario and the associated security risk.

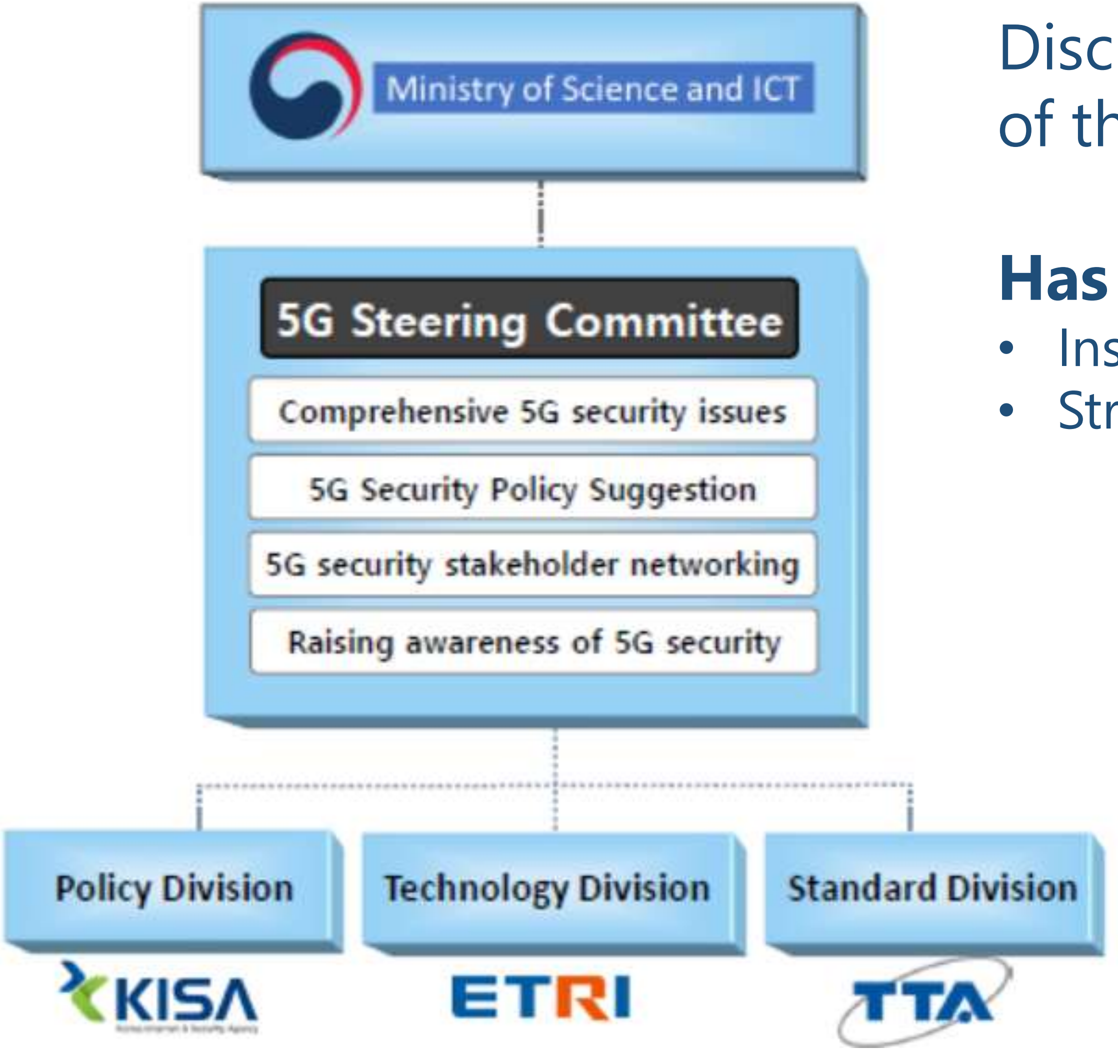

参考資料1

5Gセキュリティガイドライン第1版

2022年 4月 22日

The first version of the guideline document is released in April 2022
https://www.soumu.go.jp/main_content/000812253.pdf (in Japanese)

Work in Republic of Korea on 5G security

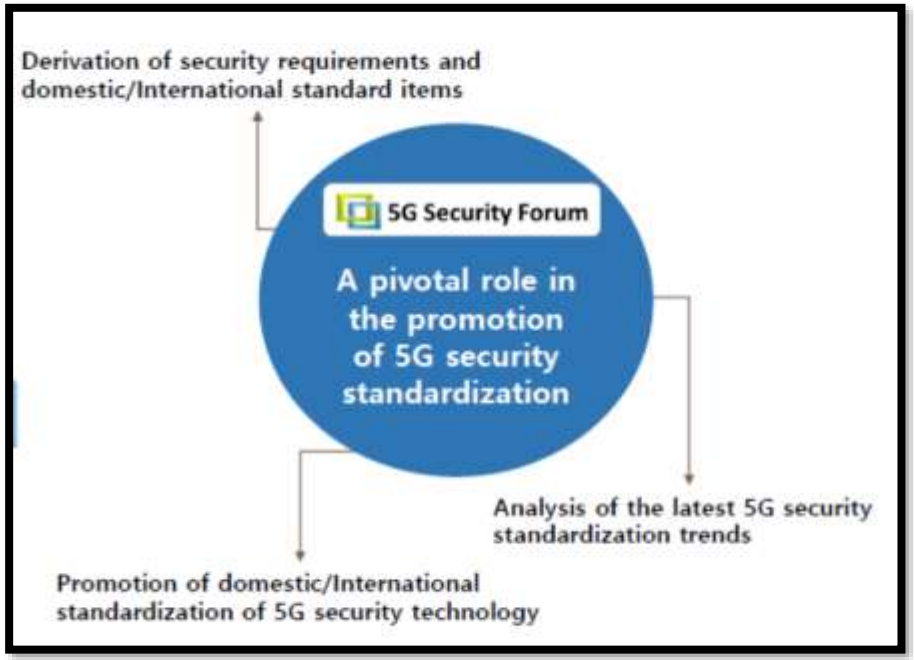


5G Security Association

Discuss issues and plans for the implementation of the secure 5G network 5G+ core services

