MALAYSIA
PROGRESSING HUMANITY

National 5G Task Force Report

5G Key Challenges and 5G Nationwide Implementation Plan

December 2019

Disclaimer

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1. Overview and Executive Summary

The Malaysian Communications and Multimedia Commission (MCMC) established a National 5G Task Force in November 2018 to study and recommend a holistic strategy for the deployment of the Fifth-Generation (5G) mobile internet in Malaysia. A collaborative effort with relevant stakeholders, the 5G Task Force comprises of members from the private sector, Ministries, and agencies representing the demand and supply side of the ecosystem.

The 5G Task Force has completed the study and has produced this final report for the MCMC and Minister of Communications and Multimedia.

The 5G Task Force was divided into 4 Working Groups with the focus areas as per the following:

Working Group	Focus Areas
Business Case	- Economic areas and benefit to the nation i.e. GDP growth, creation of new jobs, etc. - User trends, requirements, and demand study—industry and general public - Financial considerations in adoption of 5G - Proposals to encourage 5G adoption
Infrastructure	- Infrastructure requirements and coverage for optimum 5G deployment for different services—e.g. retail, wholesale, consumer, industry, etc. - Gaps analysis on current networks to deliver 5G nationwide, including expected cost, challenges, etc. - Infrastructure planning, approval and addressing right-of-way (ROW) issues (jointly with Regulatory Working Group) - Proposed strategy to deliver 5G coverage to rural areas
Spectrum Management & Allocation	- Current progress for spectrum allocation at ITU, APT and Malaysia - Required bandwidth to support national targets - Identified bands for Malaysia - Timeline for spectrum allocation
Regulatory	- Accommodating future business models for network providers and relevant stakeholders - Technical standards to be adopted - Optimum number of Telecommunications Operators - Constraints in the current regulatory framework related to communications, i.e. competition, access, consumer protection, security, licensing, and state governments and local council policies, etc. - Proposed improvements to current regulatory framework

The structure of the 5G Task Force is as shown below:

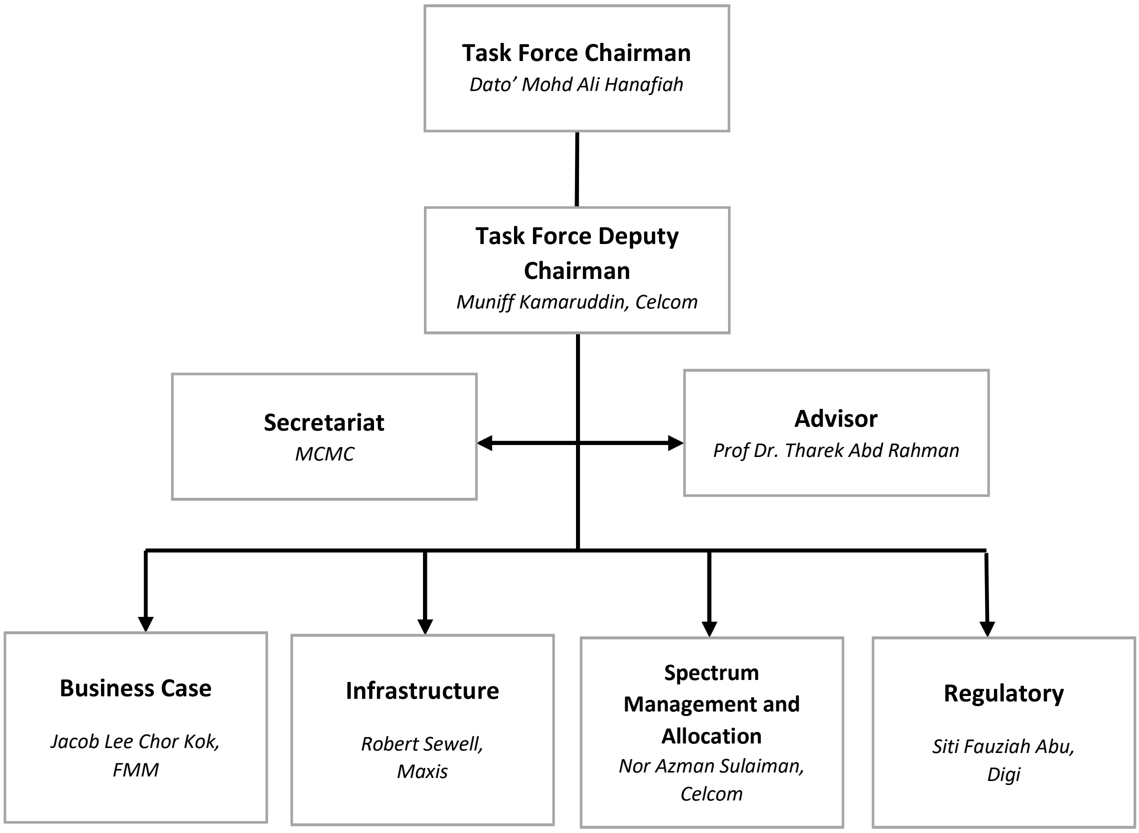


Figure 1.1: National 5G Task Force Structure

In the course of fulfilling its duties, the 5G Task Force has:

- Held monthly update sessions. A total of 8 updates sessions to MCMC were arranged during this phase of the exercise, in addition to the weekly meetings that each Working Group held internally.
- Facilitated a Public Consultation (PC) process, where 24 key questions were outlined to solicit views and comments from 37 organisations. Refer to **Appendix 1** for details.

There are three key new capabilities which are to be introduced by 5G (below):

- **eMBB** (Enhanced Mobile Broadband)
- **mMTC** (Massive Machine Type Communications)
- **uRLLC** (Ultra Reliable Low Latency Communications)

These terms and concepts will come up frequently in further sections and are the basis on which 5G use cases are identified.

Some use cases for the aforementioned capabilities include:

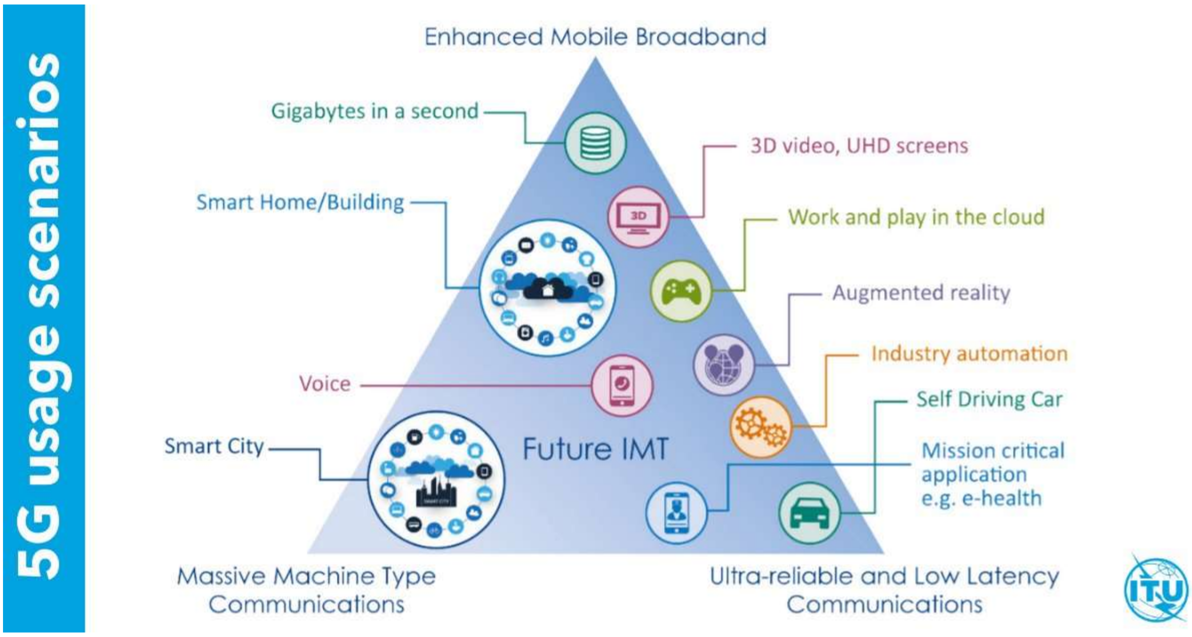


Figure 1.2: 5G Usage Scenarios Covering eMBB, mMTC and uRLLC; Source: ITU

The networks that deliver 5G are based on standards and designs evolved from 4G (including various interim enhancements typically referred to as 4.5G & 4.9G in the industry). They follow the same basic structure as 4G networks: both require distributed radio sites to provide the required coverage and capacity, primarily licensed spectrum to allow for optimal spectrum planning, and centralised network control of mobility.

5G implementation is a highly complicated process, so architecture and standards are enhanced (see 'the triangle' above) to allow for an even wider range of deployment modes and options.

Much of the key differences between 5G and 4G are directly driven by the objectives of each technology (see next page).

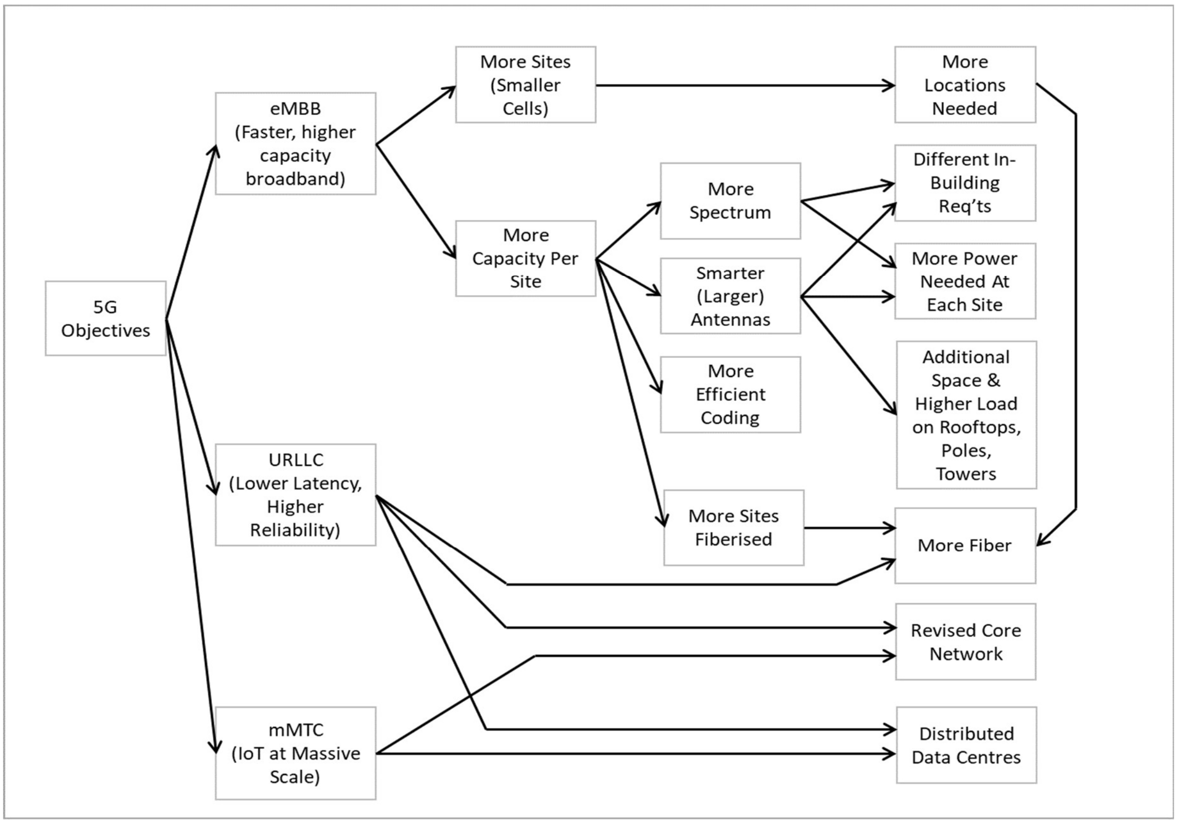


Figure 1.3: 5G Implementation Requirements

To this end:

- **Section 3** of this report will discuss the need for additional Spectrum (frequencies), and viable solutions proposed for Malaysia.
- **Section 4** will further detail the implications of the required physical infrastructure which arise from additional sites, new antenna technology, and additional fiber.
- **Section 5** will wrap things up with policy and regulatory interventions to mitigate these challenges in order to achieve rapid and cost-effective deployment of 5G for Malaysia.

Due to its increased complexity, 5G networks will require more sites than existing 4G networks. Infrastructure for both radio and fiber networks have been the most expensive to set up and maintain in every generation of cellular technology so far, and 5G is no different.

While 5G is often cited as having 'lower cost', this is an oversimplification that needs to be ironed out. The often-discussed 'lower cost' of 5G refers to the *per unit cost of data*, which is a result of the increased capacity achieved by these networks provided sufficient spectrum is available. The cost to set up 5G will still be higher than amounts spent on 4G so far.

Since 5G standards are still evolving, not all planned capabilities or modes of operating are standardised, or even available from network equipment manufacturers. Full implementation of some of the capabilities is subject to the rapid changes, like a need for more cell towers, need for Telcos to undertake large-scale fiberisation efforts, and introduction of extensive architecture changes.

However, Telcos are unlikely to make all necessary changes immediately even when the technology is available due to the high initial costs, yet uncertain revenue. As a result, introduction of the new capabilities is likely to be phased, with eMBB (faster and higher capacity broadband) to be introduced first, followed by increasing support for URLLC and mMTC over time (as per image above).

2. Business Case Exploration for 5G Implementation

2.1 Overview

Under the 5G Taskforce, the Business Case Working Group (BCWG) was created with stakeholders from sixty-two (62) public and private organisations. There are nine (9) sub-working groups/verticals based on economic sectors, which are significant to the nation in terms of Gross Domestic Product (GDP) and alignment with the national digitalisation agenda.

According to statistics by Bank Negara Malaysia, six (6) verticals i.e. Agriculture, Banking & Finance, Manufacturing & Process Industries, Oil & Gas, Retail & Services and Smart Transportation contribute to more than 80% of the country's GDP. This created a particularly good fundamental basis for the determining 5G's impact in these respective sectors.

The BCWG has also elected to add Healthcare, Education, and Smart City verticals on the premise that each sector's digitalisation journey will intensify with 5G deployment and add economic value to Malaysia.

Thus, the scopes of work for BCWG are as follows:

1. Economic areas and benefits to the nation i.e. GDP growth, creation of new jobs, etc;
2. To identify industry and general public's mobile trends, requirements, and demand;
3. To identify financial considerations in adoption of 5G; and
4. To propose an action plan to encourage 5G adoption.

The BCWG adopted a consultative approach through more than 30 engagement sessions within and between different sub-working groups to solicit and synchronise input and recommendations.

Figure 2.1 outlines BCWG's operation framework:

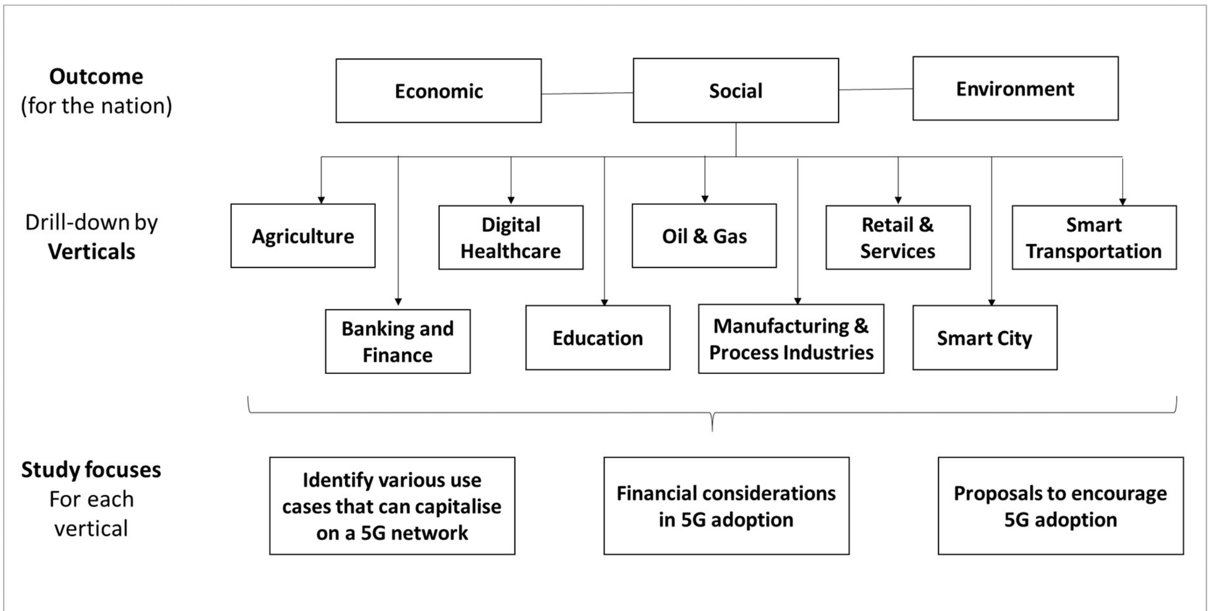


Figure 2.1: BCWG's Framework

2.2 Forecasted Future Applications

The world is experiencing paradigm shifts that are caused by several key, yet contradictory trends. Firstly, the entry of the millennial work force is changing up the demographics of Malaysia's workforce, which seems to contradict the increasingly ageing population. Secondly, the increasing population has intensified resource shortages, which has intensified concerns over food security. However, increasing demand for products and services continue to fuel climate change, thus impacting quality of life.

These factors have contributed to an increasing demand for new solutions, by both businesses and society. The result is accelerated progress on the Fourth Industrial Revolution (4IR).

Technology now takes the centre stage in driving transformations in both social and business contexts. From the 9 verticals we identified across different business cases, 3 technology trends seem to be the underlying factors driving major disruption:

1. **Internet of Things (IoT):** Advancements in this area could facilitate economic activities across the 9 vertical markets, as data is the prime driver for 4IR. IoT utilises interconnected devices that communicate seamlessly and collect data for various stakeholders to derive value. Besides functions like data collection, increasing demand for responsive and efficient decision-making positions IoT as an essential component for areas like industrial automation, connected vehicles, smart cities, agriculture etc.
2. **Cloud Computing:** Utilising IoT, the speed and scale of data will intensify pressure on infrastructure like storage, which is traditionally expensive. Cloud computing is made prominent in the 4IR-era thanks to its cost-effective, on-demand data sharing model. Furthermore, cloud computing is more easily scalable with minimal hardware upgrades and provision of centralised platforms for data sharing and exchange.
3. **Mobility:** Enterprise mobility is one of the key disruptions of the global digital transformation movement. Today, information consumption behaviours demand data that is always online for anyone everywhere. This technology trend is driving businesses to strategically decentralise their processes, from the central hub to the point of customer action.

Based on these 3 key fundamental technologies, 5G will outperform current 4G technology by granting higher bandwidth and lower latency (the time it takes to get a response on information sent). Specifically, 5G will enable latency of less than 1 millisecond (ms), and support device connectivity. As such, 5G advancements are expected to enable new applications and business cases that will transform the way humanity lives, how enterprises work, and how we interact with the environment.

A matrix was developed to map key enabling technologies' characteristics in relation to identify 5G use cases. This approach is technology-agnostic (without bias to technology tools) to provide guidance in identifying the 5G-related technologies that will accelerate digital transformation in different economic sectors.

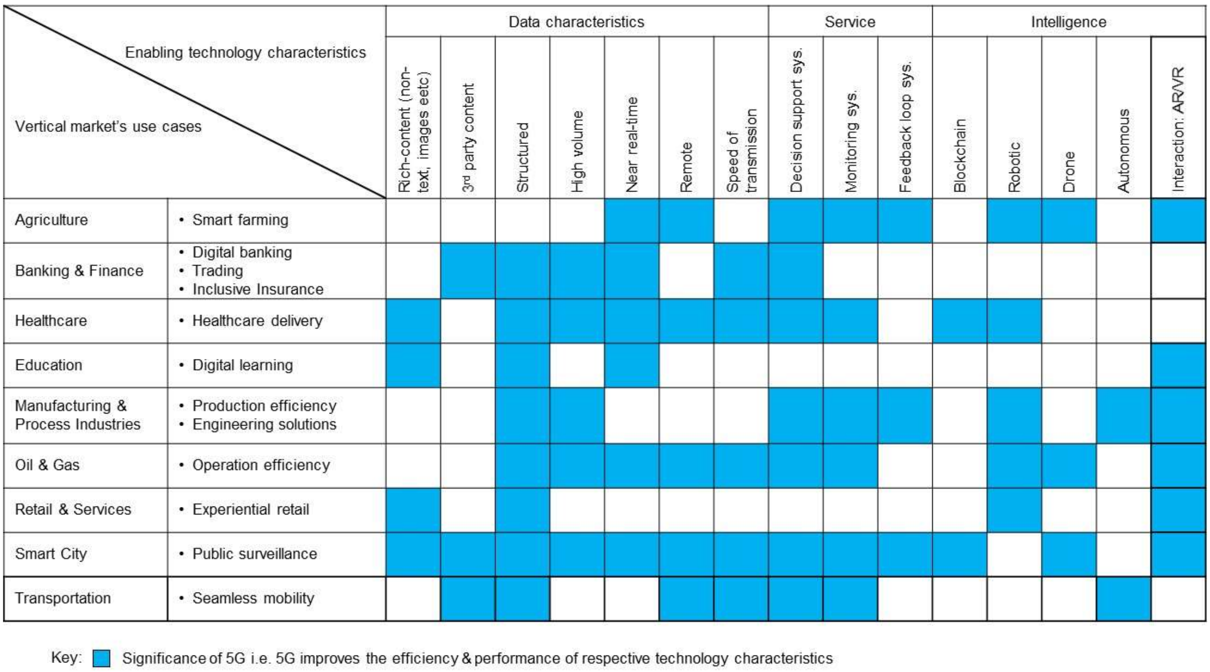


Figure 2.2: Technology Mapping for Proposed 5G Use Cases; Source: Business Case Working Group

The matrix in **Figure 2.2** segmented enabling characteristics based on 3 categories: data, services, and level of intelligence delivered.

Data analytics has empowered more proactive decision-making, and is the basis of Artificial Intelligence (AI) which is the backbone of various applications like autonomous cars, robotics, automation, etc.

2.3 Applications in Industry Verticals

The value of 5G across various verticals has been underscored by two outcome categories, namely data distribution and level of intelligence. **Figure 2.3** showcases the potential value that can be derived based on the 9 business cases outlined in **Section 2.1**.

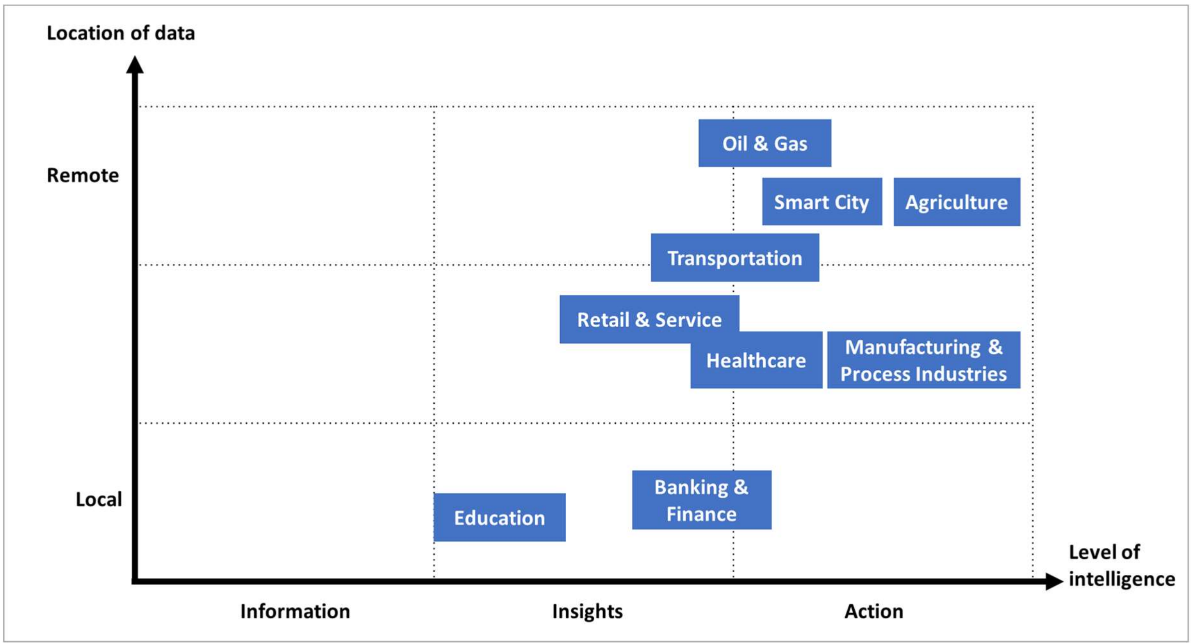


Figure 2.3: Value proposition of 5G by vertical markets

All verticals examined can potentially benefit from 5G's key features; the aforementioned Enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC) and Ultra-Reliable Low Latency Communications (uRLLC). The following highlights the business cases for the 9 vertical markets.

