BRUNEI DARUSSALAM

TASK FORCE REPORT

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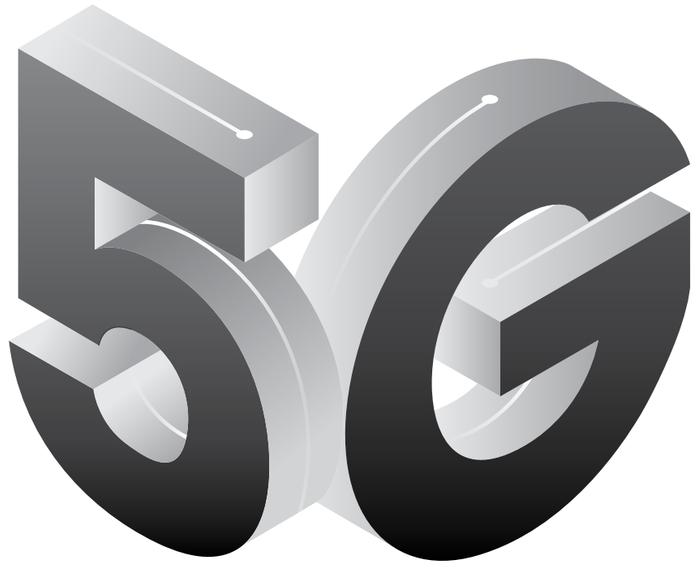

TASK FORCE REPORT

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INTRODUCTION

1. INTRODUCTION

1.1. Background

Brunei Darussalam envision a Smart Nation through Digital Transformation[1], to drive and enhance our socio-economic growth through adoption of key technological developments such as 5G, Big Data and Artificial Intelligence. Against this backdrop, in April 2020, the Authority for Info-communications Technology Industry of Brunei Darussalam (AITI) has established a Brunei Darussalam 5G Taskforce to facilitate the implementation of 5G in ensuring readiness through exploring business model across the vertical industry and to support Smart Nation initiatives to conceptualise and deliver smart services to generate social and boost economic value in Brunei Darussalam.

The 5G Taskforce's aim is to provide a set of recommendations by First Quarter of 2021, that will support the development of a modern 5G telecommunications system unlocking the benefits of mobile connectivity as well as new opportunities to enhance industry's development and drive economic growth and innovation towards achieving the government's aspiration of Wawasan Brunei 2035.

The 5G Taskforce was chaired by the Chief Executive of AITI and divided into three (3) Working Groups with members comprises from ministries, government agencies, telecommunications service providers, equipment vendors, academia and industry.

The structure of the 5G Taskforce is as follows:

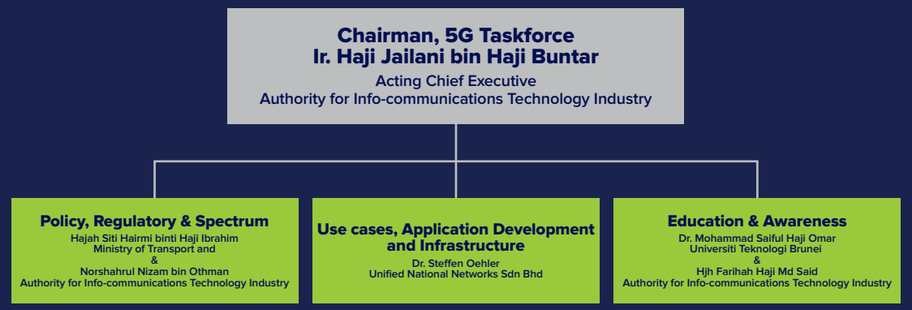


FIGURE 1: BRUNEI DARUSSALAM 5G TASKFORCE STRUCTURE

The 5G Taskforce membership are listed out in **Appendix 4**.

[1] http://www.mtic.gov.bn/DE2025/documents/Digital%20Economy%20Masterplan%202025.pdf

1.2. About 5G, Its Trends & Development

The world is currently in amidst of a technological transformation that will fundamentally change the way we live, work and communicate. It is difficult to predict precisely how this transformation will unfold and impact different industries and countries. However, we know that this transformation is unlike anything humankind has experience before due to the sheer pace and breadth of these changes. Many see these changes as an ushering of new era of growth, change and opportunity.

Similarly, mobile technology has come a long way from facilitating communication to being a necessity in our lives. The 5G technology is a breakthrough – it is not just an upgrade over 4G. It is expected to unleash new capabilities that connect virtually, reliably everyone and everything together including machines, objects and devices.

The International Telecommunication Union (ITU) announced that 5G systems should support the three (3) key components as illustrated in Figure 2; the enhanced mobile broadband (eMBB) use case, emerging use cases with a variety of applications such as massive machine-type communications (mMTC) and ultra-reliable and low latency communications (URLLC).

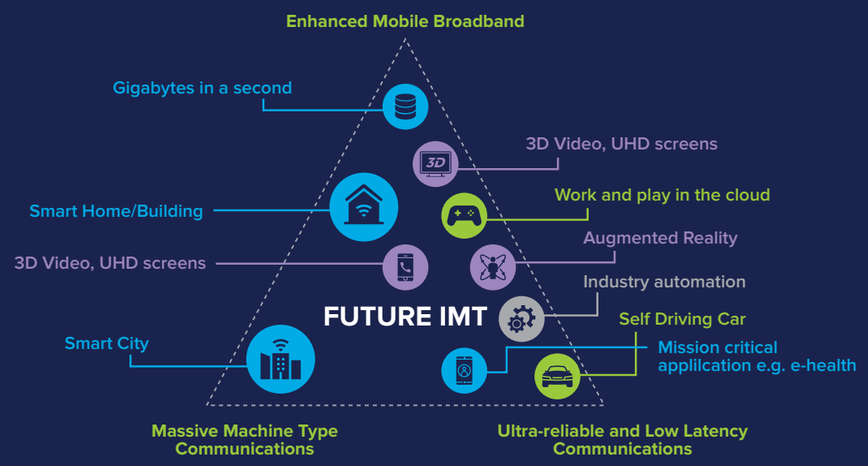


FIGURE 2: 5G USAGE SCENARIOS

a. Enhanced Mobile Broadband (eMBB)

A progression to the existing 4G LTE services with improved performance and seamless user experience, up to 10 Gigabytes per second (Gbps) peak throughput. It will be the first phase of 5G services to be commercially available worldwide. The usage scenario covers data-driven use cases requiring high data rates across a wide coverage area, like on-the go, ultra-high definition (UHD) video streaming, real-time traffic alerts, high-speed internet access or playing games involving 3D 4K video.

b. Ultra-reliable and Low Latency Communications (uRLLC)

This use case has stringent requirements capabilities butaims to cater to the digital industry's demand focusing on optimizing large amounts of data and ultra-responsive connections in less than 1ms latency. Some examples include wireless control self-driving car, mission critical application for remote medical surgery and e-health, industrial manufacturing or production processes, distribution automation in a smart grid, etc.

c. Massive Machine Type Communications (mMTC)

A communication paradigm connecting a large number of devices typically transmitting a relatively low-cost device, low volume of non-delay-sensitive data with a long battery life. These future applications target in developing a digital society services such as smart city and smart agriculture.

The key functional drivers of 5G will open the door to Fourth Industrial Revolution (IR4.0), powered by both established and emerging technologies, including Internet of Things (IoT), Artificial Intelligence (AI), advanced data analytics, robotic process automation, robotics, cloud computing, virtual and augmented reality and drones.

As of December 2020, there are 412 operators in 131 countries investing in 5G networks in the form of tests, trials, pilots, planned and actual deployments. Of those, 140 operators in 59 countries have launched commercial 3GPP-compatible 5G services and 61 operators are investing in 5G standalone[2].

FIGURE 3: GROWTH OF LAUNCHED COMMERCIAL 5G NETWORKS

Substantially, 5G will become a major economic driver-spurring the innovation of new industries, products, services and job creation. According to a study[3] done by IHS Markit that was commissioned by Qualcomm Technologies, 5G will enable growth trajectory sales at $13.2 trillion in global economic output by 2035, generating up from 22.3 million jobs in the 5G global value chain.

To better understand how to realize this large estimated economic output potential, this 5G Taskforce report highlights multiple 5G use-cases that may provide a positive impact to Brunei Darussalam. Additionally, it recommends several policy considerations. It also maps our local 5G ecosystem to identify its functions, its stakeholders and interdependencies, and the actions needed to accelerate 5G deployment and fully realize its potential.

[2] GSA NTS Snapshot December 2020
[3] https://www.qualcomm.com/media/documents/files/ihs-5g-economic-impact-study-2019.pdf

2

OPPORTUNITIES OF 5G FOR BRUNEI DARUSSALAM

2. OPPORTUNITIES OF 5G FOR BRUNEI DARUSSALAM

2.1. Brunei ICT market development

To understand the potentials of digitalization and use cases for 5G technology the ICT market of Brunei Darussalam needs to be assessed along main market indicators.

Potential of our growing youth population

Based on the 2020 figures, the population of Brunei Darussalam[4] was estimated to be 459,000. The population was expected to be between 465,000 to 470,000 which consists of 53% male and 47% female. The Bruneian population is a young population, compared to other developed countries, whereby:

66% of all population is below 40 years old

37% of the population is in the age group 15-34 years

Both indicators are important for the assessment of the needs for fixed and mobile broadband services in the country. In addition, it allows to conclude, that these are the population parts which have had access to telecommunication services and Internet, using smartphones and computers at home and during education or at the working place, hence representing the population share with solid computer literacy.

[4] The current population numbers are based on forecasts provided by the Department of Economic Planning and Statistics.

Dynamic domestic market structure

The networks of Brunei's four telecommunications providers: Telekom Brunei Berhad (TelBru), Datastream Technology Sdn Bhd (DST) and Progresif Cellular Sdn Bhd (Progresif), as well as Brunei International Gateway Sdn Bhd (BIG), have all been consolidated under a single entity, the Unified National Networks Sdn Bhd (UNN). With the target of transforming into a more connected and digitally integrated society, this step is a major milestone for progress.

High mobile penetration rate

The current mobile penetration rate[5] as of December 2020 reached 125%, more than 570,000 active SIM cards have been registered in the mobile network. The mobile network predominantly is used for mobile data and Internet, whereby 99.6% of all subscriptions are using 3G and 4G capable handsets. It is measured that 99% of all traffic in the mobile network is data, which more than 75% of data in the mobile network is created in the 4G network, the remaining part in the 3G network. It is anticipated that the 2G network will be shut down in early 2021 to reassign the frequencies to the 4G and 5G network. Moreover, 98% of mobile subscriptions are active in devises, used by humans, and with the available IoT (Internet of Things) services in Brunei it is expected that more active SIM cards will be used for Machine to Machine communication.

Increasing usage and development trends

2020 was not a typical year in terms telecommunication trends, due to the COVID-19 pandemic, where an over proportional increase in data utilization in fixed and mobile networks has been registered. However, after normalization of the COVID situation in Brunei, the data growth trends returned to the expected numbers as follows;

- In December 2020, the total amount of mobile data was 14% higher than in January 2020, with a comparable number of active SIM cards over the period. It is expected, that the mobile data traffic will continue to grow with annually 10% increase,
- In December 2020, each Fixed Broadband customer in average has used 33% more data each month, compared with January 2020. It is expected, that the FBB penetration rate will continue to grow in Brunei Darussalam, although not with the same speed as in 2020, reaching 75% by end of 2021.

[5] Number of mobile subscriptions (active SIM cards) divided by the population number of Brunei Darussalam.

2.2. Adopting Technology to Close our Innovation Gap

However, in light of our development, according to the World Intellectual Property Organisation (WIPO) - 2020 Global Innovation Index edition[6], Brunei Darussalam is ranked 71st out of 131 countries on the overall Index ranking, while achieving the 59th place in the Information and Communication Technologies (ICTs) infrastructure specific thrusts.

BRUNEI DARUSSALAM

GII 2020 rank **71**

Output rank	Input rank	Income	Region	Population (mn)	GDP, PPP$	GDP per capita, PPP$	GII 2019 rank
113	39	High	SEAO	0.4	35.9	70,177.3	71

		Score/Value	Rank
INSTITUTIONS		80.3	25
1.1	**Political environment**	83.6	18
1.1.1	Political and operational stability*	94.6	3
1.1.2	Government effectiveness*	78.1	22
1.2	**Regulatory environment**	80.7	30
1.2.1	Regulatory quality*	59.9	39
1.2.2	Rule of law*	63.1	37
1.2.3	Cost of redundancy dismissal, salary weeks	8.0	1
1.3	**Business environment**	76.6	43
1.3.1	Ease of starting a business*	94.9	15
1.3.2	Ease of resolving insolvency*	58.2	54
HUMAN CAPITAL & RESEARCH		34.3	51
2.1	**Education**	46.9	63
2.1.1	Expenditure on education, % GDP	4.4	64
2.1.2	Government funding/pupil, secondary, % GDP/cap	23.6	25
2.1.3	School life expectancy, years	14.3	66
2.1.4	PISA scales in reading, maths, & science	423.1	53
2.1.5	Pupil-teacher ratio, secondary	8.3	12
2.2	**Tertiary education**	45.4	25
2.2.1	Tertiary enrollment, % gross	31.4	80
2.2.2	Graduates in science & engineering, %	39.2	5
2.2.3	Tertiary inbound mobility, %	4.6	49
2.3	**Research & development (R&D)**	10.6	[56]
2.3.1	Researchers, FTE/mn pop.	n/a	n/a
2.3.2	Gross expenditure on R&D, % GDP	n/a	n/a
2.3.3	Global R&D companies, avg. exp. top 3, mn $US	0.0	42
2.3.4	QS university ranking, average score top 3*	21.2	49
INFRASTRUCTURE		47.0	46
3.1	**Information & communication technologies (ICTs)**	69.2	59
3.1.1	ICT access*	72.7	52
3.1.2	ICT use*	71.4	38
3.1.3	Government's online service*	72.2	68
3.1.4	E-participation*	60.7	93
3.2	**General infrastructure**	44.0	14
3.2.1	Electricity output, kWh/mn pop.	9,668.3	14
3.2.2	Logistics performance*	29.9	79
3.2.3	Gross capital formation, % GDP	46.2	3
3.3	**Ecological sustainability**	27.6	70
3.3.1	GDP/unit of energy use	8.3	75
3.3.2	Environmental performance*	54.8	44
3.3.3	ISO 14001 environmental certificates/bn PPP$ GDP	0.7	72
MARKET SOPHISTICATION		45.7	76
4.1	**Credit**	56.9	19
4.1.1	Ease of getting credit*	100.0	1
4.1.2	Domestic credit to private sector, % GDP	35.0	86
4.1.3	Microfinance gross loans, % GDP	n/a	n/a
4.2	**Investment**	22.2	124
4.2.1	Ease of protecting minority investors*	40.0	110
4.2.2	Market capitalization, % GDP	n/a	n/a
4.2.3	Venture capital deals/bn PPP$ GDP	0.0	47
4.3	**Trade, competition, and market scale**	58.1	87
4.3.1	Applied tariff rate, weighted avg., %	0.0	2
4.3.2	Intensity of local competition*	61.2	105
4.3.3	Domestic market scale, bn PPP$	35.9	114
BUSINESS SOPHISTICATION		33.5	44
5.1	**Knowledge workers**	56.9	[22]
5.1.1	Knowledge-intensive employment, %	40.7	25
5.1.2	Firms offering formal training, %	n/a	n/a
5.1.3	GERD performed by business, % GDP	n/a	n/a
5.1.4	GERD financed by business, %	n/a	n/a
5.1.5	Females employed w/advanced degrees, %	11.7	59
5.2	**Innovation linkages**	23.9	53
5.2.1	University/industry research collaboration*	39.4	78
5.2.2	State of cluster development*	44.2	80
5.2.3	GERD financed by abroad, % GDP	n/a	n/a
5.2.4	JV-strategic alliance deals/bn PPP$ GDP	0.1	35
5.2.5	Patent families 2+ offices/bn PPP$ GDP	0.2	46
5.3	**Knowledge absorption**	19.7	103
5.3.1	Intellectual property payments, % total trade	0.5	70
5.3.2	High-tech imports, % total trade	4.4	115
5.3.3	ICT services imports, % total trade	0.8	88
5.3.4	FDI net inflows, % GDP	2.1	81
5.3.5	Research talent, % in business enterprise	n/a	n/a
KNOWLEDGE & TECHNOLOGY OUTPUTS		6.5	129
6.1	**Knowledge creation**	5.6	103
6.1.1	Patents by origin/bn PPP$ GDP	0.7	75
6.1.2	PCT patents by origin/bn PPP$ GDP	0.1	77
6.1.3	Utility models by origin/bn PPP$ GDP	n/a	n/a
6.1.4	Scientific & technical articles/bn PPP$ GDP	4.3	95
6.1.5	Citable documents H-index	3.3	119
6.2	**Knowledge impact**	4.7	[125]
6.2.1	Growth rate of PPP$ GDP/worker, %	n/a	n/a
6.2.2	New businesses/th pop. 15-64	2.4	53
6.2.3	Computer software spending, % GDP	n/a	n/a
6.2.4	ISO 9001 quality certificates/bn PPP$ GDP	2.2	83
6.2.5	High- and medium-high-tech manufacturing, %	2.7	106
6.3	**Knowledge diffusion**	9.1	125
6.3.1	Intellectual property receipts, % total trade	n/a	n/a
6.3.2	High-tech net exports, % total trade	0.0	128
6.3.3	ICT services exports, % total trade	0.0	130
6.3.4	FDI net outflows, % GDP	2.1	35
CREATIVE OUTPUTS		16.5	89
7.1	**Intangible assets**	19.6	93
7.1.1	Trademarks by origin/bn PPP$ GDP	5.5	116
7.1.2	Global brand value, top 5,000, % GDP	n/a	n/a
7.1.3	Industrial designs by origin/bn PPP$ GDP	0.0	116
7.1.4	ICTs & organizational model creation*	47.5	90
7.2	**Creative goods and services**	2.6	[113]
7.2.1	Cultural & creative services exports, % total trade	0.0	111
7.2.2	National feature films/mn pop. 15-69	n/a	n/a
7.2.3	Entertainment & Media market/th pop. 15-69	n/a	n/a
7.2.4	Printing and other media, % manufacturing	0.5	89
7.2.5	Creative goods exports, % total trade	0.1	90
7.3	**Online creativity**	24.2	49
7.3.1	Generic top-level domains (TLDs)/th pop. 15-69	7.2	45
7.3.2	Country-code TLDs/th pop. 15-69	0.9	88
7.3.3	Wikipedia edits/mn pop. 15-69	66.2	46
7.3.4	Mobile app creation/bn PPP$ GDP	n/a	n/a

NOTES: ● indicates a strength; ○ a weakness; ◆ an income group strength; ◇ an income group weakness; * an index; ª a survey question. ⓘ indicates that the economy's data are older than the base year; see Appendix II for details, including the year of the data, at http://globalinnovationindex.org. Square brackets [ ] indicate that the data minimum coverage (DMC) requirements were not met at the sub-pillar or pillar level.

FIGURE 4: BRUNEI DARUSSALAM RANKING BASED ON 2020 GLOBAL INNOVATION INDEX

[6] https://www.globalinnovationindex.org/gii-2020-report# - The Global Innovation Index provide insightful data on innovation, which may help in evaluating innovation performance and making informed innovation policy considerations. Innovation is widely recognized as a central driver of economic growth and development.

As Brunei Darussalam is categorised under high-income group, the 2020 Global Innovation Index identified Brunei Darussalam to be performing below expectations for high-income group level of development, as shown in the figure below.

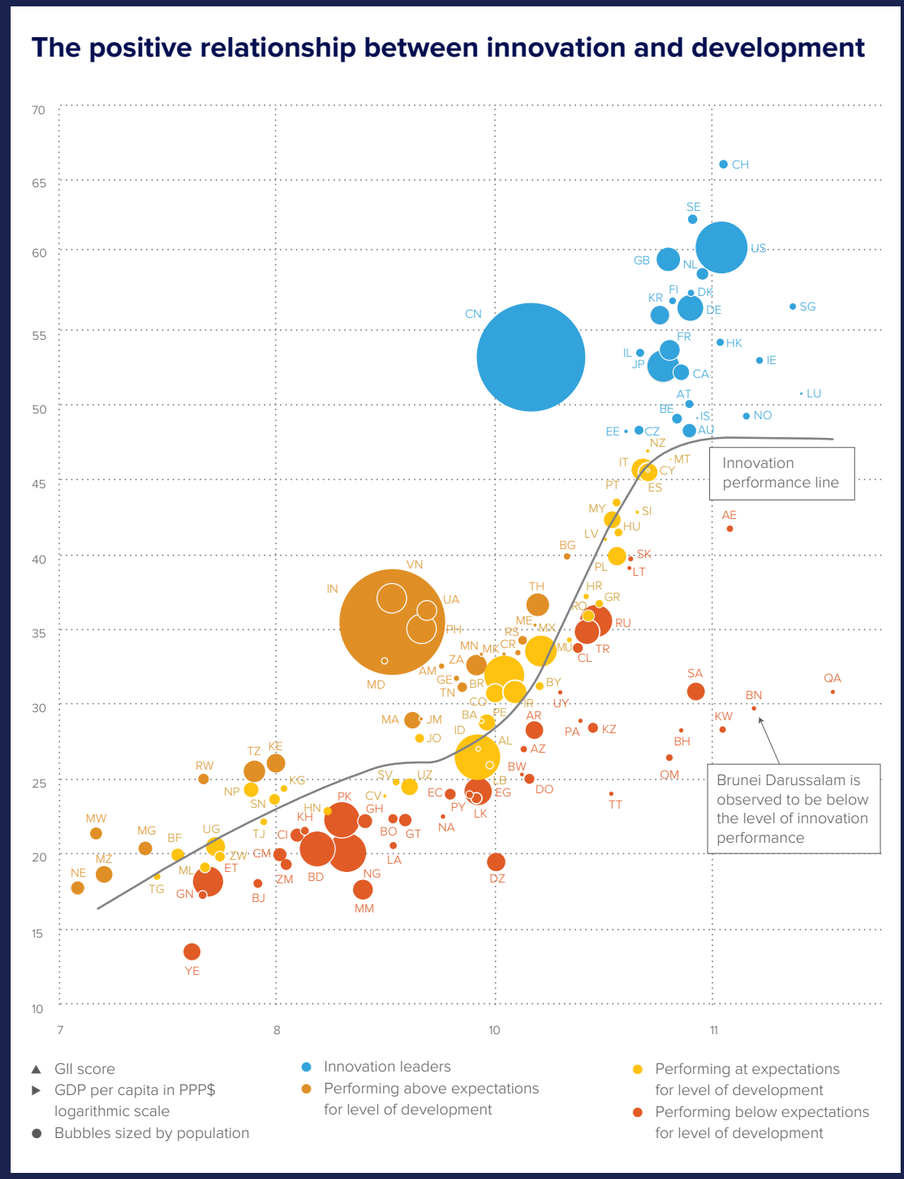


FIGURE 5: INNOVATION PERFORMANCE FOR A GIVEN ECONOMY RELATIVE TO GDP PER CAPITA BASED ON 2020 GLOBAL INNOVATION INDEX

As such, according to the 2020 Global Innovation Index Report, spurring development of industry clusters, adoption of new technologies such as 5G, protecting IPRs, financing innovative start-ups, or providing a market by buying new technologies and innovations, is central to whether or not a country will emerge as a champion in the digital economy.

2.3. 5G Technology as Enabler for Digital Economy

Investment in digital technologies is an investment in the new era of national sustainable and inclusive economic growth, development and competitiveness. Undoubtedly, 5G enables digitisation and that it is expected to bring boundless connectivity to improve human lives and automation. However, as much attention as 5G gets an emerging technology, there is still a sense of uncertainty and unfamiliarity around how mobile network will unlock its true business value in generating a sustainable economic world with 5G.