Has undertaken

- Inspection of overall 5G security
- Strengthening of global 5G security cooperation

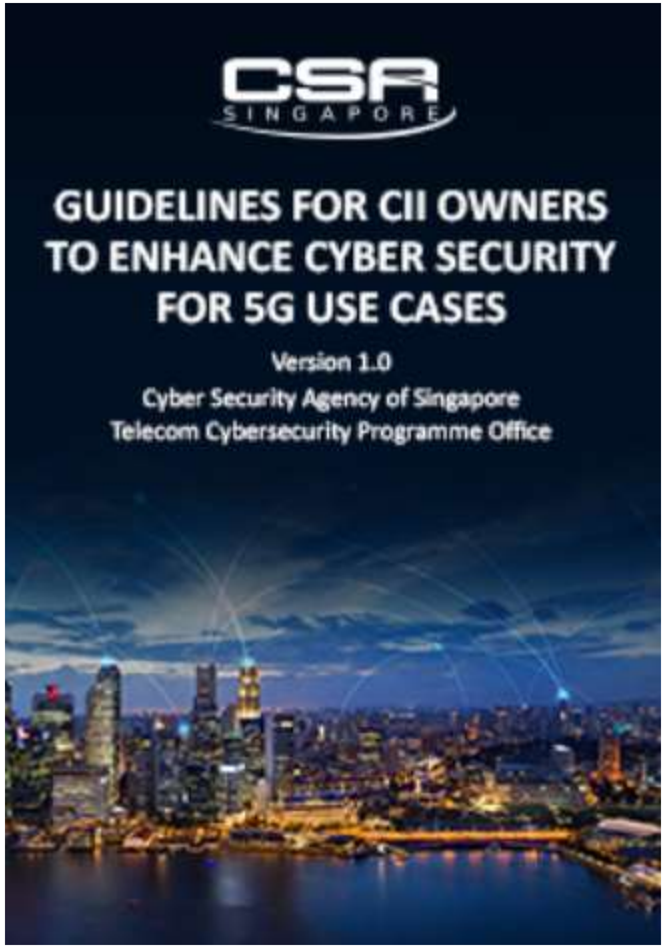


Source [ITU Workshop on "Security for 5G and beyond"](#) (ETRI)

Singapore CII security guidelines

Guidelines for Critical Information Infrastructure (CII) Owners (CIIOs) to Enhance Cyber Security for 5G Use Cases

- Suggests measures to help CIIOs to
  - *identify threats that can be introduced into systems connected to 5G services.*
  - *provides recommendations to CIIOs to mitigate the risks of such threat*
  - *Cover systems and User Equipment (UE) owned by CIIOs and do not include Multi-access Edge Computing (MEC) and application platforms connected to MNOs' 5G infrastructure or network slices from MNOs*



Source: Cyber Security Agency of Singapore

Malaysia Technical code on IMT-2020

- **Includes** security architecture and requirements for 5G network and applications

- Requires following **5G network assets to be secured** :

  1. User data information and user security configuration information;

  2. Network Element (NE) security;

  3. Transport/interface security.


MCMC MTSFB TC G028:2021

TECHNICAL CODE

IMT-2020 (FIFTH GENERATION) - SECURITY REQUIREMENTS

Developed by

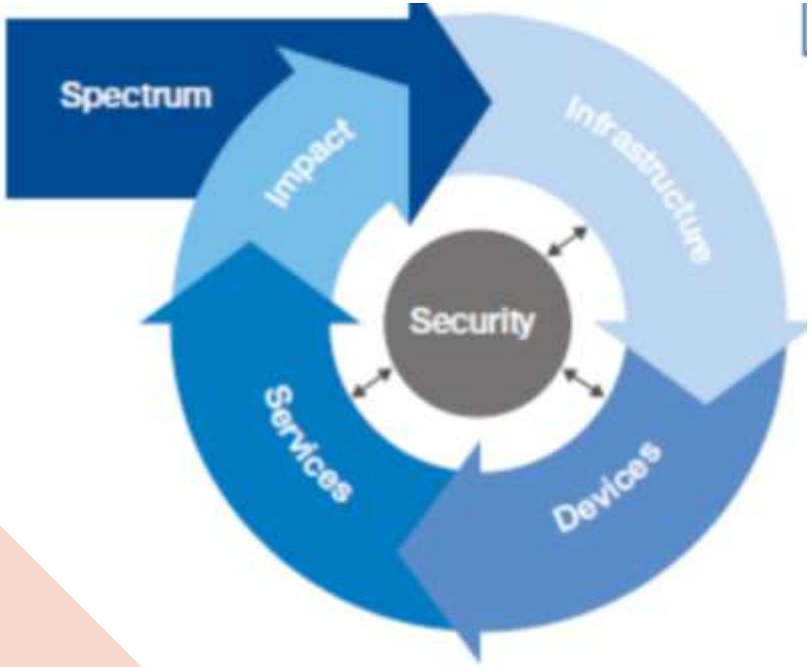
Registered by

Registered date : 24 August 2021

© Copyright 2021

Source MCMC Malaysia

Conclusion



- **From passive protection to active perception, preparation and action**

- **AI bring intelligence to security**

Convergence:

Compute + Communication + Data

New interactions:
Cloud-native + AI Native

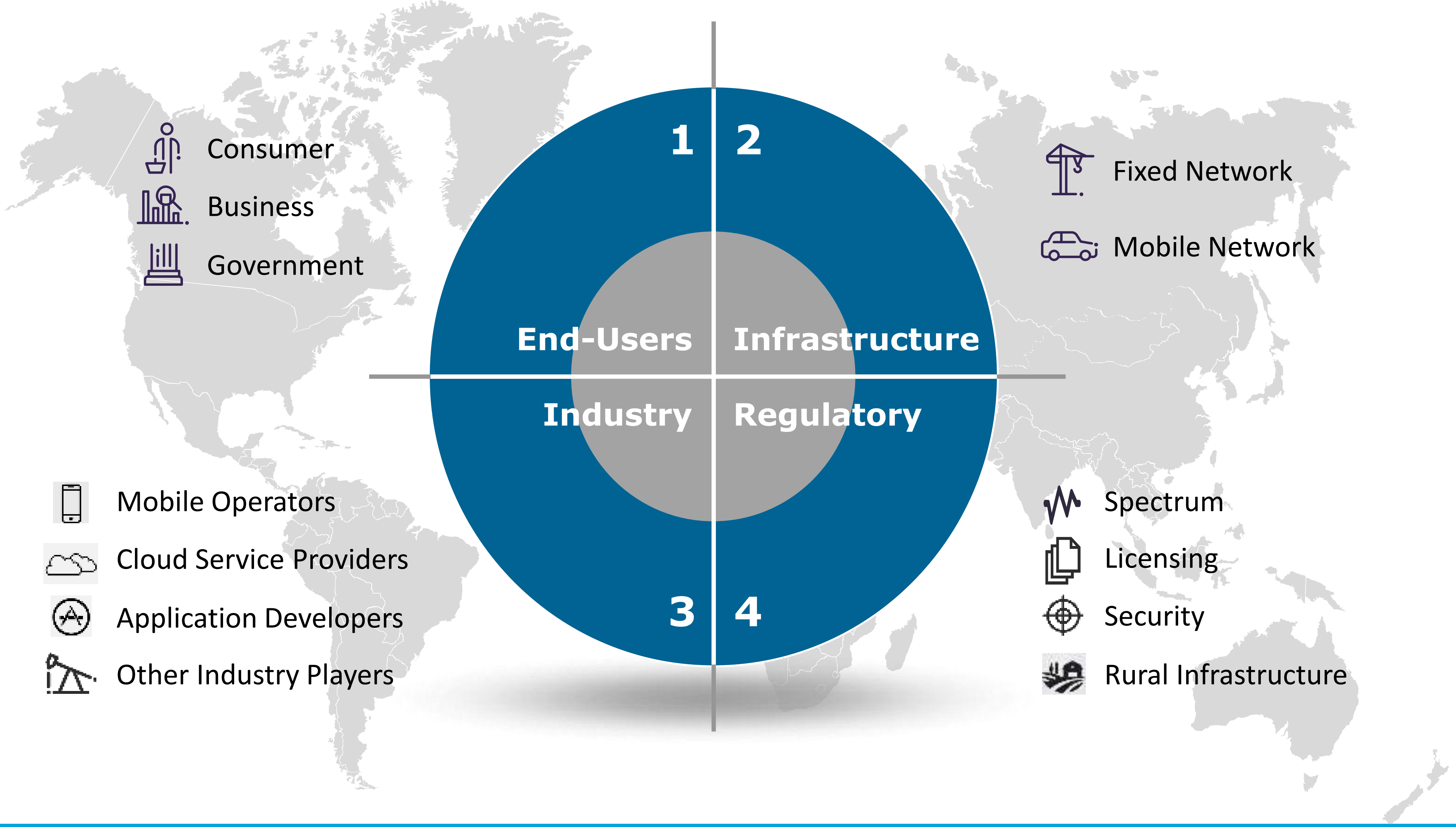
Need:

Trust-native Security, Privacy and Resilience

National roll out

Policy and Regulatory best practices

Readiness Framework



High level recommendations based on ITU 5G readiness assessments

Regulator can play a key role to drive 5G development
Concerted efforts across the industry will speed things up

SPECTRUM

Allowing 5G deployment with existing spectrum

- ✓ Create the environment for operators to gear up their planning
- ✓ Accelerate the migration of customers from legacy network to 4G/5G especially in the context of low-band (sub 1-GHz)

TRIAL

5G trials to go beyond technical testing

- ✓ Allow 5G trials to be extended for innovation and application development
- ✓ Allow enterprises and government agencies to test solutions and business case

INFRA SHARING

Promote active infrastructure sharing

- ✓ Lower the cost of deployment in the rural areas; and motivate operators to extend 5G coverage outside of main cities
- ✓ This should included passive and active elements – from towers, backhaul through to RAN and spectrum

High level recommendations based on ITU 5G readiness assessments

Taskforce

This organization will need to include relevant government, academia and industry stakeholders. The work of the organization can be divided into four working groups. There are also synergies between the activities of these working groups and the Digital Pakistan program.