1. **Agriculture**

   Agriculture is a resource-intensive industry, yet it holds a dominant position in the Malaysian economy both for exports and local consumption. The industry is facing an increasingly competitive and volatile market. Therefore, it is critical for Malaysia's agriculture industry to become more self-sufficient and resilient.

   5G is crucial in enabling smart farming technologies; specifically drones for farm monitoring, IoT for data collection and analytics, and agricultural robots. Smart farming would:
   - Reduce dependency on labour
   - Eliminate input wastage
   - Increase profits and mitigate risks
   - Enhance efficiency at every stage in the agricultural value chain
   - Create new jobs opportunities in the agriculture sectors

2. **Banking and Finance**

Mobility will be a game changer in the banking and financial services industry, as products and services can be upgraded on all three of 5G's new capabilities.

By leveraging 5G's uRLLC and eMBB capabilities, financial institutions can deliver a seamless digital banking experience to customers, and enable access to banking activities from anywhere, either via real officers or with robo-advisors (automated, algorithm-driven financial planning). 5G capabilities will also prove irresistible in mobile trading, as improved access to financial services grants more Malaysians opportunities to grow their business, facilitate trade and increase access to financial services. Health and life insurers will also be able to make more informed and precise decisions with 5G-enabled data sharing.

Therefore, the banking and finance sector will benefit from all 3 of 5G's capabilities. uRLLC will enable real-time response and control, eMBB will enable lightning-speed data rates, and mMTC will enable robust connections between a large number of devices.

3. **Digital Healthcare**

Malaysia's healthcare market is expected to grow by 127% from RM56.3 billion in 2017 to RM127.9 billion in 2027. 5G is expected to bring heightened efficiency, particularly by allowing for self-management capabilities and facilitating access to healthcare, thereby minimising costs.

As the healthcare market matures, Internet of Medical Things (IoMT) applications will amplify the growth of Massive-Machine Type Communication (mMTC). The next wave of innovation, specifically Tactile Internet and Emergency Medical Services, will spur the need for uRLLC in combination with high availability, reliability, and security.

5G will usher in an era of personalised healthcare, empowering patients with the ability to better manage their health and medical conditions. This will offer cost savings and productivity improvements to both patients and healthcare providers. Meanwhile, advances in health informatics will facilitate a shift in the way healthcare is delivered and create new business opportunities.

4. **Education**

One clear benefit is mass connectivity. Most schools, colleges, and universities in Malaysia are located in urban areas, but the high concentration of students in one space provides a last mile challenge in digital material utilisation. 5G will enable realistic use of rich digital content in highly packed environments, allowing for high-resolution video, augmented reality, 3D modelling etc.

5G's mass connectivity offerings will allow the education sector to:

- Feasibly offer a fully digital education with last-mile connectivity costs
- Allow better digital material use in education, primarily in assisting comprehension of difficult subject matters
- Increase communication capacity among institutions and schools
- Encourage the education segment to adapt to new developments in the hardware and software industry

5. **Manufacturing & Process Industries**

Making up almost 23% of the National GDP, the manufacturing and process industry is the biggest contributing sector to Malaysia’s GDP, hence the Fourth Industrial Revolution (4IR) is well underway in manufacturing and processing over the past five years or so. There is increase in production efficiency, creation of new business opportunities, and a clear advantage in ubiquitous high-speed wireless data for factories.

Artificial Intelligence (AI) can facilitate communication between massive sensors to optimise maintenance schedules. Engineering software applications like Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM) and Computer-Aided Engineering (CAE), Enterprise Resource Planning (ERP), Product Lifecycle Management (PLM), and Manufacturing Operations Management (MOM) will enhance digital continuity from design to manufacturing. Smart power grids can provide stable electricity, reducing power-caused losses. Warehousing and logistics software will help to keep track of stock and help to synchronise production.

Key drivers in strengthening the digital transformation process are:

- AI-enabled predictive maintenance
- Software applications besides AI
- Enhancing utilities infrastructure
- Warehouse and logistics industries

6. **Oil and Gas**

Oil and Gas is another core industry in Malaysia, contributing 8% of National GDP[1]. Legacy oil and gas networks were not designed to support the high volumes of real-time data generated by Machine-to-Machine (M2M) technology and massive IoT systems. The proposed adoption of 5G will enable the digital transformation of oil fields, which will result in improved operational efficiency, predictive maintenance, better workforce efficiency and safety, asset optimisation and revenue.

Relevant use cases are proposed with an accompanying assessment on market potential and technology. The 5G Task Force proposes industry-wide rollouts using localised networks for specific areas and use cases. Private companies are encouraged to invest in infrastructure development with incentives facilitated by the government where license-free spectrum is granted.

7. **Retail & Services**

Consumers expect more from the retail and service industry now that technology has evolved. The multichannel consumer of today routinely combines multiple retail channels as it's unlikely that anyone today shops entirely digitally.

Product availability, delivery speeds, and the quality of goods and services have become key differentiators in the industry's competitive edge.

Hence, the industry needs to start automating manual processes. Sensors can be implemented on shelves to reduce out-of-stock inventory. The retail and services industry will also have to overhaul its supply chain management by automating stream of queries on products to serve today's multichannel consumers and growing click-and-collect models.

In striving for growth in the highly competitive business environment, implementation of 5G will play a vital role in providing:

- Increased availability of Broadband and Media
- Indoor Positioning Services (IPS), a network of devices that allow for accurate location tracking in malls or other indoor facilities
- Smart Energy Savings to support growing consumer expectations

Bank Negara. 2019. *Economic and Financial Data for Malaysia*
http://www.bnm.gov.my/index.php?ch=statistic_nsdp

8. Smart City

As part of the nation's Smart City development, authorities can more effectively address public safety issues via more robust CCTV surveillance. The 5G Task Force proposes that authorities increase CCTV surveillance by deploying a vast number of 5G wireless CCTV cameras. Besides increasing coverage areas, high-definition video streaming enabled by the 5G network can also support more advanced features such as face recognition and autonomous incidence detection, which could further enhance the authorities' ability to maintain public safety.

The key advantages of such systems are:

- Wider areas of coverage
- High-quality data collection via high-definition CCTVs with high resolution images;
- Rapid deployment
- Autonomous monitoring

9. Smart Transportation

5G connectivity is key in realising the Automated, Autonomous and Connected Vehicle (AACV). Generally, AACVs sense their surroundings using functions like vehicle localisation, telematics, odometry (using moving sensors to estimate position changes), and computer vision. Advanced control systems interpret sensory information and transmit abundant data to identify appropriate navigation paths through a Vehicle-to-Everything (V2X) ecosystem.

The implementation of V2X is made feasible with 5G via the establishment of AACV test beds that simulate actual driving conditions. The test bed is crucial in order to identify best practices and localise the software to Malaysia's domestic conditions. Considerations must be made for communication protocols, interoperability, signal interference, etc.

2.4 Potential of 5G

2.4.1 Economic Impact

According to the Malaysian Institute of Economic Research (MIER) Report titled 'Economic Impact Analysis on the Implementation of 5G Services in Malaysia', deployment of 5G will be a catalyst to Malaysia's productivity and economic growth. Malaysia's economy is expected to undergo exponential growth in year 2030. It is estimated that 5G will contribute RM8.538 billion to Malaysia's GDP in 2025, with 8% annual growth scenario.

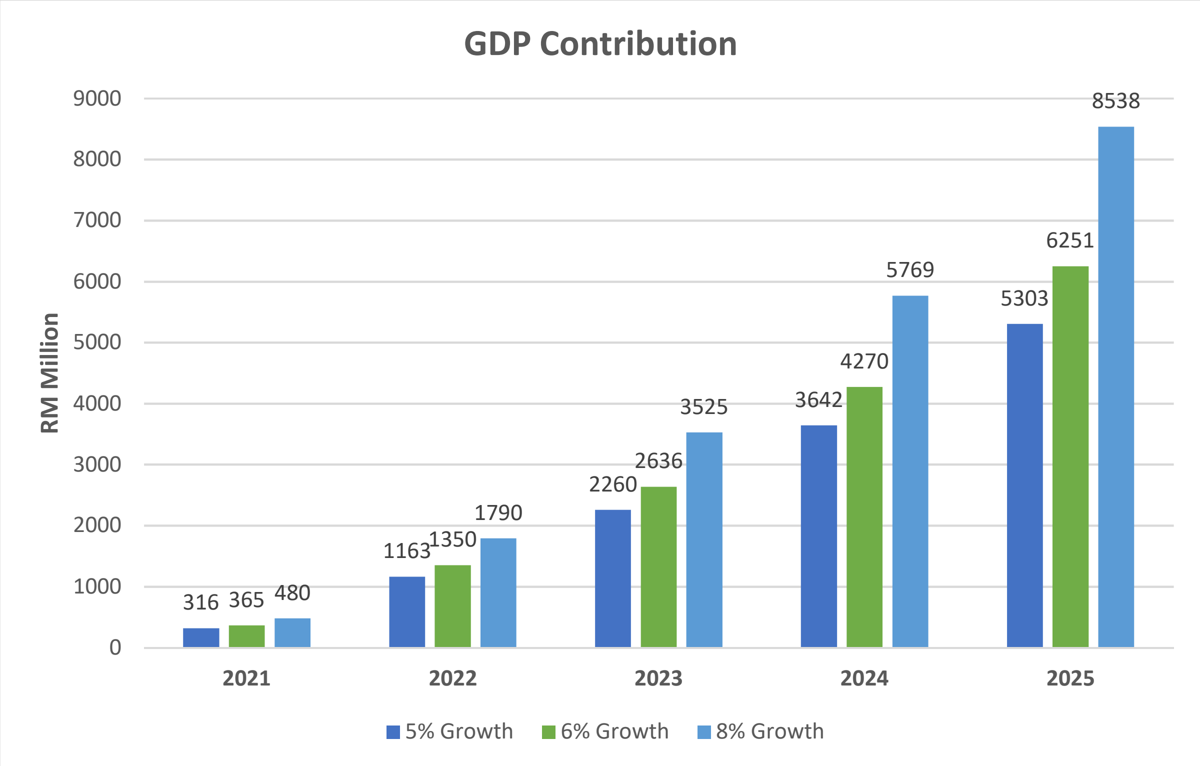


Figure 2.4: 5G's Projected contribution to GDP in different growth scenarios, 2021-2025; Source: Edited from 'Economic Impact Analysis on the Implementation of 5G Services in Malaysia' by MIER

Using HIS Economics & HIS Technologies[2] as a guide, the projected RM8.538 billion with 8% growth is sliced across the 9 vertical markets to gauge potential 5G-enabled impact in 2025 (**Figure 2.5**). Based on estimated contribution to the GDP, 5G pilot deployments should prioritise the following verticals:

Phase 1: 2020 – 2021	Phase 2: 2022-2024
1. Retail and Services	1. Transportation
2. Smart City	2. Healthcare
3. Agriculture	3. Manufacturing

Figure 2.5: Verticals to Prioritise by phase; Source: 5G Task Force

The proposed plan involves two rollout phases:

- **Phase 1** is proposed based on use cases that have a higher estimated impact on GDP, lower entry barriers from a regulatory and technical standpoint, and where 5G will assume a supporting role.

  Use cases outlined here do not require major overhauls in device or equipment. 5G-enabled mobile devices will be the primary method of integration into Malaysia both on societal and business fronts.
- **Phase 2**, meanwhile, requires updated regulatory frameworks and ecosystem support for technical feasibility before 5G can be rolled out.

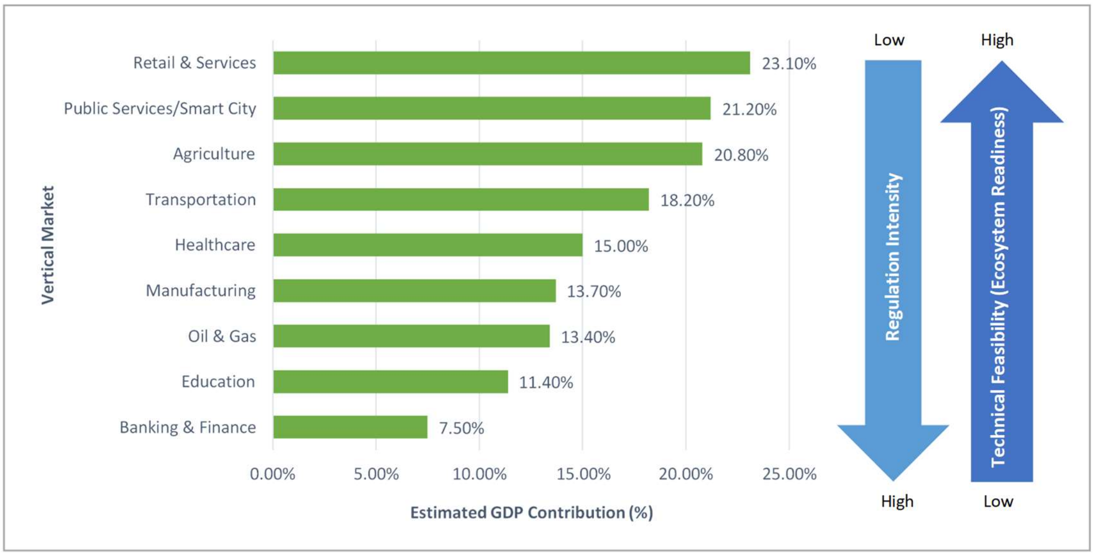


Figure 2.6: Projection of 5G's GDP contribution in 2025 by vertical market; Source: 5G Task Force

2.4.2 Social Benefits

With deployment and availability of 5G, today's workforce landscape will shift towards higher-valued jobs, as a human would still need to be in charge of final decision-making. AI will assist humans in making decisions more precisely and effectively. According to the MIER (2019), implementation of 5G-enabled services and industries in Malaysia will potentially create 39,000 new jobs opportunities with almost 40% of the jobs being available in 2025.

[2] IHS Economics & IHS Technology. 2017. https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf

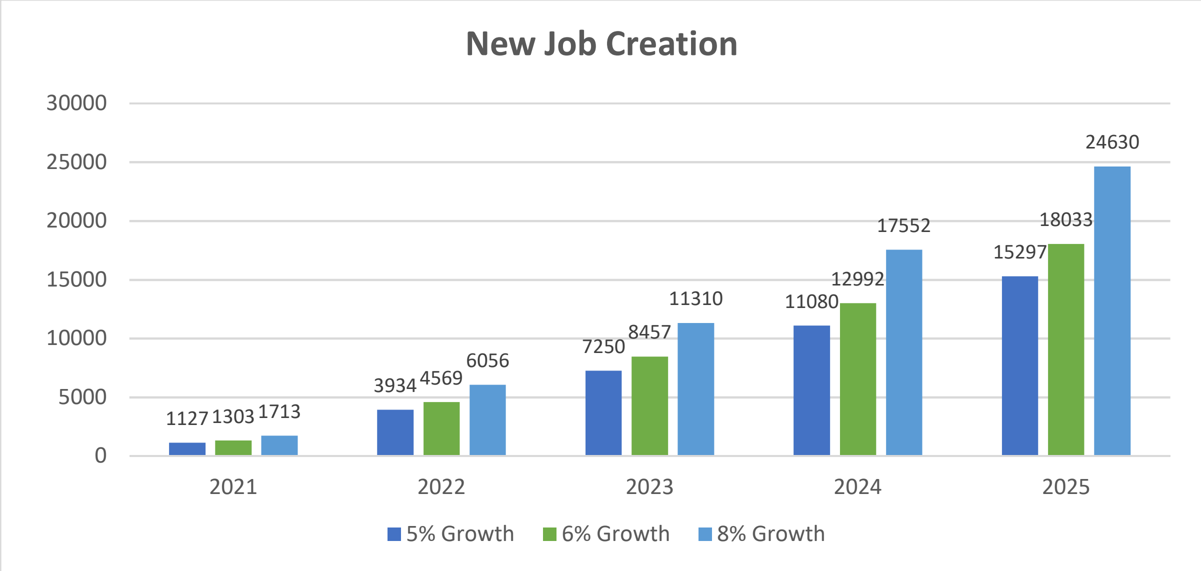


Figure 2.7: Projection of 5G's impact on new job creation in different growth scenarios, 2021-2025; Source: Edited from 'Economic Impact Analysis on the Implementation of 5G Services in Malaysia' by MIER

Highly engaged employees think, feel, and act in ways that reflect greater levels of commitment to the company. Hence, Employment Engagement Models have been deployed in Malaysia since the beginning of the 21st century. More companies now offer full or partial work from home perks to facilitate better work-life balance. Using collaborative software solutions, many jobs have shifted away from the traditional working environment to a more knowledge and service-based economy. Technology enables and facilitates those work-life models on the backbone of a strong telecommunication infrastructure.

The social implications of automation and digitisation are difficult to fully predict. Based on a research carried out by McKinsey Digital, machines will automate and replace routine and manual operations. As such, the talent landscape will encounter a paradigm shift that will value a knowledge-intensive workforce and new skills. However, this transformation may be constrained by factors like technical feasibility, costs to automate, the relative scarcity of skilled professionals, the benefits (e.g. superior performance) of automation beyond labour-cost substitution, and the regulatory and societal readiness to adapt to these changes.

2.5 Proposed Deployment Strategy for Use Cases

Just like the precedent set by IHS Economics & HIS Technologies, the 5G deployment strategy needs to consider the readiness of other critical success factors; the regulatory environment, ecosystem, market maturity etc.

Therefore, large-scale 5G deployment that leverages on existing initiatives will yield more efficiency and market readiness.

Duration	Proposed State	Proposed Focus Area	Rationale
Phase 1: 2020-2021	Johor	Smart City	- Leverage the state's existing Iskandar Malaysia Smart City
	Johor	Retail & services	- Leverage "Visit Johor Year 2020" and the state hosting the Malaysia Games
	Sabah	Agriculture	- The Sabah Agricultural Development Action Plan launched in July 2019 that aims to boost the income of farmers and landowners by planting strategic crops[3]
Phase 2: 2022-2024	Kulim High Tech Park, Kedah	Manufacturing for E&E sector	- Presence of MNCs & LCD with Export-oriented industrialisation (EOI)
	Pahang	Transportation	- Support last mile for ECRL development and connect the supply chain between east and west coast regions
	Sarawak	Healthcare	- Increase delivery of healthcare services to rural areas in Sarawak and narrow the healthcare gap between states. - The initiative can scale up to medical tourism eventually, which will serve the local market. In 2018, Sarawak saw 48,900 healthcare visitors and medical treatment with receipts totalling up to RM67.10 million in 2018[4].

[3] The Star, 26 July 2019. https://www.freemalaysiatoday.com/category/nation/2019/07/26/sabah-agricultural-action-plan-to-boost-income-of-farmers-landowners/

[4] The Star. 7 May 2019. http://www.bernama.com/state-news/berita.php?id=1723935

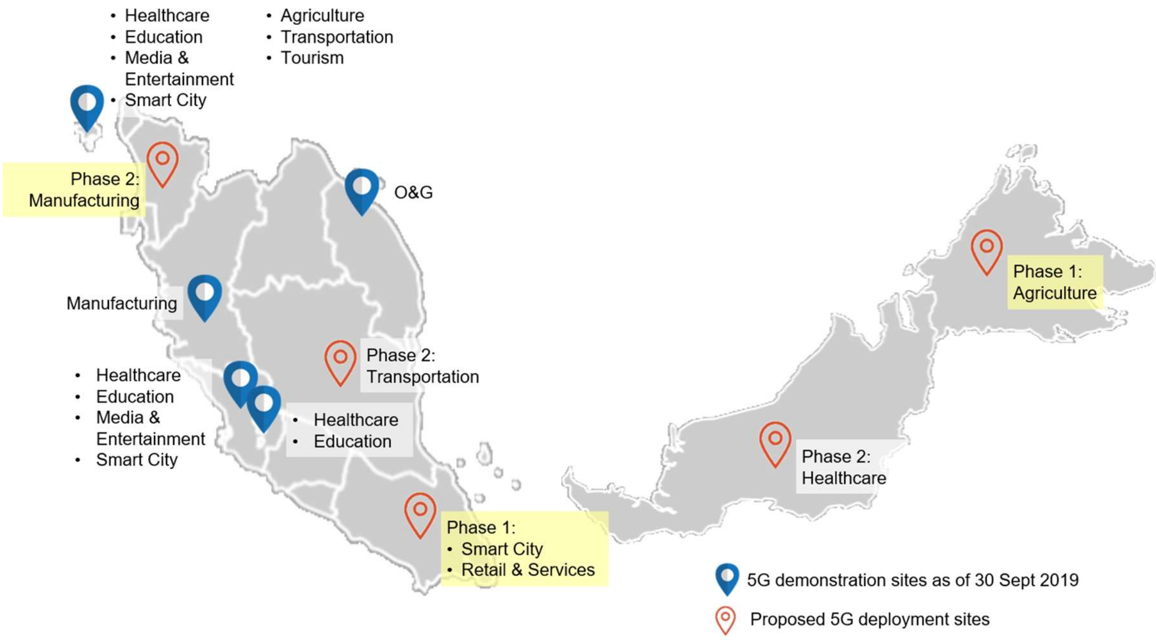


Figure 2.8: Deployment of 5G use cases: 2020 – 2024; Source: 5G Task Force

2.6 Summary of Recommendations

After considering estimated contribution to national GDP, technical feasibility and regulatory readiness, **Phase 1** deployment should prioritise 3 vertical markets:

- Retail and services
- Smart City
- Agriculture

Vertical markets suggested for **Phase 2** deployment are:

- Transportation
- Healthcare
- Manufacturing

Phase 2 deployment will depend on 2 factors:

- Regulatory readiness to support the prosed business cases;
- Technical feasibility, especially maturity and standardisation of 5G-enabled devices/equipment.

Social consideration: wider areas of coverage and the capacity to support large data transactions and analysis will benefit more Malaysians. Healthcare delivery and education benefits in particular can help reduce gaps experienced by those in remote areas.

Environmental & Financial consideration: McKinsey opines that 5G deployment requires a 60% increase in capital expenditure in infrastructure[5], in order to deliver upon intended latency, throughput, reliability, and scale. Furthermore, the communication network contributes to 24% of carbon emissions[6].

Therefore, the 5G Task Force recommends a hybrid approach towards 5G investments. Current 5G trends suggest that fiber is a fundamental infrastructure for 5G which will be offered to Telecommunications Operators (Telcos) as shared facilities and repurpose existing 4G infrastructure. This will be a more prudent and strategic path for most operators, allowing them to minimise investments while revenue returns remain uncertain.

Some business cases like the Smart City CCTV surveillance demand high-quality cables and power, thus requiring high initial investment. Cloud computing could help maximise existing infrastructure by allowing for cutting-edge computing which will facilitate data processing and analysis at local level, possibly powered using battery or solar energy. This scenario demonstrates potential cost optimisation for 5G deployment using existing infrastructure.

[5] McKinsey. 2018. *The road to 5G: The inevitable growth of infrastructure cost.*

[6] Lotfi Belkhir & Ahmed Elmeligi. 2018. *Assessing ICT global emissions footprint: Trends to 2040 & recommendation.*

3. Required 5G Spectrum

Like the existing 4G network, 5G carries information wirelessly through an electromagnetic spectrum; specifically, certain frequency bands in the radio spectrum.

It stands to reason then that spectrum is one of the most critical elements in ensuring successful and timely deployment of 5G in Malaysia. This section outlines the 5G Task Force's recommendations in implementing spectrum requirements for 5G deployment in Malaysia based on the two key principles below:

1. Significant amount of new harmonised spectrum across different countries.
   - Near 100MHz contiguous spectrum for 5G mid-bands (between 1GHz to 6GHz) and around 1GHz contiguous spectrum for 5G high-bands (>6GHz)
2. Ecosystem maturity including user devices, and network equipment readiness.