Towards achieving a future-proof strategy, our aspiration is to elevate 5G as a key technology for digital economy, innovation and smart projects in alignment with Brunei Darussalam's Digital Economy aspiration, supporting the four strategic thrusts which have been identified to support the mission and vision of the Digital Economy Masterplan 2025 as follows:

Industry Digitalization

This strategic thrust, among others, focuses on the need to evaluate the readiness of stakeholders to adopt IR4.0 technologies and to undertake a comprehensive awareness programme, especially for macro, small and medium enterprises (MSMEs);

Government Digitalization

This strategic thrust emphasizes on the important role of the government in facilitating economic growth. Among the focused areas which are emphasized are the implementation of a digital identity ecosystem, innovation of public experience and evolvement of cloud usage;

A Thriving Digital Industry

The ICT sector needs to emphasizes on the application of technologies to nurture and sustain growth for improvement of local digital and other sectors; and

Manpower and Talent Development

Manpower needs to be equipped with the capabilities required in line with the rapid advancement in technology.

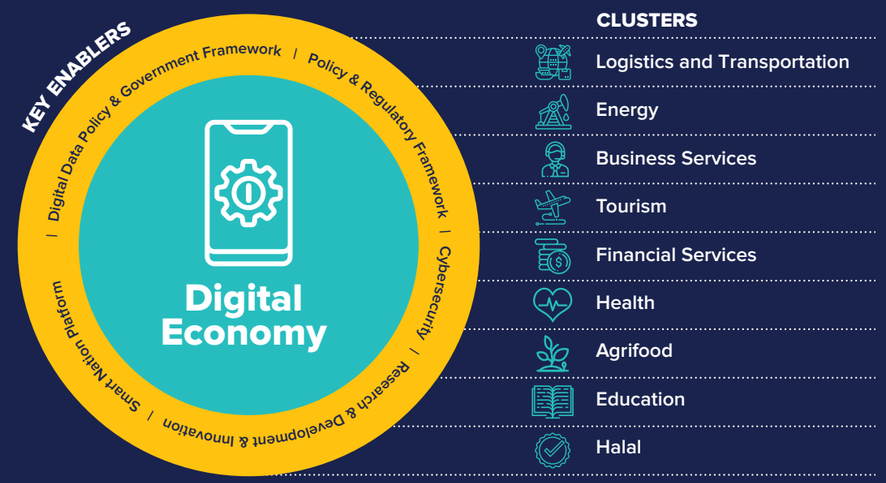


FIGURE 6: NINE CLUSTERS UNDER BRUNEI DARUSSALAM DIGITAL ECONOMY

2.4. Integrating 5G for Smart City

Smart cities are aimed at improving the use of the public resources, increasing the quality of the services with focus on comfort, maintenance and sustainability, while the operational costs of the public utilities are reduced, within an IoT framework. According to Ericsson, there will be 24 billion interconnected devices, meaning almost every object us around us: streetlights, thermostats, electric meters, fitness trackers, water pumps, cars, elevators, and even gym vests by 2050[7]. The operation of Smart City relies enormously on IoT, and 5G networks are expected to be the great IoT enabler, making them inextricably linked.

While offering efficient network infrastructure and connectivity, telecommunications operators have a fundamental role to play in this smart city value chain. Telecommunications network infrastructure is best placed to deliver digital smart city services to future citizens.

Particularly, Datastream Digital (Digital) Sdn Bhd Network has introduced the Unified Smart Metering System (USMS) that will allow households to monitor and manage their electricity and water usage in one platform. The solution aims to provide customers with up to date, real-time billing and enhanced customer service portal.

Specifically, with 5G and massive Machine Type Communications (mMTC), telecommunications industry players should play collaborative role in supporting city management by leveraging data gathered through widespread embedded sensors and controls, real time data analytics and ubiquitous communications. As industry players are also well positioned to provide the technology platform from which these future services can be delivered.

It is envisioned that various industry players could join hands on the overall smart city ecosystems, ushering in a new era of co-development, co-governance and co-existence. This includes the provision of smart city data platform - that brings together and integrates data flows within and across businesses, government and the public, to enable public agencies to rapidly shift from fragmented operations to include predictive effective operations, and innovative ways of engaging and serving community.

[7] https://www.ericsson.com/en/internet-of-things

3

STRATEGIC RECOMMENDATIONS

5G Taskforce recommended

5 Strategies

to unlock the benefits of mobile connectivity as well as new opportunities to drive economic growth and innovation towards achieving national aspiration of Wawasan Brunei 2035.

TELECOMMUNICATIONS AS UTILITY

To regard telecommunications as more than just connectivity, but rather a utility to support the key initiatives on 5G in turns to enable key innovation and smart services.

READILY AVAILABLE SPECTRUM RESOURCES

Make available spectrum of 80MHz in the 700MHz, 100MHz in the 3.5 GHz and 1GHz in the 26 GHz / 28 GHz band.

TIMELY TECHNOLOGY & INFRASTRUCTURE DEPLOYMENT

Launch 5G services in Brunei Darussalam by middle of 2022, with aim to reach 75% of the population by 2025 and foster development of base-stations sites.

SPUR COMMERCIAL 5G USE-CASES

Demonstrate 5G application and provide incentives to spur development of 5G use-cases. Encourage collaboration among industry players, public sector and academic institutions to create 5G innovation lab.

ENHANCE AWARENESS & CAPACITY BUILDING

Raise awareness and adoption programme to encourage all parties to collaborate on accelerating 5G innovation and provide capacity development program for next 5 years to be 5G-ready workforce.

3. STRATEGIC RECOMMENDATIONS

3.1. Telecommunications as utility

Telecommunications is seen to play an important role in our everyday lives. The presence of advanced technologies such as television, internet, phone and radio has definitely enhanced long distance communication in our daily lives, more so now that we are facing the new 'norm' during the COVID19 pandemic. Telecommunications is no longer a nice-to-have. Like others, water, electricity or gas, telecommunications will fit right in as part of utilities.

The next generation of mobile network is going to revolutionize our world. 5G will be connecting everyone and everything together bringing the fully connected world to life. By recognising telecommunications as a utility, everyone will have access to telecommunications as easily as having water and electricity properly deployed into their homes and businesses. This will enable people to have access to healthcare, education, public services and entrepreneurialism. Likewise, this will ease the work of service provider to properly plan for the benefits of their consumers, providing a win-win situation for both.

With 5G as key technology, priority and focus are needed to facilitate and expedite procedures to support 5G infrastructure and technology development. The rationale is to encourage industries and enterprises to adopt 5G implementation and applications in the country.

Policy consideration proposed by the 5G Taskforce is to regard telecommunications as more than just connectivity, but rather a utility to support the key initiatives on 5G in turns to enable key innovation and smart projects in the nation.

i. Enhancing support for Industry

Most know that 5G will open opportunities to capture value from new 5G use cases and widespread adoption of the IoT. At the same time, industries and enterprises alike are strictly dependent on meeting demands in order to invest. Noticing that they will have to increase their infrastructure investments in this technology, some are not keen to invest unless there is certainty and assurance to having a good ROI. In this outlook, cost can become barriers to rolling out 5G technology and applications.

Policy consideration proposed by the 5G Taskforce are as follows:

i. To provide grants, common funds and incentives among stakeholders and interested parties to commercialise the benefits of 5G use cases as well as to fuel Research & Development (R&D) in Proof-Of-Concept (POC) projects.

ii. Matching of interest and demands through Call for Collaboration (CFC) between industries, governments and potential companies to encourage collaboration and minimise cost of lone investment.

ii. Strengthen Network Security

5G builds upon existing telecommunication infrastructure to improve bandwidth and capabilities and reduce network-generated delays. However, 5G also carries over and introduces a wide range of cybersecurity risks that must be addressed to ensure its secure and safe use by the government and private sectors, including everyday citizens. Critical areas for security consideration can include the following:

- **5G Attack surfaces**
  5G increases attack surfaces that allow threats associated with data manipulation, spoofing, man-in-the-middle, eavesdropping, denial of service, rogue devices, equipment cloning, unprotected endpoint entry and piracy of premium content.

- **Supply Chain vulnerabilities**
  The 5G supply chain is susceptible to the malicious or unintentional introduction of risks like malicious software and hardware, counterfeit components, and poor designs, manufacturing processes, and maintenance procedures.

- **Deployment**
  5G will use more information and communication technology (ICT) components than previous generations of wireless networks. Improperly deployed, configured, or managed 5G equipment and networks may be vulnerable to disruption and manipulation.

- **Network Security**
  5G builds upon previous generations of wireless networks and is currently being integrated with 4G LTE networks that contain some legacy vulnerabilities, such as Distributed Denial of Service attacks and SS7/Diameter challenges. These vulnerabilities may affect 5G equipment and networks even with additional security enhancements.

- **Competition and Choice**
  Despite the development of standards that encourage interoperability, some companies are building proprietary interfaces into their technologies, which limits customers' choices to use other equipment. Lack of interoperability with other technologies and services limits the ability of trusted ICT companies to compete in the 5G market.

To address these critical challenges, the government and industry need to work collaboratively to maximize 5G's benefits and promote its security and resilience.

The following are some of the strategies for recommendations:

i. **Application of multi-layer security model**
A multi-layer approach to security is required to address the security threat from different segments of the 5G network up to the user.e.g. the consumer layer, device layer, application layer, service layer & the network layer.

ii. **Promoting best practices standards, guidelines and processes that are open, transparent, and consensus-driven.**
The government will continue to promote currently-adopted related standards such as the Brunei National Cyber Security Framework (BNCSF) to implement cybersecurity measures and processes that are open, transparent, and consensus-driven.

iii. Limiting the use of 5G equipment with known or suspected vulnerabilities including IOT devices.

The implementation of regulations and policies are required to limit the adoption of 5G equipment that may contain critical vulnerabilitiess.

iv. Engaging with the private sector on risk identification and mitigation efforts

Through close collaboration and partnership with the private sectors, it will help mitigate 5G vulnerabilities and provide insight on where government support or intervention is needed, such as the development of best practices, convening industry and government partners, and prohibiting untrusted equipment will help secure 5G technologies and networks.

v. Ensuring robust security capabilities for 5G applications and services

The government and relevant stakeholders will take a prevention-focused approach developing security capabilities that protect not only the 5G infrastructure, but also the applications and services that utilize it.

vi. Capacity-building and confidence-building measures

The implementations of cybersecurity measures to secure 5G technologies will require a competent cybersecurity technical teams. The promotion of cybersecurity related trainings and workshops will be required to acquire the required skillsets to achieve competencies.

Secure infrastructure will also guard against these threats and mitigate lateral threat movement within the 5G network.

Policy consideration proposed by the 5G Taskforce is to enhance collaboration between Cyber Security Brunei (CSB), Infrastructure Provider and Enforcement Agencies i.e. Police force are proposed for consideration by the Taskforce.

iii. Ensuring no inhibitors for site acquisition and deployment of 5G infrastructure

Gaining access to land to build towers will become more difficult as the volume of applications increases. Infrastructure provider will need to look for alternative sites including buildings, street lights and other physical structures. It is anticipated that usage of 26/28GHz bands means deployment of cells will not just be limited to telecommunication towers but rather buildings and maybe even lamp posts including IoT. Site access will require approval from different commercial and government organisations.

Currently, infrastructure provider is only allowed to build on State land and will only be granted special consideration for non-State land when there is no recourse. Under the current legislation any authorized person or public telecommunication licensee may enter any State land for the purpose of erecting and installing any telecommunication services in carrying out the necessary works subject to the Authority and Commissioner of Land approval[8]. In addition, such powers are also provided to enter any other land other than a State land by virtue of section 14. However, such powers could only be exercised with the consent of the land or property owners.

For the purpose of network densification and small cell deployments within the buildings, the current legislative framework is not sufficient in dealing with this matter.

Policy consideration proposed by the 5G Taskforce is for the relevant Authority to take into consideration in streamlining regulations to ease access to development of base stations or sites through the following:

i. To adopt of Code of Practice for Info-communications Facilities in Buildings (COPIF).

ii. To recognised telecommunications as utility. Such facilities as risers and conduits for fibre should be mandated as part of the building plan as well as ducting along access roads. Commercial building owners who rents their premises should abide by building codes and cannot refuse installation of equipment to enhance indoor coverage.

3.2. Readily available spectrum resources

3.2.1. 5G Spectrum requirement

In order to support all capabilities 5G promises to deliver, massive quantities of new radio spectrum have been allocated for 5G, notably in millimeter wave (mmWave) bands. 5G will operate on spectrum across low, mid and high spectrum ranges to deliver widespread coverage and support all use cases:

i. Low-band Spectrum

Low band spectrum refers to sub-1GHz spectrum. It provides support for widespread coverage across urban, suburban and rural areas and help to support Internet of Things (IoT) services enabling good building penetration.

8 Section 13 of Telecommunication Order, 2001.

ii. Mid-band Spectrum

This spectrum between 1GHz and 6GHz typically offer a good mixture of coverage and capacity benefits. It provides faster throughput and lower latency than the low-band spectrum. The majority of commercial 5G networks are relying on spectrum within the 3.3-3.8GHz range. Other bands which may be assigned to, or refarmed by, operators for 5G include 1800 MHz, 2.3GHz and 2.6GHz. In the long term, more spectrum is needed to maintain 5G quality of service and growing demand, in bands between 3 and 24GHz.

iii. High-band Spectrum

High-bands or sometimes referred to as millimeter wave (mmWave) are needed to meet the ultra-high broadband speeds envisioned for 5G, providing speeds up in the tens of Gbps range at even lower latency suited for hot-spot coverage. However, the high-band coverage area is limited, and building and rain penetration is poor. Currently, 26GHz, 28GHz and 40GHz have the most international support and momentum.

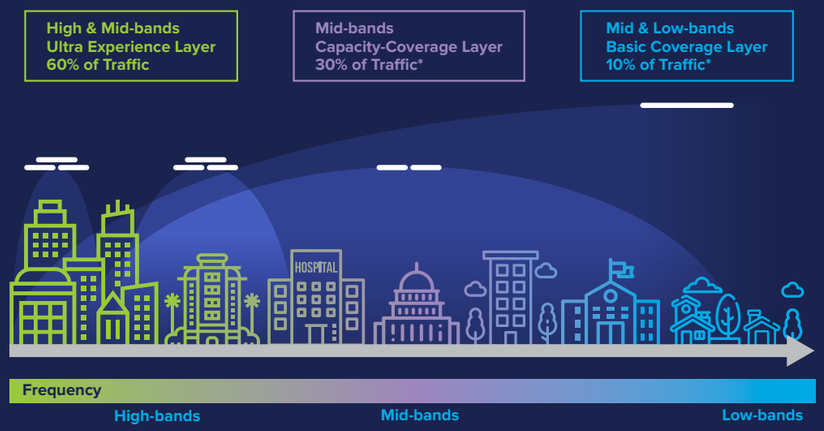


FIGURE 8: ILLUSTRATION OF 5G SPECTRUM USAGE

A critical component in enabling mobile technology has been the use of radio-frequency bands to support higher speeds and larger amounts of traffic.

700MHz Band

The digital television switch-over ('DSO') has made room for 'digital dividend' in the 700MHz band for telecommunications users. Particularly for the Asia-Pacific region, the Asia-Pacific Telecommunity ('APT') APT700 band plan has been identified for the provisioning of wireless broadband service, compatible for future 5G spectrum allocations.

In Brunei Darussalam, part of the 700MHz band currently assigned to UNN for its LTE (4G) network and is compatible for future 5G usage.

FIGURE 9: ALLOCATION OF 700MHZ FREQUENCY BAND

3.5GHz Band

The 3.5GHz is one of the pioneer bands recognised internationally, and equipment for it has made available in 2020. Brunei Darussalam has allocated 3.5GHz for Fixed Satellite Services (FSS) downlink and mainly operated for Very Small Aperture Terminal (VSAT), through FSS operators such as NiAT and RigNet. With the global harmonization of 3.5GHz frequency band as core spectrum for 5G deployment, measures are taken to ensure coexistence with existing services in the country as well as with neighboring countries.

AITI has conducted a desktop study on the co-existence deployment between 5G and FSS service in 3.5GHz frequency band, to provide flexibility and maximize its usage in the frequency band. AITI has developed the frequency band allocation and mitigation technique for 5G mobile networks and FSS (space-to-earth) operating in the 3.5GHz frequency band in order to minimise any radio frequency interference between the two services. AITI has re-allocated the frequency range of 3400 – 4200MHz in adjacent channel[9] allocation to allow 5G deployment while continuing FSS operation in the 3.5GHz band in Brunei Darussalam.

FIGURE 10: RECOMMENDATION FOR ALLOCATION OF 3.5GHZ BAND

Both Mobile Network Operator and Fixed Satellite Service Operator to ensure as follows:

- Within the 3400 – 3600MHz band, AITI has allocated 200MHz for 5G mobile networks and services.
- Within the 3600 – 3700MHz band, AITI has allocated 100MHz as a guard-band[10] between the two services. This is to ease the coordination distance between the two services and reduce potential interference between 5G and FSS equipment.
- Within the 3700 – 4200MHz band, AITI is retaining 500MHz for the assignment of FSS for downlink operation and also to cater the existing assignments migrated from 3400 – 3700 MHz.

[9] Both services allocated or assigned at the different frequency channel
[10] Guard-band lesser than 100MHz is not sufficient due to large coordination distance between the two services

26 and 28GHz Band

At the World Radiocommunication Conference (WRC-19), the member states of the International Telecommunication Union (ITU) supported a globally harmonized identification of 26GHz. The 26GHz and 28GHz bands suits dense 5G small cell networks in urban hotspots where additional capacity is vital. Globally, momentum behind 26 and 28GHz is growing, with the availability of commercial services and devices.

The Taskforce has identified for AITI to make available 80MHz spectrum in the 700MHz, 100MHz of contiguous spectrum in the 3.5GHz and 1GHz in the 26GHz / 28GHz (i.e. mmWave) spectrum.

3.2.2. Spectrum strategy

Planning ahead for future roadmaps. Refarming frequencies is sometimes difficult proposition for UNN as legacy networks need to be maintained due to business needs e.g. 2G. This slows progress. It is suggested to prevent importation of devices that work only on legacy technology or devices that do not support future road maps.

Optimum use of 700MHz, 1800MHz, 3500MHz and dynamic spectrum sharing with 4G proposed for future 5G.

RAT	Freq	Now	2020	2021	2022	2023	2024	2025
4G	700	20 A	40	80	80 C	80 C	80 C	80 C
	900	80	20	40	40	40	40	40
	1800	0	80	80	80 D	80 D	80 D	80 D
	2100	0	40	40	40	40	40	40
5G	700	0	0	0	80 C	80 C	80 C	80 C
	1800	0	0	0	80 D	80 D	80 D	80 D
	3500	0	100 B	100 B	100	100	100	100

▲ Commercial 5G

LEGEND

A. L900

B. NR3500MHz

C. 700MHz DSS 4G/5G

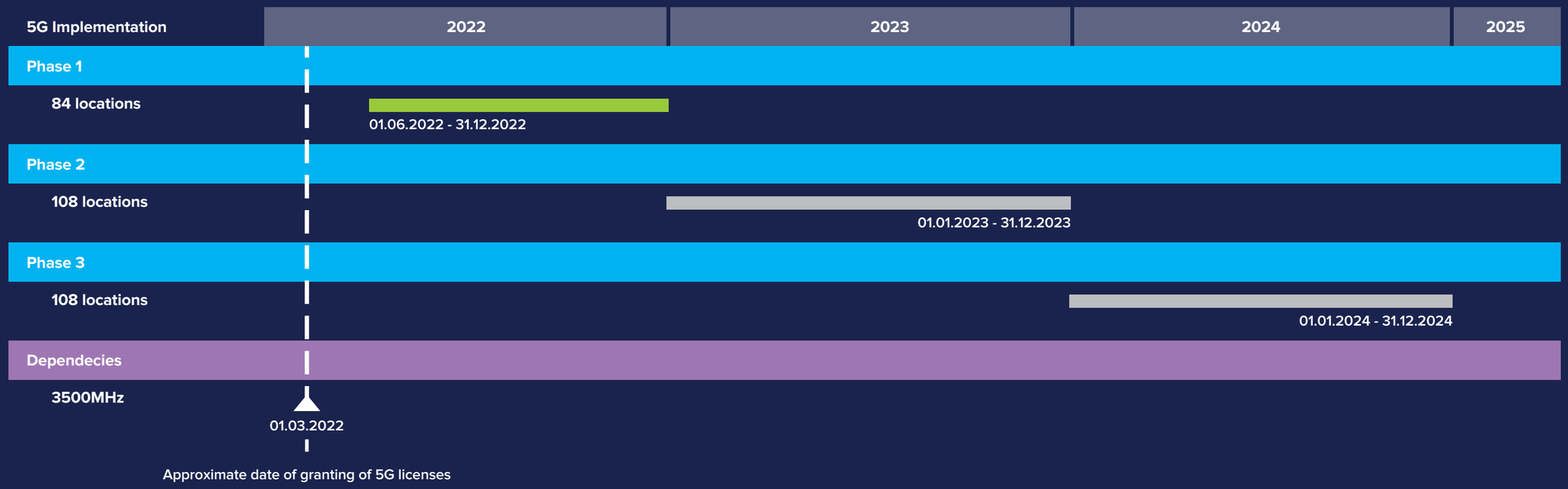
D. 1800MHz DSS 4G/5G

COMMENTS

- UNN estimates 300 5G basestations is required to fulfill coverage basestations for rural, sub-urban and urban locations.
- The strategy would be to utilize 700MHz for coverage and 1800MHz/3500MHz for capacity.

Implementation Plan

Initial study suggests 300 locations with 5G is sufficient to meet interests, but a more detailed analysis is required.



3.3. Timely Technology & Infrastructure Development

3.3.1 5G Roll out timeline

The economy is at another pivotal moment as digitalisation is vital to our businesses in terms of raising productivity, driving growth, and harnessing new innovation. The value of digitalisation is enormous, and the catalyst for this economic growth is wireless connectivity enabled by 5G.

5G is not simply an extension of 4G, nor is it merely a faster wireless capability. 5G connectivity promises to lead consumers, industries, and governments to new frontiers of productivity and innovation. According to Global mobile Suppliers Association (GSA), by mid-November 2020, there were 407 operators in 129 countries invested in 5G, including trials, acquisition of licenses, planning, network deployment and launches.

Timely deployment of 5G networks in Brunei Darussalam will offer significant economic opportunities in the long term, to increase our competitiveness and as enabler for future digital services.

> Policy consideration proposed by the Taskforce is to launch 5G services in Brunei Darussalam by middle of 2022. By 2025, 5G connectivity should reach to 75% of the population.