Working Group 1

Policy & Regulation

- ✓ Spectrum allocation & sharing regulation
- ✓ Review licensing conditions (fees, QoS, type approval, etc.)
- ✓ Review existing policy and processes that could delay 5G development

Working Group 2

Infrastructure Development

- ✓ Review processes for installing 5G BTS within buildings, and external structures (rooftop, new towers, street furniture)
- ✓ Security and risks to 5G networks
- ✓ Facilitate infrastructure sharing – guidelines and codes
- ✓ International connectivity, backhaul requirements

Working Group 3

Industry Development

- ✓ Programs to encourage startups and developers for 5G solutions
- ✓ Attract international tech firms to extend 5G solutions to Mongolia
- ✓ 5G- enabled public services and smart city solutions
- ✓ Co-innovation among operators, enterprises, academia, etc.

Working Group 4

Education & Awareness

- ✓ Create awareness among enterprises in key industries (e.g., mining, transport, utilities)
- ✓ Collaborate with academia to develop training and research programs for 5G – in partnership with mobile operators

Key Issues for Considerations 1/3 Spectrum

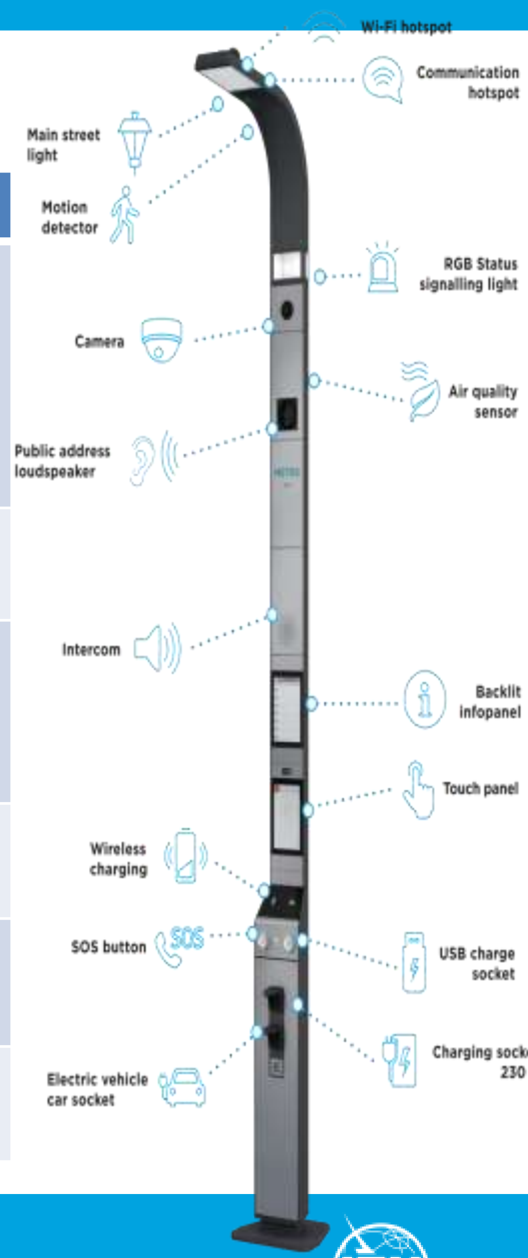
No.	Summary	For consideration…
1)	**Harmonize spectrum**	NRAs may consider allocating/assigning globally harmonized 5G spectrum bands
2)	**Spectrum roadmap**	NRAs may consider adopting a spectrum roadmap and a predictable renewal process
3)	**Spectrum sharing**	NRAs may consider allowing sharing to maximize efficient use of available spectrum, particularly to benefit rural areas
4)	**Spectrum pricing**	NRAs may consider selecting spectrum award procedures that favour investment
5)	**700Mhz spectrum**	Policy-makers may consider supporting the use of affordable wireless coverage (e.g. through the 700 MHz band) to reduce the risk of digital divide