3.1 Ecosystem Updates on Global 5G Spectrum Allocation

3.1.1 Global/Regional Update

During the World Radio Communication Conference 2015 (WRC-15) run by global mobile telecommunications regulator International Telecommunication Union (ITU), participating countries have discovered 709MHz of new spectrum for International Mobile Telecommunication (IMT) use, bringing the total to 1,886MHz worldwide. Following the conclusion of WRC-15, each administration will decide upon allocation and assignment methods based on their national regulatory processes.[7] Among the bands identified for IMT at WRC-15, the Institute of Electrical and Electronics Engineers (IEEE) designated a range of microwave frequencies (4.0GHz – 8.0GHz) as the C-band; which has emerged as the core spectrum for 5G deployment. Its propagation characteristics and potential for large contiguous bandwidths have made it an ideal band for 5G as it is able to provide both capacity and coverage. Acknowledging the importance of C-band in ensuring the success of 5G, many countries have taken the necessary steps to make portions of C-band available to the market, evident in the 64 Telecommunications Operators (Telcos) worldwide that have licensed C-band as their 5G spectrum.

In addition to the C-band, significant developments are taking place towards realising spectrum harmonisation in the Millimeter Wave (mmWave) bands, which will provide large continuous bandwidth important for supporting 5G services that require high-capacity bandwidth. WRC-19 is considering frequencies for mobile broadband between **24.25GHz – 86GHz** (mmWave frequencies). Agenda 1.13 of WRC-19 is dedicated towards successfully identifying a significant amount of these frequencies for IMT, as this is thought to be vital in realising 5G's full potential.

The GSMA, representing Telcos across the globe, are advocating for the identification of the 26GHz, 40GHz and 66GHz bands.

[7] IMT. 2018. Industry Roundtable: Partnership for Digital Economy Growth https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/Documents/Events/2018/rr2018/IMT-Identified Spectrum.pptx

Significant bands in the ecosystem right now are:

1. **The 26GHz band (24.25GHz – 27.5GHz)** is already gaining traction and has been chosen in Europe as the 'pioneer band'. Africa, the Middle East, Asia, member countries of the Regional Commonwealth in the Field of Communications (RCC) and parts of the Americas are also planning to use this band for 5G. Its IMT use is subject to favourable outcomes in WRC-19.
2. **The 28GHz (27.5GHz – 29.5GHz)** is another mmWave band which has been earmarked as a key band for 5G, even though it is not part of the agenda for WRC-19. 28GHz band has garnered a lot of interest globally mainly due to its availability in the ecosystem, unlike the 26GHz.

Globally, 34 countries have completed 5G-suitable allocations or licensing procedures in either the 26GHz and 28GHz bands, while 40 countries have formally announced their plans to allocate 5G-suitable frequencies by end 2021.[8]

Following the first commercial 5G launch in April 2017 by major Telcos in South Korean and USA, there are now 50 Telcos reported to have commercially launched 5G networks[9]. With many commercial 5G launches taking place or planned in the near future, continuous and effective collaboration between all relevant stakeholders is important in ensuring the wider success of 5G.

3.1.2 Malaysia Update

The 5G Task Force is focused on spectrum bands available in Malaysia. The following is a refined list of existing spectrum assignment in Malaysia from the 3rd Generation Partnership Project (3GPP)—the organisation that sets global standards in telecommunications technologies like 5G.

No.	Spectrum Band (MHz)	Frequency Range (MHz)	Bandwidth	Remarks
1	450	452.5 – 457.5/ 462.5 – 467.5	2 x 50MHz	- Currently used for CDMA - Existing stations allowed to operate until 31 Dec 2019
2	700	703 – 743 Hz / 758 – 798	2 x 40MHz	Available for mobile broadband service after completion of ASO
3	850	824 – 834 / 869 – 879	2 x 10MHz	Currently used for LTE
4	900	885 – 915 / 930 – 960	2 x 30MHz	Currently used for 2G, 3G and LTE
5	1800	1710 – 1785 / 1805 – 1880	2 x 75MHz	Currently used for 2G and LTE
6	2100	- 1915 – 1920 - 1920 – 1980 / 2110 – 2170 - 2010 – 2025	140MHz	Currently used for 3G
7	2300	2300 – 2390	90MHz	- Currently used for WiMAX and LTE - Reallocation by 2020*
8	2600	- 2500 – 2570 / 2620 – 2690 - 2575 – 2615	180MHz	- Currently used for LTE - Reallocation by 2020*

Legend *: Subject to targets set by the National Fiberisation and Connectivity Plan (NFCP)

Figure 3.1: Malaysian Mobile Spectrum Bands and Usage

[8] GSA-5G Spectrum Report. August/Oct 2019.
[9] GSA - 5G Market Snapshot Report. Oct 2019. www.gsacom.com

No.	Spectrum Band	Frequency Range	Bandwidth	Remarks
1	**L-Band**	1452 – 1492MHz	40MHz	-
2	**3300 – 3400MHz**		100MHz	Exclusively used by the Government
3	**C-band**	3400 – 4200MHz		Currently used for Fixed Satellite Service
4	**4400 – 4500MHz**		100MHz	Currently used for Fixed Service
5	**4500 – 4800MHz**		300MHz	Currently used for Fixed Service and Fixed Satellite Service
6	**4800 – 4940MHz**		140MHz	Currently used for Fixed Service
7	**4940 – 4990MHz**		50MHz	Exclusively used by the Government
8	**mm-wave**	24.25 – 27.00GHz	2.75GHz	-
9		27.00 – 27.50GHz	0.50GHz	Currently used for Fixed Satellite Service
10		27.50 – 29.50GHz	2.00GHz	Currently used for Fixed Satellite Service
11		31.80 – 33.40GHz	1.60GHz	-
12		37.00 – 43.50GHz	6.55GHz	-
13		45.50 – 50.20GHz	4.70GHz	-
14		50.40 – 52.60GHz	2.20GHz	-
15		66.00– 76.00GHz	10.00GHz	71.00 – 76.00GH+L73:O87z / 81.00 – 86.00GHz currently used for fixed service (backhaul)
16		81.00 – 86.00GHz	5.00GHz	

Figure 3.2: Potential Malaysian Mobile Spectrum Bands; Source: MCMC Spectrum Plan

Currently Malaysian Telcos are using existing 900MHz, 1800MHz, 2100MHz, 2300MHz, and 2600MHz to offer 2G, 3G and 4G services to more than 43 million mobile-cellular subscribers[10]. As such, these bands carry heavy voice and data traffic regularly, making any technological evolution on these bands a challenge. None of the devices circulating in the market supports 5G either.

Many of these bands were identified during the early 2G/GSM and 3G era where the spectrum bandwidth size of 200 kHz was sufficient for voice channels, and 5MHz for WAP (Wireless Access Protocol) data. Hence, there is limited bandwidth availability.

For data transmission, these technologies were designed for less than 500 Kbps speeds (2G/EDGE and 3G/UMTS) which has evolved. Thus, we are now seeing the effect of Shannon's Law[11] where it becomes difficult to achieve the data rate target required to realise many of the 5G use cases using these bands without increasing bandwidth allocation, especially when sharing with current 2G/3G/4G technologies.

In consideration of the above, the C-band (3.5GHz) and mmWave (26GHz and 28GHz), have become critical and very suitable for initial large-scale 5G commercial deployment due to the large amount of bandwidth available—thus identified as Priority 1 bands for 5G.

These new 5G bands need to first be deployed in order to offload existing 2G, 3G and 4G data users to 5G and thus reduce dependency on the majority of these Priority 2 bands, which will then see an evolution to 5G at a later stage.

[10] MCMC. Q2 2019. Communications and Multimedia: Facts and Figures.

[11] Techopedia. As seen in December 2019. Shannon's Law. https://www.techopedia.com/definition/14558/shannons-law

3.1.3 5G Ecosystem Readiness

The 5G Task Force is also tasked with studying the ecosystem availability in spectrum bands for 5G deployment, as well as the timeline for ecosystem readiness. The criteria set for a 5G-ready ecosystem is based on the readiness and availability of chipset, devices and network equipment makers that can provide 5G products for the market. The objective is to propose the 5G roadmap based on current and planned availability of these 5G products:

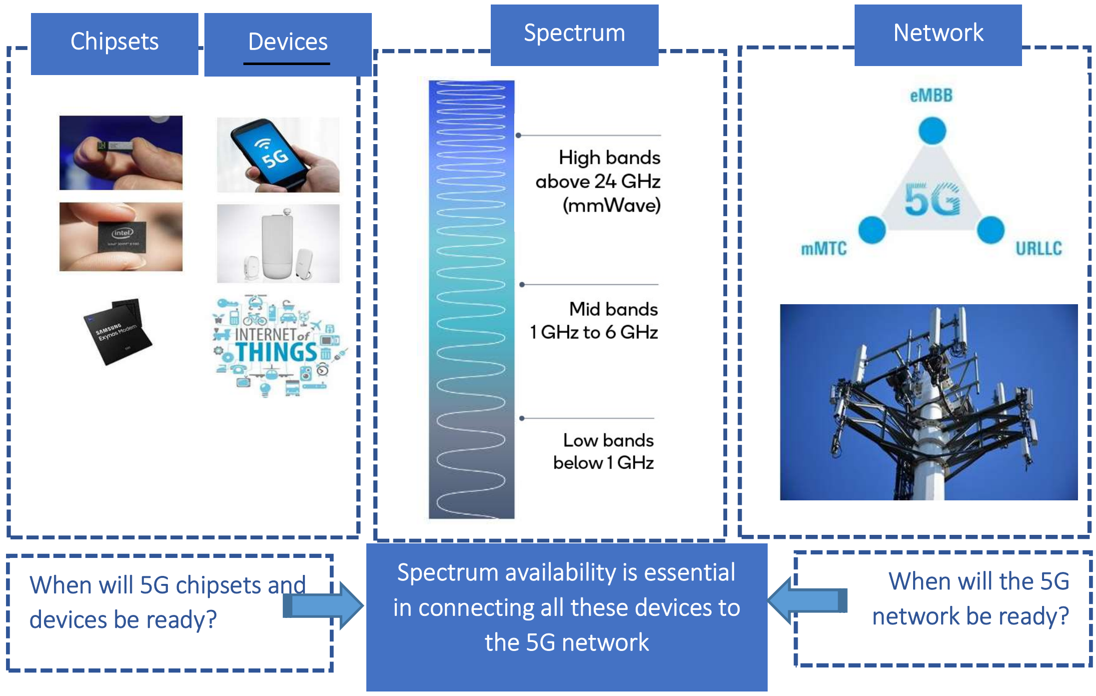


Figure 3.3: The 5G Ecosystem Criteria for the 5G Task Force Consideration; Source: 5G Spectrum Working Group

On the chipset availability front, the 5G Task Force has gathered information from chipset makers like Qualcomm and Huawei. Qualcomm has come out with primary support for the following 5G Bands: n257, n260, n261, n77, n78, n79 and n41, which is made available in premium-tier smartphones in 2019. Huawei has released their 5G chipsets back in Q1 2019, with two variants to cater to both sub-6GHz and mmWave bands. Intel has announced that it has exited the 5G mobile business but are looking into developing modems for non-smartphone devices.

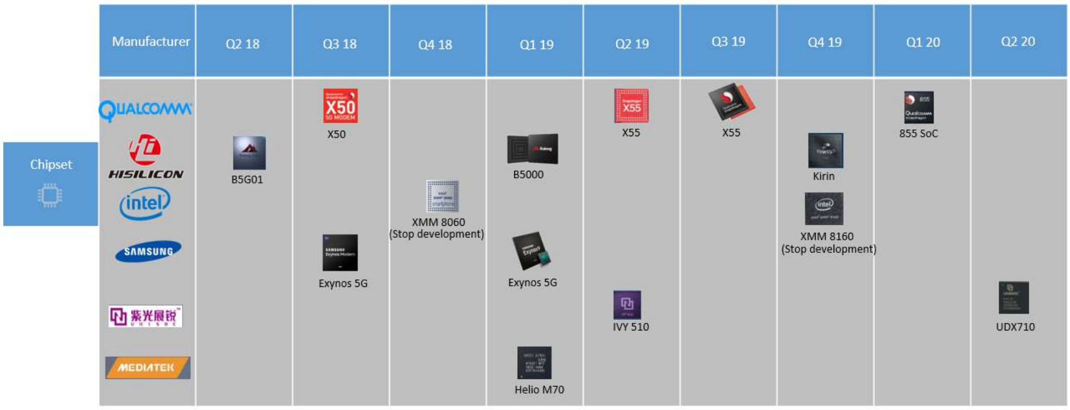


Figure 3.4: The 5G Chipset Timeline (As of Q3 19); Source: Qualcomm, Huawei, Samsung And Publicly Available Information

For industrial module availability, the 5G Task Force has collected information from module makers such as SIMCOM and Quectel, two of the top global Machine-to-Machine (M2M) wireless module providers. Both SIMcom and Quectel planned for the release of their 5G modules in Q3 2019 and are based on mMTC and Vehicle-to-Everything (V2X) applications. The modules were to be manufactured based on 2 generic models; the first on industrial application and the second on vehicle-to-vehicle (V2V) communication.

	Manufacturer	Model	Availability	Band Supported
Module	QUECTEL	RG510Q	Q4 19	Sub-6GHz, mmWave
		RG500Q	Q3 19	Sub-6GHz
		AG550Q	Q4 19	Sub-6GHz
	SIMCom	SIM8070G	Q3 19	Sub-6GHz

Figure 3.5: The Module Device Timeline (As of Q3 2019); Source: SIMCOM And Quectel

3rd Generation Partnership Project (3GPP), the organisation that oversees technical and operation standards for telecommunications technologies like 5G, developed the 5G NR, a New Radio access technology specially for 5G, and also set up the 3GPP Release 15 Standard.

The Release 15 Standard allows for 4G's LTE and the 5G NR to coexist and share the same low-frequency bands without having to fully free those bands from LTE use. With that being said, in the initial stages of 5G deployment, the new bands likely to be made available for 5G will be among those of higher frequency (e.g. C-band) and require less sub-frames for uplink (the transmission to a cell tower) compared to most existing 2G/3G/4G bands. Such bands will therefore have more uplink coverage limitations compared to existing bands.

Based on the Global Mobile Suppliers Association (GSA) Device Ecosystem Report (September 2019)[12], out of the 129 devices that have been announced; 70 devices support Sub-6 GHz bands, while 33 devices support mmWave.

In a more recent report from GSA (October 2019), 56 devices have been explicitly reported to support either N77 or N78 C-bands whilst 60 devices support mmWave.

These reports clearly show that while Sub-6 GHz is currently the best-supported by devices especially at the 3.5GHz range, the mmWave, 28GHz is the more popular choice for devices.

With regards to network equipment capabilities, the 5G Task Force has gathered information from major equipment vendors on the availability and roadmap towards the 5G Base Station (named gNB, gNodeB) as shown in **Figure 3.6**.

		Base Station Availability							
Spectrum		Available	H1' 2019	H2' 2019	H1' 2020	H1' 2021	H2' 2021	H1' 2022	H2' 2022
Low Band (MHz)	600 (n71)	1	1						
	700 (n28)			2	1				1
	900 (n8)			2	1				1
Mid Band (GHz)	2.6(n41)	2	1		1				
	3.3 – 3.8 (n78)	5							
	3.3 – 4.2 (n77)	3			1				
	4.4 – 5.0 (n79)	1			1			2	
High Band (GHz)	26 (n258)			2		1		1	
	28 (n257)	4		1					

Figure 3.6: Summary of the 5G Network Equipment Availability and Roadmap (As of Q3 2019); Source: Huawei, Ericsson, ZTE, Nokia And Samsung

In conclusion, from an ecosystem standpoint covering both device and network equipment availability, C-band is the most widely used spectrum followed by mmWave.

[12] GSA. Sept 2019. 5G Devices Ecosystem – Sept 2019 – Updated. https://gsacom.com/paper/5g-devices-ecosystem-report-september-2019/

3.2 Identified Bands for 5G in Malaysia

To support a wide range of uses cases and requirements, successful 5G implementation in Malaysia must rely on both new and existing IMT 5G spectrums that have been harmonised globally, and consist of a multi-layer spectrum within the following three key frequency ranges:

1. **Low-band (<1GHz):** For widespread coverage and to support Internet of Things (IoT) services.
2. **Mid-band (1GHz to 6GHz):** With its large contiguous bandwidth, it forms the first layer of 5G with balance between capacity and coverage.
3. **High-band (>6GHz):** For ultra-high broadband speeds envisioned for 5G.

Based on the analysis conducted on global 5G commercial launch and ecosystem readiness, Priority 1, and Priority 2 spectrum for Malaysia's 5G deployment have been identified and will be discussed in the subsequent subsections.

3.2.1 Priority 1 Spectrum

Priority 1 5G spectrum consist of 3.5GHz (Mid band in the range of 3.3 – 4.2GHz), 26GHz and 28GHz (High band in the range of 24.25GHz – 29.50GHz).

3.2.1 (a) <u>3.5GHz Band (Range of 3.3GHz – 4.2GHz)</u>

Currently, 3.5GHz (C-band) is the only core spectrum for 5G globally, as it provides the highest technical and economic value that ensures long term success of 5G deployment. As a mid-band offering wide availability in high channel bandwidth, 5G deployed using this spectrum will boost successful peak, average and cell edge throughput for affordable complexity and cost-efficiency.

Additionally, the 3.5GHz band also provides a similar coverage grid with the existing 4G spectrum grid in non-standalone architecture (NSA). A global harmonized spectrum like 3.5GHz will also provide other benefits like lower cost of end user devices, and roaming compatibility.

3.5GHz in Malaysia is currently being occupied for government use (3.3GHz –3.4GHz) and Fixed Satellite Services (3.4GHz – 4.2GHz) as depicted in the diagram below:

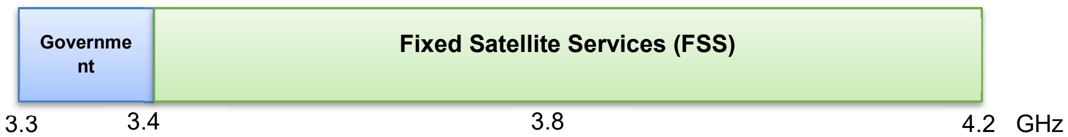


Figure 3.7: Current Allocation in the 3.3-4.2GHz Band

Considering Malaysia's 5G agenda, the 5G Task Force recommends **3.5 GHz**, as illustrated in the figure below:

*Limited use – Indoor and selected outdoor use without interfering with incumbent services

Figure 3.8: Recommendation for Re-Allocation Of 3.5GHz Band

How 5G will coexist with incumbent services will be further outlined in **Section 3.5**.

3.2.1 (b) 26/28GHz Band (Range of 24.25GHz – 29.5GHz)

The 26GHz and 28GHz bands (mmWave, from 24.25GHz – 29.5GHz) frequency range is being considered internationally to supplement 3.5GHz for fiber-like, ultra-high throughput at 5G hotspots and potential for low latency communications. mmWave is not suitable for wide area coverage as it has limited coverage range and Line-Of-Sight is needed, even though it has a mature ecosystem and adoption from Telcos globally. In view of that, coexistence between FSS and 5G is possible, with the following recommendations:

1. **24.25GHz – 27.0GHz** (total bandwidth of 2.75GHz) to be allocated to 5G with resolutions depending on coexistence with Earth Exploration Satellite Service (EESS) in WRC-19; and
2. **27.0GHz – 29.5GHz** (total bandwidth of 2.5GHz) to be allocated to 5G with appropriate interference mitigation (5G Base Station is recommended to be set at this range to avoid interference from FSS earth stations)

3.2.2 Priority 2 Spectrum

Priority 2 spectrum consist of low, mid, and high bands for 5G covering new and existing IMT bands already used in 2G, 3G and 4G. The 5G Task Force proposes that these bands cater to new use cases like 5G mMTC devices, while simultaneously complementing or offloading Priority 1 spectrum in terms of coverage, and traffic demand for 5G.

There are ongoing debates in the industry about using 700MHz as a Priority 1 5G band. From the 5G Task Force’s perspective, utilising the 700MHz spectrum alone to provide the ultimate experience required by new eMBB use cases will be a challenge for the following reasons:

1. 5G 700MHz spectrum with typically 2T2R/4T4R deployment only provides ~10-30% performance improvements compared to 4G 700MHz
2. Based on current 3GPP’s Release 16 Specifications[13], the 5G 700MHz spectrum can only support up to 20MHz carrier bandwidth, hence, it is unable to provide high throughput experience comparable to the 3.5GHz spectrum with up to 100MHz carrier bandwidth and Massive MIMO deployment
3. 700MHz in Non-Standalone Architecture (NSA) needs to be anchored on 4G mid-bands like the 1800MHz/2100MHz, without an outlined anchor to low-bands in 3GPP’s Release 16 Specification that is currently in development. Thus, coverage would be similar to 4G mid-bands.

	Base Station Configuration	Device Configuration	Bandwidth	5G Downlink Peak Cell Capacity
700MHz (FDD, n28)	2T2R	1T2R	20MHz	~230 Mbps
C-band (TDD, n78)	Massive MIMO 64T64R	2T4R	100MHz	~5.8 Gbps

Figure 3.9: Recommendation for Re-Allocation Of 3.5GHz Band

[13] 3GPP. 2019. Release 16 Description; Summary of Rel-16 Work Items. https://www.3gpp.org/release-16

In terms of device ecosystem, 5G 700MHz terminals at this early stage are only expected to cover 703MHz – 733MHz instead of the full The Asia-Pacific Telecommunity band (APT700)[14] at 703MHz – 748MHz frequency range. Furthermore, the existing 4G LTE Carrier Aggregation device ecosystem has already matured, compared to the 5G Carrier Aggregation device ecosystem which is still premature.

Aggregation of multiple LTE carriers includes the full APT700 frequency, meaning throughput of higher than 1Gbps peak is achievable, which is far higher than what the 5G 700MHz 20MHz carrier alone (i.e. 230 Mbps) can offer. This means that average 5G 700MHz throughput will be similar to 4G 700MHz at 20MHz channel bandwidth based on simulations.

Nevertheless, 700MHz is still seen as an especially important band as it can provide a wide area of 5G coverage, especially in rural areas with less capacity demand. In the future, it can be coupled with the 5G 3.5GHz carrier aggregation for enhancement of coverage, uplink capacity, and latency to handle mixed uRLLC and eMBB use cases.

As an additional benefit, 700MHz can be refarmed from 4G to 5G when 5G technology development grows more mature and affordable. Advanced features such as Dynamic Spectrum Sharing for 4G and 5G 700MHz (which requires network and new device support) may be deployed when it is available and mature later for smoother transition from 4G to 5G 700MHz. 700MHz is also useful for use in Narrowband Internet-of-Things (NB-IoT) technology, which significantly improves the power consumption of user devices, system capacity and spectrum efficiency, to provide Consumer IoT services (C-IoT) today and it may evolve to mMTC in future.

[14] APT.2013. Asia Pacific Telecommunity (APT) 700 MHz Whitepaper. https://www.gsma.com/newsroom/wp-content/uploads/2013/09/Telstra-_-Asia-Pacific-Telecommunity-APT-700-MHz-Whitepaper-FINAL.pdf

The proposed Priority 2 spectrum bands are tabulated as follows:

5G NR Spectrum Bands	Duplex	Downlink	Uplink	Total Bandwidth	Spectrum status
n1	FDD	2110MHz – 2170MHz	1920MHz – 1980MHz	2 x 60	Current utilization: 3G and 4G
n3	FDD	1805MHz – 1880MHz	1710MHz – 1785MHz	2 x 75	Current utilization: 2G, 4G
n5	FDD	869MHz – 894MHz	824MHz – 849MHz	2 x 25	Current utilization: 4G
n7	FDD	2620MHz – 2690MHz	2500MHz – 2570MHz	2 x 70	Current utilization: 4G
n8	FDD	925MHz – 960MHz	880MHz – 915MHz	2 x 35	Current utilization: 2G, 3G and 4G
n28	FDD	758MHz – 803MHz	703MHz – 748MHz	2 x 45	To be vacated from analog broadcasting (Analog switch off 31st Oct 19)
n38	TDD	2570MHz – 2620MHz		50	Current utilization: 4G
n40	TDD	2300MHz – 2400MHz		100	Current utilization: 4G
n41	TDD	2496MHz – 2690MHz		194	Current utilization: FDD mode in b7 and b38
n71	FDD	617MHz – 652MHz	663MHz – 698MHz	2 x 35	In use for broadcasting
n79	TDD	4400MHz – 500MHz		600	Current utilization: Troposcatter, Government
n260	TDD	37.0GHz – 40.0GHz		3000	Not utilised. Depending on WRC-19

Figure 3.10: Priority 2 5G New Radio (NR) in Malaysia

The 5G Task Force proposes that MCMC initiates the allocation planning for Priority 2 spectrum (i.e.: n71, n79 and n260) to Telecommunications Operators (Telcos) for 5G IMT use in Malaysia to ensure that spectrum is available in a timely manner for the next wave of 5G development, particularly the mid and low bands. The 5G Task Force also proposes that the MCMC monitors the outcome of WRC-19 closely for new potential IMT spectrum that may be identified for study and initiate timely planning for the future.