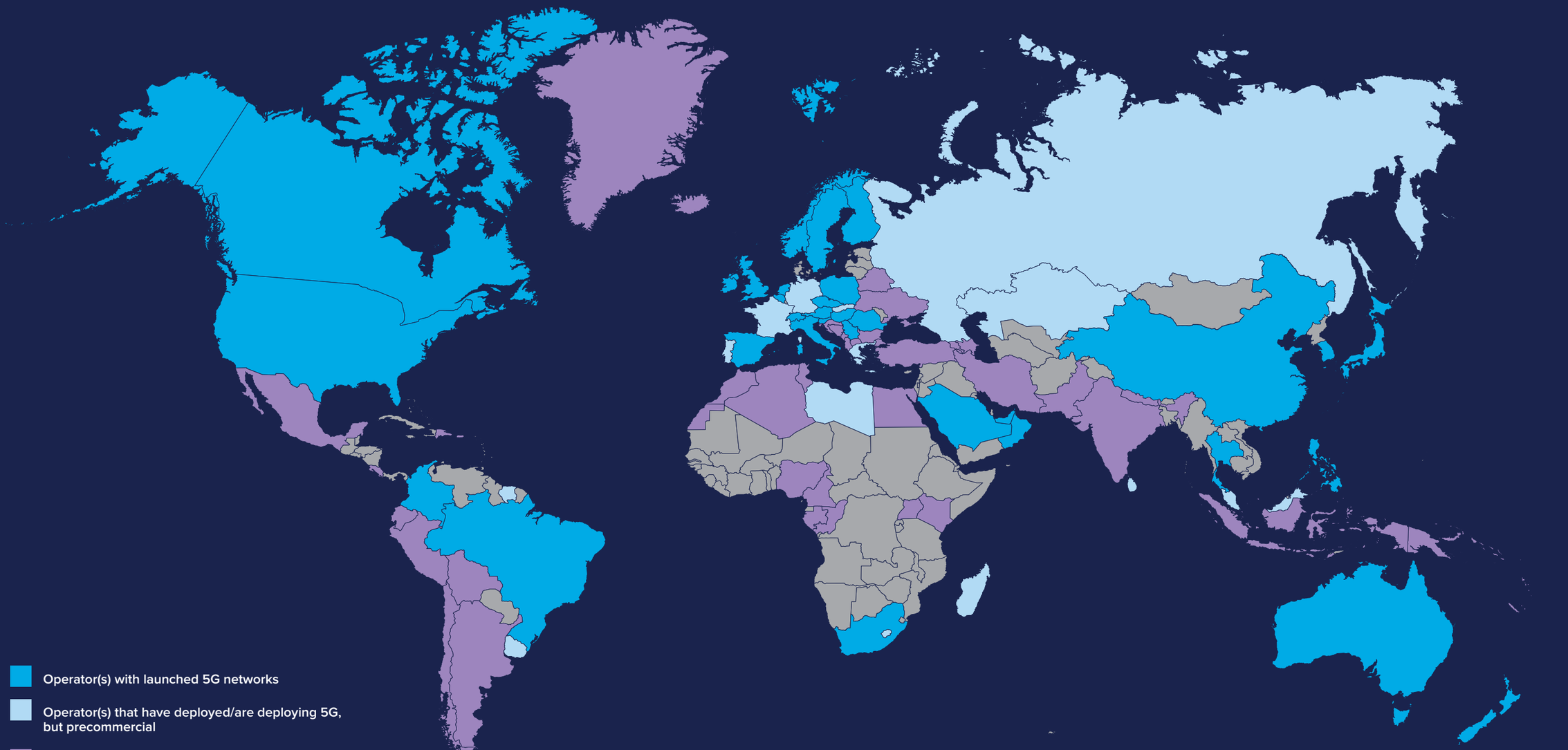


FIGURE 7: NUMBER OF OPERATORS INVESTING IN 5G AND COMMERCIAL LAUNCHES AS AT NOVEMBER 2020

3.3.2. 5G Technology & Infrastructure

5G infrastructure will require flexibility around how and where it is deployed. It is anticipated that the use of 5G small cells using mmWave will only be needed in high-demand locations rather than more widely. This will mean that greater prospect form network operator in installing 5G small cells on street furniture (street lights, bus stops, etc) as well as on buildings, to meet capacity required. This therefore requires access to suitable sites from a number of different property holders, as well as easily obtainable planning permission.

The development of infrastructure for mobile service providers have been centralized under Unified National Network (UNN). The deployment of network infrastructure typically involves erection of towers and poles to accommodate telecommunications equipment such as base stations and repeaters, digging trenches and constructing ducts for the laying of cable and installation of telecommunications equipment and cables within commercial and residential buildings.

Prior to any of the above activities taking place, permission must be obtained from land owners as applicable to access land for the erection of towers and poles. In addition, “rights of way” must also be obtained to allow fibre optic cables to be suspended or laid underground through public and private land. Permission must also be obtained from building owners for the installation of telecommunications equipment and cables.

Depending on the location of the land and rights of way, the process involves seeking approval from various Authorities such as Land Department, Town Country Planning, Department of Civil Aviation and AITI. The overall process typically would take 4-5 months.

The Taskforce has identified that streamline regulations will be needed to ease access to development of base stations/sites, e.g. smart lamp post model.

It is further proposed that the infrastructure approval process would be complemented by the setting up of an online one stop centre model. This will facilitate the licensing process by obtaining co-current permission from the relevant authorities (which may include Land Department, Town Country Planning, Department of Civil Aviation, AITI, as well as other relevant authorities).

3.3.3. Deployment strategy for 5G use cases

UNN has started its 30-month project to expand the mobile Radio Access Network (RAN)[11] starting September 2020. The RAN project includes the consolidation of the tower infrastructure previously managed by DST and Progresif, and the deployment of 120 new sites to increase coverage in rural areas and capacity in densely populated areas. It will modernise the equipment on site with modern operational practices, by adding radio spectrum to increase the capacity of the network and customer experience.

[11] https://unn.com.bn/ran-expansion-project-for-modernisation-of-mobile-infrastructure

The RAN project carries significant long-term benefits in terms of modernising the equipment in preparation for 5G deployment in the future, whilst also addressing the immediate needs of the telecommunication sector such as improving coverage through adding low-frequency carriers, using 700MHz spectrum.

RAN Site Modernisation Approach

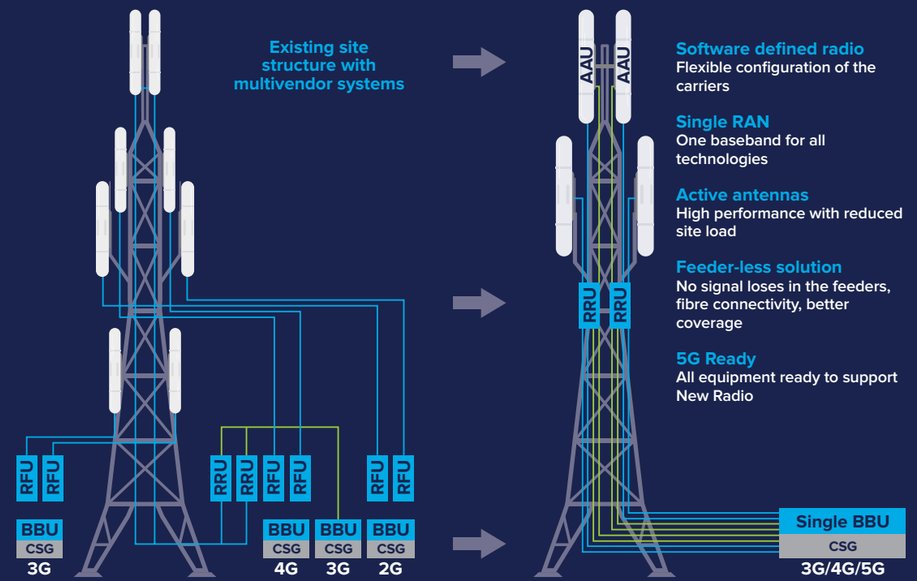


FIGURE 11: UNN RAN MODERNIZATION TOWARDS 5G-READY SYSTEM

UNN’s plan to enable a smooth transition from 4G to 5G utilizing Dynamic Spectrum Sharing (DSS) to provide nationwide 5G coverage will allow UNN to operate 5G New Radio (NR) and LTE simultaneously. When launching 5G network, UNN will deploy 5G New Radio (NR) using 3.5GHz band and introduce DSS for its 700MHz and 1800MHz LTE band. This is mainly to deliver high-speed connectivity to consumers with 5G-enabled devices, which allows UNN to leverage their existing network assets rather than deploy a completely new end-to-end 5G network.

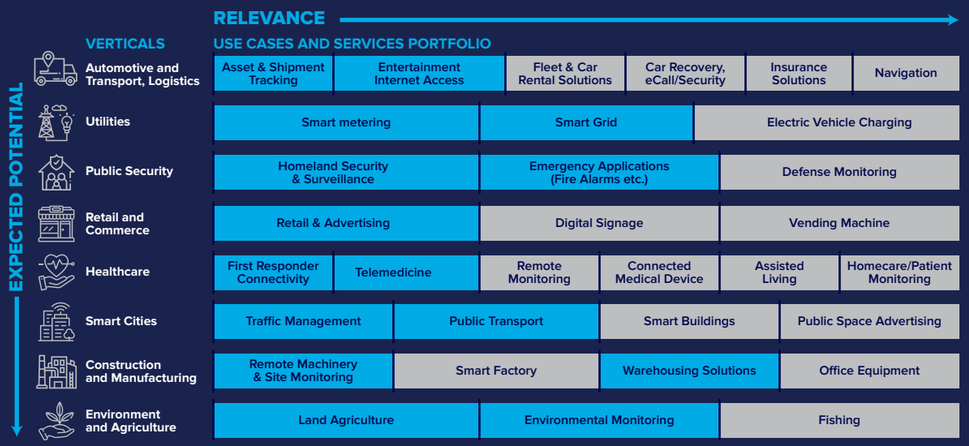
While DSS is a way to provide 5G and improves the consumer 5G experience, the ultimate target is towards the deployment of a standalone (SA) 5G network, to provide better support for 5G use cases requiring ultra-low latency and much higher capacity. 5G SA requires operators to put in place an end-to-end 5G network including a new core - with separate hardware and software from 4G. 5G SA will allow for enhanced services to enable industries network slicing (for example, allowing industrial automation to use dedicated network resources to guarantee reliability, latency, and quality of service) and brings ultra-low latency applications.

3.4. Spur Commercial 5G Use Cases

3.4.1. Spurring 5G use-cases with applicability in Brunei Darussalam

Previous generations of mobile technologies primarily satisfied human communications in the form of voice, data and Internet. 5G on the other hand equally aims for industrial communications to help digitise the economy and contribute towards global digital transformation. Vertical sectors such as transport, utilities, public security, healthcare and manufacturing will likely be the leading adopters.

Within this context, the 5G Taskforce have assessed the relevancy of 5G technology for Brunei Darussalam across various different vertical sectors:



Automotive, Transport and Logistics

While existing technology 2G/3G/4G networks already provided connectivity for numerous Internet of Things (IoT) applications, the higher data rate, lower latency and improved capacity provided by 5G system make it ideal to continue to be used to maximize the safety, efficiency and sustainability of road transportation.

There will also be significant use-cases for 5G car infotainment services, allowing passengers to have more fulfilling in-vehicle experiences, such as deliver high definition video to the car, supporting live interactions, and enabling faster connectivity, to bring the full power of the internet to the passenger.

Public Safety

5G will play an important role in connecting massive city-wide networks of CCTV cameras making high definition video feeds instantly available for situational awareness and analytics driven insights.

Enhanced Mobile Broadband (eMBB) capability of 5G would allow 4K or 8K CCTV deployments and provide enhanced capability for public agency to respond to emergency situations and ensuring the safety and security of citizens.

Retail and Commerce

5G connectivity could enable augmented reality (AR) and virtual reality (VR) capabilities that would change the way brands and consumers interact. For example, it can enable immersive experiences such as interactive in-store fitting rooms leveraging AR and VR, where users can try on clothes, request different sizes and ask for immediate assistance through interactive mirror interfaces.

Another area where 5G could dramatically affect retail is that it may boost the possibilities for big data-generated insights about customers. By supporting many more sensors in stores, integrating social media, loyalty program details, and other data, and enabling more powerful, cloud-based analytics. These data-based insights would create opportunities for mass-customized and relevant services for consumers, such as personalized shelf displays, predictive inventory management, and real-time integration of external partner data sources.

Healthcare

5G could prove valuable in many areas of healthcare, including telemedicine, remote surgery, using wearable devices for real-time monitoring and delivering information and support for patients. 5G will continue to provide essential levels of connectivity as with predecessor networks. One key feature for 5G - the ultra-reliable and low latency communications (uRLLC), healthcare experts may advance in new uses such as surgery performed remotely using robotic arms connected through communications networks. These applications can also form new revenue streams for operators, which have a central role in enabling this exciting use of modern network technology.

Smart Cities

Smart cities are generally associated with sensor networks – such as for road traffic management. 5G will enable communication between the vehicle, road infrastructure such as sensors, traffic lights, cameras, and traffic management command center. Information captured by connected sensors will enable far greater predictive power to those managing congestion and offers better insights to traffic controllers.

For public transport, mobile connectivity allows for information to be streamed almost in real-time to provide precise public bus locations and estimated arrival times and real-time dynamic traffic management. With enhanced connectivity of 5G, it will pave the way for the creation of innovative new services such as autonomous public bus services that respond dynamically to demand, or dynamic routing based on traffic conditions and crowd information.

Construction and Manufacturing

Mobile technologies are being leveraged for industrial applications, and thereby providing increasingly automation, remote operation and site monitoring. Network slicing features of 5G further strengthen the network performance requirements for real time control, massive connectivity and high bandwidth needs. This is possible because of the non-dependency of such networks on the public networks, higher control on the deployment environment and flexibility of designing the networks for optimized private network experience. 5G networks offer an immense opportunity to replace wired systems for various controllers, switches, sensors and actuators.

As 5G allows for ultra-low latency and high reliability connectivity, the use of AR and VR technologies can be used to provide employee training, and develop better and faster ways to improve productivity.

Furthermore, as we venture in industry 4.0 to transform how things are distributed, warehouse automation based on a foundation of 5G connectivity is the key to more scalable, flexible and automated logistics operations.

Environment and Agriculture

The use of Internet of Things (IoT) may help optimise agricultural and environmental monitoring processes. IoT is helping to optimize farming operation, such as water management, fertigation and maturity crop monitoring – allowing farmers to view and control their agriculture management systems online. For environmental monitoring, IoT can play a vital role in understanding our real-time data insights into air, soil, and water condition.

There is also potential for 5G-connected drones to be equipped with cameras and sensors collect data and extract meaningful information. New drone solutions allow a fleet of drones to communicate over wireless networks with a control center. This information is processed and transmitted on multi-tier platforms for aerial insight for various agricultural and environmental monitoring solution.

The Taskforce has identified various use cases for future development in Brunei Darussalam. Among 5G use-cases identified were:

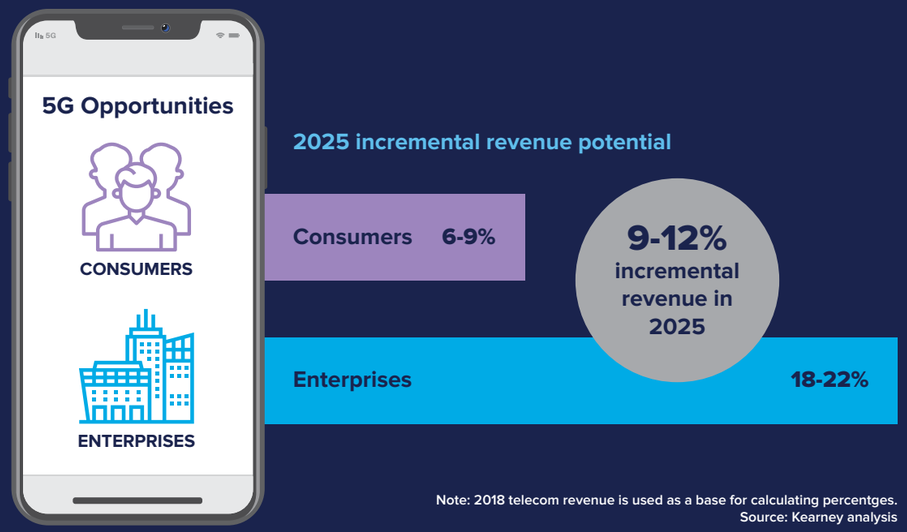
- E-Health Ecosystem
- Industrial IoT Application
- Digital Healthcare
- Oil & Gas Digital Transformation
- Smart Tourism Ecosystem
- Smart Campus
- VR/AR for Consumer Application

Relevant parties are to develop "5G Use-Cases Toolkit" to assist various sectoral agencies and organisations in integrating 5G and other mobile communications technology towards digitalisation of services and applications.

Policy consideration proposed by the 5G Taskforce is to leverage on existing high-level platform to highlight the importance of 5G. It is recommended for the establishment of Brunei 5G Industry Alliance with the purpose to spearhead 5G-enabled innovation and changes, bridging the industry groups in driving the agenda including Digital Economy Council and Smart City Steering Committee.

3.4.2. 5G business case

According to a study by Kearney[12], 5G could add 6 to 9% to consumer revenues and 18 to 22% to enterprise revenues by 2025 in ASEAN. Indonesia is expected to capture the biggest share, followed closely by Malaysia, Singapore, and Thailand. To deliver this value, ASEAN operators will likely to invest in total about $10 billion into the region's 5G infrastructure by 2025.



Note: 2018 telecom revenue is used as a base for calculating percentges.
Source: Kearney analysis

FIGURE 12: POTENTIAL MONETIZATION FOR 5G IN ASEAN

Generally, the business case for the investment required for the deployment of 5G is still at the early stage. 5G is still a technology in development, and the market needs time to understand how to deploy infrastructure at commercial scale and invest in 5G applications and services profitably.

Given the complexity of future 5G systems, it is likely that its development will be building upon existing mobile networks and the ongoing development of fixed network infrastructure, with different investment required across the 5G architecture to deliver different use cases in different areas.

[12] https://www.southeast-asia.kearney.com/article/?/a/5g-in-asean-reigniting-growth-in-enterprise-and-consumer-markets

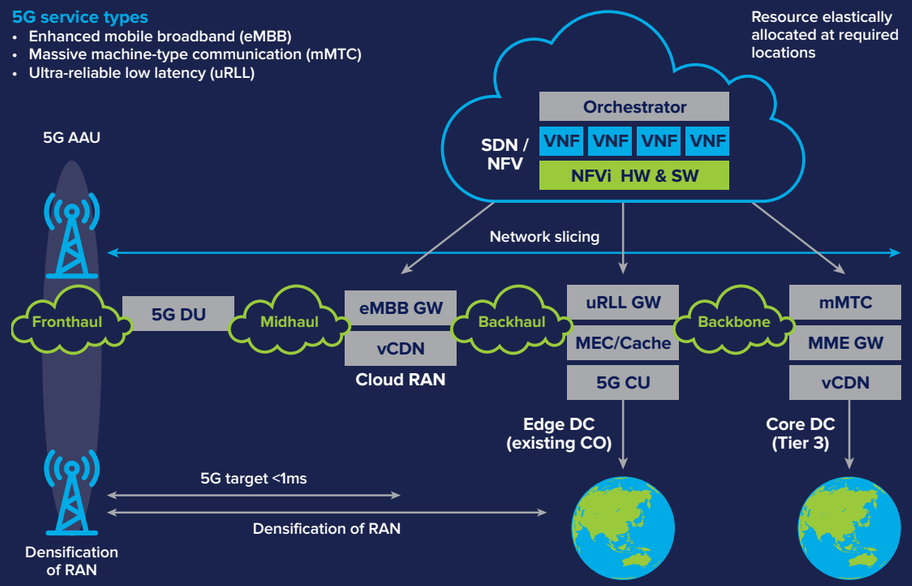


FIGURE 13: 5G REFERENCE ARCHITECTURE

While 5G networks at the initial phase is mainly used to deliver greater capacity to meet the increasing demand from consumers. Over time, it may extend the use of 5G beyond mobile broadband and leverage innovation such as network slicing to offer services to industry verticals, for example oil and gas, healthcare and transport. As such, it will be imperative for operators to look holistically at the potential business models and use cases in 5G through vertical industry engagement and collaboration in order to build the right 5G network catering enterprise needs.

The proposed "Brunei 5G Industry Alliance" will act as a platform for collaborative stakeholder engagement across various industry verticals, encouraging partnership across ecosystem of technology, services and application, to create new industry-specific 5G solutions and use cases for Brunei Darussalam.

3.5. Development programs to capitalise on 5G

3.5.1 Development programs to capitalise on 5G

To spur the development of 5G business case, the establishment of facilities that will provide the access to 5G network infrastructure to support the testing of 5G use cases is needed. These facilities could include partnerships between public sector agencies, industry players and academic institutions.

> The Taskforce has identified the requirement for the Government to create "5G Innovation Lab" to demonstrate 5G application and provide funding for the facilities through cooperation among industry players and academic institutions, to ensure development of 5G services and application in the Brunei Darussalam can be scaled up and is open to a range of businesses, including MSMEs.

Joint collaborative effort between the developers, start-ups, enterprises, academia and government agencies to generate the development of use cases based on 5G capabilities and its eco-system. The "5G Innovation Lab" provide platform for community to research, prototype, applications, test new innovative technologies and enhance existing project. It is also aim to support a series of new educational and training platform through various types of 5G application.

It will be beneficial to have "5G Innovation Lab" situated at higher learning institutions, such as UBD and UTB, in order to promote active participations from academics and students to engage in 5G use cases projects. In particular, smart campus applications can be applied in UBD and UTB campuses in order to replicate a small-scale smart city. With this replication, universities can act as a testbed before smart city applications are deployed on a national level. With the support from AITI, this lab will become a collaborative platform between academia and industry. The lab will also become a testbed for any Proof of Concept (PoC) or new products designed by the industry. This will further narrow down the gap between academia and industry.

3.5.2. Awareness to accelerate 5G adoption

Examining consumers' understanding and perceptions on 5G is important prior to recommending the ways to accelerate awareness and adoption. The Taskforce has conducted a nationwide 5G survey in November 2020, that was aim to gauge public understanding about 5G. The survey also seeks to measure our perception on 5G applications and use-cases towards various sectors including public sector agencies, industry players, MSMEs, as well as consumers.

Survey outcome

Among the notable outcomes from the 5G survey is the need to conduct awareness, whereby 91% of respondents agreed on necessity for public awareness. It was found that 80% of respondents either don't know or have little knowledge on 5G.

Looking into demand for 5G technology in Brunei Darussalam, the survey found that 42% of respondents requires 5G services, while another 46% states on the possible requirement for 5G and only 12% think 4G technology is sufficient.

Looking at respondents' stage of digitalisation, 36% are in the exploration phase (i.e. on learning and information gathering), with another 14% on the planning stage, additional 25% are working with vendors, 7% on the development stage and the remaining 19% are not considering or embarking on digitalisation.

It is also observed that 42% of respondents required 5G to be made available now, 41% wants for 5G to be available in 1-2 years, and 17% wants it available in 3-5 years time.

OBSERVATIONS FROM 5G SURVEY

Is 5G Awareness necessary for the public?

91.6%

8.4%

How much do you know about 5G?

A little knowledge	Very good knowledge	Don't know
64.6%	20.3%	15.1%

Do you require 5G services?

46% Maybe

42.3% Yes

11.7% No, 46 is sufficient

At what stage of digitalisation are you in?

- 25% Working with Supplier / Vendor / System int...
- 13.4% Planning Stage
- 18.3% Not considering at this time
- 35.9% Learning and information gathering stage
- 7.4% Developer stage

When do you want 5G to be available?

NOW	1-2 YEARS	3-5 YEARS
42.4%	41.2%	16.4%

Do you think 5G will benefit Brunei?

77% Yes

19% Don't know

4% No

Overall, 77% of respondents thinks that Brunei Darussalam will benefit from 5G deployment. Further, with omnipresent changes in smart technologies and applications, a central public platform has been created to keep consumers and industry players informed and updated on the 5G development in Brunei Darussalam through an official website 5G.BN (www.5g.bn), which was made available since September 2020. **5G.BN** aims to provide consumer awareness and bring enthusiasm towards new 5G capabilities. It also serves to create communications channel for government, businesses and society to collaborate in the evolving 5G ecosystem.

Furthermore, national awareness activities would allow participants with various backgrounds to be excited with what 5G has to offer. Moving forward, more events should be organised with exciting themes and demonstrations that would make various stakeholders including the general public to be more curious and accepting of 5G.

LIST OF THE 5G NATIONAL AWARENESS BEING HELD DURING 5G TASKFORCE PERIOD

National 5G Seminar 2021

Brunei Darussalam 5G Seminar was held on 28 January 2021 at Design & Technology Building, Anggerek Desa. The Seminar was held in collaboration between AITI and Brunei Darussalam 5G Taskforce. Brunei Darussalam 5G Seminar attended by Minister of Transport and Infocommunications, and representatives from Government, Academia and private Sector. The objective of the seminar is to raise awareness on 5G economic impact and opportunities with advent of various 5G emerging applications towards innovation and digital transformation. Carrying the theme "5G: Enabling Digital Transformation", the seminar explored the reality of 5G and how 5G can pave the way towards digitalisation and innovative solutions.