Key Issues for Considerations 2/3 Backhaul

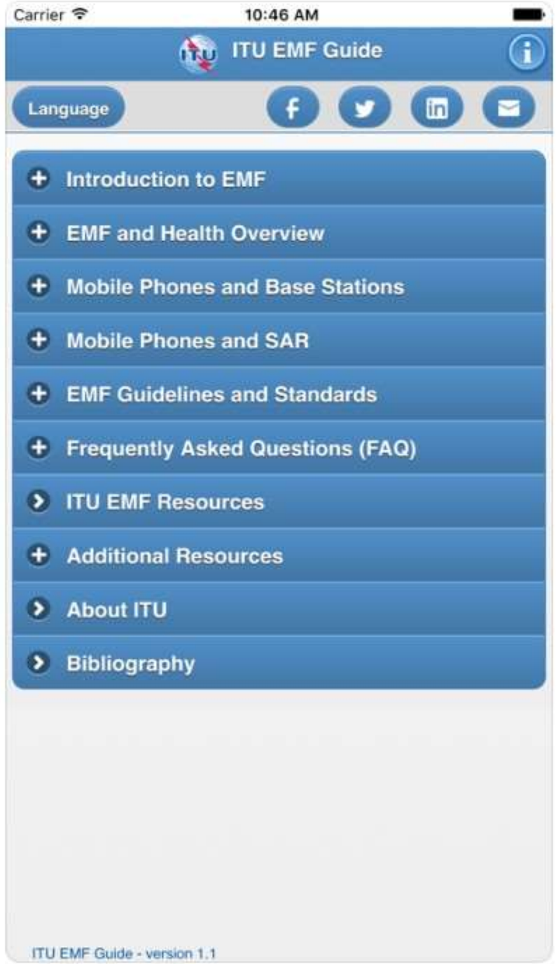
No.	Summary	For consideration…
1)	**Fibre investment incentives**	Policy-makers, where the market has failed, may consider stimulating fibre investment and passive assets through PPPs, investment funds and the offering of grant funding, etc.
2)	**Fibre tax**	Policy-makers may consider removing any tax burdens associated with deploying fibre networks to reduce the associated costs
3)	**Copper migration to fibre**	Policy-makers may consider adopting policies/financial incentives to encourage migration from copper to fibre and stimulate deployment of fibre
4)	**Wireless backhaul**	Operators may consider a portfolio of wireless technologies for 5G backhaul in addition to fibre, including point-to-multipoint (PMP), microwave and millimeter wave (mmWave) radio relays, high altitude platform systems (HAPS) and satellites
5)	**Wayleave (rights of way) agreements**	Policy-makers may agree upon standardized wayleave agreements to reduce cost and time to deploy fibre and wireless networks

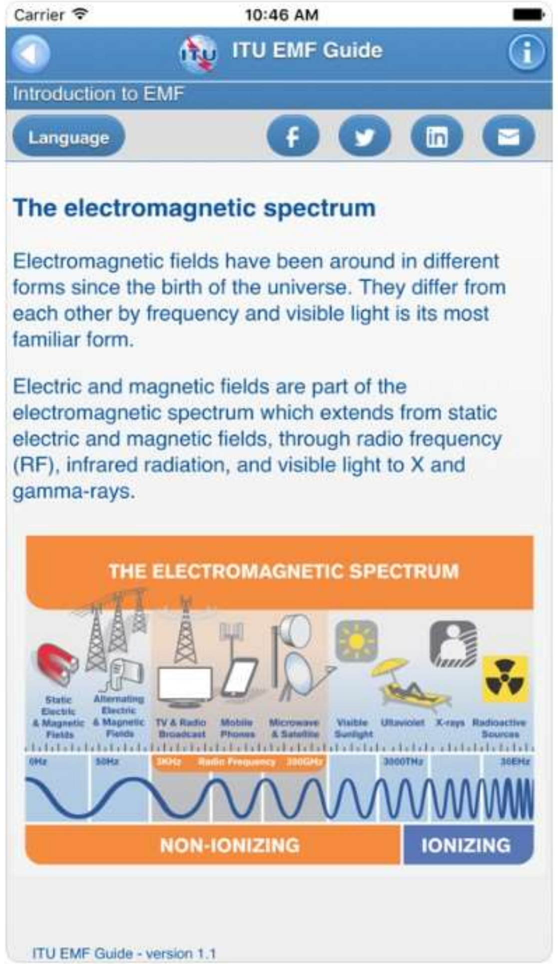
Key Issues for Considerations 3/3 Policy

No.	Summary	For consideration…
1)	**Access/sharing of passive infrastructure**	Policy makers may consider allowing access to government-owned infrastructure such as utility poles, traffic lights and lampposts to give wireless operators the appropriate rights to deploy electronic small cell apparatus to street furniture NRAs may consider continuing to elaborate existing duct access regimes to encompass 5G networks allowing affordable fibre deployments
2)	**Access costs**	Policy-makers/NRAs may consider ensuring reasonable fees are charged to operators to deploy small-cell radio equipment onto street furniture
3)	**Asset database**	Policy-makers may consider holding a central database identifying key contacts, showing assets such as utility ducts, fibre networks, CCTV posts, lampposts, etc. This will help operators cost and plan their infrastructure deployment more accurately
4)	**Investment case**	Policy-makers may consider undertaking their own independent economic assessment of the commercial viability of deploying 5G networks
5)	**4G network strategy**	Until the case for 5G networks can be clearly made, policy makers may consider enhancing the availability of and boosting the quality of 4G networks
6)	**5G test beds**	Policy-makers may consider encouraging 5G pilots and test beds to test 5G technologies, and use cases, and to stimulate market engagement



Addressing Public apprehensions





Working together

Component	Regulatory / Policy Makers	Enterprises/ Organization/ Associations	Service/ Technology operators	PPP organization	Challenges
Spectrum	•	•	•		• Local permits and planning for spectrum usage • Auctions and high fees for spectrum procurement • Fragmentation during allocations of spectrum
Infrastructure	•	•	•	•	• Fibre backhaul: capacity, availability, deployment cost and long- distance reach • New funding models for fibre deployment/ownership • Small cell deployments: local permits and planning
Devices		•	•		• Availability of devices compatible with local spectrum and allocations, and in line with harmonized global standards • Lack of clear roadmap for device manufacturers
Services	•	•	•	•	• Guidelines and standards related to data exchange across borders • Use cases arising from integration with new technologies (artificial intelligence, big data, internet of things) • Lack of incentives for cross-industry collaborations • Skills upgrade of service provider resources
Impact		•			• Limited focus on societal and environmental benefits due to 5G • Disintegration of benefits provided by 5G vs benefits by other IT technologies
Security	•		•	•	• Security of personal data collection • Device vulnerability • Network data transmission vulnerabilities