3.2.3 5G Private Network

The continuous improvements in cellular technology on a global scale are making it compelling for governments and industries to explore its use for private networks. Private networks leveraging on 4G or 5G technology become a dedicated network with unified connectivity, optimised services, and a secure means of communication within a specific area.

Private networks are mainly driven by industry and public safety needs. Public safety systems tend to be very large and focused on a handful of nationwide opportunities. For the industry/manufacturing segments, potential deployments tend to be relatively small in terms of the number of radio sites. Refer to **Appendix 4.1** for more on drivers for public networks.

The 5G Task Force fully supports the availability of private 5G networks in Malaysia and believes that it should be provided via the most effective and efficient way: Telcos. The 5G Task Force believes that Telcos play a necessary role in private network setup to guarantee inevitable long-term heavy network investments needed for 5G, and to ensure high quality of service. Telcos are also able to provide customised private 5G network services to each enterprise based on their different needs via network slicing feature unique to 5G.

The collaboration between enterprises and Telcos allows for flexibility in the deployment of the private network through either a wholesale capacity agreement or managed solutions offering using the Telcos' network. Telco-managed private networks will increase spectral utilisation and efficiency (e.g.: no guard band), minimise interference and avoid complexity of spectrum regulations.

3.3 Required Bandwidth for 5G Spectrum Allocation

5G networks will provide major gains in spectral efficiency. 5G is able to support 100MHz of bandwidth for 3GPP Frequency range 1 (FR1, <6GHz) and at least 400MHz of bandwidth for 3GPP frequency range 2 (FR2, >6GHz). Benefits of large and contiguous block size are as follows:

1. Allows for wide channelization, thereby boosting speeds and capacity exponentially; and
2. Effectively support mobile traffic growth. Based on Ericsson Mobility Report June 2019, mobile traffic in South East Asia and Oceania will grow at least sevenfold from 2018 to 2024 based on the Ericsson Mobility Report[15] (as per the September 2019 version). Refer to **Appendix 4.2**.

[15] Ericsson. Sept 2019. Ericsson Mobility Report. https://www.ericsson.com/en/mobility-report?

3.3.1 Bandwidth Options for Priority 1 Spectrum

Recommendations for Priority 1 bandwidth block sizes are as below:

Priority 1 Bands	Frequency Range (Per Block Bandwidth)	Proposed Total Bandwidth
3.5GHz	3.3GHz – 3.4GHz (5MHz)	**50MHz x 2** 50MHz | 50MHz
	3.4GHz – 3.8GHz (100MHz)	**100MHz x 4** 100MHz | 100MHz | 100MHz | 100MHz
26/28GHz	Within 26.5GHz – 29.5GHz (400MHz)	**400MHz x 6** 400MHz | 400MHz | 400MHz | 400MHz | 400MHz | 400MHz 24.25 GHz 27.10 GHz 29.5 GHz The proposed 2.4GHz to fall within the range of 27.1 – 29.5 GHz due to the maturity of the ecosystem in the 28GHz band. The usage for 5G 24.25 to 27.1GHz will be subject to the outcome of WRC-19 under Agenda item 1.13

Figure 3.11: Proposed Block Size for 3.5GHz and 26/28 GHz Bands

3.3.2 Bandwidth Options for Priority 2 Bands

Recommendations for bandwidth block sizes for the Priority 2 bands are based on the following:

5G NR Spectrum Bands	Duplex	DL	UL	Total Bandwidth	Bandwidth block size
n1	FDD	2110MHz – 2170MHz	1920MHz – 1980MHz	2 x 60	Follow existing allocation
n3	FDD	1805MHz – 1880MHz	1710MHz – 1785MHz	2 x 75	Follow existing allocation
n5	FDD	869MHz – 894MHz	824MHz – 849MHz	2 x 25	2 x 10MHz
n7	FDD	2620MHz – 2690MHz	2500MHz – 2570MHz	2 x 70	Follow existing allocation
n8	FDD	925MHz – 960MHz	880MHz – 915MHz	2 x 35	Follow existing allocation
n28	FDD	758MHz –803MHz	703MHz – 748MHz	2 x 45	2 x 10MHz
n38	TDD	2570MHz – 2620MHz		50	Follow existing allocation
n40	TDD	2300MHz – 2400MHz		100	50MHz
n41	TDD	2496MHz – 2690MHz		194	50MHz
n71	FDD	617MHz – 652MHz	663MHz – 698MHz	2 x 35	2 x 10MHz; or 2 x 15MHz
n79	TDD	4400MHz – 5000MHz		600	100MHz
n260	TDD	37.0GHz – 40.0GHz		3000	400MHz

Figure 3.12: Bandwidth Options for Priority 2 Bands

3.3.3 Synchronisation in TDD Networks

In most parts of the world, former network generations have been based on Frequency Division Duplex (FDD), i.e. one channel for the downlink (DL) and a separate channel for uplink (UL). However, for 5G, there is a clear trend towards Time Division Duplex (TDD), which uses a single frequency band for both transmission and reception.

As all the Priority 1 spectrum and many of the Priority 2 spectrum operate on a TDD format, synchronisation of frame structure among all the spectrum assignees is necessary. There will also be interference if the TDD frame structure DL:UL ratio is not synchronised among Telcos. Additional guard band will be required among Telcos' spectrum blocks, which will lead to wastage of spectrum. Hence, the 5G Task Force recommends that the regulator facilitate or regulate synchronisation of 5G TDD spectrums. During early stages, it is also proposed that DL:UL ratio of 4:1 (i.e. most commonly selected globally) be adopted in Malaysia for both C-band and mmWave.

3.4 Timeline for Spectrum Allocation/Implementation

Appropriate spectrum allocation based on aggressive, yet practical timelines will allow Malaysia to be a frontrunner in the deployment of efficient 5G networks and subsequent adoption of 5G use cases.

The 5G Task Force would like to recommend the following timeline for spectrum allocation:

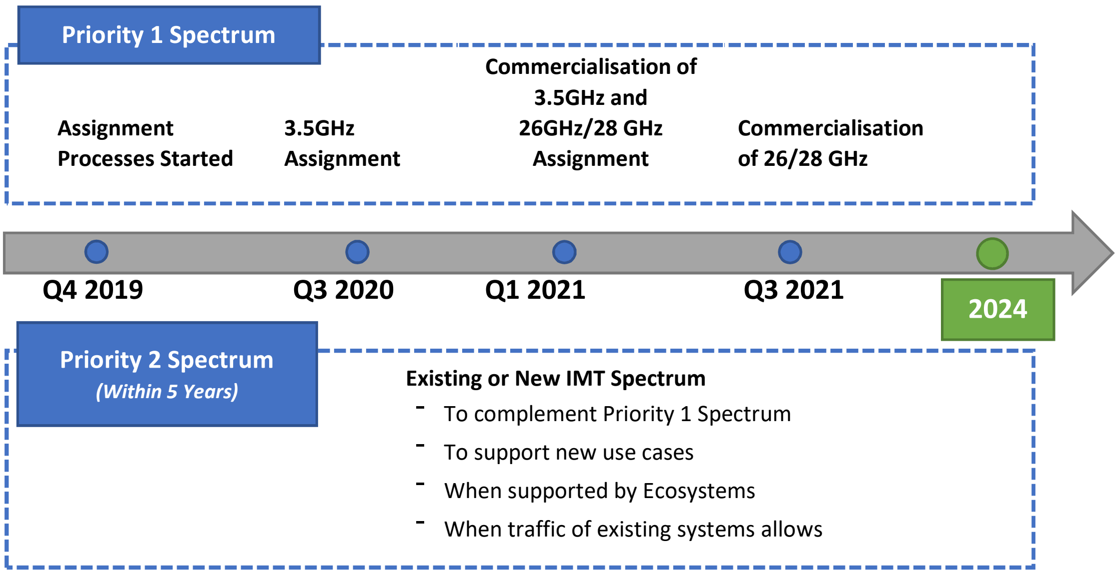


Figure 3.13: Proposed timeline for Priority 1 and Priority 2 bands

3.5 Challenges of Identified Bands For 5G

3.5.1 Coexistence with Incumbent Services

3.5.1 (a) C-band (3.4-4.2GHz)

The 3.5GHz band (C-band) is currently utilised by Malaysia East Asia Satellite (MEASAT) for their operational satellites, of which installation and testing of equipment for a satellite control station is set on Langkawi Island. MEASAT-3, MEASAT-3a, and Africasat-1a will continue to use the C-band spectrum for the upcoming MEASAT-3d satellite, scheduled for launch in the second half of 2021. The C-band is also used to perform critical commands, telemetry, a range of controls for MEASAT satellites, and to monitor the satellites' overall health. Control links are transmitted through stations located in Cyberjaya (primary) and Bukit Jalil (back-up). The Cyberjaya and Bukit Jalil control stations also monitor live traffic on the entire C-band payload of the MEASAT satellite fleet to ensure quality of service.

Deployment of the 5G Base Station adjacent to the incumbent receiver in the reallocated C-band spectrum will no doubt generate interference in the incumbent's receiver system. Therefore, the 5G Task Force recommends a segregated approach in allocation of the C-band.

3.4GHz – 3.8GHz should be allocated to mobile services, and the remaining spectrum should be re-allocated to FSS, with a yet-to-be-determined guard band in between the two services. Based on the analysis, an initial total of 100MHz for limited 5G use (indoor and selective outdoor use if there are no interference issues with incumbent services) and 400MHz (general use) should be allocated for 5G deployment.

Due to the technically sensitive nature of FSS operation within the 3.5GHz band, there is potential harmful frequency interference between the 5G and FSS systems that operate in co-bands or adjacent bands, as illustrated below.

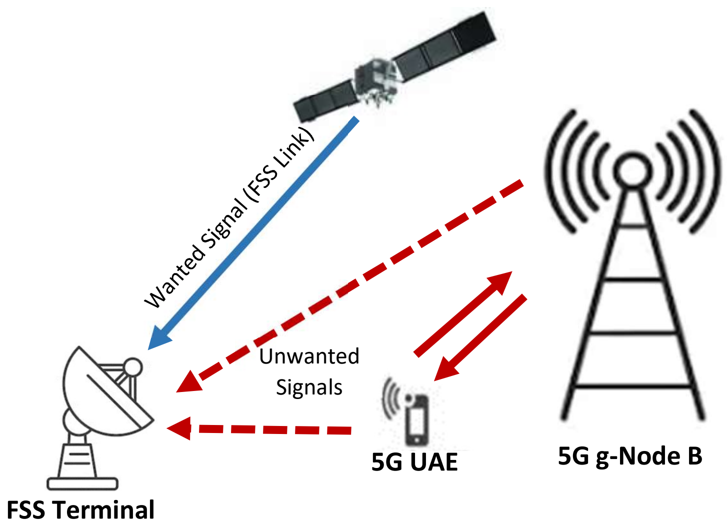


Figure 3.14: Potential Interference Scenario from 5G to FSS; Source: 5G Spectrum Working Group

The 5G Task Force is proposing a quantitative evaluation on the technical feasibility of coexistence between 5G and FSS, by conducting theoretical studies, lab tests and field tests at selected locations to produce recommendations on how to mitigate interference.

One benefit of these technical studies is to potentially specify the necessary guard band, emission power limits, separation distance, and mitigating efforts required for coexistence. Potential techniques listed in this report are proposed based on global best practices, to be verified by theoretical study and field trials as these techniques would be used for interference mitigation for both local and cross-border scenarios.

To date, there are about 2,000 C-band receivers nationwide serving applications such as mobile backhaul, VSAT, video distribution and government links, as illustrated below:

Figure 3.15: Location of FSS Receivers in 3,400MHz – 4,200MHz nationwide; Source: MEASAT Database

Malaysia's proximity to Brunei, Indonesia, Singapore, and Thailand also requires cross-border coordination and possible harmonisation with use of the proposed 5G spectrum within the 3.4GHz – 3.8GHz band. Existing bilateral and multilateral border coordination meetings can be leveraged to ensure harmonisation of the 5G spectrum.

3.5.1 (b) 26GHz and 28GHz Bands

The current use of 26GHz and 28GHz bands in Malaysia is depicted below:

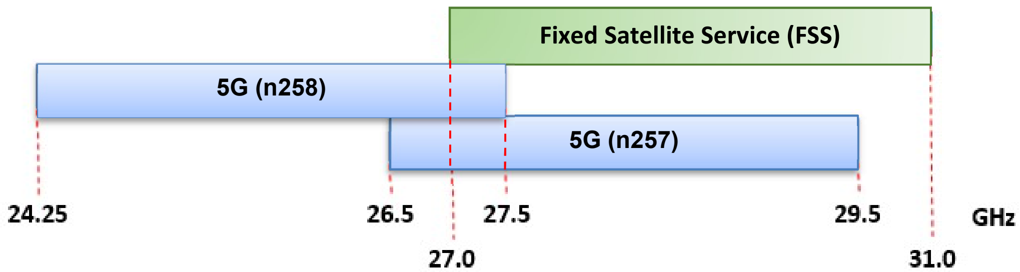


Figure 3.16: Current Allocation and Proposed Frequency Arrangement in 26GHz and 28GHz Bands

MEASAT currently uses the Ka-band for commercial satellite communication, which utilises frequencies between 27.0GHz – 30.0GHz for the MEASAT-5 satellite and will continue to use the Ka-band with frequencies between 27.0GHz – 31.0GHz on the upcoming MEASAT-3d satellite to provide High Throughput Satellite (HTS) service that involves the deployment of many small, transmit-receive user terminals in Malaysia.

A major debate is taking shape in WRC-19 over concerns that mobile use of the popular 26GHz band for 5G could cause harmful interference to EESS in 23.6GHz – 24GHz. It is expected that the number of EESS earth stations in the 25.5GHz – 27GHz frequency band will remain limited. To ensure that there are still possibilities for future deployment within this frequency band though, provisions need to be made in the authorisation of 5G to define precisely how existing and future earth stations will be protected and safeguard opportunities for installation of future earth stations.

Mobile equipment makers are having difficulties complying with these limits and said it is highly unlikely that manufacturers will bring to market any equipment capable of functioning below 26 GHz by 2020.

In mmWave, there is a need to address the coexistence between FSS and 5G in 27.0GHz – 29.5GHz as FSS is expected to create interference in 5G. Nevertheless, preliminary studies by global renowned organisations indicate that sharing is feasible between FSS and 5G in the mmWave.

Coexistence scenarios between 5G and FSS in 27.0GHz – 29.5GHz is depicted in the table below:

Coexistence scenario	Conclusions
5G to FSS (Space Station)	Coexistence between 5G and FSS space station is feasible at national level.
FSS (Earth Station) to 5G	Large FSS earth stations can c-exist with 5G at national level. Future small terminals for the high-throughput satellites require some coordination to mitigate interference with 5G.
Other Systems to 5G	ITU-R is preparing a Draft Recommendation to protect mobile stations operating in the 27.5 GHz – 29.5 GHz frequencies from potential interference by other systems.

Figure 3.17: Coexistence Scenarios Between 5G and FSS in 27.0GHz – 29.5GHz; Source: 5G Spectrum Working Group

3.5.2 Mitigation Techniques

To enable coexistence of the 5G mobile service and FSS in the C-band, mitigating steps should be applied. The emphasis is on co-channel and adjacent-channel interference from the 5G Base Station to the FSS receiver.

Based on the proposed spectrum allocation, potential interference risks to the FSS system are:

- Receiver blocking (out of band power saturation caused by 5G Base Station)
- Spurious emissions in the FSS spectrum range
- Intermodulation products generated in FSS system by multiple 5G Base Stations

Based on the three possible interference scenarios (refer to **Appendix 4.3**) in the coexistence setup between 5G and the FSS system, the 5G Task Force recommends mitigation techniques that can be applied to either 5G Base Stations or the FSS system to suppress interferences in the FSS receiver. These recommendations are a team analysis with reference to other mitigation techniques implemented in other countries, which are as follows:

Interference Solutions	Interference Type
A guard band is added between interfering systems	- Spurious emission - Blocking interference
Expand the distance between the interference source and the interfered party	- Spurious emission - Blocking interference - Co-channel interference
The RF optimisation of the 5G Base Station is optimised to reduce the antenna gain in the interference direction	Blocking interference
A band-pass filter is added to the satellite's earth station	Spurious emission
Improve the spurious emission indicator on the 5G Base Station	- Spurious emission - Blocking interference
Adjust the transmit power (Reduce the NR transmit power and improve the demodulation capability of the satellite's ground station)	- Spurious emission - Blocking interference - Co-channel interference
Add a physical isolation cover opt the satellite ground station	- Spurious emission - Blocking interference - Co-channel interference

Figure 3.18: Mitigation technique for protecting FSS in coexistence scenario; Source: Huawei

The 5G Demonstration Projects (5GDP)[16] installed at the Langkawi International Airport (LIA) is aimed at facilitating, building, and spurring development of cases utilising 5G. To ensure that 5GDP faces minimal interferences from 5G Base Stations, a step-by-step workflow has been developed.

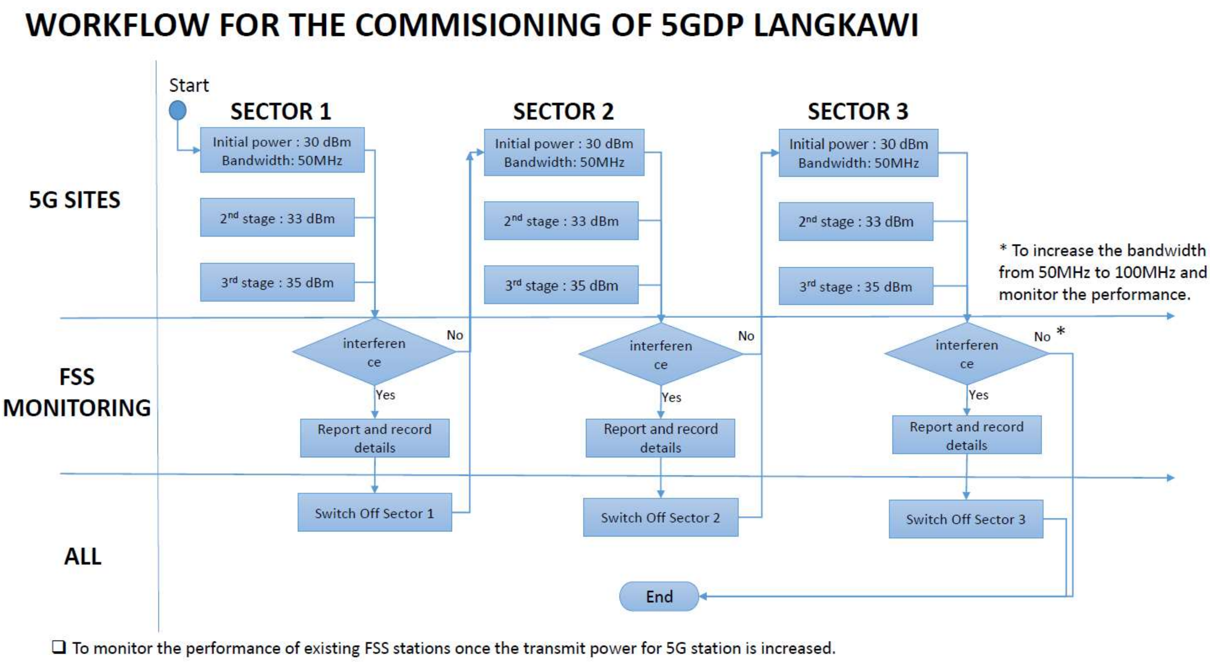


Figure 3.19: 5G Demonstration Projects (5GDP) at Langkawi International Airport (LIA); Source: 5G Spectrum Working Group

5G Base Stations will be activated with the initial configuration (Sector 1, 50MHz bandwidth, 30dBm transmit power), and if no interference is detected from the nearby FSS receiver, the configuration will be stepped up with the following pre-defined sequences:

1. Transmission power will be stepped up from 30dBm to 33dBM and later to 35dBm
2. The bandwidth will be stepped up from 50MHz to 100MHz
3. The 3 sectors will be activated one-by-one after the completion of configuration steps of the previous sector

If interferences are detected at the initial configuration of any Sector, then the whole Sector will be switched off. Meanwhile, if interferences are identified at a further step, then the 5G Base Station will immediately roll back to the previous configuration.

3.5.3 Global Reference on Coexistence Scenarios

Malaysia is able to look to global references on sharing feasibility between 5G IMT and incumbent FSS as a guideline to speed up the release of C-band spectrum in Malaysia. Guard band, LNB/filter upgrade, separation distance coordination and 5G Base Station RF optimisation are among the commonly adopted mitigation techniques. Supporting regulatory policy also plays an important role in accelerating the process. Summary of reference on mitigation solution from Hong Kong and China can be found in **Appendix 4.4**.

[16] Bernama. Nov 2019. 5GDP installation at Langkawi airport is on track, says edotco http://www.bernama.com/en/news.php?id=1793392

3.5.4 Theoretical Studies on Mitigation Techniques for Coexistence Between 5G IMT And FSS in C-band

3.5.4 (a) Objectives

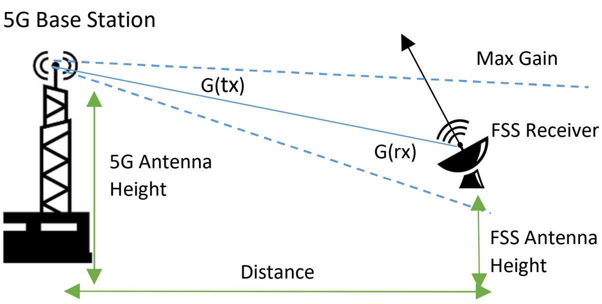
The objective of this study is to summarise the theoretical calculation of distance required between the 5G Base Station and FSS Receivers so they can coexist adjacent to each other in the C-band spectrum.

The outcome of the theoretical study can serve as a reference for field trials and interference mitigation techniques in Malaysia. However, the number derived should not be used as a mandatory requirement for separation distance during commercial deployment of 5G IMT just yet. The potential interference to be covered in this theoretical study is Spurious Interference and Blocking Interference.

There was no interference analysis done between 5G IMT and MEASAT TT&C stations in Cyberjaya and Bukit Jalil. Based on a Hong Kong reference case, a ~10x20 km^2 restriction zone is considered a co-channel interference (between two access points that are on the same frequency channel) case. However, in the case of adjacent-channel scenario, the area of restriction zone should be smaller.

3.5.4 (b) General Assumptions Used in This Theoretical Study

The path loss between the 5G Base Station and FSS Station is calculated using formula below.



$$P(rx) = P(tx) + G(tx) - CL(tx) - L(FS) + G(rx) - CL(rx)$$

P(rx) = FSS receive max allowable input power
P(tx) = Output power of 5G BTS
G(tx) = 5G BTS transmit antenna again
G(rx) = FSS receive antenna gain
CL(tx) = cable loss 5G Base Station 90dB in AAU case)
CL(rx)= cable loss FSS receiver (assume 1dB in analysis)
L(FS) = Path Loss

Figure 3.20: Analysis Model for Path Loss Between 5G Base Station and FSS Station; Source: 5G Spectrum WG

Two different propagation models are being considered in the study; Free-space for LOS (Line-Of-Sight) scenario and 3GPP Uma for NLOS (Non-Line-Of-Sight) scenario. The assumptions used in this study can be found in **Appendix 4.5**.