CIIS Conference 2020

The International Conference on Computational in Information Systems (CIIS 2020) also highlighted on the main capabilities of 5G especially when it comes to providing wireless connectivity for a wide range of new applications and use cases. This includes industries such as automotive, logistics, public safety, media, and manufacturing. Also discussed, on how Artificial Intelligence (AI) has been identified as a key enabler for end-to-end network automation in 5G in all network domains, including the domains subject to the standardization process of Radio Access Network (RAN), Core Network (CN), and Management System, also known as Operations, Administration and Maintenance (OAM).

3.5.3. Engaging businesses and consumers on 5G opportunities

Whilst there is a need to raise general awareness on the potential applications and benefits of adopting 5G in Brunei Darussalam, immersive media, which refers to technologies like Virtual Reality (VR) and Augmented Reality (VR), is one of the 5G applications that have the potential to be developed. Immersive AR/VR technology will require fast, low latency bandwidth data connection in order to deliver an ultra-high resolution 4K or 8K viewing experience. 5G will be able to deliver this via its network capabilities as well as a more reliable experience through edge cloud, which opens up ultra-low latency services.

Case Study – 5G Living Lab@PIXEL

IMDA of Singapore has launched a 5G Living Lab@PIXEL in September 2020 to facilitate industry efforts to develop new 5G solutions and build up technical capabilities which focuses on augmented reality/virtual reality. Businesses, including SMEs, will be able to develop and test 5G-enabled devices and applications, as well as gain insights from sharing sessions and masterclasses with PIXEL's broader ecosystem of innovative infocomm media start-ups.

PICTURES FROM 5G LIVING LAB@PIXEL

The Taskforce has identified the need to raise awareness and adoption programme aim to encourage all parties to collaborate on accelerating the delivery and deployment of 5G-based AR/VR services.

3.5.4. Building skilled workforce

Skills gaps across all industries continues to grow due to rapid advances in technological developments such as 5G, big data and artificial intelligence. The World Economic Forum estimates that more than half (54%)[13] of all employees will require significant reskilling by 2022. Thus, it is necessary to devise solutions to reskill and upskill workforce. These include the identifying types of skills needed in the digital economy and future labour market, new jobs and associated skills requirements, specific digital technologies and their impact on skills development.

As part of the plan for 5G-ready workforce, the Taskforce has identified training requirements, Appendix 3, with the purpose of building capacity to meet the requirements for 5G industries in the next 5 years.

[13] https://www.weforum.org/agenda/2019/03/the-digital-skills-gap-is-widening-fast-heres-how-to-bridge-it/

3.5.5. Enhancing Brunei ICT Industry Competency Framework

The development of the Brunei Darussalam ICT Industry Competency Framework (BIICF) is in progress. This framework serves as a comprehensive guidance for ICT occupations, trainings and certifications. The BIICF will provide a consistent competency structure for ICT professionals, employers and training providers in Brunei Darussalam so that they will have a clear reference on the types of skills and competencies required for various ICT professions and to develop training courses to develop relevant skillsets through accredited training providers.

There are currently seven (7) sub-sectors identified in BIICF namely: IT Services, Telecommunications & Networks, Applications & Solutions Development, Digital Media, Project Management, ICT Security and Data and Artificial Intelligence.

With regards to the 5G, it cuts across several sub-sectors in BIICF such as Telecommunications & Networks and Applications & Solutions Development sub-sectors. In relation to the trainings identified in the roadmap, they will be cross-checked and aligned with the BIICF to ensure the current industry needs are satisfied.

4

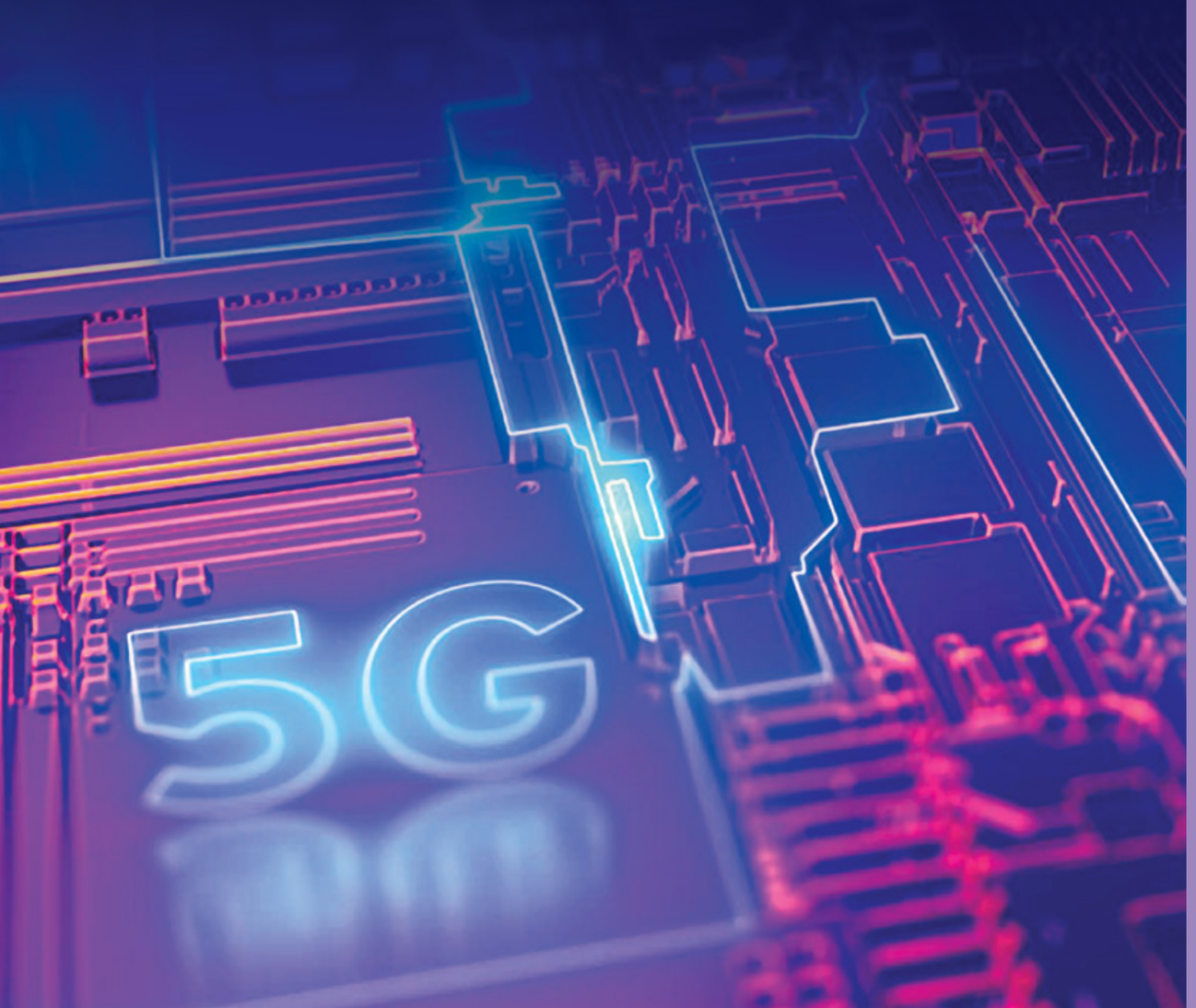
CONCLUSION

4. CONCLUSION

The 5G Taskforce has established 5G action plan for Brunei Darussalam to ease 5G implementation of ecosystems. 5G frequency allocation plan has been identified to incorporate low, mid and high spectrum to support widespread coverage and capacity, altogether unlocking the 3-dimensional of 5G capabilities. With the availability of spectrum resources, 5G services in Brunei Darussalam to be launched in middle of 2022 and progressively target to increase about 75% of population coverage by 2025.

Towards achieving the 5G potential towards digital transformation and innovation, digitalisation across government and industries is needed to spur and drive the demand for 5G use cases. Among others, trainings and awareness activities are planned to be carried out for the next 3 years to develop and hone 5G domain expertise and related skills that will enable the delivery of innovative products and services to meet the needs of consumers and enterprises.

Finally, collaboration among public, private and academia is crucial to support 5G ecosystem roll out. Through joining hands among all sectors involved that can only we reap the benefits of 5G deployment in Brunei Darussalam.



APPENDIX 1: LIST OF RECOMMENDATIONS & PROPOSED KEY ACTIONS

RECOMMENDATION ON POLICY, REGULATORY AND SPECTRUM

1. INTRODUCTION

The Sub-working group on policy, regulatory and spectrum seeks to propose recommendations that address the pertinent issues on policy, regulatory and spectrum based on the collective views and perspective of its members. Since the formation of the 5G Task Force, Working Group 1 has convened for 9 meetings to share views and discuss regional trends, opportunities and challenges that shape the recommendation of the Working Group.

The Working Group has also had the opportunity to learn from GSM Association (GSMA) on the 5G priority spectrum bands in Asia Pacific countries. It was highlighted that harmonisation of spectrum bands plays a major role in enabling the greater economies of scale for low cost-devices. Among others, the importance of industry and government partnership in action is needed to enable a connected future.

The recommendations from WG 1 are to be addressed in three (3) Strategic Considerations due to the importance of policy, regulatory and spectrum that cuts across these considerations:

- **Strategic Consideration 1: Demand**
- **Strategic Consideration 2: Resources**
- **Strategic Consideration 3: Coverage**

2. STRATEGIC CONSIDERATION 1: DEMAND

2.1. Recommendation 1.1: Elevating ICT and broadband services as essential utilities at par with water and electricity

The need for ICT and Broadband services are undeniable nowadays, not just for emergency services but also as an underpinning requirement for various personal, commercial and official transactions. To equip areas and premises with the necessary infrastructure will have to go through various processes ranging from site acquisition to building of towers and installation of equipments. Some would also require construction works to be done in order to integrate the necessary cables into the structure of the premises.

While some processes are very much facilitated by the relevant Government agencies, there are still issues faced that has affected the service providers, including long process and procedures, duplication of unnecessary construction work and reluctance of premise/building owners to permit installation of equipments despite requirement of tenants for ICT and broadband services. This set-up for 5G connectivity has to be conducted in a streamlined and seamless manner as much as possible.

PROPOSED KEY ACTIONS

a. Incorporate the requirement for ICT and broadband services as part of the necessary approvals for buildings and premises. This is comparable to the requirements for installation of necessary equipments for water, electricity and safety);

b. Amendment and revision on the related legislation. This would entail updating the Telecommunications Order, by taking reference to the Fire Safety Act (tbc) which is under the purview of Fire and Rescue Department that mandates for the approval from the Department as part of the permit prior to occupying the premise;

c. Removal of barriers to entries to sites and buildings; and

d. Encourage sharing of infrastructure, facilities and utilities to address issues of limited sites and environmental concerns.

2.2. Recommendation 1.2: Elevating 5G to national agenda through existing high level fora and establishing industry-led alliance

In line with the aspiration to achieve the objectives of Wawasan 2035 and to transform Brunei Darussalam as a Smart nation, 5G needs to be regarded as more than just connectivity. 5G is in fact among the key enablers to various services and applications. There are several high level fora that can be leveraged on to strengthen collaboration between the Government, industry leaders and users, while also establishing an industry-led alliance to put 5G in the forefront as the preferred technology enabler for innovative services.

PROPOSED KEY ACTIONS

a. Elevating 5G, through use cases and pilot projects, proposed by the industry to existing high level for a such as the Digital Economy Council, Smart City Steering Committee and the Brunei Research Council.

b. Formation of industry driven 5G Industry Alliance comprising of industry leaders and players from various economic activities and sectors to explore the use and deployment of 5G in their respective fields. This would entail the involvement of the industry beyond UNN and SalesCo.

2.3. Recommendation 1.3: Sustaining Demand for 5G technologies and services

In order to ensure sustainable demand for 5G technologies, continuous awareness and efforts to support demand and usage of 5G have to be in place.

PROPOSED KEY ACTIONS

a. Continuous showcase of 5G use cases to be driven in various sectors. Through the 5G Industry Alliance, use cases can be put forward to encourage innovation and stimulate interests from the public to come up with innovative ideas and products.

b. To come up with a 5G toolkit that is customizable to the respective sector considering the various stakeholders involved. This can be a guide for budding technopreneurs and innovators for them to plan their actions and develop their ideas.

c. To ensure compatibility of available handsets with 5G services that are offered. Problems arising from incompatibility can hamper any interests and plans to further sustain usage and demand for 5G services. This can be taken up and emphasized through the 5G Industry Alliance.

2.4 Recommendation 1.4: Emphasis on security considerations

Crucial to instilling users' trust and confidence are cybersecurity. In embracing new technologies and services, users' concerns need to be mitigated by providing assurances as illustrated by initiatives taken up by the relevant agencies.

Cybersecurity and personal data protection concerns have become more highlighted nowadays. As such, the role of agencies such as CSB and AITI are very relevant in allaying any concersn on cybersecurity and data protection respectively.,

Proposed key action include developing guidelines or strategies that can be taken up by users, industry players, services providers emphasizing their respective roles in ensuring sufficient cybersecurity and data protection measures.

Examples of recommended measures for cybersecurity are:

a. **Application of multi-layer security model.**
A multi-layer approach to security is required to address the security threat from different segments of the 5G network up to the user e.g. the consumer layer, device layer, application layer, service layer & the network layer.

b. **Promoting best practices standards, guidelines and processes that are open, transparent, and consensus-driven.**
The government will continue to promote currently-adopted related standards such as the Brunei National Cyber Security Framework (BNCSF) to implement cybersecurity measures and processes that are open, transparent, and consensus-driven.

c. **Limiting the use of 5G equipment with known or suspected vulnerabilities including IOT devices.**
The implementation of regulations and policies are required to limit the adoption of 5G equipment that may contain critical vulnerabilities.

d. **Engaging with the private sector on risk identification and mitigation efforts**
Through close collaboration and partnership with the private sectors, it will help mitigate 5G vulnerabilities and provide insight on where government support or intervention is needed, such as the development of best practices, convening industry and government partners, and prohibiting untrusted equipment will help secure 5G technologies and networks.

e. **Ensuring robust security capabilities for 5G applications and services**
The government and relevant stakeholders will take a prevention-focused approach developing security capabilities that protect not only the 5G infrastructure, but also the applications and services that utilize it.

f. **Capacity-building and confidence-building measures**
The implementations of cybersecurity measures to secure 5G technologies will require a competent cybersecurity technical teams. The promotion of cybersecurity related trainings and workshops will be required to acquire the required skillsets to achieve competencies. Secure infrastructure will also guard against these threats and mitigate lateral threat movement within the 5G network.

3. STRATEGIC CONSIDERATION 2: RESOURCES

3.1. Recommendation 2.1: Spectrum

5G needs spectrum across low, mid and high spectrum ranges to deliver widespread coverage and support all use cases.

ALL THREE HAVE IMPORTANT ROLES TO PLAY:

- Low-bands (e.g. sub-1 GHz) support widespread coverage across urban, suburban and rural areas and help support Internet of Things (IoT) services.
- Mid-bands typically offer a good mixture of coverage and capacity benefits. The majority of commercial 5G networks are relying on spectrum within the 3.3-3.8 GHz range. Other bands which may be assigned to, or refarmed by, operators for 5G include 1800 MHz, 2.3 GHz and 2.6 GHz. In the long term, more spectrum is needed to maintain 5G quality of service and growing demand, in bands between 3 and 24 GHz.
- High-bands are needed to meet the ultra-high broadband speeds envisioned for 5G. Currently, 26 GHz, 28 GHz and 40 GHz have the most international support and momentum.
- A critical component in enabling mobile technology has been the use of radio-frequency bands to support higher speeds and larger amounts of traffic.

Proposed key actions **recommends for AITI to make available 80MHz spectrum in the 700MHz, 100MHz of contiguous spectrum in the 3.5 GHz and 1GHz in the 26 GHz / 28 GHz (i.e. mmWave) spectrum.**

3.2. Recommendation 2.2: Technology

To facilitate the deployment of technologies and ubiquitous usage also requires consideration from various stakeholders. This includes consideration from taxation perspectives. A revised approach on taxation of 5G equipment will facilitate the growth of usage as well as contributing to a sustainable ecosystem for industry players to continue their 5G plans and innovations.

Proposed key action recommends for active and continuous engagement or dialogue between relevant Government agencies and industry players to further evaluate and assess the considerations involving taxation matters. This engagement can be featured as among the key strategy for the proposed 5G Industry Alliance.

3.3. Recommendation 2.3: Education

Education and awareness are important to ensure sustainable demands for 5G services as well as ethical and responsible usage of technologies. Equally important is that education and awareness are also aimed to inspire new minds to be venture into 5G technologies.

Proposed key action recommends for alignment with initiatives and activities as proposed under WG 3 (Education and Awareness).

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4. STRATEGIC CONSIDERATION 3: COVERAGE

It is important to ensure timely and proper roll out of 5G services to ensure cost-effectiveness and optimized utilization of the technologies. Coverage and roll-out are to be determined by the following recommendations.

4.1. Recommendation 3.1 focuses on key actions on setting of prioritization (either by area, usage or sectors), as follows:

a. Prioritisation between urban and rural areas taking into consideration the plans of infrastructure and service providers. As indicated earlier, 5G services are expected to available by 2022;

b. Setting of KPI and targets are to also consider the scope of which access and utilization are to be measured. Current targets can be used as a reference.

c. Priorities can also be driven via the respective sectors and activities. For example, coverage of 5G can be pursued in the oil and gas sector where appropriate targets and KPIs can be set.

RECOMMENDATION ON EDUCATION AND AWARENESS

The sub-working group on Education and Awareness seeks to propose recommendations that assess the development programs/campaigns to upskill target audience or workforce to address 5G applications, network deployment and technologies and entrepreneurship.

The recommendations from WG 3 are to be addressed in two (2) Strategic Considerations, in close collaboration with relevant stakeholders and academia to educate the public on 5G possibly through creating a platform to showcase applications and solutions:

- **Strategic Consideration 1: Accelerate 5G digital awareness in various sectors**
- **Strategic Consideration 2: Bridging the skills gap to seize the 5G opportunities**

STRATEGIC CONSIDERATION 1: ACCELERATE 5G DIGITAL AWARENESS IN VARIOUS SECTORS

The 5G Taskforce under Working Group 3 recommends the following actions to further widen the awareness and accelerate the adoption of 5G technologies:

Recommendation 1.1: Promoting awareness on 5G impact and opportunities

5G will be a major enabling technology and will transform various industry digitalization use cases including smart manufacturing, remote robotic surgery, immersive gaming, autonomous driving and others. Across the world, 5G is recognised as the optimal communication platform for many industries including the smart educational system and, in particular, the opportunities to the manufacturing sector, driving the future of industry 4.0. For a nationwide recognition of 5G impact and opportunities to the government, business and industry, the Working Group 3 recommends the following activity:

PROPOSED KEY ACTIONS

Collaborative national awareness programmes.

Joint collaborative effort with relevant government agencies, educational institutions, businesses and other stakeholders through seminars/webinars, conferences and roadshows to promote awareness on the economic impacts of 5G and opportunities with the advent of various 5G emerging applications.

Recommendation 1.2: Engaging businesses and consumers on 5G opportunities

In the anticipation for the future with the increase in volumes of data that will be generated, collected and stored across sites, 5G connectivity provides various vertical sectors the opportunity to improve methods of working to increase efficiency and productivity in all operations and daily activities. The Working Group 3 recommends the following activities:

PROPOSED KEY ACTIONS

Demonstrate Augmented Reality (VR)/Virtual Reality (AR)

Among the various types of data traffic, video data is more dominant as the traffic has already showed quite stringent challenges to the existing mobile networks. Theoretically, up to 10 Gbps traffic is required for VR and AR devices. Through 5G Showcase on VR and AR, the promising 5G speeds (up to 10 times faster than 4G) will enable consumers to recognise the 5G capabilities to satisfy new VR and AR experience using up to Ultra HD (UHD) (4K and 8K) quality. The 5G network technology will present vast opportunities to accelerate the adoption of AR and VR in various areas such as e-tourism, e-education, e-health and so on.

Recommendation 1.3: Nurturing talents for emerging and creative applications leveraging on 5G network

In the hope of attracting bids and prototypes for various industries that are more competitive with 5G, businesses are encouraged to be more innovative and open to new opportunities and markets. Some organisations and companies potentially welcoming creative applications that are highly consumed or used by the public are in sectors such as energy, water, healthcare, education, transportation and logistics. The Working Group 3 recommends the following activity:

PROPOSED KEY ACTIONS

Promote competition to catalyse 5G innovation

Joint collaborative effort with relevant government agencies supported by big industry players to encourage local developers and entrepreneurs in developing new use cases and business models for 5G applications and services, along with improving the quality of product in the markets by leveraging 5G network through national competitions which may encourage the commercial use of 5G technology and opportunity to turn them into sought after local developers. For instance, the annual Brunei ICT Awards (BICTA) and Coding Conquest may introduce a 5G theme for Internet of Things, digital solutions or applications requiring low latency and that would improve and make daily routines more efficient. The participants shall be given access to 5G network to test their prototypes, and they are also to be mentored by big industry players to build new use cases potentially be used by respective organisations.

STRATEGIC CONSIDERATION 2: BRIDGING THE SKILLS GAP TO SEIZE THE 5G OPPORTUNITIES

Future anticipation is the demand for wireless applications and infrastructure leveraging 5G networks will continue to grow and may exceed the industry's existing labour force and talents. The expertise in technology professionals, engineers and field technicians need to be enhanced or upskilled and re-trained or reskilled to address the high demands of the industry in the future. The Working Group 3 recommends pursuing the following:

Recommendation 2.1: Building the significant potential of 5G ecosystem

Various applications ranging from VR, IoT, smart manufacturing, smart surveillance, e-health and many others are possible with 5G. As deployments will increase and technological viability becomes apparent, the 5G ecosystem will help accelerate collaboration between industries, allowing players to capture synergies from other industries. The collaborative efforts will bring significant opportunities among developers, start-ups, enterprises, academia and government agencies to support them to develop, test and bring to market new cases and its ecosystem that unleash the potential of 5G networks. The Working Group 3 recommends the following action:

PROPOSED KEY ACTIONS

Establishing 5G innovation technology lab

Joint collaborative effort between the developers, start-ups, enterprises, academia and government agencies to generate the development of use cases based on 5G capabilities and its ecosystem. The lab shall provide the platform for a 5G testbed to enable the community to research, build prototype applications, test new innovative technologies and enhance existing products or solutions. The lab shall also provide opportunities to support a series of new educational and training platforms through various types of 5G applications.

It is beneficial to have 5G use cases labs in higher learning institutions, such as UBD and UTB, in order to promote active participations from academia and students, and even start-ups and industry players to engage in 5G use case projects. In particular, smart campus applications can be applied on UBD and UTB campuses in order to replicate a small-scale smart city. With this replication, universities can act as a testbed before smart city applications are deployed on a national level. With the support from AITI, this lab will become a collaborative platform between academia and industry. The lab will also become a testbed for any proof of concept (PoC) or new products designed by the industry. This will further narrow down the gap between academia and industry.

Recommendation 2.2: Building the right skills for workforce towards 5G revolution

The current skills gap have raised concerns over the country's ability to expand knowledge of wireless applications and infrastructure by leveraging on the 5G network. Thus, the collaborative effort between the government, educational institutions and industries are prerequisites for developing the right and relevant training and educational programs to attract students or workers to the industry, and to provide the cutting-edge skills required by the industry as wireless demand continues to evolve in various aspects.

The necessity to cope with the rapid changes in the ICT and digital industries, alongside with the emergence of 5G cellular technology have brought about the need for developing training programmes to reskill and upskill both graduates and industry workers alike. Unlike the previous cellular telecommunication technologies, namely 1G, 2G, 3G and 4G where technology monetization focuses on subscribers, 5G NR Technology's focus is on business vertical use cases and only partially subscribers. Additionally, it is important for local Bruneians to be well trained in 5G NR Technology to design and plan for the infrastructures facilitating 5G NR technology demands.

PROPOSED KEY ACTIONS:

Implementation on various 5G trainings and courses

To implement holistic training programs and activities as outlined under Appendix 3 - proposed training programme, to enhance and further develop 5G ecosystem in Brunei Darussalam.