Source*:* World Economic Forum (WEF) and PWC - *The Impact of 5G: Creating New Value across Industries and Society*

Upcoming study

IMT2020 (5G) Enablers in the Asia-Pacific

HUAWEI

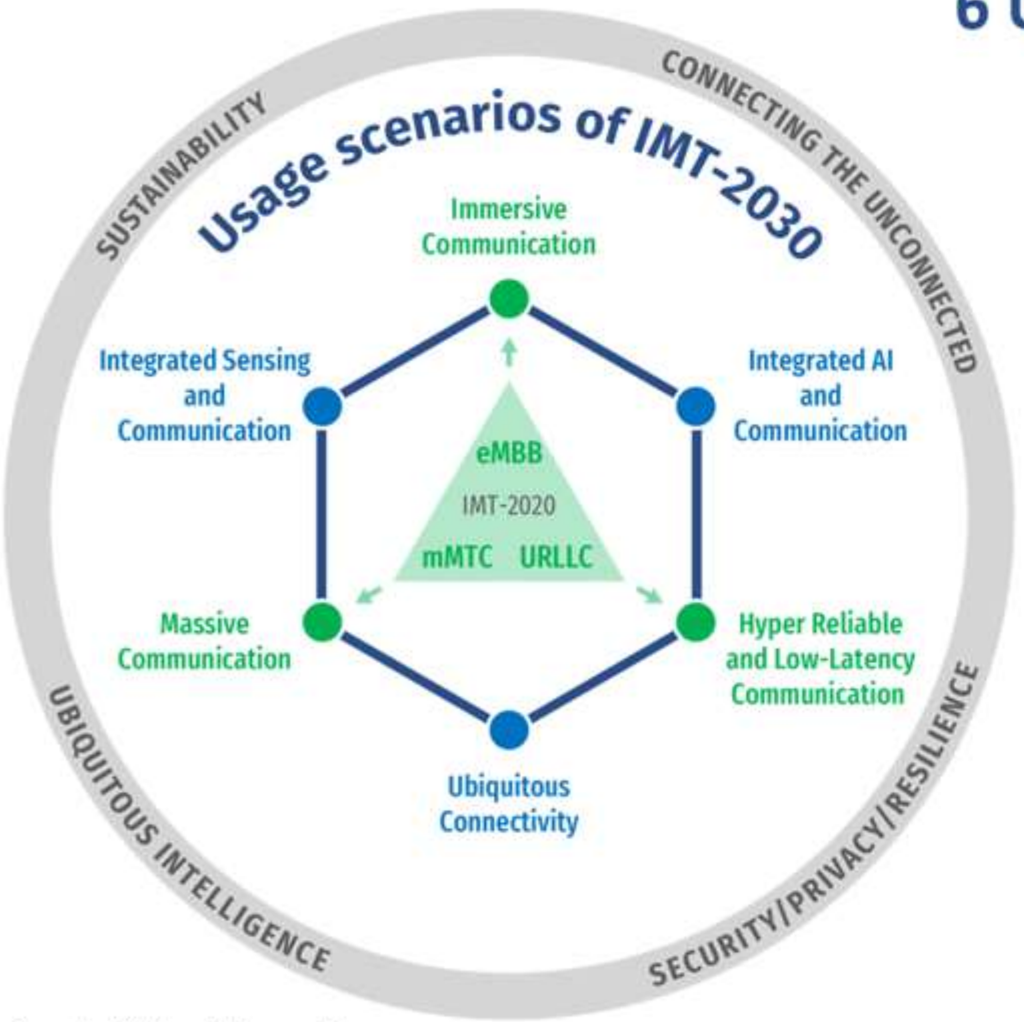
构建万物互联的智能世界
Building a Fully Connected, Intelligent World

- Determining the key enablers and the relevant indicators and available data
- Econometric analysis of 5G Enablers results, including specific trends
- Conclusion and recommendations

IMT towards 2030 and beyod

Already working ahead ...

IMT towards 2030 and beyond



So called "Wheel diagram"

6 Usage scenarios

Extension from IMT-2020 (5G)

- eMBB ➡ **Immersive** Communication
- mMTC ➡ **Massive** Communication
- URLLC ➡ **HRLLC** (Hyper Reliable & Low-Latency Communication)

New

- Ubiquitous Connectivity
- Integrated AI and Communication
- Integrated Sensing and Communication