3.5.4 (c) Analysis of Results

Using the free-space model for LOS and the 3GPP Uma model for NLOS, the separation distance requirement between the 5G Base Station (assumed height =30m) and FSS receiver (assume height = 5m) is as follows:

	Spurious Interference				Blocking Interference			
	Single site; Tx gain 19dBi	**Multiple sites;** Tx gain 19dBi	**Single site;** Tx gain 24dBi	**Multiple sites;** Tx gain 24dBi	**Without Rejection Filter;** Tx gain 19dBi	**With Rejection Filter 55dB;** Tx gain 19dBi	**Without Rejection Filter;** Tx gain 24dBi	**With Rejection Filter 55dB;** Tx gain 24dBi
Path Loss, dB	85.9	91.9	90.9	96.9	121	66	126	71
Isolation Distance (model: Free-space LOS), meter	135	270	240	480	7690	14	13675	24
Isolation Distance (model: 3GPP Uma NLOS, urban), meter	50	70	65	95	400	15	530	20
Isolation Distance (model: 3GPP Uma NLOS, suburban), meter	68	95	90	130	550	21	720	28

Figure 3.21: Summary of distance requirement for spurious and blocking interference; Source: 5G Spectrum Working Group

Once FSS receiver is upgraded with the 55dB rejection filter:

- In Line-Of-Sight (LOS) scenario, based on typical 5G Base Station gain of 19 dBi and FSS Receiver gain of -10 dBi, the isolation requirement is 135m and 270m for single and multiple (4) 5G site deployments respectively.
- In Non-Line-Of-Sight (NLOS) scenario, based on typical 5G Base Station gain of 19 dBi and FSS Receiver gain of -10 dBi, the isolation requirement is 70m and 95m for urban and suburban contexts respectively in multiple (4) 5G site deployments respectively.

Based on the theoretical study and global reference cases, the coexistence of 5G and FSS is possible with proper mitigation technique applied with a 100MHz guard band. Lab and field tests can be carried out to verify the separation distance required with different input parameters. Details of the proposed tests and a corresponding Field Test Plan can be found in **Appendix 4.6**.

Moving forward, it is recommended that the regulator issue a relocation notice to FSS as soon as possible without waiting for the completion of field trials, in order to accelerate the spectrum assignment process.

3.6 Summary of Recommendations

The summary of recommendations for Spectrum Management & Allocation is in **Figure 3.22**:

Global Update:	***C-band and mmWave identified as strongest candidates for 5G:*** 1. Globally, C-band has been licensed to 64 Telecommunications Operators 2. Existing bands in Malaysia does not have large contiguous bandwidth needed and also heavily utilised 3. Strong device ecosystem—56 devices supporting C-band N77 and N78
Identified bands:	**1. Priority 1:** • C-band: 3.3GHz to 3.4GHz (5G limited use)/3.4GHz – 3.8GHz (normal 5G use) to coexist with FSS (3.8GHz - 4.2GHz) • mmWave 26GHz and 28GHz (27.1GHz – 29.5GHz) -Depends on resolution coexistence with EESS in WRC-19 **2. Priority 2:** • Other bands including existing bands such as 700MHz (~11 bands) **3. 700MHz band has been identified as the future 5G band to support mMTC**
Bandwidth: (Block size)	**1. Bandwith block size for Priority 1 bands:** • C-band: 3.3 to 3.4GHz (limited use) — 50MHz/3.4GHz — 3.8GHz (5G normal use)—100MHz • mmWave 26GHz and 28GHz – 400MHz **2. Bandwidth for Priority 2 bands:** same principle as Priority 1 **3. Private network:** 5G Task Force fully supports the availbility of Private 5G networks in Malaysia and believes that it should be provided in the most efficient way: through Telecommunications Operators (Telcos) and Network Slicing
Timeline:	**1. Priority 1:** • C-band: assignment in Q3 2020 and will go live by Q1 2021 • mmWave: assignment in Q1 2021 and will go live by Q3 2021 **2. Priority 2:** Completed within 5 years depending on utilisation and ecosystem
Challenge:	**1. 5G to coexist with FSS especially in C-band using mitigation techniques such as Guard Bands (FSS), band pass filter (FSS), Cage (FSS), RF optimisation (5G) and Distance (5G).** **2. Theoretical study suggests that the band pass filter will resolve blocking interference and distance separation between 70m & 270m for both LOS and NLOS scenarios, and will overcome spurries interferences.** **3. Test plan on C-band coexistence provided as a guide for future testing.**

Figure 3.22: Spectrum Management & Allocation Summary of Recommendations; Source: 5G Spectrum Working Group

4. Infrastructure Study for 5G Deployment

4.1 How A 5G Network Differs from Previous Network Generations

The key differences between 5G and its 4G predecessor stems directly from the differences in objectives for 5G:

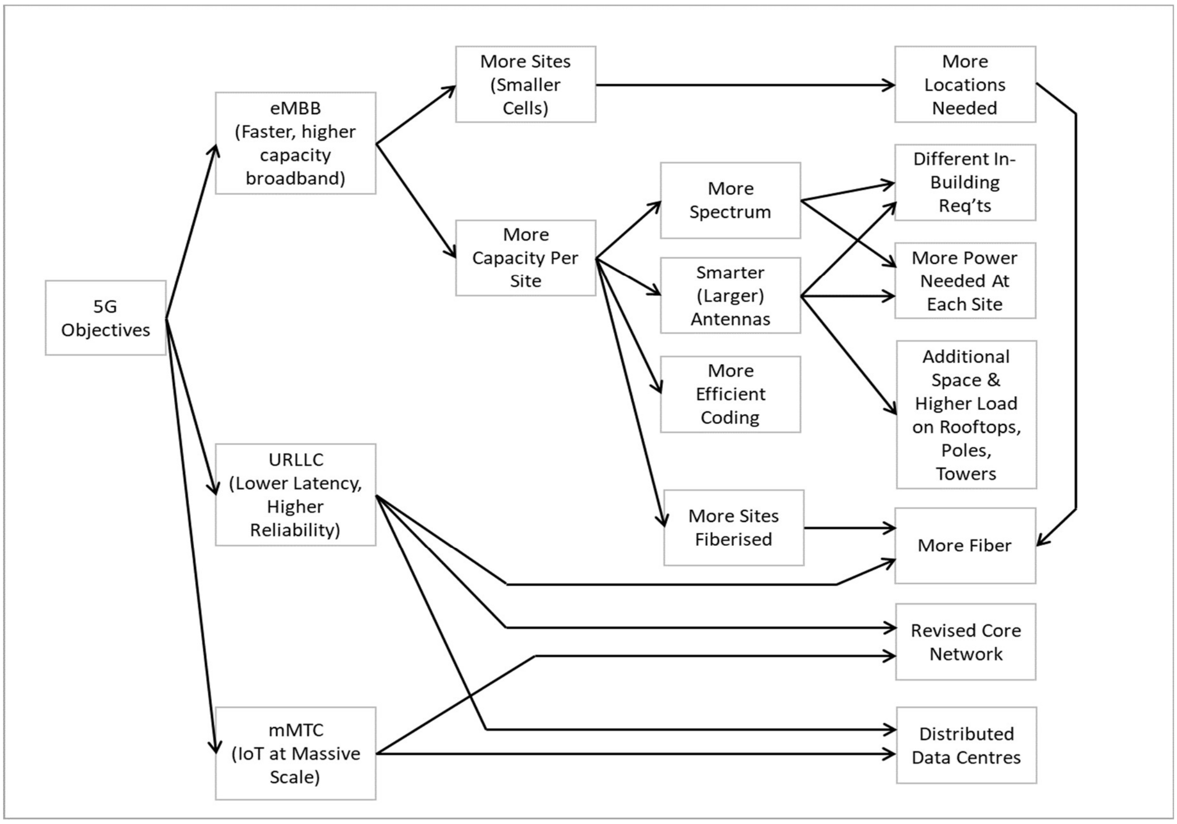


Figure 4.1: Expanded 5G Infrastructure Requirements

In addition to the macro differences driven by 5G as highlighted in the diagram above, there are specific technology differences that network builders must consider, which will impact costing. These include:

- Use of Stand Alone (SA) vs Non-Stand Alone (NSA) radio options. In the case of NSA, the 5G network has a high dependence on an underlying 4G network but can offer more cost-effective coverage.
- Use of Distributed vs Centralised radio network architectures. Centralised radio architectures may offer some reduction in cost and improvement in performance but require revised transmission networks.
- The introduction of 'Network Slicing' to separately support different use cases, and even different customers on a single network without long-reaching impact.

Aspects of the infrastructure outside of Telcos' core locations are those that will be the biggest driver of cost, and most impacted by policy and regulation. These are mostly radio sites and backhaul solutions, often fiber, and therefore addressed in detail in:

- **Section 4.2** (radio planning and number of sites required);
- **Section 4.3** (acquiring the required sites and achieving the required strength and electrical power while balancing against other objectives such as aesthetics); and
- **Section 4.4** (transmission requirements and challenges in deployment of sufficient fiber).

5G implementation requires a lot of fiber. As showcased in the figure above, 5G leads to higher demand for sites, space, power (at many sites) and an increased demand on the backhaul network from those sites, which will allow interconnectivity and support for billions of devices form the core network.

Hence, most of the policy and regulation issues that impacted 4G and fibre rollout will continue to into 5G, but on a bigger scale.

The biggest factor behind cost will be the required number of sites, and the balance of macro-sites vs small-cell sites that will likely be used. The upgrade of existing sites to the required mechanical and power standards, and deployment of fibre, will also be major factors. Overall impact estimates/gap analysis is given in **Section 4.5**.

Expected need for very high speeds, data volumes and very low latencies suggests a design which pushes network and computing resources close to the end customer, rather than bringing all traffic to a centralised location (higher delays and congestion). Mobile Edge Computing is the name of architecture that meets this purpose, and discussed in **Section 4.6**.

4.2 Radio Access Network Options and Coverage

5G offers many Radio Access Network (RAN) architecture options compared to 4G, which is driven by the variety of use cases, demand for higher performance and ongoing standardisation of more complex solutions.

4.2.1 Stand-Alone (SA) vs Non-Stand-Alone (NSA) 5G Networks

Stand Alone (SA) networks are dedicated 5G networks requiring a new 5G Core Network as well as radio, which are expected to enable all 5G use cases. A Non-Stand Alone (NSA) 5G architecture will allow 5G radio to leverage on existing 4G core and connectivity management, allowing for lower initial costs in both core and coverage.

Globally, most deployments are based on NSA due to the reasons below:

- Quick rollout by leveraging on existing 4G infrastructure and core
- Voice continuity
- Dual-connectivity with lower band to improve 5G coverage significantly
- Increased performance through dual-connectivity aggregation between 4G/5G
- Mature ecosystem

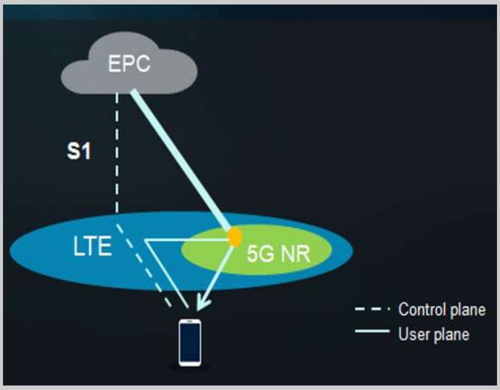
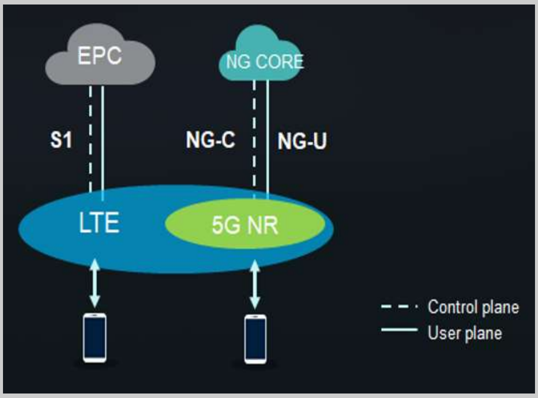
<table>
<tr><th>NSA (Non-Standalone)</th><th>SA (Standalone)</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>• Focus on eMBB
• Reuse current EPC and LTE as anchor, enable 5GNR quick introduction</td><td>• eMBB/uRLLC/mMTC and network slicing
• New core required
• High requirement for 5G NR coverage</td></tr>
</table>

Figure 4.2: NSA & SA Architecture; Source: Huawei

Assuming 5G launches in Malaysia within the next 2 years, Telcos are most likely to launch Non-Stand-Alone (NSA) networks for lowest cost coverage and best customer experience of eMBB. In the end, options to deploy NSA or SA will depend on the Telcos' strategy for their respective 5G deployment.

4.2.2 Distributed (D-RAN), Centralised (C-RAN), and RAN Layer Split

Another area of architectural consideration is whether radio equipment deployment will be in a distributed (D-RAN) or centralised (C-RAN) arrangement as per **Figure 4.3**. Centralisation will provide coordination benefits such as Inter-Site Carrier Aggregation and Coordinated Multi-Point Transmission/Reception (CoMP) for improving system capacity and cell edge user throughput. However, this requires a fiber connection for 'front haul' from the antenna site to the centralised radio equipment site with very stringent latency requirements.

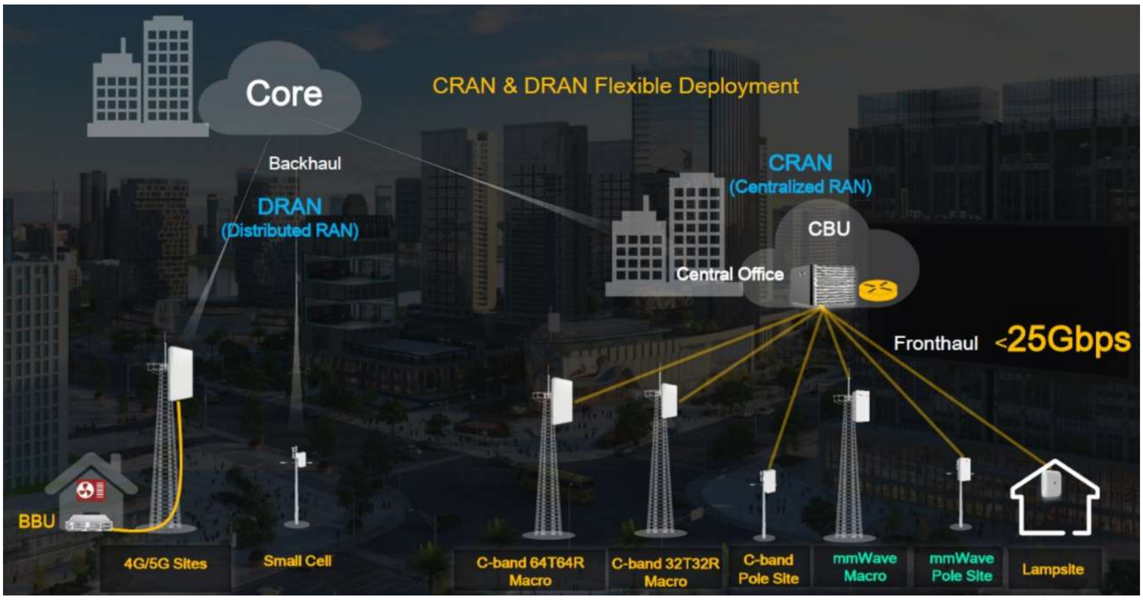


Figure 4.3: Distributed & Centralised Architecture; Source: Huawei

There is also various Split Radio architecture in 5G that splits RAN functions, including the separation of the user plane and the control plane in higher layers. The split will allow parts on Non-Critical Real Time Functions to be centralised, allowing for some benefits from processing resource coordination. However centralised unit implementations will require additional investment into virtualised-based hardware platforms which could lead to higher overall total cost of ownership and complexity. As of today, most Telcos adopt the co-deployment (D-RAN) mode where the radio and processing functions are in the same location, and the 5G Task Force proposes the same deployment approach in Malaysia

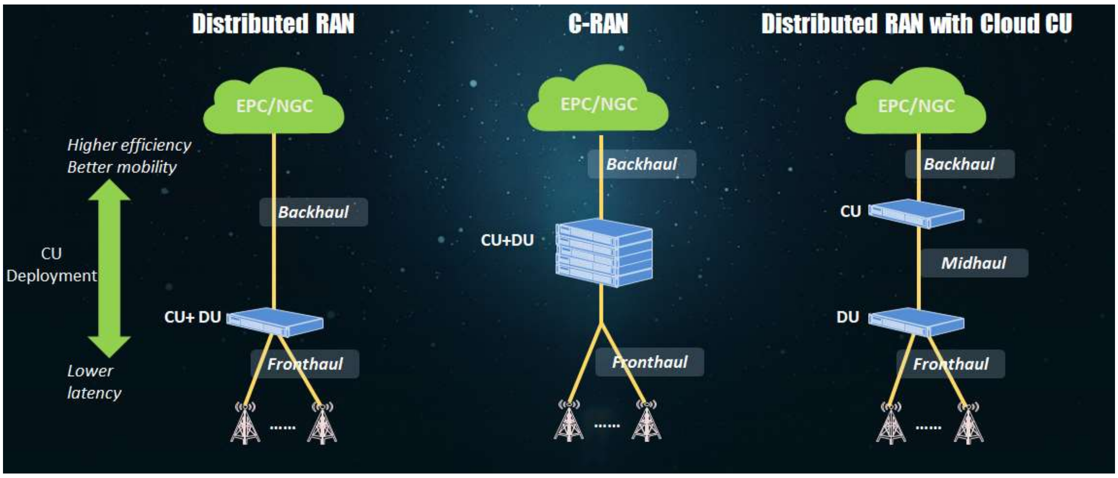


Figure 4.4: 5G RAN Layer Split; Source: ZTE

4.2.3 Expected Initial Deployment Architecture

The decision to deploy NSA or SA based networks will depend on the Telcos' strategy, network readiness and use cases supported. Malaysia, like most global deployments will use NSA architecture initially to minimise initial costs as well as a D-RAN, which is the current 4G architecture. Then based on demand and use cases, slowly introduce SA at different points of the networks over time. Options such as RAN layer split and Data Centres will be integrated into parts of the network later depending on the performance and use case requirement.

4.2.4 5G Radio Site Requirements

Outdoor: 5G sites will require new radio, Baseband (a signal that has a near-zero frequency range) and power system upgrades which will directly impact site infrastructure.

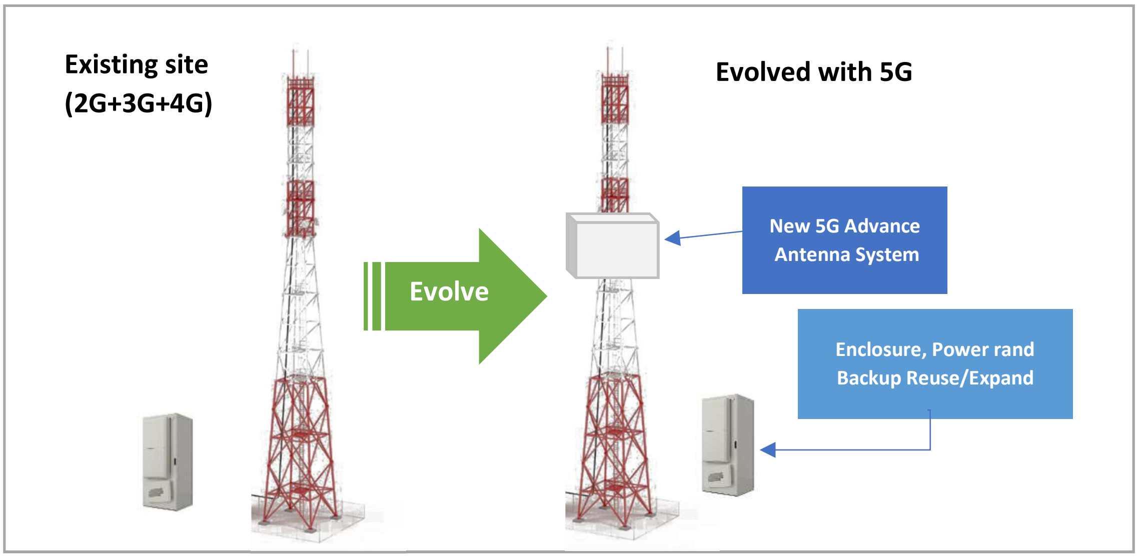


Figure 4.5: Typical 5G Site Evolution From 4G; Source: Derived from Ericsson

In terms of site deployment, it is expected that existing Telcos will locate 5G on existing 2G/3G/4G sites to minimise costs. A typical deployment will see 2G/3G/4G combined in one antenna unit and a second antenna unit will be set aside for 5G.

Indoor: In today's 4G network, it is observed that 7% – 80% of traffic is generated from indoors. Indoor systems will be required in buildings where outdoor macro coverage cannot penetrate. Indoor coverage will become even more critical in 5G due to high demands from new use cases. Furthermore, the utilisation of high band frequencies of 3.5GHz increases the challenge of indoor signal penetration from outdoor macro sites.

The current 4G indoor system deployed by Telcos is unable to support the 3.5GHz spectrum. Hence, new 5G indoor systems will be required to satisfy demand from consumers, and the various business verticals outlined in **Section 2**.

There are two types of indoor system solutions:

- **Passive Indoor System:** found to have low future-proof capabilities.
- **Digital Indoor System (DIS):** provides abundant benefits in terms of better link budget for improved coverage, flexible capacity expansion to support 5G data explosion, indoor digitalisation services that require positioning, navigation and high precision, and simplified operation and maintenance.

4.2.5 RAN Rollout

Between 3.5GHz and the mmWave spectrum which have been discussed in **Section 3**, 3.5GHz offers better coverage by far. Wide area mobility networks in the mmWave spectrum are not practical or economically feasible due to limited coverage and likely be a targeted deployment based on use cases such as hotspots.

5G 3.5GHz (C-band) networks with Massive MIMO (64T64R) antennas offer decent downlink coverage, but uplink range is much smaller than current 4G (L1800) networks. This presents a challenge as there is now a need for additional sites to cover the same areas as existing 4G networks, dramatically increasing initial and ongoing network costs.

Analysis and trials done by vendors show that utilisation of 5G at 3.5GHz in conjunction with a lower band such as 4G through NSA 'Dual-Connectivity', effectively extends uplink range by using the L1800 uplink (although at least weak NR3500 uplink is always required as well). In this case, coverage of a NR3500+L1800 site becomes close to that of an L1800 site, but with higher speed and capacity.

Even though 5G at 3.5GHz may close the coverage gap with 4G at 1.8GHz through NSA Dual Connectivity, it is likely that more 5G sites will be required compared to 4G depending on the 5G uplink-downlink (UL/DL) throughput requirements and deployments moving towards suburban/rural scenarios.

In terms of pace, 5G rollout will be similar to 4G: slow for the first 1 – 2 years but will accelerate once cheaper and more affordable 5G devices come to market in 3 – 4 years. However, 5G will be more difficult to implement because:

- Cost of 5G radio is expected to be 4 – 5 times more expensive compared to 4G.
- 4G ecosystem will still be dominant in the next 4 – 5 years, meaning network investments will still be focus on improving 4G.
- 4G was quicker to scale and roll out as it reused existing 1800MHz radio from the2G-era and had minimal impact on existing architecture. 4G upgrade only required software activation on radio with baseband upgrades.
- Meanwhile, 5G will require new radio and basebands, and thus impact existing infrastructure as they will require strengthening.

Gap analysis and number of 5G sites required to cover a population of 90% is outlined in **Section 4.5**.

4.3 Site Acquisition and Engineering (SAE)

SAE deals with all aspects pertaining to the provisioning of sites for the deployment of 5G. SAE is not expected to differ too much from 4G and earlier deployment. The sites need to be acquired and prepared with necessary Civil, Mechanical & Electrical (CME) work prior to installation of 5G. On the other hand, there exists a number of new requirements for 5G that will necessitate further enhancement at sites. Considering the increased number of sites for 5G, proper plans should be put in place in order to ensure its smooth deployment.

4.3.1 Components of SAE

There are a few different elements that will make up the overall requirements at site. For the purposes of assessing these requirements, the elements can be categorised into three different CME aspects: Structures, Dimensioning & Loading, and Power Requirement.