APPENDIX 2: DETAILS OF 5G USE CASES, APPLICATION & INFRASTRUCTURE

INTRODUCTION

The Working Group 2 (WG2) of the taskforce is focussed on the development and analysis of Use Cases and Applications for the upcoming 5G technology rollout in Brunei Darussalam. Consequently, the Infrastructure part is also in scope of WG2, not only the radio access part but any other infrastructure which is related to the implementation of feasible Use cases or Applications, which require 5G technology.

Specific topics like 5G Spectrum availability and usage, basic infrastructure requirements to deploy 5G New Radio (NR) and related policy requirements are the focus of the WG1 of the taskforce, with multiple alignments carried out between the Working Groups during the term of the Taskforce.

In accordance with the Terms of Reference defined for the 5G Taskforce, the focus of development within WG2 was on initiation of discussions and development of use cases amongst the members of WG2 to create the base for future trials and more detailed development supporting the adoption of the potentials of the 5G technology. To account for the scope of WG2, representatives from various organizations have been invited to participate and contribute to the outcome of the WG2:

- The Government of Brunei Darussalam, represented by Ministries and Agencies
- Small and medium businesses in Brunei Darussalam
- Companies representing national key industries (oil and gas)
- Telecommunication companies and AITI
- 5G and telecommunication equipment manufacturers/suppliers
- Educational sector

The broad participation shall ensure, that various and differing views related to the future perspectives of 5G technology application can be shared and discussed to create a common base and alignment between potential stakeholders. In addition, the discussion of Use Cases created a platform to assess the readiness and potential obstacles for the adoption of the benefits of 5G technology and services in Brunei Darussalam.

DEVELOPMENT APPROACH

For the development of 5G related Use Cases, a specific methodology was created and applied to ensure that the Use Cases are commonly evaluated along several categories which provides the base to assess possible synergies between the Use Cases and common requirements in terms of infrastructure and implementation. The reason for the specifics of the methodology created is part of the 5G technology approach defined by the Industry Forum 3GPP, responsible for the functionality and evolution roadmap of 5G.

5G as the successor of 4G was developed from the functional perspective, defining service capabilities first and addressing the technology standards afterwards. This is a complete mind-set change compared with the previous technology generations 3G and 4G, where advances of Radio and Chipset technology led to development and standardization.

The functionalities and respective service requirements have been derived from the lessons learned over the implementation and operations of 4G networks across the world and from shortfalls of 4G technology to serve specific demands of population, manufacturing and utility/services industries. In addition, the impact of new Radio access requirements on the end-to-end telecommunications network infrastructure has been assessed to ensure a 5G ecosystem wide standardization of interfaces and protocols for reduced complexity and ease of implementation. The approach is depicted below:

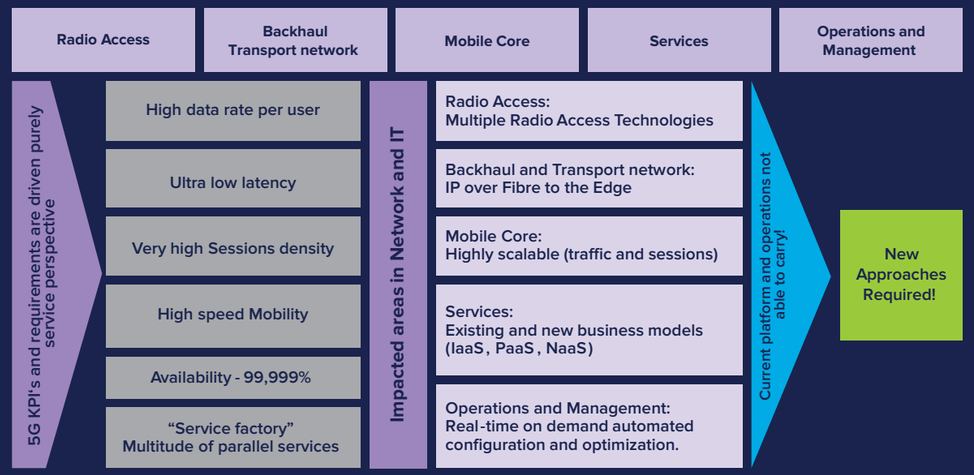


FIGURE 1: 5G DEVELOPMENT APPROACH

In parallel, the acceleration of development in inexpensive digital devices such as drones, smartphones and sensors and respective chipsets and applications over the past decade has amplified the efforts of development of digital solutions, now widely recognized as "Digitalization" and "Industry 4.0".

Specific requirements emerged from a multitude of Use Cases across a broad spectrum of areas with the development of digitalization approaches. The areas can be grouped by the nature of service scope and value creation/benefits provided:

- Population and society, focussing on the aspects of community, healthcare, urban living, education, public services and entertainment,
- Industry verticals, focussing on efficiency and enhancement of product and service quality, production processes and creation of end-to-end seamless service delivery chains.

The following figures illustrate the current status achieved in this development and shall not be considered as a final or target picture due to massive ongoing development across all the areas.

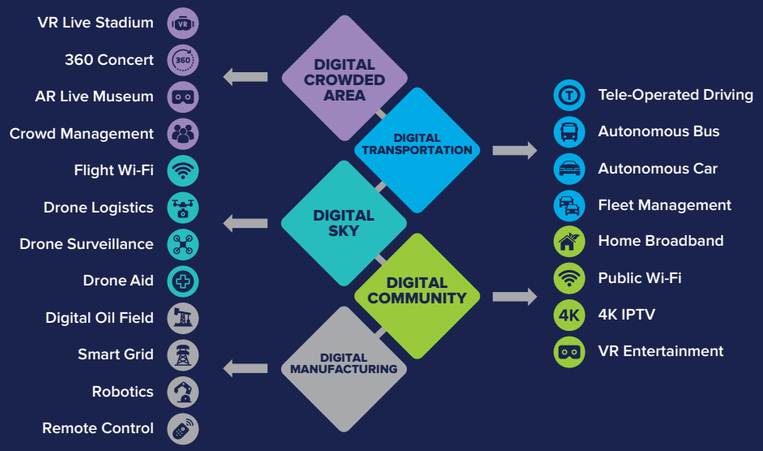


FIGURE 2: AREAS OF DIGITAL DEVELOPMENT AND CURRENT DEMANDS TOWARDS 5G

It is obvious, that 5G drives the consumer experience, but the potentials are in the digitalization programs of the Industry & Verticals due to massive machine communication and connected machine & production, summarized as Internet of Things (IoT).

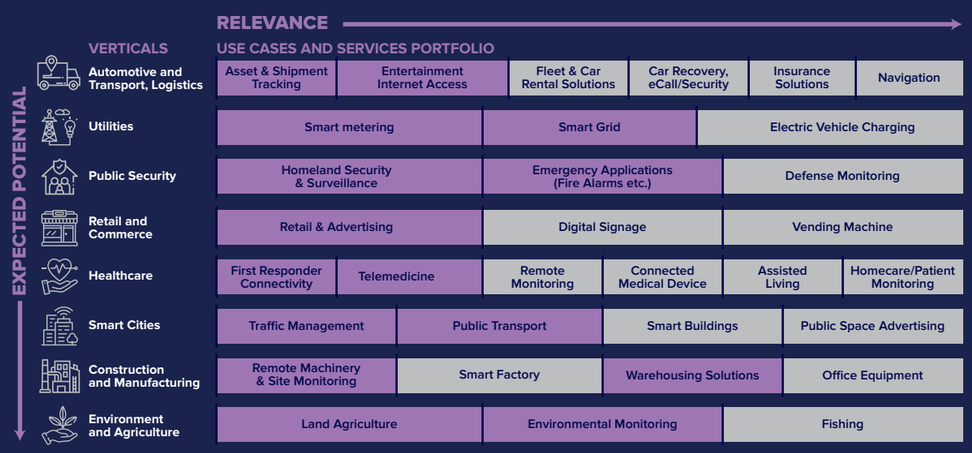


FIGURE 3: EXAMPLES OF USE CASES FOR THE DIGITALIZATION OF INDUSTRY VERTICALS

The opportunity for the 5G and Digitalization Use Case development in Brunei Darussalam is to exploit the results, lessons learned and the experience generated in other parts of the world related to Digitalization and 5G deployment. However, there are only limited options of “Copy and Paste” to make digital and 5G Use cases available in Brunei Darussalam due to the need to integrate the specifics of Brunei Darussalam into the deployments such as:

- Socio-economic specifics of Brunei Darussalam,ndustrial portfolio of the Bruneian economy,
- Presence of a multitude of companies in Brunei Darussalam supporting the development of applications and software, solution integration and process optimization.

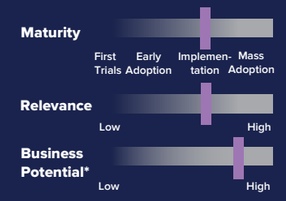
In consideration of the requirements to identify and assess Use Cases and Applications applicable in Brunei Darussalam, the Use Case methodology is contains the following elements:

- Use Case description: tangible description of the usage scenario and value creation, combined with a first (preliminary) assessment of the maturity of these kind of solution, the relevance for the respective area and the business potential of the deployment,
- Assessment of the Challenges posed by the Use Case,

Preliminary listing of all (known) requirements associated with the Use Case from a functional and operational perspective.

DIGITAL HEALTHCARE DATA, TELE-CONSULTATION AND CONNECTIVITY

Health landscape in Brunei is characterized by centralized Hospitals, regional Clinics and GP’s. Rural areas have more difficulties to access medical consultation and advice. GPs in remote communities are seeking easy and digital access to imagery and existing patients data from previous examinations. Teleconsultations in remote areas are desired based on standard devices/screens. Health checkpoints at border control posts incl. airport and connectivity for ID & data verification and mobile swab teams.



CHALLENGES

- Legacy equipment in Hospitals without or with proprietary interfaces and data formats, no central storage
- Connectivity for medical equipment in hospitals and clinics not sufficient (fixed and wireless/mobile)
- Less digital health equipment used by GPs, users/ public – not IT literate / hesitance to change
- Currently no integration between Hospital/ Clinic/ GPs (Data access and data sharing)
- Legal framework for e-health applications (i.e. Personal Data Protection, ID verification, AI and liability)
- Human resources for digital applications
- Equipment usage - No transfer knowledge

REQUIREMENTS

- Patient data storage, indexing and availability based on standard formats/interfaces–framework to be created
- Unique patient ID and patient related data consolidation
- PACS (1.0/2.0) implementation for all medical/imaging data, data generated digitally
- Definition of the tangible objectives for a digital healthcare system required (still pending)
- Training and experience (i.e. new technology and equipment)
- Broadband coverage in remote areas (fixed and mobile)*
- Remote consultation during emergency between paramedics/hospitals

FIGURE 4: EXAMPLE TEMPLATE FOR THE USE CASE DIGITAL HEALTHCARE DATA AND TELECONSULTATION

The evaluation results along relevant criteria are compiled in the second template:

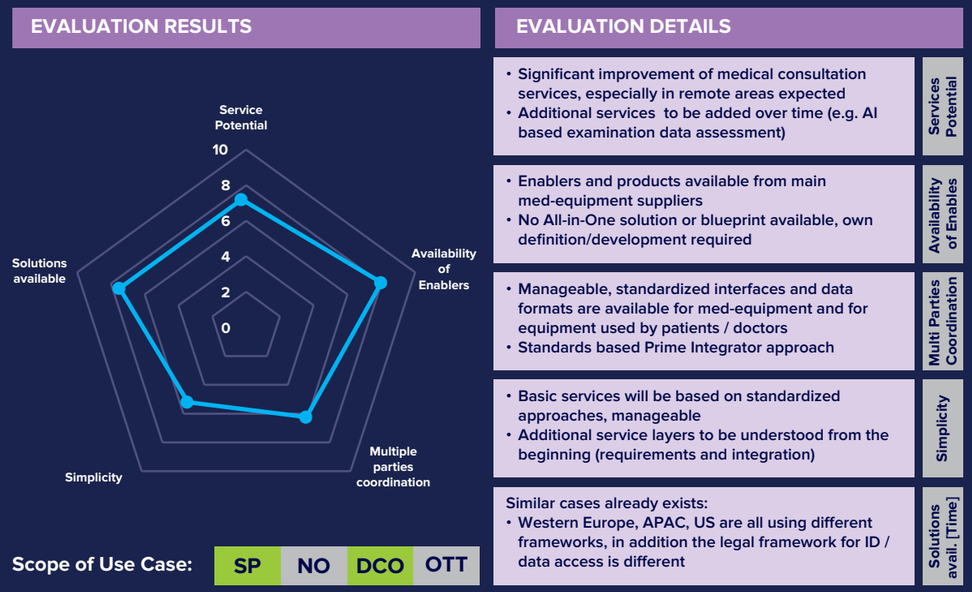


FIGURE 5: EVALUATION DETAILS TEMPLATE FOR THE USE CASE DIGITAL HEALTHCARE

The additional infrastructure requirements, which is important for the end-to-end integration, and operations of the Use case have been compiled and the service requirements to be provided by the 5G and telecommunication network have been assessed.

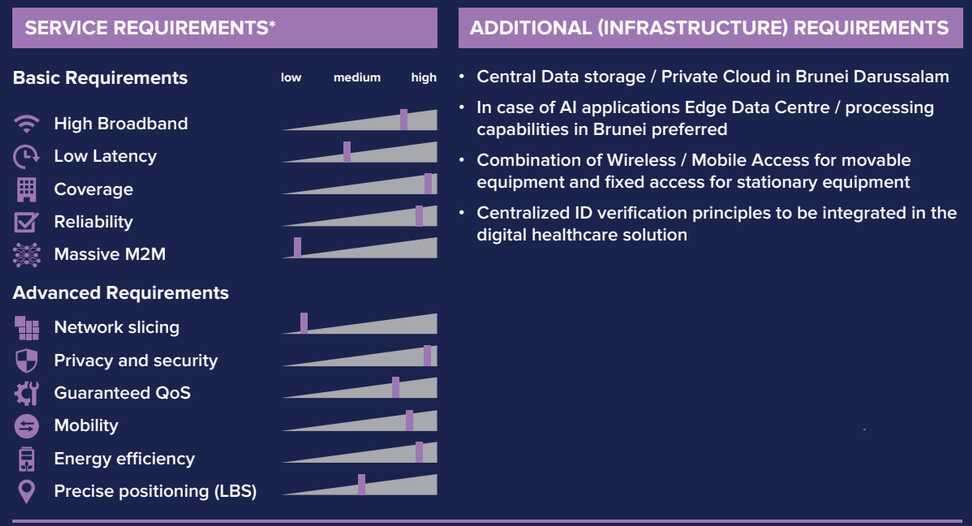


FIGURE 6: SERVICE AND INFRASTRUCTURE REQUIREMENTS TEMPLATE FOR THE USE CASE DIGITAL HEALTHCARE

The Use Case methodology was introduced and discussed in the initial WG2 meeting and fine-tuned based on the comments from the participating stakeholders.

Specific Use Cases have been proposed and introduced from a network operator's perspective by UNN. Other Use Cases have been created in workshops with Industry representatives for Oil and Gas, Health and Tourism sectors and supported by equipment suppliers. These Use Cases and respective assessment results have been discussed in WG2 meetings.

USE CASE DEVELOPMENT

General assessment of Bruneian national environment and potential to leverage 5G technology

The 5G technology is ready to be deployed in Brunei Darussalam in the near future but will not create instantly a completely new environment for telecommunication services. Although 5G is a new access technology with much broader service capabilities, the existing fixed and mobile telecommunication networks in Brunei Darussalam, which are currently undergoing a significant modernization, will coexist with the new 5G technology over a significant period of time. The fixed fibre network in the country will require upgrades in capacity and coverage, as the 5G technology mandatory requires fibre connectivity to cope with the technical requirements of data volumes, speed and latency. The full deployment of fibre in the entire national network together with the deployment of Data Centre and private/public cloud will provide the base for all digitalization efforts of the country and support for the development of respective ICT indicators.

Assessment of Brunei Darussalam ICT market indicators

The traditional ICT market indicators can be used as a proxy in respect of preconditions to enable the benefits of 5G. The comparison of Bruneian indicators with the global average and with Singapore as one of the leading countries in the world indicates development in the right direction. The following indicators are considered:

- Fixed Broadband (FBB) household penetration rate, currently 66% in Brunei Darussalam (as of December 2020),
- Mobile penetration rate, currently 125% in Brunei Darussalam (as of December 2020),
- Fixed Broadband average broadband speed (bandwidth),
- Mobile Broadband (Data and Internet) speed.

The comparison is depicted below with data from November 2020, all download/upload bandwidth values in Mbit/sec:

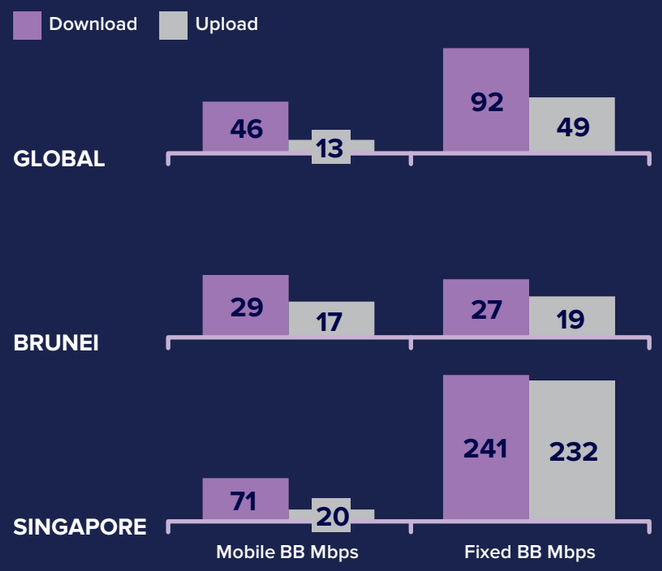


FIGURE 7: COMPARISON OF ICT INDICATORS FOR BRUNEI AND SINGAPORE WITH THE GLOBAL AVERAGE, DATA FOR NOVEMBER 2020

More important is the development of these indicators over the past 12 months, from November 2019 to November 2020. Data used from source © Ookla Global Speedtest Index, https://www.speedtest.net/global-index#mobile. The data is generated by BB customers triggering a speed test on their devices with many millions of data points across the countries for each month.

Global average

The average broadband speed increased between November 2019 and November 2020:

- For the Mobile Broadband by 50%,
- For the Fixed Broadband by 22%.

Brunei Darussalam

The average broadband speed in the country increased between November 2019 and November 2020:

- For the Mobile Broadband by 69%, representing an improvement from global rank 107 to rank 74;
- The Mobile Broadband speed increased has improved Brunei Darussalam global rank by 33 positions, the single best improvement worldwide over the period; Brunei Darussalam is in front of Malaysia (global rank 88) and Indonesia (global rank 117);
- For the Fixed Broadband by 31%, representing an improvement from global rank 113 to rank 105 (August 2020 data only);
- Based on UNN statistics the national average Fixed Broadband speed increased steadily with a boost in 2020; November 2018 ~ 17 Mbps, November 2019 – 20.4 Mbps; August 2020 – 26.9 Mbps;
- The Fixed Broadband household penetration rate increased from 48% in 2019 to 65.6% by November 2020.

Singapore

The average broadband speed increased between November 2019 and November 2020:

- For the Mobile Broadband by 30%, representing a decline from global rank 12 to rank 16;
- For the Fixed Broadband by 20%, keeping global rank 1.

The indicators are showing encouraging development for Brunei Darussalam, however the fixed broadband speed will need significant improvement over the next 24 months.

Assessment of stakeholders

The stakeholders of Digitalization and 5G utilization process, participating in the WG2 of the 5G taskforce, broadly represent organizations and businesses of the Bruneian economy, which are interested in the potentials of new technologies like 5G.

It needs to be stated specifically, that the term, 5G, has been widely used during the discussions in the WG2 as synonymous to capabilities to enable and carry digital solutions. This is critical from the perspective that the very general association of 5G with capabilities for Digitalization poses the risk, that a general perception of “5G technology will provide everything required for Digitalization” is supporting a rather baseless belief in technology solving all problems and answering all questions.

This is a common fact in many other regions of the world and the root cause lies in the limited knowledge about the technologies and components of a Digitalization approach.

The approach taken in other markets (which have started earlier with the 5G/Digitalization), was to assess the own/specific areas of service delivery, products and solutions, processes within own production or organization to understand, where current approaches are limiting to improve or the create new capabilities and to identify areas to create value for customers, processes, products by applying digital technologies.

Starting with the well-known areas of own services and processes the insight and skills shall be available in each organization to identify potentials to improve or innovate by applying digital technologies.

However, the organizations will require support in understanding, what is available and what could be a meaningful combination of digital technologies to support a digital solution.

This was the approach taken in the discussion by WG2; focussing on the topics in terms of value creation and discussing technology afterwards. The technology scope, in this case, will be broader than 5G/new radio access technology only, targeting areas like Edge Computing, Data Centre and Private/Public Cloud.

It became apparent, that all stakeholders in the process have been keen to participate and to embark on the journey but lacking the ability to pass the entry barrier for own development.

From WG2's perspective, the effort required to make meaningful progress with Digitalization is widely underestimated in the respective organizations and could lead to early resignation in pursuing the implementation of digital approaches.

In addition, there are quite common issues from the legacy As-Is status, to be addressed by comparable organizations first, which are seen by the stakeholders as an obstacle to start the Digitalization/5G journey quickly.

It is recommended to support the stakeholders in joining forces and approaching legacy issues and entry level development together as far as type of business or organizations are supporting this.

In addition, the cooperation between the Educational sector and Businesses/Administrations would be useful if focussed on very specific and tangible topics and objectives.

The absence of specialized/consulting companies for incubation and development of digitalization prototypes (not selling products and solutions) together with interested stakeholders is another obstacle for a more agile development into digital approaches amongst Bruneian stakeholders.

Use Cases developed by interactive engagement with Industry/Services representatives

In the workshops conducted by WG2, several use cases have been discussed and developed based on the insight of the respective participants and examples/deployment cases provided by supplier industry representatives. The Use cases are listed below:

NO	USE CASE TOPIC	ASSESSMENT	PROPOSED BY
01	E-Health Ecosystem	Pre-assessment done	UNN, 06.06.2020
02	Industrial IoT: Operator view	Pre-assessment done	UNN, 06.06.2020
03	Digital Healthcare (e-Health Workshop 06.07.2020, supported by Huawei)	Pre-assessment done	Outcome from WS
04	Oil & Gas Upstream and Processing (Oil& Gas Workshop 06.07.2020, supported by Huawei)	Pre-assessment done	Outcome from WS
05	Brunei Tourism Eco-System (WS10.08.2020, supported by Huawei & Pridiq)	Pre-assessment done	Outcome from WS
06	Educational Campus (UTB), Multipurpose approach	Pre-assessment done	Created by UTB

TABLE 1: LIST OF USE CASES DEVELOPED IN WG2

Perspectives

The main perspectives to develop the listed Use Cases into application for the Bruneian market are tangible as they have been developed from the Bruneian requirements perspective. More effort needs to be invested in the detailing of the requirements and the verification of the specific conditions in the respective industries or service areas. A conceptual design of the targeted solution shall follow including the identification of all relevant stakeholders required for implementation and operations of the Use cases.

As a special effort to amplify the UTB Education Smart Campus approach and to provide real life 5G access experience for multiple applications, a 5G POC Base Station of the UNN network will be redeployed on the UTB campus in February 2021.

Limitations

Then main limitations for development into applications for the Bruneian market in a short time frame are the availability of skills and resources in the respective organizations and the focus on tangible first steps. However, this may differ for the Use cases discussed.

Status of technology, standardization and equipment availability

The 5G technology development is following a fast track and unified standardization approach. Following the lessons learned from 3G (regional specific standards) and 4G (long time of standardization) development, the 5G approach of standardization is focussed on time to market, compatibility of feature sets between the release candidates and focus on functionality requested from the market. The full range of relevant organizations is participating in the standardization and development of the 5G ecosystem.