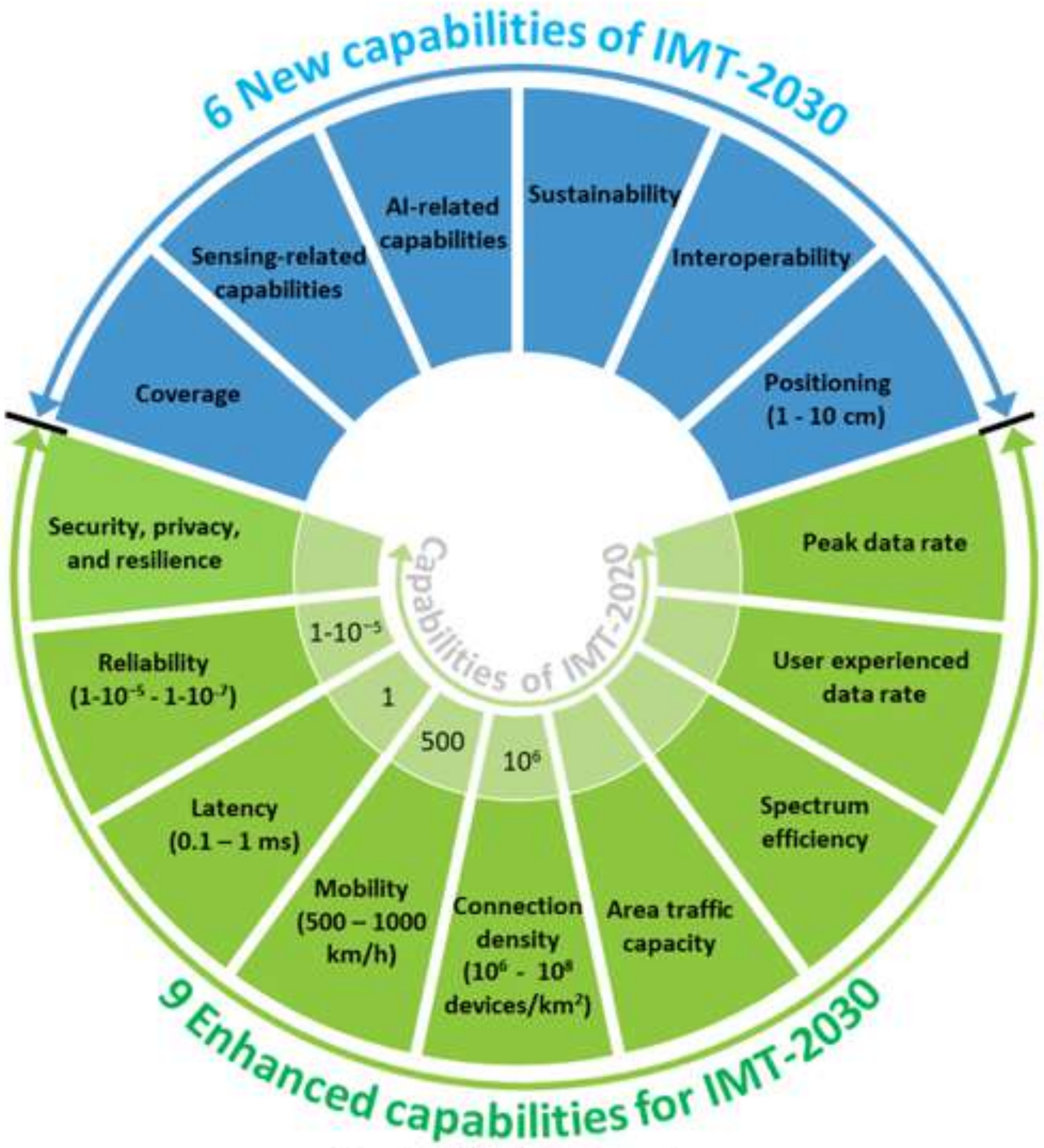
4 Overarching aspects:

act as design principles commonly applicable to all usage scenarios

Sustainability, Connecting the unconnected,
Ubiquitous intelligence, Security/privacy/resilience

Source: **ITU** https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2030/Pages/default.aspx

Capabilities of IMT-2030



So called "Palette diagram"

The range of values given for capabilities are estimated targets for research and investigation of IMT-2030.

All values in the range have equal priority in research and investigation.

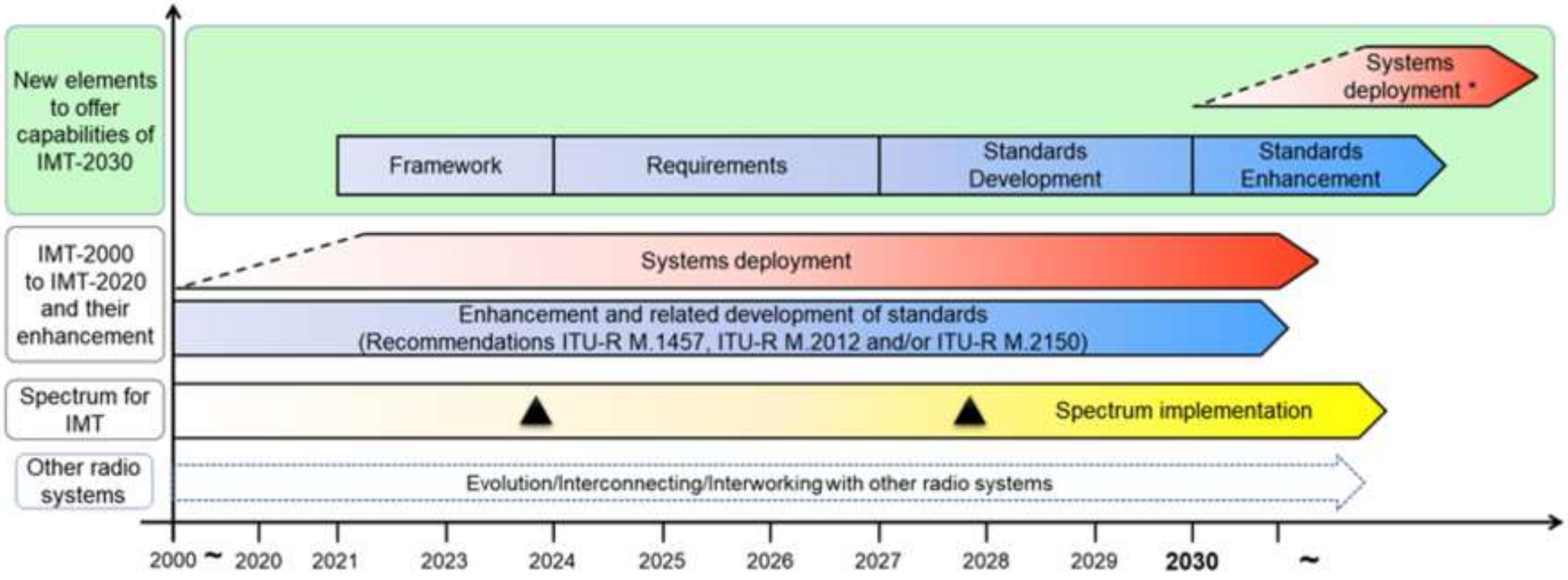
For each usage scenario, a single or multiple values within the range would be developed in future in other ITU-R Recommendations/Reports.