4.3.1 (a) Structures

Different types of structures exist for the housing of telecommunications equipment at sites. In general, the structures can be categorised into 3 different categories as depicted in the Diagram below. (next page)

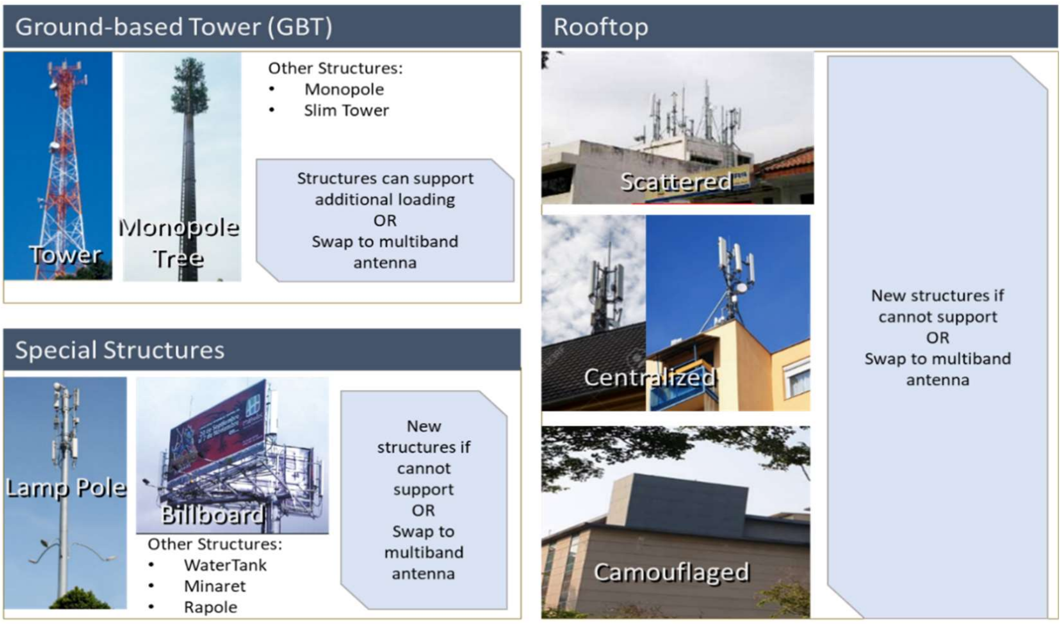


Figure 4.6: Types of Structures; Source: edotco

Deployment by Telcos in the past depended on heavy duty and tall structures of Ground-Based Tower (GBT) types, though current trends have moved towards the Roof Top Tower (RTT), Roof Top Pole (RTP) and Special Structures like Lamp Poles, Rapid Assembly Pole (Rapole), etc.

For the past few years, Special Structures with improved designs have made its way to certain areas. The trend is expected to continue for the deployment of 5G, thus the 5G Task Force expects to see enhanced versions of Special Structures for 5G use. Some samples of Special Structures are: (next page)

Various Street Pole Designs

Figure 4.7 (a): Samples of new special structures; Source: edotco

Landmark Tower **Advertisement Pillar** **Signage**

Figure 4.7 (B): Samples of New Special Structures; Source: edotco

These relatively new approaches have the benefit of lower cost and less visual impact, but the downside is that the potential for passive sharing (multiple Telcos using shared tower and power facilities) at a site is lower than more traditional structures. New 5G small cells (aimed to alleviate load on macro cells) will cause a further shift towards these lower impact facilities.

In urban areas where 5G requires more dense architecture than 4G to deliver its best performance, more 5G antennas will be mounted on Street Furniture to facilitate expansion of network coverage.

These new structures such as bus stops, smart poles, etc. can also be used for CCTV, security cameras, Wi-Fi hotspots, digital advertising, and different types of sensors. Street furniture is more suitable for small cell deployment due to limited space. **Figure 4.8** (next page) depicts an example of Street Furniture suitable for 5G deployment:

Figure 4.8: Example of Bus Stop Street Furniture; Source: edotco

Today, there are few 4G sites that deploy Street Furniture. However, Street Furniture may become significant for 5G deployment with the right design and deployment strategy. This is more important in supporting uRLLC use cases outlined in above sections such as Automated, Autonomous and Connected Vehicle (AAVC), unmanned aerial vehicles, and Smart Cities. However, there could be limits on Street Furniture's ability to accommodate 5G deployment due to constraints on space and loading capability. The 5G Task Force expects that future generations of 5G equipment will more easily integrate with the natural environment and be more compact so that more types of this structure can be used, following technological advancements.

4.3.1 (b) <u>Dimension and Loading</u>

There are some changes in the dimension and weight of 5G network elements compared to the previous generations of mobile solutions, which will require changes at the sites as well. The biggest difference for 5G will be the massive MIMO features at Sub-6 GHz and mmWave bands. Current trends in 5G network elements combine the traditional Remote Radio Unit (RRU) into the back of the antenna, thus placing heavier equipment on telecommunication structures. This recent development will impact sites in the following ways:

1. Increase loads on telecommunication structures due to increasingly heavier antennas.
2. Load increases will also be due to additional wind load from the new 5G antenna. Even though the new antenna is relatively smaller than existing 2G/3G/4G antenna, the new antenna will stand alone, which increases overall wind load.
3. The cabinet at-site is also expected to be larger, as they are expected to cater to additional mobile technologies and higher power consumption.

The 5G Task Force expects many existing telecommunication structures to require upgrades, and new structures will be built to higher specifications than before.

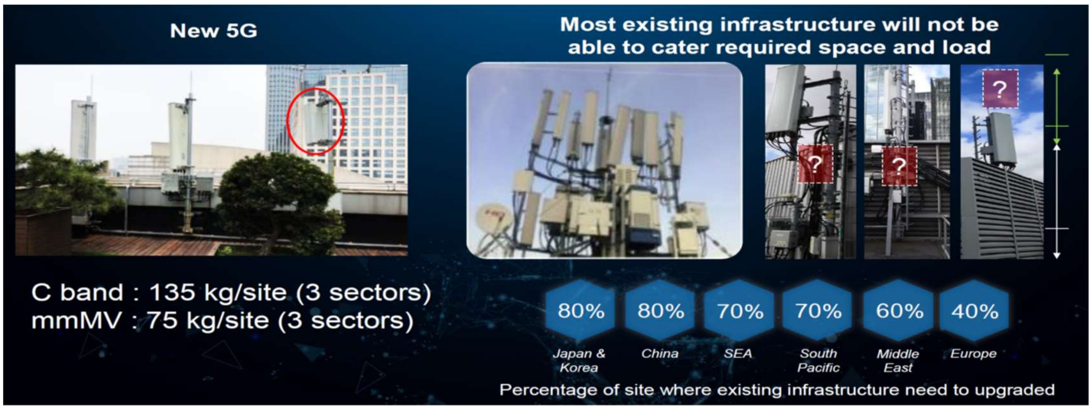


Figure 4.9: Space and Loading Constraints; Source: Huawei

Preliminary assessment of structure Portfolios in Malaysia

Structure Type	Ground-base Tower	Special Structure	Rooftop	TOTAL
Portfolio of deployment	40-50%	20-25%	30-35%	100%
Capability for 5G	70%	10%	20%	
Net % of capability for 5G	28-35%	2-2.5%	6-7%	36-45%

Figure 4.10: Structure Assessment in Malaysia; Source: edotco

4.3.1 (c) Power

The 5G system will draw more power to enable it to carry much more data than 4G. Even though it will be more power efficient *per unit of data* than 4G, the overall system will still require more power at sites. Power-supplying equipment at existing sites will require substantial upgrades. This will be a substantial driver of network rollout cost, and a significant increase in recurring network operating expense.

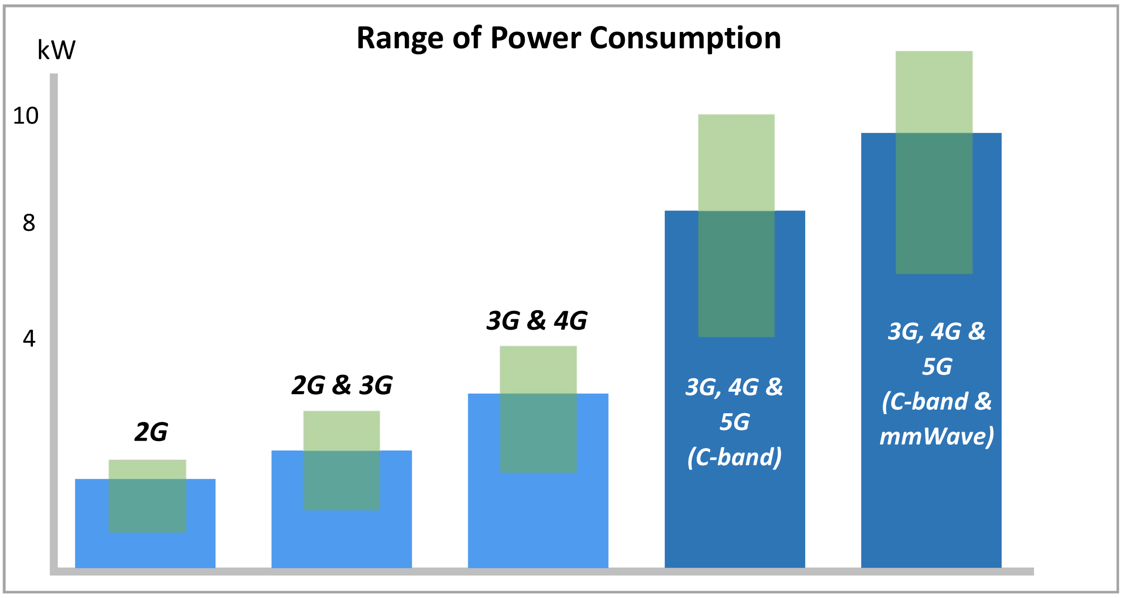


Figure 4.11: Power Requirements; Source: edotco

4.3.2 Challenges

With increasing number of sites required for full coverage of 5G, site acquisition will present new challenges for timely deployment of 5G. New range of equipment poses a new challenge in terms of power requirements, structure loading and space availability at sites.

1. Telcos will also be required to make careful judgment on the combination of 2G, 3G, 4G and 5G technologies to reduce operational expenses.
2. Since NSA will be most likely deployed in Malaysia, existing types of structures will still be used. For new site deployment, low height structures such as lamp poles, and Street Furniture will become more prevalent. Hence, it will require enhancements on the current process.
3. The increase in both total number of sites and antenna size at existing sites will raise aesthetic considerations. Although some degree of aesthetic improvement is possible though careful design of installations and use of camouflage, these solutions will increase cost and decrease speed of network rollout, both directly, and through the impact of any additional further approval processes.
4. Telcos are expected to face the same challenges in enabling 5G services at sites. Considering the relatively high number of sites for 5G compared to the existing 4G or 3G systems, any complications in this area will impact on the smooth deployment of 5G.

4.3.3 Mitigations to Reduce Cost

Considering the massive upfront investment required for 5G, some mitigating methods should be collaboratively supported by different stakeholders:

1. Some level of sharing should be encouraged. While Telcos do practice some form of sharing today, there is a need to assess deeper collaboration methods. Active sharing in the form of MORAN, MOCN, antenna sharing, etc. can be mixed among Telcos. However, all of these methods should be carefully evaluated to ensure no impact on quality.
2. The 5G Task Force urges MCMC to work with both state governments and local councils to ensure that Street Furniture is made available and suitable for Telco use. The necessary specifications such as size, height, etc. should be considered.
3. The 5G Task Force understands that some Street Furniture would require enhancements and thus, require collaborative efforts with Street Furniture providers, equipment vendors and local councils to customise solutions.
4. A concessionary electricity use rate to be applied for Telcos.
5. Public complaints will result in higher costs due to the need to provisions for aesthetic features on these structures.
6. Align with the Regulatory Working Group on changes required such as Low Impact Facilities (LIF), to manage cost increases.

4.4 Fiber and Transmission

4.4.1 The Importance of Fiber in 5G Networks

Fiber is a critical part of the 5G network, more so than 4G. Based on prior 4G experience, there are areas where current policies or regulations add costs and delay network rollout. The Infrastructure Working Group (IWG) worked alongside the Regulatory Working Group (RWG) to produce the following recommendations in these areas.

On average, we are likely to see increase in fiber transmission and subsequent decrease in microwave implementation amongst Telcos.

Figure 4.12 shows average transport readiness in Malaysia:

Transport readiness	4.5G as-is	5G Mature
Sites with fiber	35%	60%
Sites with microwave	65%	40%

Figure 4.12: Average transport readiness percentage amongst Telcos; Source: Estimated figures from Telcos in Malaysia

Building a fiber network is costly. However, deployment costs vary quite significantly among the different options. The main contributor to cost is the need to dig trenches, and civil work. Digging trenches in urban or city areas will require a great deal of civil work to restore roads and pavements. In rural areas, part of the trench may be built on soft soil that would require less civil work.

Deploying fiber in existing infrastructure, (e.g.: in existing ducts, sewers or along train lines) will be much cheaper.

Infra-sharing including fiber (core, sub-duct, or duct) is already part and parcel of infrastructure network building already adopted by Malaysian Telcos. In general, Telcos share the high costs amongst themselves, which also helps to reduce duplicate common infrastructure from being built in most places.

Another method that could ease the implementation of fiber infrastructure is by leasing (dark fiber or bandwidth) from fiber network providers. However, the current Mandatory Standard on Access Pricing (MSAP), which regulates leasing prices was released without explicitly taking into consideration 5G needs. The 5G Task Force believes that a review of the current MSAP provisions will benefit current and prospective 5G that will be run by Telcos.

Building fiber networks in Greenfield areas is often prohibitively costly for Telcos, and timely deployment is subject to challenges such as getting appropriate wayleave and permit approval from local authorities.

4.4.2 Expectation of Microwave Transmissions

The 5G Task Force's assessment found that while fiber is the most suitable type of transport backhaul thanks to its high capacity and ability to support high capacity traffic, deployments would be done gradually starting from high-impact areas to less-impacted areas in line with 5G capacity usage and ecosystem growth. The assessment takes into consideration the existing fiber network footprint which is not ubiquitous in all high impact areas, (i.e. urban areas), and even less so in suburban and rural areas.

In this case, Telcos are expected to use microwave links during the beginning of 5G deployment and eventually roll out more fiber as demand for high capacities grow.

Relaxed transport backhauls similar to the deployments done in 2G/3G/4G networks will remain. Malaysia is likely to employ the aforementioned D-RAN (Distributed Ran) at the beginning of 5G deployment, as it is adopted by most Telcos. Once 5G usage scenarios move toward massive site distribution, it will be prudent for Telcos to start implementing C-RAN (Centralised RAN), where immediate impact on transport will require the fiber network to support 10Gbps – 25Gbps fronthaul connectivity.

5G eMBB	Total 5G Sites 3.5GHz 64T64R 100MHz DL/UL 30 Mbps/ 3Mbps	5G Site Distribution	5G Site to Site Distance	4G	4.5G	5G Initial	5G Mature
Zone 1: Du/(U)	**90% PoP**	60% – 70%	0.5km – 0.8km	350 Mbps	1 Gbps	2 Gbps	10 Gbps – 15 Gbps
Zone 2: SU	**10,000 Sites (± 10%)**	15% – 20%	1.5km – 2.0km	250 Mbps	600 Mbps	1 Gbps	5 Gbps – 10 Gbps
Zone 3: RU	**DRAN**	10% – 15%	2km – 3km	100 Mbps	400 Mbps	<1 Gbps	1 Gbps – 3 Gbps
Zone 4: RU	**NSA**	3% – 5%	3km – 5km	100 Mbps	200 Mbps	<1 Gbps	<1 Gbps

Figure 4.13: Likely 5G capacity requirement; Source: Infrastructure Working Group

The figure below shows likely fiber and microwave implementation to address 5G requirements:

5G eMBB	Total 5G Sites 3.5Ghz 64T64R 100Mhz DL/UL 30 Mbps/ 3Mbps	5G Site Distribution	5G Site to Site Distance	4G	4.5G	5G Initial	5G Mature
Zone 1: Du/(U)	**90% PoP** **10,000 Sites (± 10%)** **DRAN NSA**	60% – 70%	0.5km – 0.8km	**400 Mbps MW** K-Band 18-23 GHz 2+0 2x28MHz 4kQAM	**1.6 Gbps MW** K-Band 18-23 GHz 4+0 4x56MHz 4kQAM	**Fiber** or **10 Gbps MW** at 99.97% availability E-Band 70-80 GHz 1+0 2000MHz 128QAM	**Fiber** or **2x10 Gbps MW** at 99.97% availability E-Band 70-80 GHz 2+0 2000MHz 128QAM
Zone 2: SU		15% – 20%	1.5km – 2.0km	**400 Mbps MW** K-Band 18-23 GHz 2+0 2x28MHz 4kQAM	**800 Mbps MW** K-Band 18-23 GHz 2+0 2x56MHz 4kQAM	**1.6 Gbps MW** K-Band 18-23 GHz 4+0 4x56MHz 4kQAM	**Fiber** or **10 Gbps MW** at 99.97% availability E-Band 70-80 GHz 1+0 2000MHz 128QAM
Zone 3: RU		10% – 15%	2km – 3km	**200 Mbps MW** K-Band 13-15 GHz 1+0 1x28MHz 4kQAM	**400 Mbps MW** K-Band 13-15 GHz 2+0 2x28MHz 4kQAM	**800 Mbps MW** K-Band 13-15 GHz 4+0 4x28MHz 4kQAM	**Fiber or 1.6 Gbps MW** K-Band 13-15 GHz 2x(4+0) 8x28MHz 4kQAM
Zone 4: RU		3% – 5%	3km – 5km	**200 Mbps MW** K-Band 7-15 GHz 1+0 1x28 MHz 4kQAM	**200 Mbps MW** K-Band 7-15 GHz 1+0 1x28MHz 4kQAM	**400 Mbps MW** K-Band 7-15 GHz 2+0 2x28MHz 4kQAM	**800 Mbps MW** K-Band 7-15 GHz 4+0 4x28MHz 4kQAM

Figure 4.14: 5G fiber and microwave solution to address likely 5G capacity requirement Source: Infrastructure Working Group

Microwave is a valid solution to real-world challenges due to:

- Possibility for fast rollout
- Flexibility for short-term or long-term deployments
- Reliable
- Can be reused from existing structures
- Any required terrain changes can be implemented relatively easily
- Relatively uncomplicated structural requirements

Hence, microwave is said to be more popular than fiber, as The Cost of Ownership (TCO) is a critical factor to consider when deploying a transmission backhaul network.

Figure 4.15 below is a comparison between building connectivity up to 10Gbps using self-built fiber, and using microwave solutions.

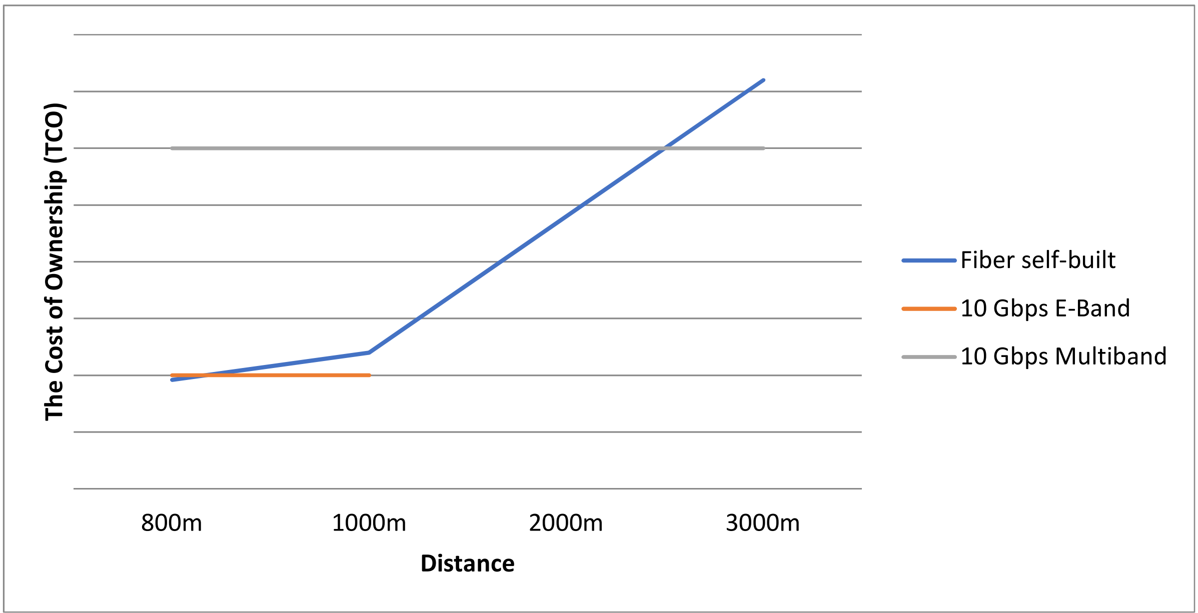


Figure 4.15: 5G Fiber And Microwave TCO vs. Distance

Self-built fiber is more costly at longer distances, and microwave appears to offer the lowest cost of ownership depending on reliability tolerance due to rain fading. Typically, E-Band operating at the 70/80GHz spectrum is less reliable compared to microwave traditional band 6GHz-42GHz over longer distances. Thus, combining the traditional band and E-Band in a Multiband setup should provide a certain level of reliability against signal fading due to rain.

Digging efforts towards installing fiber cables in the ground will usually result in long lead times and sizeable initial costs, but on the other hand fiber can offer large capacity, and upgradeability both in terms of capacity and functionality: such as flexibility, reconfigurability, resilience, traffic engineering and QoS capabilities suited to high capacity networks.

Fiber is a future-proof technology. By contrast, while microwave offers short lead times and relatively low initial costs, the technology offers limited capacity. Eventually, when transmission capacity needs increase, microwave technology will incur considerable hardware upgrade costs, and is vulnerable to frequency congestion or interference problems.

It is often natural to base a Greenfield network on a microwave depending on anticipated initial capacity needs. However, when capacity needs increase, the fiber network will be extended from the centre of the network towards the edge. Furthermore, the 5G Task Force predicts that as capacity demands increase, fiber over time will become the more economical choice compared to microwave.

In anticipating capacity increases, the fiber solution becomes increasingly attractive from a purely economic point of view (i.e., required capital expenses) as well. The main cost in implementation of fiber is mainly a need to build the passive fiber network, as active transmission equipment costs are relatively low. Hence, the brunt of the cost for fiber is, in effect, independent of capacity. Microwave costs, on the other hand, increase linearly and significantly with rising capacity needs.

4.4.3 Alternative Bearers

As mentioned in **Section 3.3.3**, usage of the Time Division Duplex (TDD) format will probably become more widespread in the 5G era, especially since all recommended Priority 1 spectrum would utilise the TDD format.

The Wireless Sub-6 Unlicensed Band System (which utilises commonly used frequencies below 6GHz) system shares channel spectrum with Wi-Fi systems such as 2.4GHz and 5GHz. The system may be able to provide Gigabit (Gbps) speeds by implementing the TDD format. TDD would enable variable speed allocation between upload and download, thus allowing for more capacity compared to FDD systems with similar bandwidth.

However, latency performance of the Wireless Sub-6 Unlicensed Band System is rated longer than 1 millisecond (ms): though respectable range can be achieved with Parabolic Antenna and support of Non-Line-Of-Sight (NLOS) Transmission with a Flat Sectorised Antenna (noted to look better than the former, but at the cost of range of transmission).

Hence, while Sub-6 may provide Gigabit capacity, concerns on latency and interference handling may put Telcos off from considering the technology as a replacement to the traditional licensed band.

Satellite transmission can support 5G deployment in offloading and caching the fixed network, and also as backhaul. Existing satellite and hub technology can provide throughput in excess of 300Mbps, and is expected to cross the 1 Gigabit mark with the upcoming launch of the High Throughput Satellite (HTS).

Satellite transmission can be provisioned as alternative or overlay paths for connecting data centres to 5G core network gateways where there are no terrestrial or economically viable paths; and to connect the core network to semi-centralised or centralised virtualised 4G Base Station processing centres.

Hence, satellite transmission can be positioned as backhaul connections to 5G cells at both macro and micro levels. Opportunities include:

- Backhaul to installed cells in remote areas to achieve a specific coverage obligation, for example, to satisfy license or contractual requirements, and where terrestrial link is not economically viable;
- Cells that need fast deployment and cannot wait for terrestrial provisioning;
- Deployment of cells for temporary events; and
- Deployment of small mobile cells mounted on public transportation, high-end cars, or on emergency service vehicles.

4.4.4 Design and Performance of The Upper Layers of The Transmission Network

5G needs to meet a wide range of scenarios and service needs, but Telcos are concerned about challenges like higher capacity, lower end-to-end latency, capital, and considerable operational costs.

Hence, 5G transport should be service-driven and hyper-scalable. Open and disaggregated networks should be considered for their flexibility, allowing Telcos to select needed solutions that meet service and cost needs. The addition of a simple network layer, moving higher functionalities to the cloud should further optimise network capital and operational costs.

To implement the 3GPP Release 15 Standard which would allow 4G and the 5G NR to coexist, the 5G Task Force believes that Time Sensitive Network (TSN) will be particularly useful among all low-latency transport options available to accommodate the massive densification efforts necessary.

Malaysia will likely require these large-scale densification efforts upon implementation of 3GPP's 5G Radio Access Network (RAN)[17] architecture: a set of Radio Base Stations connected to core 5G networks incorporating three main functional modules: the Radio Unit (RU), Distributed Unit (DU) and Centralised Unit (CU).