Category	Organization
Industry Alignment & Adoption (includes Spectrum)	ITU-R
	GSMA
	NGMN
Access Technology	3GPP
	IEEE 802.11
	ETSI ISGmWT
	ETSI RRS

Category	Organization
Network Architecture & Core Network	ITU-T SG13 IMT-2020
	3GPP
	NGMN
	ETSI ISG NFV
	ETSI ISG MEC
	OPNFV
	IETF
	Small Cell Forum
Network Management	3GPP
	TM-Forum
	NGMN
Others	OMA
	IEFT
	Etc.

IMT-2020: Requirements (ITU-T/R)
- Timelines for 5G development
- Performance requirements
- Evaluation criteria

Technical Specification of 5G
- Definition of the 5G system
- Evaluation of solutions
- Technical specification of 5G

5G Enablers
- Standardization of 5G enabling technologies and frameworks like NFV, SDN, etc.

and others

Source: Infocommand Media Development Authority; Note: List not exhaustive

FIGURE 8: MAIN INDUSTRY ORGANIZATIONS RELATED TO THE DEVELOPMENT OF 5G

The key standardization body for driving the 5G technology specifications is the 3GPP, which combines the operator side, the supplier side and the service side and is following a strict roadmap for the development of the technology releases.

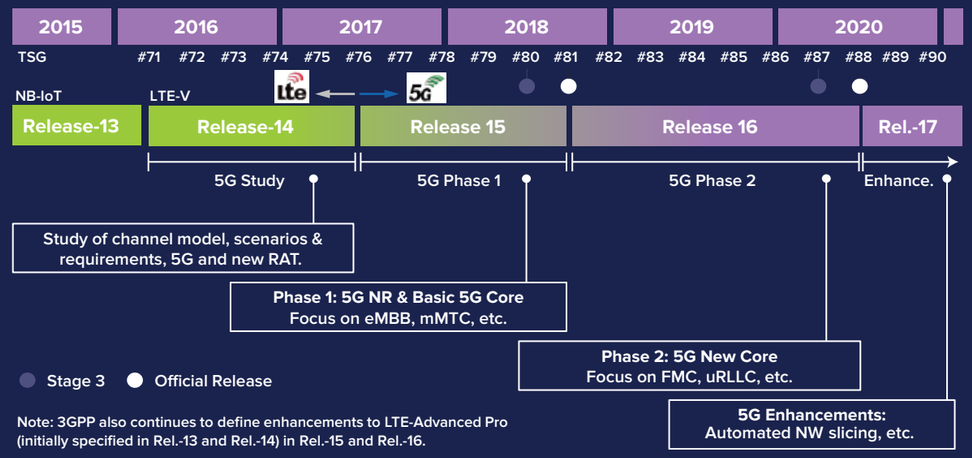


FIGURE 9: 3GPP TIMELINE FOR THE 5G RELEASE DEVELOPMENT

The 3GPP Phase 1 (Release 15) was pushed to provide the base for first Proof of Concepts and Pilot deployments of 5G in the initial areas of service demand:

- Focuses on 4G LTE, 5G NR Release-15, and the next generation system architecture,
- NR Release-15 lays the foundation for eMBB and URLLC use cases.

The 3GPP Phase 2 (Release 16) was developed in parallel and overlapping with Release 15 focussing on additional service capabilities:

- Continues with 5G NR optimization and introduces new use cases with 5G NR,
- Release 16 was approved in the 3GPP Plenary Session 88e in July 2020,
- NR Release-15 will be forward compatible with NR Release-16.

The participation of network operators, equipment manufacturers and entities focussed on service delivery is ensuring convergent standards and roadmaps aligned with expected demands. On the positive side, this means a high level of interoperability of network equipment from different suppliers and the interoperability of devices with the newly deployed 5G networks. It means as well, that devices and equipment will be available quickly after specifications standardized and approved, due to unified worldwide demands.

On the backside, the features development roadmaps within the Release Candidates will be dominated by the demands of the biggest network operators participating in the development.

The standardization work of 3GPP defines technical specifications for mobile communications, including user equipment, wireless access, core network and related service frameworks.

3GPP is organized into 16 specialized Working Groups to manage the complexity of different system components.

Radio Access Network (RAN) Technical Specification Group	Service/System Aspects (SA) Technical Specification Group	Core network & Terminal (CT) Technical Specification Group
Defined the radio communications between UEs and core network.	Responsible for overall architecture & service capabilities	Responsible for core network; defines terminal interfaces & capabilities
RAN WG1 Layer 1 (physical) specification	SA WG1 Service requirements	CT WG1 Mobility Mgmt., Call Ctrl, Session Mgmt.
RAN WG2 Layer-2 and 3 (RR) protocols	SA WG2 Architecture	CT WG3 Policy, QoS and Interworking
RAN WG3 Access network identification + O&M	SA WG3 Security	CT WG4 Network protocols
RAN WG4 Performance requirements	SA WG4 Codecs, multimedia systems	CT WG6 Smart card application
RAN WG5 UE conformance testing	SA WG5 Telecom management	
RAN WG6 Legacy RAN, e.g. GSM, HSPA	SA WG6 Mission critical services	

FIGURE 10: 3GPP WORKING GROUPS FOR 5G

These Working Groups are organized along with the three governing technical specification groups (TSGs), where most technical work and decisions are accomplished.

The 3GPP organization has published the roadmap with the expected availability of key 5G service features, to be considered for the Use Cases and applications planned in Brunei Darussalam.

Category	Related Specifications	Requirements	Main Use Case	Expected Availability
eMBB	TR22.863 TR22.261	High data rate, high traffic density, diverse coverage, high user mobility	Indoor, hotspots - Wide area	2019/2020
uRLLC	TR22.862 TR22.261	High reliability and low latency, high reliability, high availability and low latency, very low latency, high accuracy positioning	Virtual presence, tactile internet, remote control, telemedicine, remote firs aid and drone control	2021+
mMTC	TR22.861 TR22.261	Improved operation, diversified connectivity and improved resource usage efficiency in relation to IoT	Improved IoT devices initialization, large capacity support, wearable device communication, bio connectivity and wide area monitoring	2021+
NEO	TR22.864 TR22.261	System flexibility, scalability, mobility. Efficiently content delivery and improved security. Diverse backhaul/ access considerations and migration/ interworkingconsiderations	Common system requirements independent of services	2019/2020
eV2X	TR22.886 TR22.186	High data rate, high reliability, high availability and low latency. Wide area coverage	Autonomous driving, convoy (platooning) driving and remote driving	2021+

TABLE 2: 3GPP 5G USE CASE CLASSIFICATIONS AND AVAILABILITY ROADMAP

5G NR Technology

5G New Radio (NR) is a completely new radio communication system without backward compatibility to LTE/LTE-A. However, the passive antennas currently in deployment for the common spectrum bands between 700MHz and 2600MHz are combining capabilities to send and receive radio signals for LTE/LTE-A and 5G NR.

New technologies, supported by progressing chip miniaturization and processing power, are integrated in 5G NR to serve on the requirements defined for 5G networks, which include:

- Support for very diverse spectrum,
- Optimized modulation,
- Modern antenna technology like
  - Massive MIMO, supporting multiple signal streams from and to the device,
  - Beamforming & tracking,
- Advanced Channel coding.

All these new technologies need to be integrated not only into the Radio Access Network (RAN) equipment but also into the devices developed for the 5G network. To make the 5G RAN technology generation future proof, massive amounts of spectrum (Frequency Bands) have been considered for 5G by the ITU. The bands are covering the traditional bands of mobile communication, low bands from 450MHz, Medium bands above 3500MHz and mmWaves bands starting from 24GHz and up to 86GHz. The implementation of the Frequency bands into devices will take time and start with the most common bands in the world.

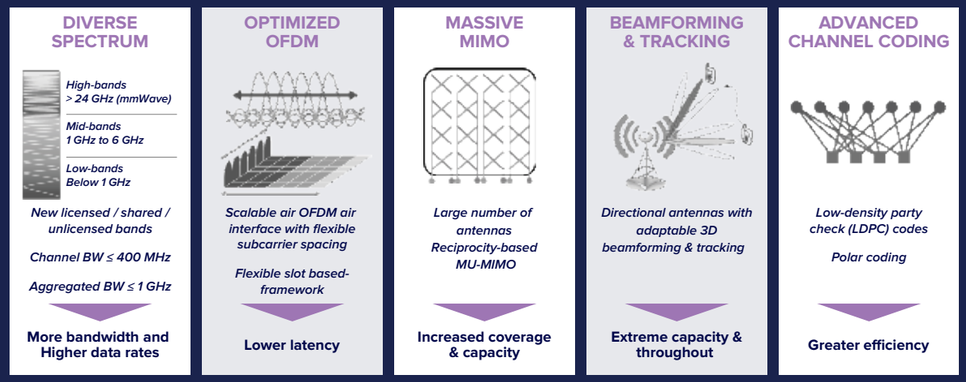


FIGURE 11: NEW KEY TECHNOLOGIES IMPLEMENTED IN 5G NEW RADIO (NR)

Spectrum

The deployment options of the 5G NR radio access network is highly dependent on the spectrum utilized. All deployments with spectrum bands above the currently used for 3G and 4G networks will require a completely new radio planning based on use cases and radio propagation/penetration.

For the Low and Medium Bands from 450MHz to around 2600MHz proven propagation models can be used for outdoor environments, considering Non-Line of Sight (NLOS) and Line of Sight (LOS). This spectrum is suitable for macro cell deployment, which is currently the deployment option for the 3G and 4G networks in Brunei Darussalam.

Leading 5G markets consider portions around 3.3 GHz - 4.2 GHz as a primary 5G band. Asian Markets are using this band especially for satellite services, therefore only a smaller portion of this band will be available at the beginning of the 5G implementation.

Note: (1) Listing of frequency bands under consideration; (2) Frequency band that are not globally allocated

FIGURE 12: OVERVIEW OF FREQUENCY BANDS CONSIDERED FOR 5G BY THE ITU

Spectrum above 2100MHz is generally more difficult, if the outdoor equipment is supposed to penetrate indoor space within buildings. The illustration shows the relative outdoor performance of 900MHz spectrum (below 1GHZ) relative to three mid-band spectrum bands (2.1GHz, 2.5GHz and 3.5GHz) to support the statement above.

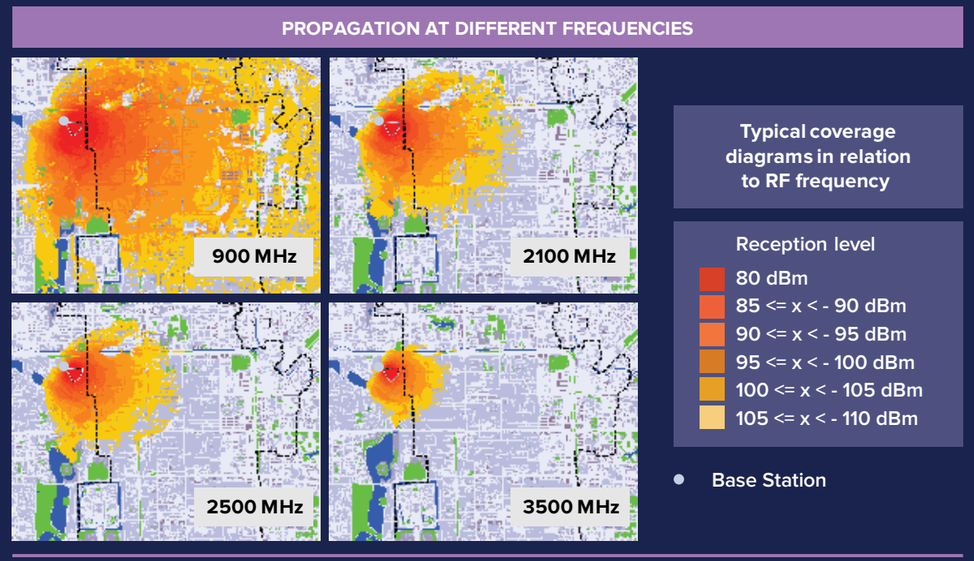


FIGURE 13: PROPAGATION AT DIFFERENT FREQUENCIES, COVERAGE COMPARISON OF BANDS

The Sub 1 GHz frequencies (including the 700 MHz and in some areas) have better coverage, but will lack the capacity required for the target data rates, considering the significant larger coverage area with more active subscribers.

Deployment of 5G at the various frequency bands will enable small businesses and consumers to experience far higher speeds than they do now. However, modern architecture with steel-reinforced structures and sun-reflecting windows (metalized coating) are shielding indoor space from outdoor radio, requiring separate approaches to deploy In-Building Solutions (IBS), covering each floor and in extreme situations each room separately.

With higher bands spectrum and specifically mmWaves offering nearly limitless bandwidth the deployment options and deployment cost becoming a main obstacle:

- No penetration through concrete walls,
- Mainly for indoor and urban hotspot environments,
- Capacity boosting and Self-Backhaul for easy site acquisition.

The dependencies are depicted in the figure below:

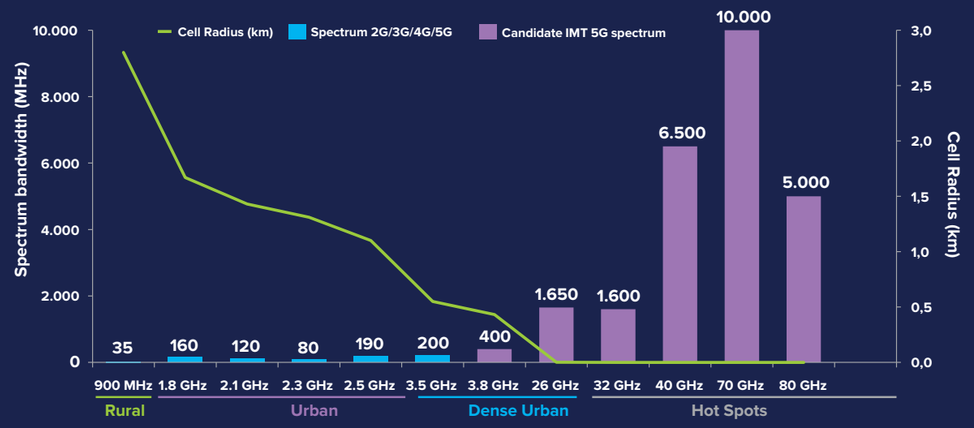


FIGURE 14: FREQUENCY BANDS, AVAILABLE BANDWIDTH AND RESPECTIVE PROPAGATION CHARACTERISTICS

Specific attention to be paid to the Cell Radius of a Base station dependent on the frequency utilized. Where the 3.5 GHz band is still providing a cell radius of 200-500 meters strictly LOS and outdoor, the mmWave spectrum will provide coverage with cell radius measured in meters and comparable with the reach of Bluetooth technology today, of course with bandwidth of up to 10 Gbps.

A more detailed assessment of deployment options for mmWave RAN is currently not possible due to limited availability of standardized equipment and devices. Analysing further the IMT-2020 performance requirements, the mapping of spectrum bands to use case categories becomes obvious, see figure below.

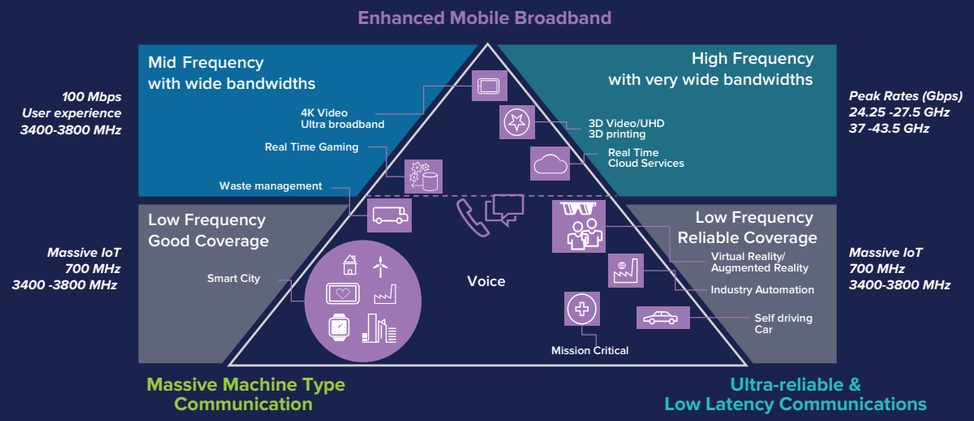


FIGURE 15: IMT-2020 5G USE CASE DOMAINS AND BAND MAPPING

For the current 5G strategy and for the foreseeable future till 2026, the spectrum bands defined for 5G utilization in Brunei Darussalam (700MHz, 900MHz, 3500MHz) with a total bandwidth of 2x160 MHz shall ensure a user experience for the Enhanced Mobile Broadband (eMBB) in the range of 1,000 Mbps (1Gbps), supported by a comparable experience in the coexistent 4G LTE-A network.

Suppliers

As stated earlier, the 5G technology (5G NR RAN) over a significant period of time will co-exist with 3G and 4G RAN networks in the country. Deployment scenarios for the 5G RAN, which are supporting seamless handover between 4G and 5G RAN are crucial to lower the barrier for 5G Use Cases implementation and to ensure a fast uptake for 5G based mobile services within the Bruneian market.

This scenario can be supported by equipment suppliers, which are providing a full portfolio of legacy and new RAN technologies and respective core network and service equipment.

Due to the supplier market consolidation over the past 2 decades, only 4 full profile suppliers are serving the world market (in alphabetical order):

- Ericsson (Sweden)
- Huawei (PRC)
- Nokia (Finland)
- ZTE (PRC)

For 5G RAN equipment, only Samsung (South Korea) has invested in R&D and has been able to gain a competitive position amongst the traditional suppliers. Many more suppliers are developing equipment and solution in very specific and niche areas, which needs to be assessed based on specific detailed Use Case requirements as soon as developed to that level.

Due to the high degree of standardization and resulting interoperability, the 5G technology already in the early stages of deployment has sufficient level of maturity, compared with 3G and 4G technology during similar stages of lifecycle.

Specific concerns related to Health and Safety for 5G Radio

In the past year, several press releases all over the world have reported specific concerns related to 5G radio have been discussed in the public. In all of the cases, the discussions have been initiated not by health or scientific research organizations but have been initiated by interest groups to seek attention. In some countries this led to wild theories, that 5G radio is responsible for the Covid virus and some other dubious claims resulting in agitated citizens burning down mobile base stations.

Despite these reports, the topic of public health related to technical installations like mobile radio communication is an important one. With the introduction of digital mobile communication in 1991 and deployment of nation-wide networks in many countries, the impact of radio waves in the spectrum range between 800MHz and 2600MHz have been assessed, researched and published in thousands of studies all over the world.

The nature of mobile radio communication from the radio physics perspective has not changed moving from 2G standard to 3G, 4G and now to 5G. However, many people have expressed health concerns about 5G. This is a complicated issue, which has both short and long explanations, sometimes neither of which will satisfy. The short answer is that 5G has not been found and is not believed to cause any harmful effects in humans. However, to understand why, requires an appreciation of physics.

On the electro-magnetic scale RF spectrum for mobile networks are confined to spectrum higher than 300 x 10^6 Hz (300 MHz) which has a 1m wavelength, and below 300 x 10^9 Hz (300 GHz) corresponding to a mmWave length (3x10^{-3} m).

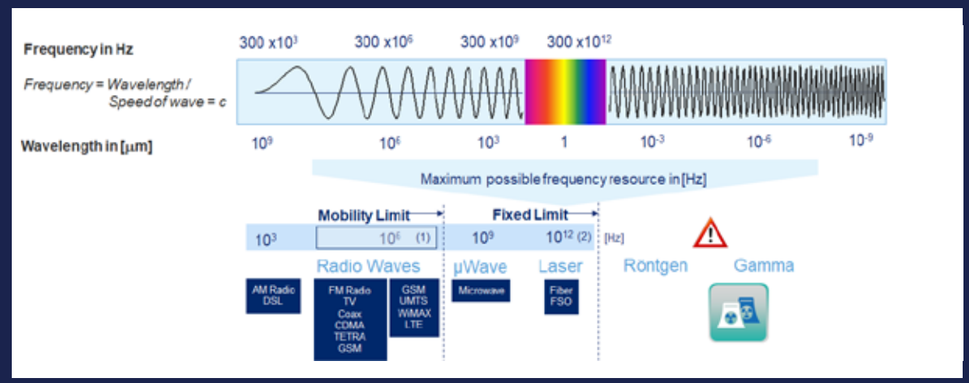


FIGURE 16: 5G VARIETIES GROUPED BY SPECTRUM BAND

The energy of an electro-magnetic wave increases with frequency. The energy of an electro-magnetic wave (E(rf)) is decreasing with the third power of distance (d) between sending antenna and receiver (e.g. smartphone), E(rf) ~ 1/d3.

The antenna output power level is typically between 10 and 40 Watts for an outdoor base station. Television transmitters, by comparison, usually have a thousand times higher output power than outdoor base stations. Antennas mounted indoors have about the same power output as mobile phones (100 mW – 1000 mW) and comparable with WiFi hotspots used in the households.

It is well known that there are certain RF bands that have a higher absorption rate by water vapour and rain. However, mobile RF equipment avoid such spectrum zones, as the radio wave would get absorbed more readily by the air and rain. Indeed, mmWave is used currently by microwave and some satellite systems experiencing a higher signal attenuation in case of rainfall. People rallying against 5G would do better to refine their argument not on 5G per se, however instead on the mmWave spectrum which 5G potentially could use (so as to distinguish these bands from below 6GHz IMT bands).

Having said this, the only thing which can be attributed to electromagnetic spectrum is the absorption by human tissues, which may cause localized heating of up to 1°C in case of long exposure with higher power output. Mindful of this, regulators set limits on the electro-magnetic field strength emitted by mobile equipment. The mobile base station on the tower operates at a higher power, however the lower-power handset is closer to the users face.

Two documents which have established RF safe exposure limits are:

1. The Guideline from the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which has been in existence since 1998.
2. The International Institute of Electronic and Electric Engineers (IEEE) C95.1 “IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields” and released in 2005, which covers spectrum from 3kHz to 300GHz.

Mindful of 5G and technical evolution in mobile, both documents were updated in 2019. The ICNIRP guidelines used in Europe and most other countries set the safe specific absorption rate (SAR) limit at around 2.0 W/kg, while some countries e.g. FCC in the USA set a lower limit of 1.6 watts per kg. Several other countries e.g. Russia, and India set their limits even below these guidelines.

Current exposure measurements are done in the most countries, to verify the real exposure of a human by the radio waves of 3G/4G/5G networks. The measurements are complex, based on a standardized/predefined combination of several factors which are contributing to the exposure of the human body to the radiation of the mobile networks. In general, these studies published results, where the current consumer exposure is between 0.5% and 4% of the defined exposure limits (SAR limit 2W/kg = 100%).

The fact, that the exposure limits are set by independent organizations, not involved in production and marketing of mobile communication equipment, should provide the base to consider the finding so far. The exposure levels have been established by independent expert organizations and they are subject to research by state, private and other public organizations for almost 60 years.

The limits are recommended by the World Health Organization (WHO), among others, and include large safety margins. 5G equipment, whether it be mobile devices or base stations, will meet the same safety standards as the equipment used in previous mobile communication networks. In addition, the mobile handsets are optimized for long battery life. That means, the handset will emit radio waves on the lowest possible power level required to ensure stable signal quality for the service in use.

The World Health Organization (WHO) states: “From all evidence accumulated so far, no adverse short- or long-term health effects have been shown to occur from the RF signals produced by base stations” and “A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established as being caused by mobile phone use.“
(WHO fact sheets No 304 and No 193).

5G Architecture and Network slicing

As discussed earlier, the 5G technology is developed service driven, a number of design principles are applied in the development of 5G as illustrated in the figure below.