Source: **ITU**
https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2030/Pages/default.aspx

IMT towards 2030 and beyond

Relationship and Timelines

- Roadmap for technology/standard development, deployment and spectrum
- In addition, enhancement of existing IMTs and relationship with other radio systems



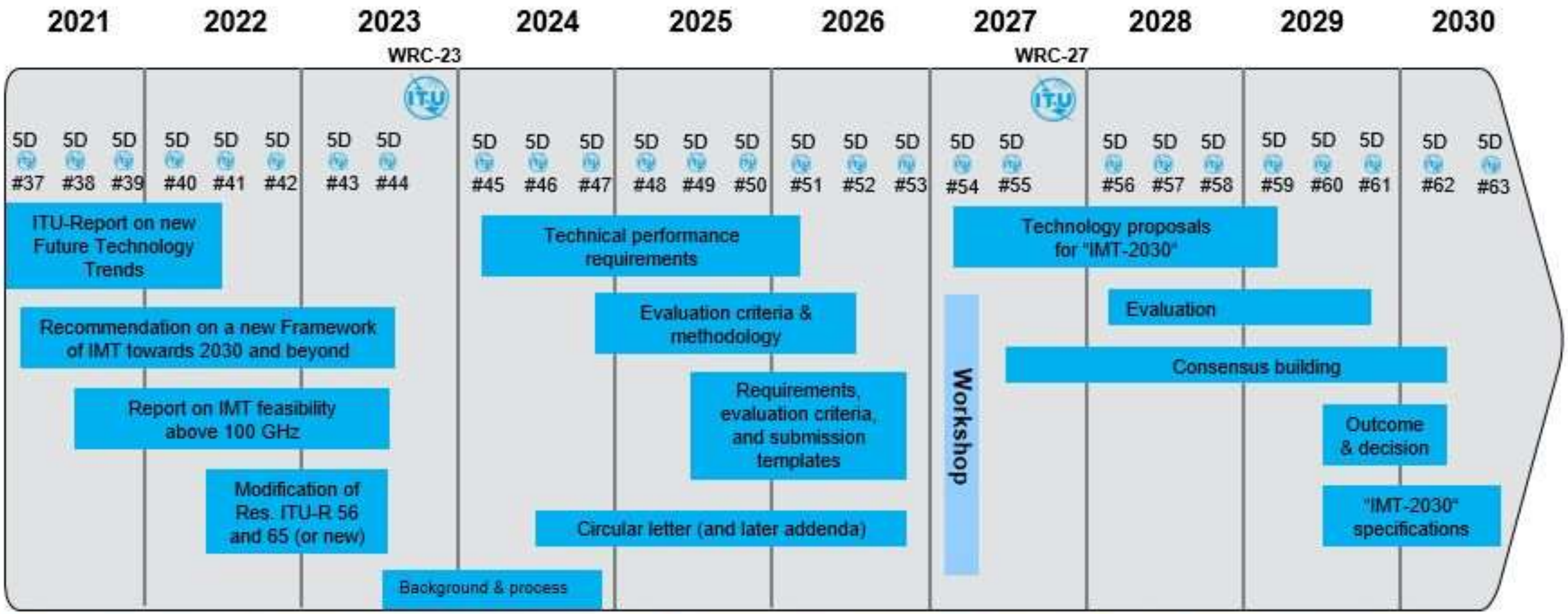
The sloped dotted lines in systems deployment indicate that the exact starting point cannot yet be fixed.

▲ : Possible spectrum identification at WRC-23, WRC-27 and future WRCs

* : Systems to satisfy the technical performance requirements of IMT-2030 could be developed before year 2030 in some countries.
: Possible deployment around the year 2030 in some countries (including trial systems)

Source: **ITU**
https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2030/Pages/default.aspx

ITU-R timeline for IMT-2030



Note 1: WP 5D #59 will additionally organize a workshop involving the Proponents and registered Independent Evaluation Groups (IEGs) to support the evaluation process

Note 2: While not expected to change, details may be adjusted if warranted. Content of deliverables to be defined by responsible WP 5D groups

Note by the ITU-R Radiocommunication Bureaux: *This document is taken from Attachment 2.12 to Chapter 2 of Document 5D/1361 (Meeting report WP 5D #41, June 2022) and adjustments could be made in the future. ITU holds copyright in the information – when used, reference to the source shall be done.*

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