However, the functional split of CU, DU and RU will likely introduce a new set of challenges towards transport network design concerning latency, capacity, and performance. There are now several possible X-haul combinations such as fronthaul, midhaul, and backhaul deployment scenarios that should suit the various combinations of split options. Beyond deployment scenarios, there are also design considerations, i.e., applying suitable technology like microwave, or fiber-based transport solutions such as Ethernet/IP, Packet Optical or PON.

4.4.5 Addressing Phase Synchronisation

Synchronisation of 5G essential services operating in the Time Division Duplex (TDD) spectrum requires absolute (±1.5 microseconds, or µs) precision in the transmission of a Time Reference Signal (e.g., Global Navigation Satellite System Signal or GNSS) from its source to the 5G Base Stations. The goal is to ensure relative time error between two radios is less than 3 microseconds.

As previously stated in **Section 3.3.3**, the majority of Telcos operate within the Frequency Division Duplex (FDD) spectrum in the 2G/3G/4G network, which did not require strict time alignment unless implementing advanced features like CA (carrier aggregation) and CoMP. Since TDD is preferred in the implementation of 5G, now the requirements for strict time alignment must be met.

Depending on the scale of initial 5G deployment, strict time alignment will be implemented in pockets with each site individually connected to a time/clock source, e.g., Global Positioning System (GPS).

As 5G continues to grow, strict time alignment could be distributed partially over the transport network to a cluster of sites from a single aggregator site. Broader site coverage will likely require full-on path support from a centrally located time/clock source for cost-efficiency.

[17] ITU-T. Feb 2018. GSTR-TN5G Transport network support of IMT-2020/5G. https://www.itu.int/dms_pub/itu-t/opb/tut/T-TUT-HOME-2018-PDF-E.pdf

Main Sync Input Redundant Sync Input	GNSS 2MHz/2Mbps	GNSS PIP sync input	GNSS	GPS/GNSS
Sync output protocol	PTP compliance to Frequency & Phase sync profile	PTP compliance to Frequency & Phase sync profile	PTP compliance to Frequency & Phase sync profile	Non-PTP
Number of PIP slave/e NB supported	0~6x1024 (=6144)	0~1024 (max)	0~64	Only 1
Application	PTP GM @TOC is ideal for PTP frequency, profile sync where compliance requirements are easily achieved.	APIS is applicable for PIP Phase sync (& PIP Frequency too) with more stringent requirements on 4.5G/5G max allowable time error APT5 is installed closer to eNB/end site for better Phase sync delivery compliance	Moderate maintenance required and dependent on Router/Switch which the SFP PTP GM is plugged	GPS/GNSS receiver normally comes with vendor supplied e NB and only catered to serve sync for individual eNB
Maintenance	Moderate maintenance required	Moderate maintenance required	Moderate maintenance required & dependence on Router/Switch which is where the SFP PTP GM is plugged	Higher maintenance due to possibility of GPS/GNSS antenna failure in remote sites
PTP Sync Output Signal Availability	High availability	High availability	Mid availability	Mid availability

Figure 4.16: Phase Sync deployment options; Source: Infrastructure Working Group

4.4.6 Securing the Network

The drivers for security technology evolution will remain as it always has even into 5G technology: a drive to provide a trustworthy basic connectivity service. However, other driving forces will enter the scene, like new uses cases besides mobile broadband, adoption of new network design paradigms like Software-Defined Networking (SDN) and Network Functions Virtualisation (NFV). The result will be a push towards security mechanisms that are more flexible and adaptive than before.

Today, LTE networks are dominated by large monolithic deployments; each controlled by single Telcos that owns the network infrastructure while also providing all network services.

By contrast, 5G networks may see several specialised stakeholders providing end-user 5G network services realised via network slicing services. Hence, security mechanisms need to be handled in an integrated manner to ensure cost effective implementation.

Different security mechanisms are likely to enter the market to protect new or varying 5G use cases; requiring a high level of security and privacy for their users and traffic. Moreover, introduction of new network design paradigms will drive a need for more resilient networks against all kinds of cyber-attacks.

These two-fold challenges will require the implementation of security mechanisms in a more integrated, flexible, and adaptive manner. For example, coexisting security recommendations can be adapted for use in 5G transport networks. These include IPSec/MACSec encryption of traffic backhaul as a transport security function against any L2/L3 breaches, and encryption of its transport Management Plane (M-plane) with Transport Layer Security (TLS) to secure management traffic E2E with full payload encryption and integrity protection.

Meanwhile, mechanisms can also be strengthened with reliable authentication of the 5G Base Station using Public Key Infrastructure (PKI) certificates with automated Certificate Life Cycle Management by the PKI Certificate Authority.

4.4.7 Automation

5G envisions a rapid increase in automated services (as mentioned in **Section 2.2**); which puts similar requirements on transport network services. Furthermore, to support rapid service deployment, provisioning of services should be automated. SDN/NFV providers (as mentioned in **Section 4.4.6**) offering 5G-ready solutions to Telcos will help quicken time-to-market for their 5G-powered communications services or applications, as well as improve network or service deployment rates and efficiency. As a result, both costs to acquire assets and maintain operations can be reduced.

Network and service automation addresses challenges seen in today's traditional network such as information silos and open-loop control systems that transmit initial instructions to equipment, but cannot gather data to check if the underlying assumptions in its instructions are accurate. Dynamic 5G use cases and new networking paradigms will introduce a virtualised network that enables a silo-less and close-looped automation linking intent and outcome.

Automation can be further realised by building a transport domain management system with key component capabilities like programmable orchestration, software-driven controllers, health insights and change management, and data platforms to manage programmable networks.

4.5 Estimating Network Size

4.5.1 Scenario Modelled

The size and characteristics of a future 5G network will depend on:

- What the network is built for
- When it was built (as technology will evolve, with upcoming changes clear in the discussion of future standards releases)
- Network builder's design choices

Therefore, it has become necessary for the 5G Task Force to develop a 'scenario' based on what the IWG team considers the most likely approach in Malaysia's near future so that an estimate could be prepared. This should not be taken to mean that the IWG team believes that this is the only scenario, nor that this scenario is recommended. In order to ensure timely and cost-effective rollout, it is important that regulation and policies enable all scenarios.

The scenario modelled by the IWG considers:

Coverage	The scenario assumes that the network builder has rapidly expanded coverage to approximately 90% of the population. This isn't a likely scenario (as Telcos are likely to start in high-demand/high-economic-activity areas and gradually expand), but it aligns with the scope defined in the 5G Task Force Terms of Reference.
Site Selection	The scenario assumes a network builder will primarily deploy 5G as upgrades to existing 2G/3G/4G network sites, as this is expected to minimise capital and operational costs for 5G deployment. There may be a need for additional sites to infill coverage or additional capacity, leading to the densification discussed in **Section 4.4.4.**
Spectrum	The scenario assumes that the network builder is using 50MHz – 200MHz of the Extended C-band (3.5GHz) spectrum.
Radio Option	The scenario assumes Non-Stand-Alone (NSA) networks in which 5G works in tandem with the L1800 4G network.
Use Cases Supported	The scenario assumes a network designed for the speed/capacity capability of 5G (eMBB) and supporting mMTC or uRLLC once the relevant standards are released, and only as long as the latter can be supported without major changes in network architecture. Early releases of 3GPP Standards, meaning early networks, will not support mMTC or uRLLC. Introduction of other features will be driven by the standardisation process, ecosystem development and demand. (Worth noting that a large number of IoT use cases can be supported by 4G).
Fiberisation	At launch, 5G sites will be connected via a mix of microwave and fiber, and although all sites will offer higher speeds than 4G, the 'full 5G experience' may only be available on sites with fiber. Telcos will progressively upgrade the connectivity of sites.

4.5.2 Radio Network Sizing and Cost Estimates

Network size will depend on coverage requirements which are set by what is considered the minimum speed and capacity at cell edge. The report tabulates the requirements needed for a network to cover up to 90% of the population, based on existing 4G coverage.

5G speeds will depend on the services or use cases associated. Generally, initial speeds will be based on device capability and applications available today such as internet browsers, Facebook, streaming services (YouTube/Netflix), etc. The network requirements assume a cell edge speed of 30Mbps at launch, consistent with the proposed National Fiberisation and Connectivity Plan (NFCP) objectives and aligns with support for 4K video. This will evolve based on demand for applications such as high definition VR, 8K video, cloud gaming, etc.

Non-Stand-Alone (NSA) networks will extend 5G coverage by leveraging on dual-connectivity with 4G, so the coverage plans built are based on this scenario (likely to be favoured by operators as per **Section 4.2.1**). Overall coverage planning is based on link budget calculation, where these values are used to estimate number of sites required to cater to 90% population coverage.

C-band will be used with LTE 1800MHz as the anchor layer for 5G NSA dual-connectivity. The edge user throughput is set at 30Mbps downlink and 3Mbps uplink.
Based on these inputs, it is estimated that the total number of 5G sites required to achieve 90% population coverage is approximately (±10% 10,000 sites on 3.5GHz 100MHz C-band 64T64R). This is using LTE1800 20MHz (4T4R) as the NSA anchor layer for 5G.

Zones	Radio	
5G eMBB	Total 5G Sites 3.5GHz 64T64R 100MHz	5G Site Distribution
Zone 1 DU/(U)	90% PoP 10,000 Sites (± 10%)	60-70%
Zone 2 (SU)		15-20%
Zone 3 (RU)		10-15%
Zone 4 (RU)		3-5%

Figure 4.17: 5G Sites; Source: Infrastructure Working Group

Note that this is an estimation based on a theoretical study on link budget (an accounting of all of the power gains and losses a signal experiences in a telecommunication systems); 5G requires special propagation tools with model tuning of live sites in order to establish a proper 5G propagation model. Operators have yet to obtain such tools.

These values may differ between operators due to certain factors such as distribution of number of existing 4G sites per operator, existing 4G spectrum holdings, coverage areas, location, and antenna height.

Our high-level estimate assumes that a 5G radio can cost about RM510K per site including software. Hence, a total of RM5.1 billion is required for 10,000 sites.

4.5.4 Fiberisation Costs

Individual operators (Telcos) are likely to spend between RM50 – 150 million a year to supplement as-is fiber and microwave footprint in building a last-mile transmission network to support 5G implementation.

Zone	MW	Fiber	Sites	MW @ Sites	Fiber @ Sites
Z1	43%	28%	6,600	4,339	2,755
Z2	10%	4%	1,750	1,023	380
Z3	9%	2%	1,250	881	237
Z4	3%	1%	400	299	85
Total	**65%**	**35%**	**10,000**	**6,543**	**3,457**

Figure 4.18: Breakdown of microwave and fiber based on working Zones (4.5G) Source: Infrastructure Working Group

Zone	MW	Fiber	Sites	MW @ Sites	Fiber @ Sites
Z1	24%	42%	6,600	2,392	4,208
Z2	7%	10%	1,750	736	1,014
Z3	8%	5%	1,250	784	466
Z4	2%	2%	400	221	179
Total	**41%**	**59%**	**10,000**	**4,133**	**5,867**

Figure 4.19: Breakdown of microwave and fiber based on working Zones (5G mature) Source: Infrastructure Working Group

Zone	Microwave @ Sites	Fiber @ Sites
Z1	2,392	1,453
Z2	736	634
Z3	784	229
Z4	221	94
Total	**4,133**	**2,410**

Figure 4.20: 5G to 5G last mile transmission infrastructure gap analysis Source: Infrastructure Working Group

Notes:

1. All 5G microwave @ Sites to be upgraded as per 5G Mature Capacity Requirements
2. 5G Fiber @ Sites shares similar fiber infrastructure built for 4.5G, therefore only Greenfield fiber built is to be considered
3. Unit cost assumptions:

	Unit Price (RM)
Microwave @ 200 Mbps	25,000
Microwave @ 400 Mbps	50,000
Microwave @ 800 Mbps	100,000
Microwave @ 1.6 Gbps	200,000
E-Band @ 10 Gbps	100,000
E-Band @ 2x10 Gbps	200,000
Fiber @ 1 KM	120,000

Calculation of average cost for Microwave upgrades:

Microwave @ Sites	UoM	Qty	Unit Cost	Total cost
2,392	Link	2,392	200,000	478,421,837
736	Link	736	200,000	147,131,961
784	Link	784	150,000	117,669,492
221	Link	221	75,000	16,591,634
4,133		**4,133**		**759,814,924**

Cost on Average = RM76 million/year over 10 years

Calculation of average cost to build Fiber:

Fiber @ Sites	UoM	Qty	Unit Cost	Total cost
1,453	KM	1,162	120,000	139,462,583
634	KM	1,269	120,000	152,259,035
229	KM	687	120,000	82,409,753
94	KM	468	120,000	56,191,631
2,410		**3,586**		**430,323,002**

Cost on Average = RM43 million/year over 10 years

4.5.5 Other Network Costs

Fully meeting 5G requirements means upgrading the core network as well as radio and transport networks, with some of the potential upgrades discussed in **Section 4.6** below. IT systems thus need to be upgraded to manage the new capabilities in the core, and to manage the overall 5G network designed with dependence on a higher level of automation than previous generations. No cost modelling has been completed for this component of the network. For the purposes of the financial gap analysis, it is estimated at an aggregate 20% of the radio and transport costs.

4.5.6 Summary: Estimate of Costs

The estimate prepared is for the upgrade of a single large, mature 4G network in Malaysia to achieve 90% population coverage. This will occur progressively over a period of years – operators will determine their own pace of rollout. The actual costs will depend on many factors including:

- Timing of rollout (equipment prices drop, standards evolve introducing new options)
- Vendor negotiations and arrangements
- Success of the regulatory interventions proposed by the 5G Task Force to reduce cost of rollout (not taken into consideration for these numbers)

As a result, any estimates can only be considered as broadly indicative, not definitive.

The costs are also only for a coverage network, and do not consider any ongoing investment in capacity which may be required. Long-term forecasts of usage were not feasible to determine, nor any ongoing evolution of features and capabilities of the network as standards evolve constantly.

Based on the estimates above, overall cost for one such network upgrade would be:

Aspect	Quantity	Cost Estimate (RM Million)
Radio Site Upgrades to 5G	~ 9000 sites	5,100
New 5G Radio Sites	~ 1000 sites	
Microwave Upgrades	~ 4100 sites	760
Site Fiberisation	~ 2400 sites	430
Core and Other Costs		1,250
	TOTAL	**RM 7,540**

4.6 Mobile/Multi-Access Edge Computation

The expected need for very high speeds/data volumes and very low latencies suggests a design which pushes network and computing resources close the end customer, rather than bringing all traffic to a centralised location which would face higher delays and congestion. Mobile Edge Computing is the name for architecture that meets this need.

4.6.1. Impact Estimation and Gap Analysis: Deployment Location

The goal for network data centres is to provide a cloud computing facility within the transport network, with the idea of hosting Virtual Network Functions (VNFs) and virtualised applications in these facilities. The Multi-access Edge Computing (MEC) approach takes the concept of the network data centre one step further by distributing network data centres closer to the network's edge. The aim is to place functions closer to the end user, which should improve the end user's service experience, reduce load on the transport infrastructure and minimise the impact radius of any possible failures.

This has impact on network architecture, as functions traditionally considered as part of the 'core' of a network will logically and physically be placed closer to the 'edge' of the network. Managing and maximising this system will require a combination of solutions which are designed for distribution and centralised aspects to work together to meet the customer demand, and/or automated management of virtualized network functions to make applications available at required locations.

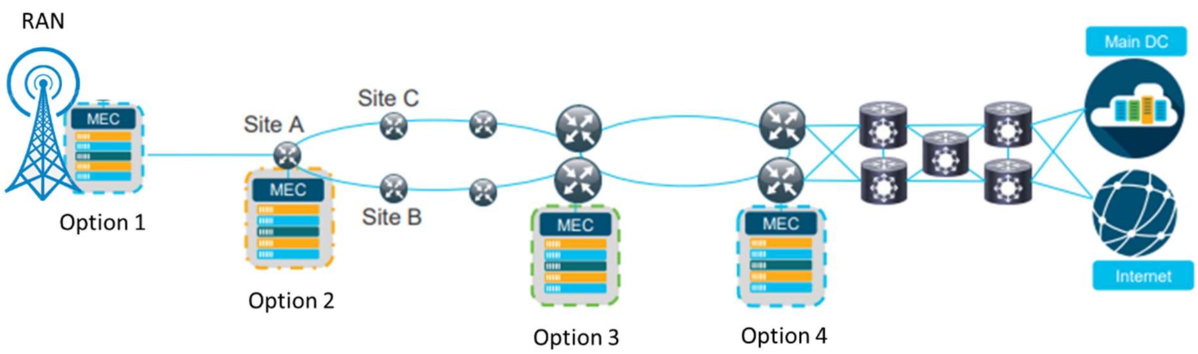


Figure 4.21: Examples of the MEC Deployment Location; Source: Infrastructure Working Group

While MEC is envisaged in the 5G standards and in other standards there is very little global experience with such network architectures in either the fixed or mobile environments. The extent to which this change affects the final cost and the physical infrastructure requirements (outside of Telco Data Centres) is not yet clear. Reasonable expectations would be:

- Computing resources might be pushed out as far as the most centralised aspects of the radio network, which may reduce traffic on some backhaul links and impact on the detailed design of transport networks, but it likely will not impact the requirement for physical fiber architecture between sites.
- Additional Small Distributed Data Centre environments to house such systems may be required to store MEC resources. Alternately, they could be co-located with either radio or core equipment at those locations.
- Primary network architecture design will apply to aspects of the network traditionally considered the core. Even as these become distributed the cost impacts are likely to be smaller than those of the radio and backhaul networks. These costs will likely be incurred gradually based on customer demand for uses cases which require such capability.

Alongside MEC, the overall design of core network and core computing resources is changing, favouring software running on virtualised functions on generic computing equipment. This change is already underway in 4G networks and will continue in parallel with the 5G build.

As highlighted in **Figure 4.21**, there are four potential options for MEC server deployment locations, as follows:

Option 1 (Base Station Site)

- Computing and storage capabilities on telecommunication towers
- Typically deployed in tens to hundreds of thousand per country
- Latency 1ms (5G) – 20ms (4G)

Option 2 (Access Site / Transmission Site)

- Computing and storage capabilities at the central office
- Typically deployed in hundreds per country. Latency 5ms – 20ms.
- MEC and the local UPF collocated with the 5G Base Station
- MEC collocated with a transmission node, possibly with a local UPF

Option 3 (Network Aggregation Site)

- Computing and storage at aggregation sites
- Typically deployed in ten to hundreds per country. Latency is less than 20ms.
- MEC and the local UPF collocated within a network aggregation point.

Option 4 (Core Site)

- Centralised data centre serving mobile traffic.
- Typically, 2-3 per country. Latency 20ms - 50ms.
- MEC collocated with the core network functions (i.e., in the same data center).

The European Telecommunications Standards Institute (ETSI) defined these four MEC "locations" in the White Paper no. 28 MEC in 5G, published in June 2018.

4.6.2. Impact Estimation and Gap Analysis: Latency

ETSI had also defined different latency values for the various use cases in a White Paper[18].

Service	Content Sever	Characteristic			Cloud-Edge Coordination	Possible Location
		Latency	Bandwidth	Privacy		
AR/VR	Local	<5ms	100Mbps - 9.4Gbps	No	Sync but not real-time	Access ring (Edge DC)
V2X	Local	<10ms	>100Mbps	No	Processed data real- time sync	Access ring (Edge DC)
Video Surveillance	Local	Variable	>20Mbps	No	Processed data real-time sync	Access ring (Edge DC)
Smart Factory	Local	<10ms	Variable	Yes	Only in private Cloud	Factory (Edge DC)
Enterprise Cloud (e-health)	Local	<10ms	Variable	Yes	Only in private Cloud	Enterprise (Edge DC)
IoT Management	Local/ Cloud	Variable	Variable	No	Processed data but not real-time sync	Access ring or Collector ring (Edge DC or Local DC)
Entertainment (8K TV and Gaming)	Cloud	10ms	>100Mbps	No	Local caching	Collector ring (Local DC)

Figure 4.22: ETSI Examples of Use Cases

[18] ETSI. Feb 2018. White Paper No. 23 Cloud RAN and MEC: A Perfect Pairing https://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp23_MEC_and_CRAN_ed1_FINAL.pdf

5G Americas which is an industry trade organisation composed of leading telecommunications service providers and manufacturers, is also advocating for the evolution to 5G and thus, defined its own set of latency requirements in a White Paper[19].

Scenario	Max. allowed end-to-end latency (Note 2)	Survival time	Communication service availability (Note 3)	Reliability (Note 3)	User experienced data rate	Payload size (Note 4)	Traffic density (Note 5)	Connection density (note 6)	Service area dimension (Note 7)
Discrete automation	10 ms	0 ms	99.99%	99.99%	10 Mbps	Small to big	I Tbps/km²	100, 000/km²	1000 x 1000 x 30m
Process automation : remote control	60 ms	100 ms	99.9999%	99.999%	1Mbps – 100 Mbps	Small to big	100 Gbps/km²	1, 000/km²	300 x 300 x 50
Process automation monitoring	60 ms	100 ms	99.9%	99.9%	1 Mbps	Small	10 Gbps/km²	10, 000/km²	300 x 300 x 50
Electricity distribution medium voltage	40 ms	25 ms	99.9%	99.9%	10 Mbps	Small to big	10 Gbps/km²	1, 000/km²	100km along power line
Electricity distribution high voltage (Note 2)	5 ms	10 ms	99.9999%	99.9999 %	10 Mbps	Small	100 Gbps/km²	1, 000/km²	200km along power line
Intelligent transport systems Infrastructure backhaul	30 ms	100 ms	99.9999%	99.99%	10 Mbps	Small to big	10 Gbps/km²	1, 000/km²	2km along a road

Figure 4.23: 5G Americas Definition of Requirements for Applications; Source: Infrastructure Working Group

Based on the latency requirements defined by various associations and bodies, the placement of applications within MEC deployment scenarios are depicted as per below. The list of applications is non-exhaustive, and their placements are flexible depending on their specific latency requirements.

[19] 5G Americas. Nov 2018. New Services and Applications with 5G Ultra-Reliable Low Latency Communications. https://www.5gamericas.org/new-services-applications-with-5g-ultra-reliable-low-latency-communications/

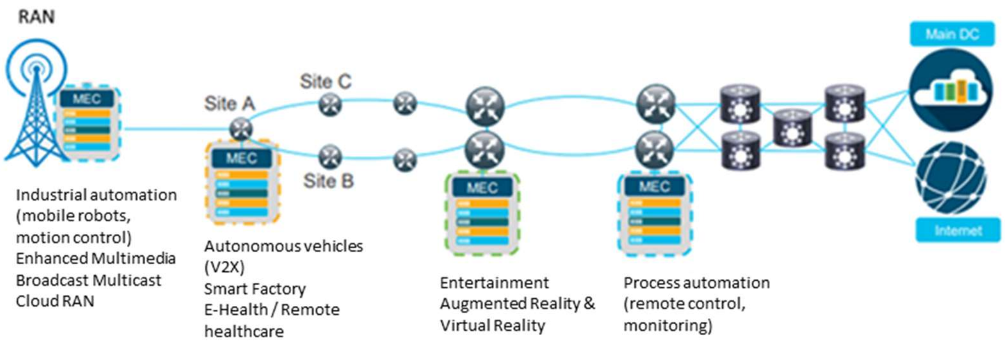


Figure 4.24: Potential Applications Deployment Sites in the MEC; Source: Infrastructure Working Group

4.6.3. Network Integration and Upgrade Path

Upgrading from 4G LTE to 5G NR for the earliest 5G adopters in South Korea, such as KT and SK Telecom, is illustrated below. Most of these early 5G operators opt for 5G NSA Option 3 as their typical 5G NR deployment.