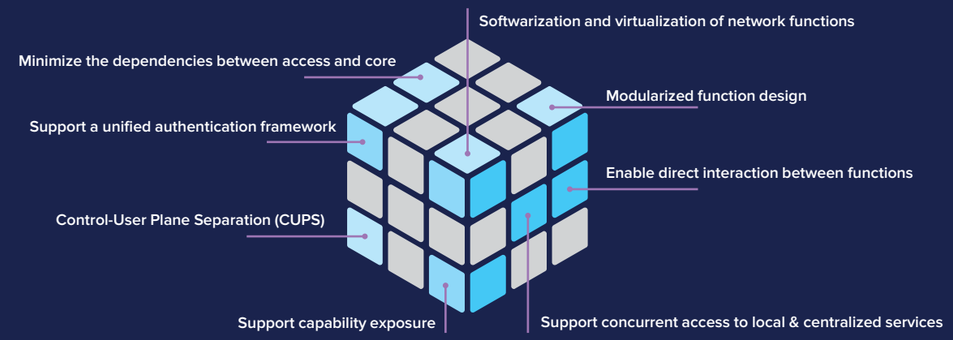


FIGURE 17: 5G NETWORK AND TECHNOLOGY DESIGN PRINCIPLES

The technology behind the 5G network and network slicing has proven efficient and reliable over the past decade, being deployed in the most advanced Data Centres. It is virtualization and Cloud, which is now entering the telco equipment rooms and transforming them to Data Centres (Telco Cloud). The following points are key:

- No more network elements – 5G only uses network functions (NF),
- Full softwarization (SDN) and virtualization of network functions (NFV) for flexibility and efficiency,
- Deployment on a Telco Cloud infrastructure.

The most important 5G network enablers related to the core network are NFV and SDN for a cloud native network design. This is the precondition to serve on the requirements from commercial and Use Case perspective.

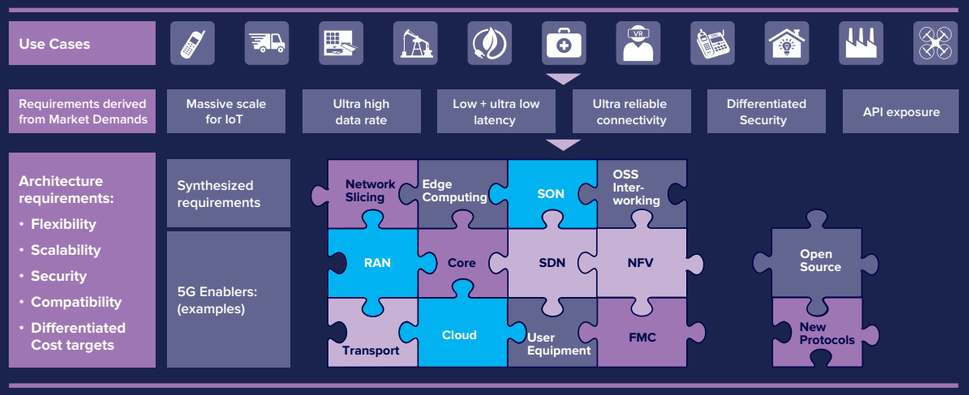


FIGURE 18: ARCHITECTURE REQUIREMENTS FOR 5G SERVICES AND USE CASES

That means, the 5G deployment is not only the rollout of 5G NR radio access network, which is already a challenge for the network operators. It is the deployment of a next generation architecture, which implies new design principles for network and operations and requires completely new skills like Software architects and Developers, DevOps professionals in the network operator's organization.

The skills required and the organizational transformation for traditional telecommunication providers is considered one of the biggest challenges on the way towards 5G.

The virtualization and software based orchestration of all network and service functions is one of the preconditions to provide services for the main service domains for

- Enhanced mobile broadband (eMBB),
- Massive machine-type communication (mMTC),
- Ultra-reliable low latency (uRLL).

The service domains have generally very different requirements towards resources, locations and response time. The Use Cases discussed in WG2 in certain aspects have identified these requirements, so the deployment of the 5G technology in Brunei Darussalam has to consider a level of flexibility to be able to deliver service capabilities cost efficient despite the scale of the national market.

The architecture principles and technologies defined for 5G are serving these demands with a simplified logical network but with much more complex deployment options of functionality related to locations.

The schematic 5G network architecture in the figure below is indicating key functions and possible distribution in the network.

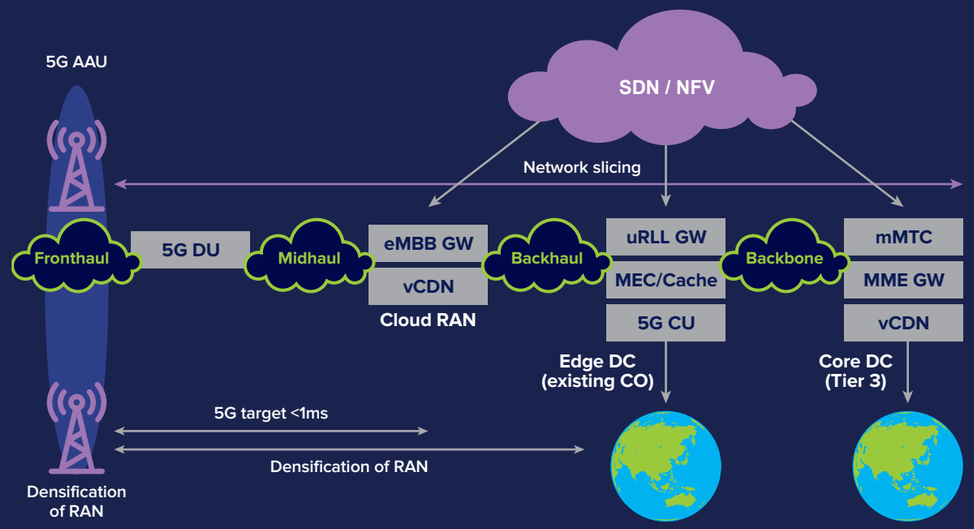


FIGURE 19: 5G NETWORKS ARCHITECTURE IS BASED ON SOFTWARE DEFINED (SDN & NFV) NETWORKS

The implementation of all the functions in software and virtualized allows to reserve and allocate a portion of each network function to different service clusters as required by the services.

What are the Specific benefits of network slicing and application to identified use cases and future scenarios?

Unlike 4G, 5G will support different industry verticals with diverse services and network requirements. Network slicing allows establishment of independent quality of service for each network slice used for specific use cases. The virtualization provides the option to allocate the resources in an elastic way, changing the allocation in near real time as per requirement profile of the service. Logically each service type or service cluster will be provided with an own "Network Slice", ensuring they are provided on a common infrastructure without impacting each other negatively.

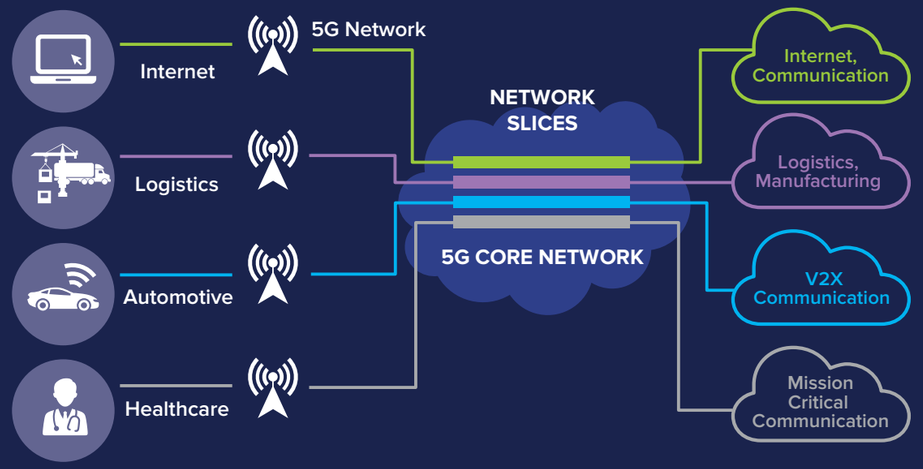


FIGURE 20: NETWORK SLICING BASED ON SOFTWARE DEFINED NETWORKS (SDN & NFV)

The slicing principles in general are:

- Private networks are implemented as a software layer on top of common physical infrastructure,
- Network functions and quality of service will adapt to specific use cases,
- Resources can be dedicated or shared,
- Networks are managed independently by network slice,
- Network slicing opens up new business models,
- Network slicing forms the basis for private campus networks.

However, the actual scoping of network slices requires a thorough mapping process. Application programming interfaces serve as connectors between the mapping domains.

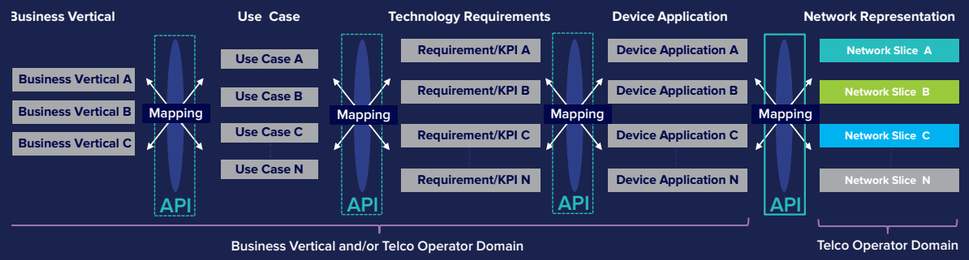


FIGURE 21: NETWORK SLICING – THE MAPPING EXERCISE

A dedicated multi-stage mapping exercise is the prerequisite in order to ensure that network slices meet

- the actual business (Use case) demand,
- operator‘s expectations in terms of scalability and flexibility of network operations.

The actual mapping is not necessarily a 1:1 relationship but can encompass many-fold relationships.

Application programming interfaces are required, where business verticals and telco operator spheres are touching each other – in an abstract sense this might even be applicable for all the mapping interfaces shown above.

The evolution of the 5G deployment in Brunei Darussalam shall be targeted on the benefits of network slicing to serve the Use Cases and Applications in the country. For the initial deployment of 5G and based on the assessment of currently specified service requirements (Use Cases) network slicing will be not required.

Skill development to support not only network deployment and operations but also the support of parties looking for the development of 5G based solutions for Use Cases identified will be an early priority for the companies involved in 5G.

Edge computing

The 5G core network architecture relies on a number of technology building blocks or technology enablers, as defined by NGMN. All these enablers are defined from the perspective of Service requirements or more specifically Use Case requirements. The Cloud native network design as a main principle behind the 5G network architecture is providing a set of functionalities, relevant for the future Use Cases:

- Smart edge node (Functionality deployed close to the user location),
- Software-defined networking (SDN),
- Micro services (Software/API),
- Traffic optimization,
- Big Data capabilities,
- Context-aware and user centric network,
- Content-optimization and adaptive streaming,
- Information-centric networking,
- Privacy and security,
- Technologies for massive connectivity.

Edge computing is a solution, which serves on parts of the functionalities listed above. With the main requirement of low latency for specific Use Cases which in addition are requiring access to Big data, data analysis and Use case related “decision making” which cannot be processed on the device itself, processing power for the specified tasks has to be allocated close to the Use case activities.

A specific requirement of below 10ms response time between device and service application would require to make the application data and processing results available within this time. In case of sensitive applications like drone and VR based activities or autonomous vehicles, the two approaches to serve the response time requirements are high processing power and elimination of data transport time in the network, which leads to low scale/high processing power units deployed close (less than 20 km) to the user.

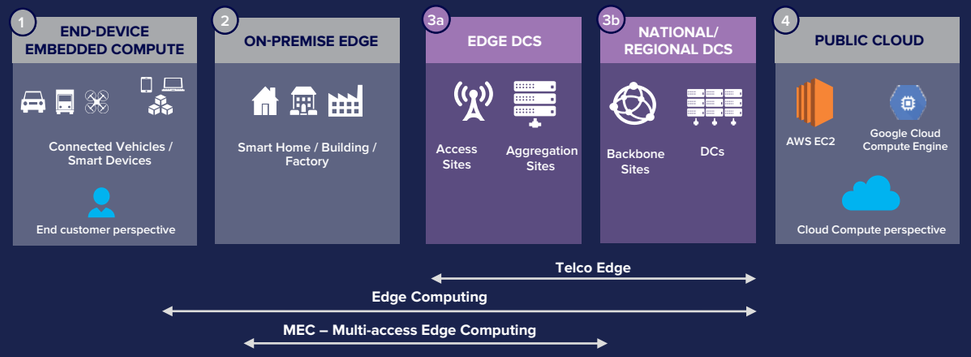


FIGURE 22: 4 PRINCIPAL SITES OF EDGE COMPUTING

Some of the Use Cases discussed could benefit from Edge Computing, however the current specific level of details is not sufficient to set this requirement as mandatory. The evolution of the 5G deployment in Brunei Darussalam shall be flexible to incorporate the benefits of Edge Computing as soon as commercial Use Cases and Applications are emerging in the country. For the initial deployment of 5G and based on the assessment of currently specified service requirements (Use Cases) Edge Computing will be not required.

Devices and end user terminals

As 5G is aimed to support and penetrate much more areas of human work and life, the diversity of 5G enabled devices will be much broader than experienced in the past years for 3G/4G radio access networks.

All devices have one common functionality related to 5G. It is to establish and to manage the connectivity to the 5G network, including authentication of the device, the user or the application, requiring access to telecommunication networks.

However, for the variety of Use Cases envisaged for Digitalisation and 5G, the requirements towards the devices will be very specific and different, which will require specific research & development and production for these device classes:

Sensors and Actors

- Inexpensive,
- 10 years autonomous work from battery,
- Robust towards environmental impact,
- Robust sending/receiving of information based on signal quality (antenna technology),
- Low processing power, low data volume processing, local intermediate storage.

Machine type Communication device

- Programmable,
- Inexpensive,
- Robust towards environmental impact,
- Backup battery and loss free data storage,
- Robust sending/receiving of information based on signal quality (antenna technology) in industrial environment (EMP),
- Various processing power for data processing and analysis, medium to high data volume processing, local storage,
- Open API and interfaces for integration ion industrial solutions.

Command and Control type Communication device

- Programmable,
- High processing power for data processing and analysis, high data volume processing, local storage,
- Processing of Audio-Visual information,
- Local processing capabilities for AI and Machine Learning,
- Robust sending/receiving of information based on signal quality (diverse and use case scenario adapted antenna technology).

Human devices

- Highly customizable and programmable,
- High processing power for data processing and analysis, high data volume processing, local storage,
- Processing and generation of Audio-Visual information,
- Local processing capabilities for AI and Machine Learning,
- Autonomous work based on battery power for more than 24 hours,
- Robust sending/receiving of information based on signal quality (diverse and use case scenario adapted antenna technology).

Due to the phased introduction of 5G networks and related spectrum bands, most of the devices shall provide 4G connectivity as a fall-back in case 5G coverage is not available.

In most countries, 5G will be deployed both on specifically acquired spectrum (3.4GHz-6 GHz) and spectrum re-farmed from the existing technology generations (IMT spectrum).

For the current deployment of 5G in Brunei Darussalam, the Frequency Range 1 (450MHz – 6.0GHz) is of concern. The 5G frequency bands are following the numbering scheme of 4G and have the index “n” in front of the band number.

For example, the band 8 (900MHz) is used for 2G, 3G and 4G and will be the n8 band for 5G radio networks. The table for the 5G frequency bands and channel bandwidth is provided below:

Band	Duplex mode	Frequency (MHz)	Common name	Subset of	Uplink (MHz)	Downlink (MHz)	Duplex spacing (MHz)
n1	FDD	2100	IMT	n65	1920 – 1980	2110 – 2170	190
n2	FDD	1900	IMT	n25	1850 – 1910	1930 – 1990	80
n3	FDD	1800	PCS		1710 – 1785	1805 – 1880	95
n5	FDD	850	CLR		824 – 849	869 – 894	45
n7	FDD	2600	IMTE		2500 – 2570	2620 – 2690	120
n8	FDD	900	IMT		880 – 915	925 – 960	45
n12	FDD	700	PCS		699 – 716	729 – 746	30
n14	FDD	700	DCS		788 – 798	758 – 768	–30
n18	FDD	850	CLR		815 – 830	860 – 875	45
n20	FDD	800	IMT E		832 – 862	791 – 821	–41
n25	FDD	1900	Extended GSM		1850 – 1915	1930 – 1995	80
n28	FDD	700	Lower SMH		703 – 748	758 – 803	55
n29	SDL	700	APT		N/A	717 – 728	N/A
n30	FDD	2300	WCS		2305 – 2315	2350 – 2360	45
n34	TDD	2100	IMT		2010 – 2025	N/A	5, 10, 15
n38	TDD	2600	IMTE		2570 – 2620	N/A	5, 10, 15, 20
n39	TDD	1900	DCS–IMT Gap		1880 – 1920	N/A	5, 10, 15, 20, 25, 30, 40
n40	TDD	2300	S-Band		2300 – 2400	N/A	5, 10, 15, 20, 25, 30, 40, 50, 60, 80
n41	TDD	2500	BRS	n90	2496 – 2690	N/A	10, 15, 20, 30, 40, 50, 60, 80, 90,100
n48	TDD	3500	CBRS (US)		3550 – 3700	N/A	5, 10, 15, 20, 40, 50, 60, 80, 90,100
n50	TDD	1500	LBand		1432 – 1517	N/A	5, 10, 15, 20, 30, 40, 50, 60, 80
n51	TDD	1500	LBand Extension		1427 – 1432	N/A	5
n65	FDD	2100	Extended IMT		1920 – 2010	2110 – 2200	190
n66	FDD	1700	Extended AWS		1710 – 1780	2110 – 2200	400
n70	FDD	2000	AWS4		1695 – 1710	1995 – 2020	300
n71	FDD	600	Digital Dividend (US)		663 – 698	617 – 652	–46
n74	FDD	1500	Lower LBand (Japan)		1427 – 1470	1475 – 1518	48
n75	SDL	1500	LBand		N/A	1432 – 1517	N/A
n76	SDL	1500	Extended LBand		N/A	1427 – 1432	N/A
n77	TDD	3700	C-Band		3300 – 4200	N/A	10, 15, 20, 40, 50, 60, 80, 90, 100
n78	TDD	3500	C-Band	n77	3300 – 3800	N/A	10, 15, 20, 40, 50, 60, 80, 90, 100
n79	TDD	4700	C-Band		4400 – 5000	N/A	40, 50, 60, 80,100
n80	SUL	1800	DCS		1710 – 1785	N/A	N/A
n81	SUL	900	Extended GSM		880 – 915	N/A	N/A
n82	SUL	800	Digital Dividend (EU)		832 – 862	N/A	N/A
n83	SUL	700	APT		703 – 748	N/A	N/A
n84	SUL	2100	IMT		1920 – 1980	N/A	N/A
n86	SUL	1700	Extended AWS		1710 – 1780	N/A	N/A
n89	SUL	850	CLR		824 – 849	N/A	N/A
n90	TDD	2500	BRS		2496 – 2690	N/A	10, 15, 20, 30, 40, 50, 60, 80, 90,100

TABLE 3: 5G FREQUENCY BANDS AND CHANNEL BANDWIDTHS IN FREQUENCY RANGE 1 (3GPP TS 38.101-1)

The 5G bands marked with colour (**n1, n3, n8, n28, n78**) are the frequencies which are either currently used for 2G/3G/4G and are subject for re-farming over the coming years, or they are the new spectrum bands acquired or prepared for acquisition in Brunei Darussalam.

For devices like smartphones, tablets and other use cases, the 5G bands **n8** and **n28** should be part of the specification. These bands will be launched initially with the commercial launch of 5G in 2022.

The band **n78** (3500MHz) is the 5G native band in Brunei Darussalam and will be deployed for high data throughput in urban areas from 2022 onwards.

With handsets supporting **n8, n28** and **n78** users can benefit from the full scope of spectrum available in the country.

The band 1 (2100MHz) and band 3 (1800MHz) is used currently and the foreseeable future for 4G and partly 3G data services. With more customers and applications moving to 5G radio access, these bands will be re-farmed for 5G as bands **n1** and **n3**.

The bands **n8, n28** and **n78** shall be considered as required specification for handsets purchased now and for the next 18 months, they will deliver the best customer experience in the 5G network.

The 5G spectrum bands shall be published in the public space (AITI, UNN, SalesCo webpages) and promoted in other media channels to allow customers and businesses to make the right decisions for the purchase of 5G ready devices. This should include explicitly information provided to handset and device importers for 5G equipment to be used in Brunei Darussalam.

Availability of 5G devices in Brunei Darussalam

Beside the new iPhones (Apple) and Galaxy (Samsung) devices, which are marketed with significant budgets, many other device manufacturers have 5G devices available on the markets.

The reason for that is the limited set of System on a Chip (SoCs) used today to manufacture handsets. These SoC are including the processing cores (CPU, 4-8 cores), the graphic processing unit (GPU) and the modems required to send and receive radio signals in the specified frequency bands. Each modem is capable to send and receive information on several but specified and hardware coded bands. These modems are covering the 2G/3G/4G/5G specific bands, the specification and bands supported can be assessed at www.gsmarena.com.

The chipsets supporting 5G modems and frequency bands currently are:

- **Apple A14 ff, high end smartphones,**
- **Qualcomm SD865, high end smartphones,**
- **Qualcomm SD888, high end smartphones,**
- **Qualcomm SD765/750 series, midrange smartphones,**
- **Qualcomm SD480, budget smartphones,**
- **Huawei Kirin 9000 series, mid and high end range smartphones,**
- **MediaTek Dimensity 800, 1000 series, midrange and high end smartphones,**
- **Samsung Exynos series, budget and midrange smartphones,**

The bigger part of the SoCs is already on the market and devices are available or announced for the launch in the next few months. This will enable the availability of smartphones from high end (above BND 1500 purchase price) till budget level (below BND 300 purchase price).

Considering a handset usage time of 2-3 years in the mainstream user groups, the purchase of 5G enabled devices is advisable for each budget level, special attention to be paid for the 5G bands available in Brunei Darussalam and provided in the handset modems.

The following brands/manufacturers of 5G handsets are represented in Brunei Darussalam, each with a variety of flagship, midrange and budget smartphones, with the new launches providing 5G access:

- **Apple**
- **Asus**
- **Lenovo**
- **Huawei**
- **Honor**
- **LG**
- **OnePlus**
- **Oppo**
- **Realme**
- **Samsung**
- **Vivo**
- **Xiaomi**
- **ZTE**

With the 5G enabled available brands and device portfolio in Brunei Darussalam, it is expected that up to 10% of all smartphones would be capable to use 5G in Brunei Darussalam by 2022 with the commercial launch of 5G services. Specific measures of public communication and stakeholder engagement provide the potential to increase this number.

Assessment of EcoSystem readiness for 5G Use Cases applications and deployment

The 5G Ecosystem shall be defined as the stakeholders required to contribute to digitalization approaches and 5G adoption for Use Cases and Applications. In Brunei Darussalam this would consist of:

a. Telecommunication network provider (e.g. UNN),

b. Telecommunication Services providers (e.g. SalesCos),

c. Manufacturer/supplier of 5G network equipment (main suppliers present in Brunei Darussalam),

d. Sales & Distribution channels for 5G smartphones and other terminals,

e. Sales & Distribution channels for 5G enabled devices required for Use Cases deployment,

f. Industries and Service organizations (including Government Agencies) seeking implementation of digitalization approaches and 5G Use Cases,

g. Specialized consulting and/or Professional Services companies, able to provide support and skills to the most parties mentioned above.

The assessment of the stakeholders identified provides a differentiated result:

i. The telecomunications industry is implementing 5G radio access and all correlated technology to be able to provide 5G based services from 2022 onwards. However, the industry part responsible for the marketing and customer value proposition is not actively pursuing own 5G development ideas beyond standard mobile BB and Internet services (a) and b)).

ii. The suppliers of 5G network equipment and supporting the industry in terms of rollout and capacity building/skills transfer, the supply chain for 5G terminals and smartphones is established, awareness campaign for spectrum and other specifications to take place (c) and (d).

iii. Due to 5G development in premature stage in Brunei Darussalam, no local parties are in place to support early development with digitalization skills, IoT devices and related application prototypes (e) and (g).

iv. The main obstacle and limiting factor is the lack of sufficient skills and specialist knowledge in areas related to digitization and respective applications in 5G, Private/Public Cloud and beyond.

A special attention has to be paid to the clarity of roles and responsibilities on the Digitalization and 5G topics discussed in the report.

a. Telecommunication network provider, in this case UNN is responsible to deploy the infrastructure based on the known and expected demand and requirements for 5G network and corelated technologies, without tangibly articulated specific requirements out of industry specific digitalization needs this will be based on UNN assessment of demand and business potential only.

b. Telecommunication Services providers (SalesCos) role is to assess and predict demand of own and potential new customer base and to articulate this in forecasts towards the network provider.

c. Manufacturer/suppliers of 5G network equipment role is to deliver specified equipment/services ordered by the parties and to advise on service potentials available on the equipment provided.

d. Sales & Distribution channels for 5G smartphones and other terminals are adopting the technical and spectrum information about 5G into their strategy to deliver most siutable handsets and terminals for the market in Brunei Darussalam. They are maintaining a direct B2C relationship with the customers in Brunei Darussalam.

e. Sales & Distribution channels for 5G enabled devices required for Use Cases deployment need to be addressed by the parties seeking to deploy/purchase the specific 5G digitalization directly.

f. Industries and Service organizations (including Government Agencies) seeking implementation of digitalization approaches and 5G Use Cases need to develop the own digitalisation ideas into value driven concepts, probably using the support of specialized consulting companies in that area.

The following initiatives are recommended to provide more dynamics for the development of digital solutions and 5G Use Cases:

- Bundling of efforts to overcome initial limiting factors to start Digitalization and 5G adoption within Government Agencies and Bruneian Service industries,
- Consolidation and cleansing of common data sources used in the agencies and required for digital transformation,
- Cross industries/government initiatives to support capacity building and development for digitalization skills,
- Identification of specialized companies capable and trusted to support the initial development of 2-3 show cases related to Digitalization and 5G adoption,
- Evaluation and piloting of potential international collaboration options in enhancing the development of 5G applications.

5G Use Case assessment results

The assessment results for the 5G Use cases discussed within the WG2 of the Task Force are following a common structure:

- Relevance for the Bruneian market,
- Business Potential,
- Complexity of adoption and implementation,
- Availability of enables and driving stakeholders,
- Expected implementation, in case obstacles and limitations are removed.

Two Use Cases are developed by UNN as an initial set of ideas to support development of other Use cases within the WG2:

EHEALTH ECOSYSTEM – CAMPUS AREA NETWORK APPROACH	
Relevance for the Bruneian market	The relevance is high, Bruneian Health sector is well developed and technology used widely.
Business Potential	Above average, however the specific benefits of the services summarized in the eHealth Ecosystem need to be quantified based on specific examples.
Complexity of adoption and implementation	Complexity is high due to the significant amount of potential parties involved in a full scale eHealth approach.
Availability of enables and driving stakeholders	Some enablers are not existent currently e.g. common data models for eHealth applications, secure unified eHealth authentication.
Expected implementation	Pilots could be explored from 2022, implementation after 2023.

IoT – OPERATOR VIEW	
Relevance for the Bruneian market	The relevance is above average, multiple parties are interested in IoT approaches, but development is premature.
Business Potential	Above average, however the specific benefits of the specific IoT services within the solution not developed to business case level, only value proposition is known.
Complexity of adoption and implementation	Complexity is above average, several competing technical implementation approaches to be considered, early commitment and driving party would encourage the NetCo to implement NB-IoT as soon as possible.
Availability of enables and driving stakeholders	NB-IoT not decided, technically implementation within acceptable time frame is possible.
Expected implementation	Pilots could be explored from 2021, implementation from 2022.

Use cases developed within WG2:

DIGITAL HEALTHCARE, TELE-CONSULTATION

Relevance for the Bruneian market	The relevance is high due to more teleconsultation capabilities are required in remote areas, however the development is still in conceptual phase.
Business Potential	High, however the implementation is dependent on high bandwidth broadband available in remote areas.
Complexity of adoption and implementation	Complexity is average, common data standards and Health ID authentication/data security concepts to be developed first.
Availability of enables and driving stakeholders	Enablers and driving stakeholders in place, technically implementation within acceptable time frame is possible.
Expected implementation	Pilots could be explored from 2021, implementation from 2022.

OIL & GAS UPSTREAM, PROCESSING AND MIXED CAMPUSES

Relevance for the Bruneian market	The relevance is high due to Oil & Gas industries are present in Brunei Darussalam and the main GDP contributor, Bruneian entities linked to respective MNCs and their innovation potential.
Business Potential	High, the implementation is piloted internationally and lessons learned could be available instantly in Brunei Darussalam deployment.
Complexity of adoption and implementation	Complexity is high due to HSE standards of the industry and the variety of age and status for the installed base, new Oil & Gas deployments are preferable for pilots.
Availability of enables and driving stakeholders	Enablers and driving stakeholders in place, technically implementation within acceptable time frame is possible although decided in the HQs of the respective industry entities.
Expected implementation	Pilots could be explored from 2021, start of implementation from 2022 onwards.

BRUNEI TOURISM ECO-SYSTEM

Relevance for the Bruneian market	Tourism in Brunei Darussalam has a big potential for development, however the basics needs to be in place first to create platform for digitalization.
Business Potential	Average, currently only conceptual ideas available, content development and international digital marketing of Bruneian proposals could be underestimated.
Complexity of adoption and implementation	Complexity is average, common data standards and interfaces are defined, and application layers are available and need adoption/ customization in Brunei Darussalam.
Availability of enables and driving stakeholders	Enablers and driving stakeholders currently not identified, bottom-up development from the tourism industry perspective preferred.
Expected implementation	Pilots could be explored from 2021, implementation from 2023.

SMART CITY – SMART CAMPUS PILOT ZONE

Relevance for the Bruneian market	The relevance is high, Smart City as part of Smart Nation development should provide tangible value creation cases, which can be piloted in a Smart Campus approach.
Business Potential	Currently estimated as average, however the specific benefits of the Smart services considered in Smart Campus/City within the overall solution currently not developed to business case level, only value proposition is known.
Complexity of adoption and implementation	Complexity is average, common data standards and APIs are available for the cases identified so far as part of the Smart campus approach, data security concepts to be developed as precondition.
Availability of enables and driving stakeholders	Enablers in parts and driving stakeholders in place, technically implementation within acceptable time frame is possible, UTB campus as a starting base.
Expected implementation	Ideas could be explored from 2021 onwards, bigger scale pilots implementation from 2022 onwards is possible if business case is providing the base.

The expected implementation is assessed based on the assumption, that all obstacles are removed and all resources required are available. This means the assessment is looking on the shortest possible time to enter into tangible deployment steps.

CONCLUSION

The opportunity for the 5G and Digitalization Use case development in Brunei Darussalam is to exploit the results, lessons learned and the experience generated in other parts of the world related to Digitalization and 5G deployment. However, there are only limited options of “Copy and Paste” to make digital and 5G Use cases available in Brunei Darussalam due to the need to integrate the specifics of Brunei Darussalam.

For the current 5G strategy and for the foreseeable future till 2026, the spectrum bands defined for 5G utilization in Brunei Darussalam (700MHz, 900MHz and 3500MHz) with a total bandwidth of 2x160 MHz shall ensure a user experience for the Enhanced Mobile Broadband (eMBB) in the range of 1,000 Mbps (1Gbps), supported by a comparable experience in the coexistent 4G LTE-A network.

The skills required and the organizational transformation for traditional telecommunication providers is considered one of the biggest challenges on the way towards 5G. Skill development to support not only network deployment and operations but also the support of parties looking for the development of 5G based solutions for Use Cases identified will be an early priority for the companies involved in 5G.

Due to the phased introduction of 5G networks and related spectrum bands, most of the devices shall provide 4G connectivity as a fall-back in case 5G coverage is not available. The 5G spectrum bands shall be published in the public space (AITI, UNN and SalesCo webpages) and promoted in other media channels to allow customers and businesses to make the right decisions for the purchase of 5G ready devices. This should include explicitly information provided to handset and device importers for 5G equipment to be used in Brunei Darussalam.

Considering a handset usage time of 2-3 years in the mainstream user groups, the purchase of 5G enabled devices is advisable for each budget level, special attention to be paid for the 5G bands available in Brunei Darussalam and provided in the handset modems.

With the 5G enabled available brands and device portfolio in Brunei Darussalam, it is expected that up to 10% of all smartphones would be capable to use 5G in Brunei Darussalam by 2022 with the commercial launch of 5G services. Specific measures of public communication and stakeholder engagement provide the potential to increase this number.

APPENDIX 3: PROPOSED TRAINING PROGRAMME

5G Technical Training

The following trainings are identified to provide the necessary skills and competency required by the telecommunication industries, following the 5G infrastructure plan for Brunei. The target audience of these trainings are also identified for each of the training disciplines. The Technical Training Roadmap shown in Figure 1.

TECHNICAL TRAINING ROADMAP

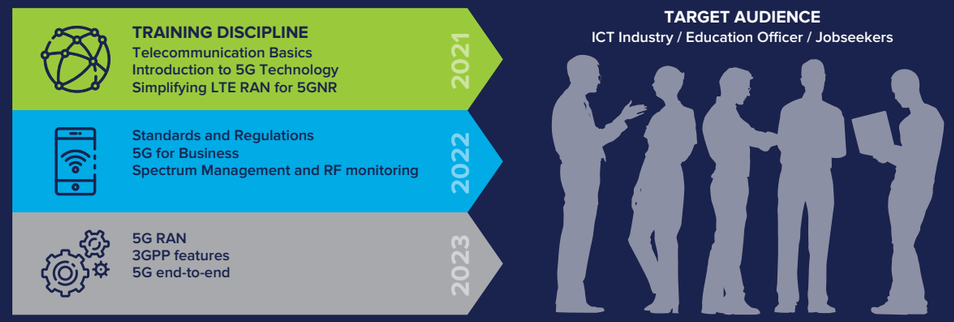


FIGURE 1: 5G TECHNICAL TRAINING ROADMAP

i. **Telecommunication Basics**
This training is intended to provide basic telecommunication knowledge to the public which provides an avenue for participants to enter into the industry. Upon taking these trainings, participants can upskill themselves on the inner workings of the technology. The objective of this training is to prepare Technical Level Workforce.

ii. **Introduction to 5G Technology**
This training is intended to upskill the current industry personnel as well as job seekers in 5G NR Technology. This introduction to 5G Technology aims to provide a basic understanding of 5G NR Technology hence providing basic competency in the technology. The objective of this training is to prepare Technical Level Workforce.

iii. **Simplifying LTE RAN for 5G NR**
This training is intended to reskill the current industry personnel as well as job seekers in 4G Radio Access Technology (RAN) to prepare them for 5G NR Technology. 4G Technology provides the foundational basis to 5G NR Technology. The objective of this training is to prepare Technical Level Workforce.

iv. **Standards and Regulations**
This training is intended to provide the current industry personnel and job seekers the knowledge on standards and regulations governing the cellular telecommunication industries. The understanding of these standards and regulations allow the candidates to make informed decisions which are within the guidelines set by governing bodies. The objective of this training is to prepare Technical to Engineer Level Workforce.

v. **5G for Business**
This training is intended to provide businesses with the necessary knowledge on 5G NR Technology to leverage on the different use cases for different industries. The objective of this training is to prepare Technical Level Workforce.

vi. **Spectrum Management and RF Monitoring**
This training is intended to provide regulators and telco personnel the skills and competency required to design and plan for Spectrum Management and RF Monitoring. The objective of this training is to prepare Engineer to Senior Engineer Level Workforce.

vii. **5G RAN**
This training is intended to provide technical competency for 5G NR Technology Architecture. This includes aspects of design, planning, troubleshooting and optimization of RAN infrastructures. The objective of this training is to prepare Engineer to Senior Engineer Level Workforce.

viii. **3GPP Features**
This training is intended to provide in depth understanding on the standards governing 5G NR Technology. This training shall include overview of key 3GPP Specifications within 5G NR Technology. The objective of this training is to prepare Engineer to Senior Engineer Level Workforce.

ix. **5G End-to-End**
This training is intended to provide technical competency for 5G NR Technology from end-to-end, Access Stratum and Non-Access Stratum. This includes aspects of design, planning, troubleshooting and optimization of 5G Network Infrastructures. The objective of this training is to prepare Engineer Level Workforce.

5G Business Training

The following trainings are identified to provide the necessary skills and competency required by the technopreneurs following the 5G infrastructure plan for Brunei. The target audience of these trainings are also identified for each of the training disciplines. The 5G Business Training shown in figure 2.

BUSINESS TRAINING ROADMAP

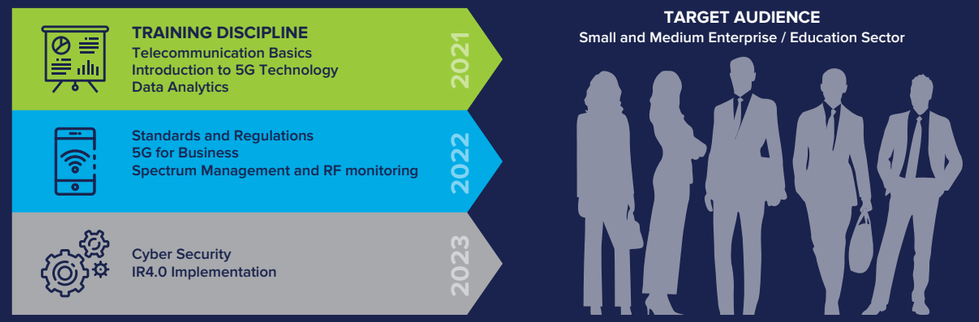


FIGURE 2: 5G BUSINESS TRAINING ROADMAP

i. **Telecommunication Basics**
This training is intended to provide basic telecommunication knowledge to the business industry. The objective of this training is to prepare Technopreneurs.

ii. **Introduction to 5G Technology**
This training is intended to provide introduction to 5G Technology for the business industry. The objective of this training is to prepare Technopreneurs for 5G Technology.

iii. **Data Analytics**
This training is intended to provide Data Analytics knowledge to the business industry. The objective of this training is to prepare Technopreneurs within the Data Science Industry.

iv. **5G for Business**
This training is intended to provide introduction to 5G Business usecases. The objective of this training is to prepare businesses for the different business verticals.

v. **5G Sales and Support**
This training is intended for MVNOs to understand the sales and effect of 5G in the industry. The objective of this training is to prepare MVNOs to perform effectively in sales.

vi. **Cyber Security**
This training is intended to provide an introduction to Cyber Security Trainings to businesses. The objective of this training is to prepare Technopreneurs in the importance Cyber Security.

vii. **IR 4.0 Implementation**
This training is intended to provide an introduction to IR 4.0 Implementations to the industry and businesses of Brunei. The objective of this training is to prepare them for IR 4.0 implementations.

5G Application Training

The following trainings are identified to provide the necessary skills and competency required by the technicians, engineers and managers in vertical industry sectors following the 5G infrastructure plan for Brunei. The target audience of these trainings are also identified for each of the training disciplines. The 5G Application Training Roadmap shown in figure 3.

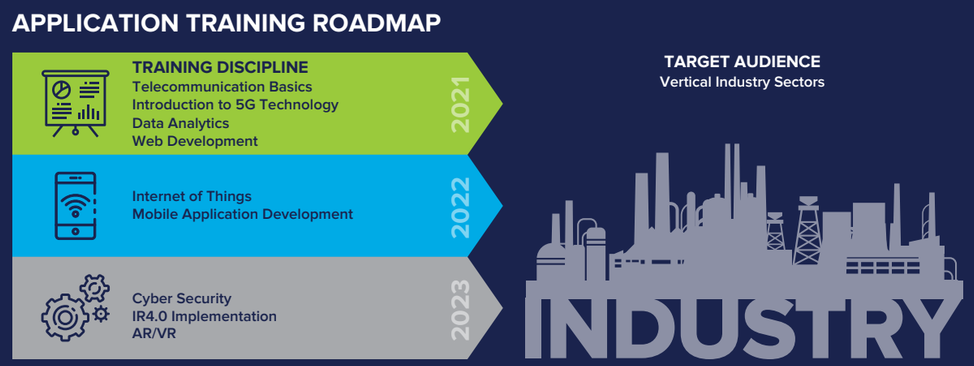


FIGURE 3: 5G APPLICATION TRAINING ROADMAP

i. **Telecommunication Basics**
This training is intended to provide basic telecommunication knowledge to the public which provides an avenue for participants to enter into the industry. Upon taking these trainings, participants can upskill themselves on the inner workings of the technology. The objective of this training is to prepare Technical Level Workforce in vertical industry sectors.

ii. **Introduction to 5G Technology**
This training is intended to upskill the current industry personnel as well as job seekers in 5G NR Technology. This introduction to 5G Technology aims to provide a basic understanding of 5G NR Technology hence providing basic competency in the technology. The objective of this training is to prepare Technical Level Workforce in vertical industry sectors.

iii. **Data Analytics**
This training is intended to provide Data Analytics knowledge applied in vertical industry sectors. The objective of this training is to prepare managers within the Data Science department.

iv. **Web Development**
This training is intended to provide the fundamental knowledge and skills of web development process, tools and techniques using up-to-date widely used tools and programming languages in the industry. In addition, this training will demonstrate how web systems can be applied to solve problems in a variety of applications. The objective of this training is to prepare both Technical and Business Level Workforce in vertical industry sectors.

v. **Internet of Things (IoT)**
This training is intended to provide an introduction to Internet-of-Things technology for the vertical industry sectors. The objective of this training is to prepare technicians and engineers for Internet-of-Things (IoT) industry.

vi. **Mobile Application development**
This training is intended to provide basic understanding of mobile communication network as well as the introduction to Mobile Application. This is followed by Web services for Mobile devices, Mobile user interface design and Mobile Websites. Finally, the training provides knowledge and skills for Mobile application development using up-to-date common tools and programming languages. The objective of this training is to prepare both Technical and Business Level Workforce in vertical industry sectors.

vii. **Cyber Security**
This training is intended to provide introduction to Cyber Security Trainings to vertical industry sectors. The objective of this training is to prepare managers and engineers in the importance Cyber Security.

viii. **IR 4.0 Implementation**
This training is intended to provide an introduction to IR 4.0 Implementations to the vertical industry sectors and businesses of Brunei. The objective of this training is to prepare them for IR 4.0 implementations.

Training Providers

Training providers may come from the government agencies, academic institutions and industry players. Several training providers have been identified, but not limited to:

No.	Organisation Name	Organisation Profile
		GOVERNMENT AGENCY
1	**Darussalam Enterprise (DARe)**	DARe which stands for Darussalam Enterprise is the national SME body and their main goal is to support local businesses in Brunei Darussalam. Micro and Small, Medium-sized enterprises are the way forward for the nation to grow not just in terms of the Gross Domestic Product, but MSMEs are the ones that will diversify the economy from oil and gas. MSMEs are also the ones who will provide employment opportunities to the local talent and fresh graduates. Since the very start in February 2016, DARe is constantly looking to develop and improve their programs and initiatives, whether it's by providing capacity building programmes, industrial land and complexes, marketing and promotion, financing and growth outside of Brunei.
		ACADEMIC INSTITUTION
2	**Institute of Brunei Technical Education (IBTE)**	In IBTE we provide the guidance you need to become a professional and productive contributor's to today's society. Once you've reached the end of your journey with IBTE, you will have succeeded in achieving your goals and be ready to enter the industry equipped with the knowledge, confidence and the ability to perform at your best. Inspiring Bruneians toward Excellence is not simply a catchphrase in IBTE. We hold true to our aspiration to develop our students' capabilities to be job-ready and to be resourceful individuals in meeting the challenges dictated by globalization. To succeed in a future of integrated industry and adapting to the changes brought by automation and the digitization of industries, IBTE is continuously reviewing and revising its curriculum, working hand-in-hand with its industry counterparts to ensure that students are prepared and digitally capable with future ready competencies to meet the challenges brought about by the digital revolution, Industry 4.0. With the counsel and direction from IBTE's experienced and knowledgeable instructors, our graduates are trained with the relevant skillsets and competencies to face the ever-changing job market. Focusing on competency-based training, our programmes are capped by an on-the-job-training element that gives our graduates hands-on experience which allows them to practice and develop their skills in a stimulating and rewarding environment.
3	**Universiti Teknologi Brunei (UTB)**	Universiti Teknologi Brunei (UTB) is an Engineering and Technology University in Brunei Darussalam that specialises in the niche areas of Engineering, Business, Computing, Applied Sciences & Mathematics, and Design. UTB was first established in 1986 as Institut Teknologi Brunei (ITB). In 2008, ITB was upgraded from a higher learning institution offering Higher National Diploma (HND) programmes in Engineering, Business and Computing to a university, and was then changed to Universiti Teknologi Brunei on 1 March 2016. UTB specialises in the area of Engineering, Business, Computing, Applied Sciences & Mathematics and Design. Since the upgrade, the university has seen tremendous development including the expansion of its academic programmes portfolio, establishment of partnerships with industries and universities, embarking on the process of programme accreditation by professional bodies, and intensification of research activities.
		INDUSTRY
4	**Beyond Tomorrow Sdn Bhd**	Beyond Tomorrow is a renowned Bruneian ICT organisation that strives to provide its clients with multitude of ICT services, locally and internationally. Among them are the state-of-the-art training methodologies in Subject Matter Expert (SME) Certifications™© which encompass Cellular Communications such as 4G LTE, 5G NR and beyond, WiFi, Internet-of-Things (IoT), IR4.0, Waste Management; CCTV technologies, Network Securities as well as Talent Acquisition. We accomplish these by always analysing each client's needs and situation by customising solutions catering to our clients. Beyond Tomorrow is proud to be affiliated with the Malaysia Board of Technologist (MBOT), a Malaysian Government Body. Beyond Tomorrow has recently signed a Memorandum of Understanding (MOU) to forge a work together to help improve the Telecommunication and Broadcasting sector. Beyond Tomorrow has been appointed as Technology Expert Panel (TEP) as well as Authorised Training Institution by MBOT in the field of Telecommunication and Broadcasting Technology. Beyond Tomorrow courses are also recognised and approved by the Ministry of Education Brunei.

5	**Huawei Technologies Sdn Bhd**	Founded in 1987, Huawei is a leading global provider of information and communications technology (ICT) infrastructure and smart devices. We have more than 194,000 employees, and we operate in more than 170 countries and regions, serving more than three billion people around the world. Our vision and mission is to bring digital to every person, home and organization for a fully connected, intelligent world. To this end, we will drive ubiquitous connectivity and promote equal access to networks; bring cloud and artificial intelligence to all four corners of the earth to provide superior computing power where you need it, when you need it; build digital platforms to help all industries and organizations become more agile, efficient, and dynamic; redefine user experience with AI, making it more personalized for people in all aspects of their life, whether they're at home, in the office, or on the go.

Brunei ICT Industry Competency Framework

Matching the skills demand of the industry with the training supply is crucial to ensure the right competencies and skills are taught and trained. The Brunei Darussalam ICT Industry Competency Framework (BIICF) is currently being developed by the BIICF Working Group led by AITI. This framework serves as a comprehensive guidance for ICT occupations, trainings and certifications. The BIICF will provide a consistent competency structure for ICT professionals, employers and training providers in Brunei Darussalam so that they will have a clear reference on the types of skills and competencies required for various ICT professions and to develop training courses to develop relevant skillsets through accredited training providers. There are currently seven (7) sub-sectors identified in BIICF:

With regards to 5G, it cuts across several sub-sectors in BIICF such as Telecommunications & Networks and Applications & Solutions Development. The trainings identified in the 5G Training Roadmap and any future trainings must be aligned with the BIICF to ensure the current industry needs are satisfied and continuous feedback on 5G related job positions must be conveyed accordingly to ensure seamless alignment of ICT workforce supply and demand.

In addition, funding for selected trainings may also be proposed by the training providers to the Manpower Planning and Employment Council (MPEC) for considerations under the Human Resource Development Fund.

APPENDIX 4: LIST OF 5G TASKFORCE MEMBERS

Many thanks to our 5G Taskforce Chair, Co-Chair and members, for contributing their hard work, research and support in an effort to facilitate the implementation of the 5G. With these efforts, it is hoped that all of our recommendations will be implemented in the near future towards achieving Wawasan Brunei 2035.

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