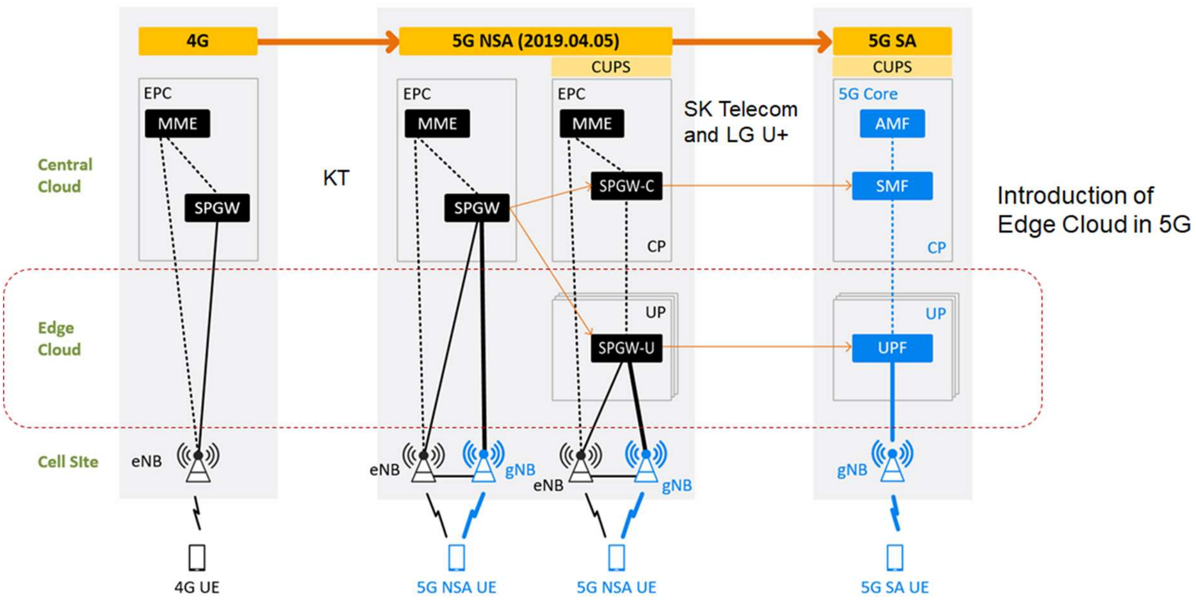


Figure 4.25: Upgrade Path from 4G to 5G by South Korea Operators; Source: GSM Association (GSMA)

NSA Option 3, as illustrated in **Figure 4.26**, applies the dual connectivity approach that provides simultaneous LTE and NR radio access for 5G NSA UE without deploying 5G Core (5GC) in their network design. For NSA Option 3, the control interface of S1 is only provided to LTE eNB while the user plane interfaces of S1 is provided to both LTE eNB (4G Base Station) and NR gNB (5G Base Station). Traffic flows are classified and split at the 4G LTE EPC. When 5GC is ready for deployment, a combination of NSA Option 7 and SA Option 5, NSA Option 3 and SA Option 2; as well as NSA Option 4 and SA Option 2 can be deployed.

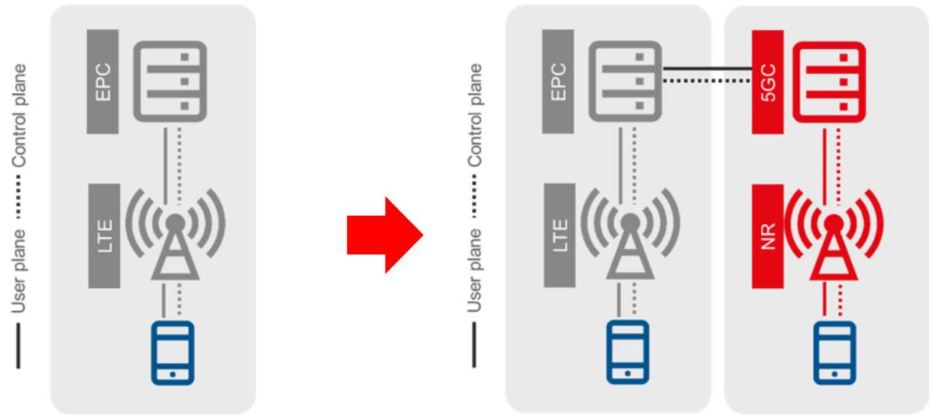


Figure 4.26: 5G NSA Option 3

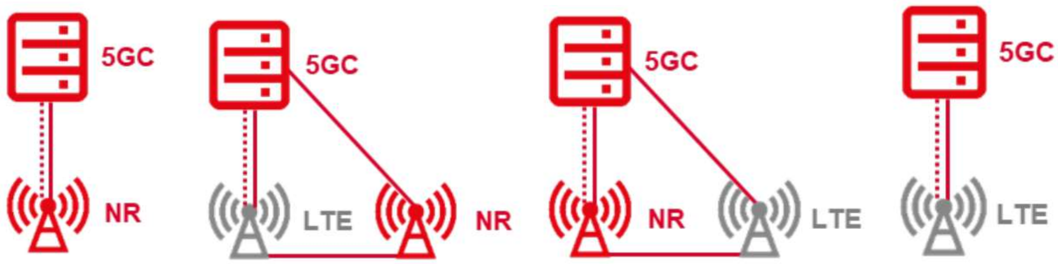


Figure 4.27: 5G SA Option 2; 5G NSA Option 7; 5G NSA Option 4; SA Option 5; Source: GSM Association (GSMA)

SA Option 2 as illustrated in **Figure 4.27** is 5G NR directly connected to 5GC and thus requires inter-RAT (Radio Access Technologies) handover support and redirection between LTE/EPC (Evolved Packet Core) and NR/5GC. For NSA Option 7, both control and user interfaces for eLTE eNB is connected to 5GC while gNB has only the user interface connected to 5GC. Meanwhile, for NSA Option 4, the network design applies similar dual connectivity approach that provides simultaneous LTE and NR radio access with the control plane only located at 5G NR. SA Option 5 is with both user and control plane of eLTE eNB connected to 5GC. Based on **Figure 4.28**, use cases for uRLLC cannot be supported by NSA Option 3 that most early 5G adopters opt for. Due to no 5GC introduction, MEC is hard to deploy as User Plane Function (UPF) interface is not supported. Operators may need to fallback to 4G MEC deployment in this case.

As discussed, LTE is not able to fulfil the stringent latency requirements for all the uRLLC use cases due to its 5ms radio latency. If an operator has not deployed any MEC for 4G LTE, the recommendation is that MEC deployment begin using SA or NSA options that interface with 5GC. 5GC contains UPF interface and this could ease the difficulty of MEC integration. Next, the latency requirements for different uRLLC use cases can be fulfilled by the placement of MEC including the Centralised Unit (CU), Distributed Unit (DU) and UPF as illustrated in **Figure 4.29** – **Figure 4.32**. CU is a logical node that includes the gNB (5G Base Station) functions, such as user data transmission, mobility control, radio resource sharing, positioning, session management etc. Meanwhile, DU is a logical node includes a subset of the gNB functions depending on the functional split option and its operation is controlled by the CU. For different options illustrated in the figures below, operators may need to consider the number of UPF as this number will increase whenever MEC deployment is closed to the edge.

If MEC deployment has been done on 4G prior to that, the migration can be done as illustrated:

	EPS to SA Option #2	EPS to NSA Option #3
5G Use Case Support	eMBB, uRLLC, mMTC	eMBB
Ease of Deployment	Yes	Yes
UE Type	Full CP/UP for both 4G and 5G	CP/UP for 4G with Radio of 5G
Upgrading for LTE eNB	No	Yes
Voice Service Continuity	No, Neet interworking of 5GS with EPS	Yes
Introduction of 5GC	Yes	No

	NSA Option #7 and SA Option #5	NNSA Option #3 and SA Option #2	NSA Option #4 and SA Option #2
5G Use Case Support	eMBB, uRLLC, mMTC	eMBB, uRLLC, mMTC	eMBB, uRLLC, mMTC
Ease of Deployment	Migration from NSA Option #3	Migration from NSA Option #3	Migration from NSA Option #3
UE Type	CP/UP for 4G with Radio of 5G (SA Option #3)	CP/UP for 4G with Radio of 5G	CP/UP for 4G with Radio of 5G (NSA Option #3)
Upgrading for LTE eNB	Yes	Yes	Yes
Voice Service Continuity	Yes	Yes	Yes
Introduction of 5GC	Yes	Yes	Yes

Figure 4.28: SA/NSA Options Supporting uRLLC

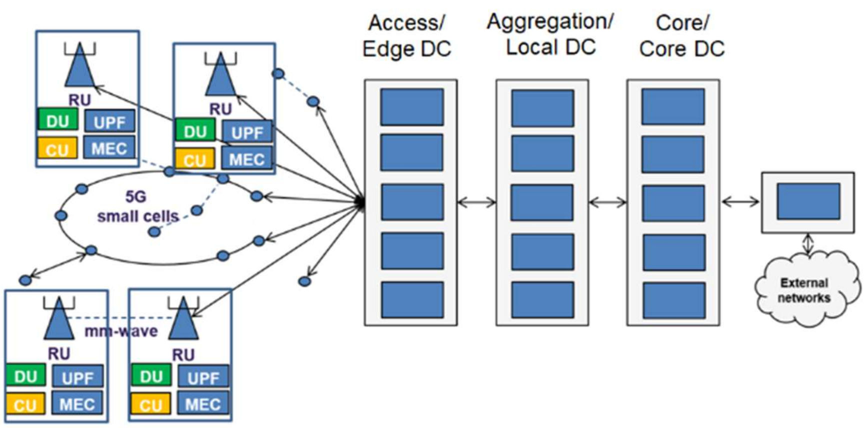


Figure 4.29: Option 1 MEC Deployment Location for Ultra-Low Latency (Approximately Max. 1ms RTT)

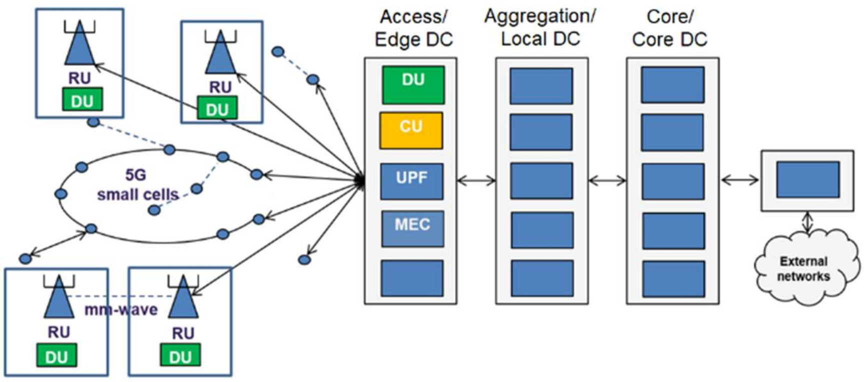


Figure 4.30: Option 2 MEC Deployment Location for Very Low Latency (Approximately Max. 5ms RTT)

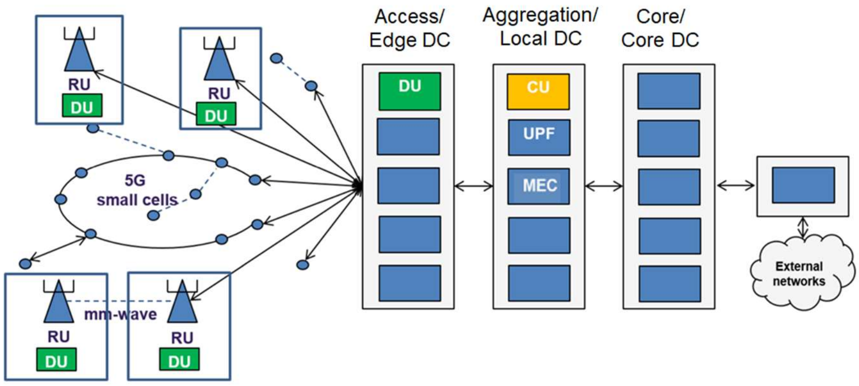


Figure 4.31: Option 3 MEC Deployment Location for Low Latency (Approximately Max. 10ms RTT)

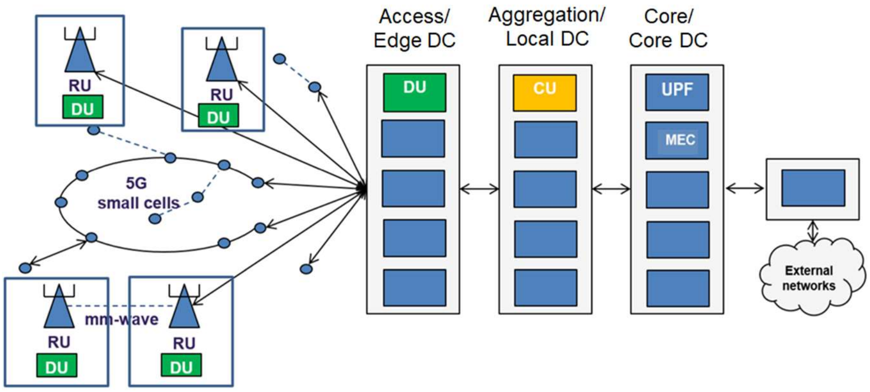


Figure 4.32: Option 4 MEC Deployment Location for Latency Approximately Max. 20ms RTT

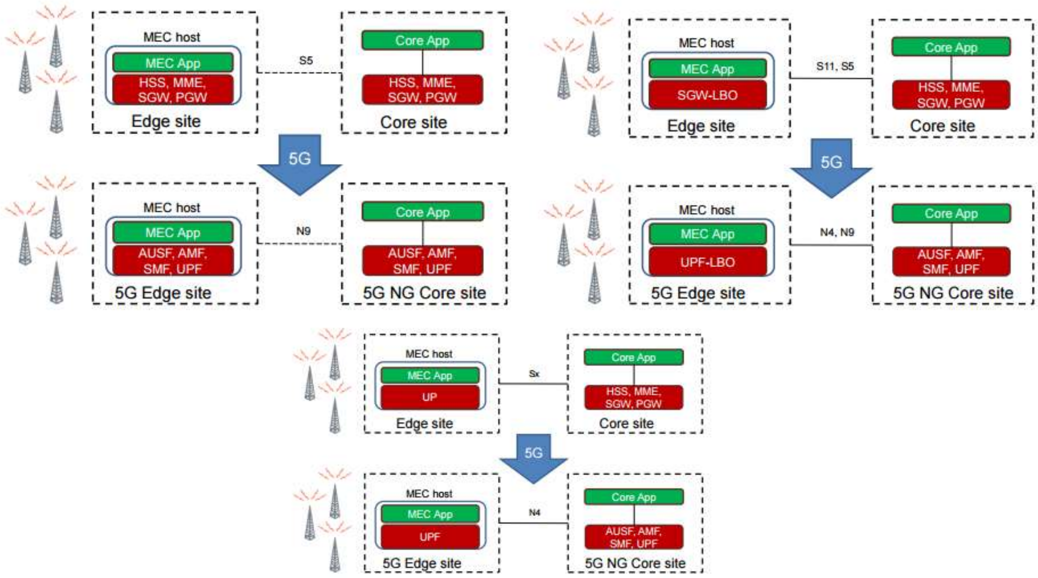


Figure 4.33: 4G to 5G Migration involving MEC Deployment

4.6.4. Regulatory and legal considerations

For the development of the MEC platform, regulatory and legal requirements will be taken into account. Potential examples include:

1. **Privacy:** Restricted information should not be passed to applications if the user has not given consent.
2. **Net neutrality:** Hosting an application on a network edge platform may provide certain ‘specialised services’, like low latency for video streaming.
    - Evolving net neutrality principles should allow some leeway for such services to ensure sufficient quality.
    - Analysis can be conducted to identify applications that would benefit from specialised treatment, and how to best configure these networks to ensure sufficient capacity for non-specialised services as well.
    - Transparency and non-discrimination among both specialised and non-specialised traffic can be observed as part of a net neutrality framework that allows the acceptance of payment to access specialised treatment, subject to reasonable consumer protections. Payment can come from end users, content owners, applications, or services to pay.
3. The introduction of an MEC server in the Radio Access Network (RAN) should not reduce the provision of lawful interception.
4. Roaming charges for access to services. For example, if the same services are offered in both the home and destination networks, should different charge requirements apply? Ongoing regulatory changes to roaming charges would need to be considered

5. Regulatory (Infrastructure Building and Government Policies)

5.1 Facilitating Timely Infrastructure Deployment

5G deployment is expected to include additional infrastructure in new forms, including smaller cells and more densely-located sites particularly in the use of high-band spectrum. The laws and regulations covering infrastructure building and approval is not offered in a streamlined national way, but defined by state, territory, and local governments.

Considering the circumstances, it is important to reduce regulatory friction in building mobile networks to ensure that planning and approval requirements wont' be a barrier to 5G deployment. After all, rapid deployment of 5G will introduce advanced communications to benefit local communities and conversely, hindrance to deployment will hamper adoption of ICT services.

5.1.1 Amendment to Relevant Legislations and Guidelines

Amendments to relevant legislation will be pertinent to the treatment of telecommunications services as public utilities. These amendments should include simplified approval processes to facilitate more efficient rollout.

While telecommunications services are recognised as public utilities under Section 6 of the Communications and Multimedia Act 1998 (CMA), current realities do not reflect this status so further amendments need to be made to related legislations:

1. Town and Country Planning Act 1976 (TCPA):
   - Amendments to recognise telecommunications as utility and remove the need for planning permissions for Low Impact Network Facilities (LINFs).
   - Require the provision of telecommunications services as part of draft local plans prior to getting approvals for new development.

2. Uniform Building By-Laws 1984 (UBBL): Include provision of cellular network facilities (alongside other recognised utilities like water, electricity) as prerequisite for certificate of completion and compliance for occupation. To be included in Uniform Building by Laws (UBBL) for all states.

3. Street Drainage and Building Act 1974 (SDBA): amendments to recognise telecommunications as a utility and remove the need for planning permissions to build LINFs as needed.

In addition, it will be important to streamline policies concerning infrastructure planning and approval mechanisms with coherent adoption by all government agencies to allow for timely deployment of 5G infrastructure. Key recommendations are set out below: (next page)

1. Consideration for Ministry of Housing and Local Government (KPKT)'s Smart Cities guideline to facilitate 5G and infrastructure rollout:
   - Accept and adopt *MCMC's Garis Panduan Perancangan Infrastruktur Komunikasi*, and Low Impact Network Facilities (LINF) guidelines (as developed) to facilitate the rollout of infrastructure including 5G.
   - Consider amending *KPKT's Garis Panduan Pembinaan Menara dan Struktur Pemancar Komunikasi dalam Kawasan Pihak Berkuasa Tempatan (PBT) 2002* to be consistent with the above.

2. Embed new infrastructure standards required for 5G in the relevant guidelines for infrastructure planning and implementation (i.e. Garis Panduan *Perancangan Infrastruktur Komunikasi, Garis Panduan Pembinaan Menara dan Struktur Pemancar Komunikasi dalam Kawasan PBT).* PBTs shall henceforth be referred to as 'local authorities'.

3. Review *KPKT's Garis Panduan (Pindaan) Pembinaan Menara dan Struktur Sistem Pemancar Komunikasi Dalam Kawasan Pihak Berkuasa Tempatan*, *2002* to include:
   - Standardised process from application submission to OSA/OSC until decision-making by local authorities.
   - Standardised checklist for application submission to local authorities.
   - Standardised fees to be paid to local authorities.
   - Requirements for other types of structures i.e., local authorities/Temporary Structure, Lamp Pole, Monopole, Monopole Tree, Billboard, Minaret, Pylon, Street Furniture.

4. Operationalisation of Section 215 (1)(b) of CMA98 on LINF:
   - LINF should not require approval of state authorities prior to deployment.
   - MCMC to work with KPKT, local authorities and industry players to develop a guideline specifically for LINF, building on existing documents drafted by MTSFB (INF-R WG), e.g., definitions of LINF (to be updated as and when needed).
   - Network facilities categorised as LINF should be treated differently; not subject to local authorities' permitting.

Finally, the 5G Task Force is also supportive of NFCP's proposal for a Cabinet decision to implement a moratorium of planning permission in the next 5 years, subject to:

- Local council blanket approval: Subject to meeting a minimum checklist, and subject to the guidelines being met (including the *Garis Panduan Perlaksanaan Infrastruktur Telekomunikasi*, yet to be developed LINF and KPKT guidelines once updated).
- Infrastructure sharing policy (to avoid duplication) to be developed as per Section 4.4.1 of this report.
- Minimum specifications on infrastructure to facilitate sharing
- Revision of access instruments (e.g. Access List) to facilitate sharing

5.1.2 Coordination Body at Federal Government and Local Government

Establishing a Telecommunications Task Force under the *Mesyuarat Majlis Negara bagi Kerajaan Tempatan (MNKT)*, with representation across the relevant ministries, agencies and telecommunication providers will be critical in reducing hindrances to rollout, promote standardisation and streamlining the process at national level. In parallel, close engagements with local governments will be necessary to facilitate timely 5G delivery. The local government may establish a coordination committee comprising senior officials from relevant government departments at federal and state levels as well as private sectors for this purpose too.

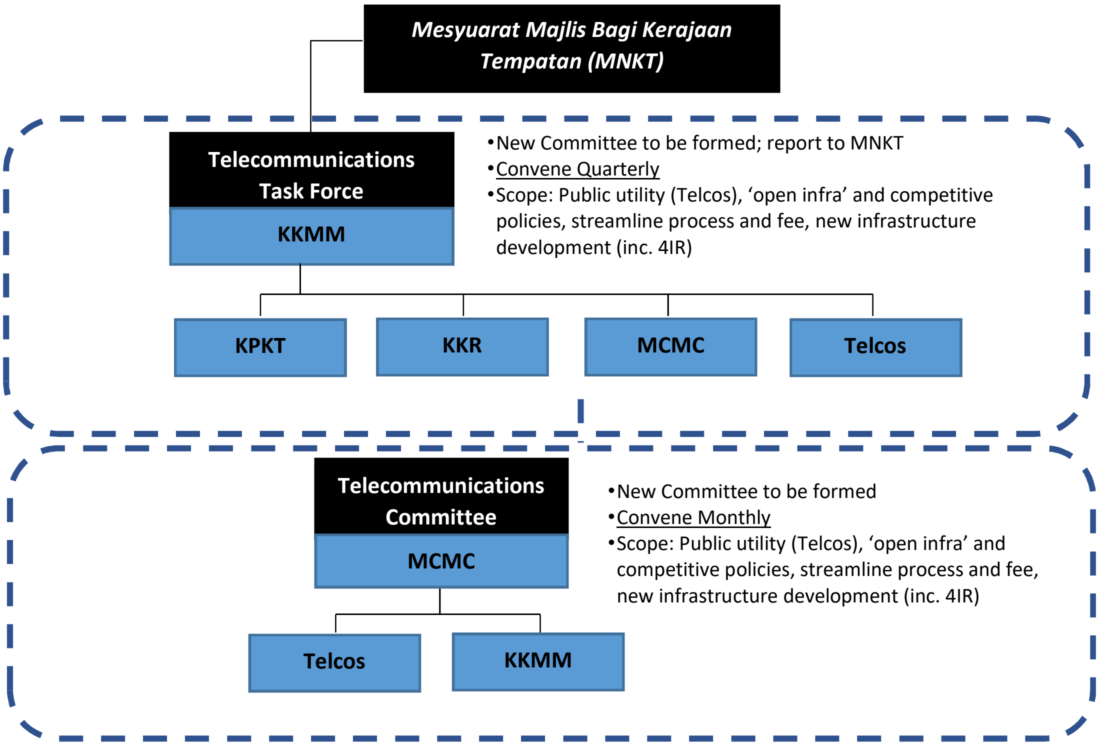


Figure 5.1: Telecommunications 5G Task Force under MNKT; Source: Regulatory Working Group

5.1.3 Ensuring Open Access Policy to Promote Healthy Infrastructure

Current legislations need to be strengthened to prevent anti-competitive conduct by licensees. The 5G Task Force proposes that this could be done via:

- Insertion of a new clause/license condition for Non-Exclusivity in each Network Facilities Provider (NFP) licence; or
- Issuance of Ministerial Determination which prohibits NFP licensees from getting involved in or to accept appointment of Exclusive Deals from state/local authorities.

The 5G Task Force further proposes that the Federal Authorities (i.e. MCMC and Ministry of Communications and Multimedia or *KKMM*) establish a discussion platform at state level co-chaired by MCMC/*KKMM* and State Authorities (e.g. ICT exco, State Secretary or Chief Minister). The platform should be attended by industry players to address and resolve issues pertaining to the provision of telecommunication and broadband infrastructures and services. Issues such as blind spots, exclusivity, Universal Service Provision (USP), fees, illegal sites, etc. could be raised and properly addressed at this platform.

5.1.4 More Access to Government Land, Building or Assets and Further Land Reforms

To support the 5G rollout plan (including network densification), the 5G Task Force recommends a Government or Cabinet decision to consider the following:

- Free or affordable access to government land, building and assets for telecommunications infrastructure including key airports, schools, public transport stations and hubs (e.g., MRT) and highways.
- As a new government policy, to consider allowing only 'established' (e.g. nationwide) Network Facilities Provider (NFP) and Network Service Provider (NSP) to provide telecommunications services in key airports, schools, public transport stations, hubs (e.g. MRT), highways.

In addition, the 5G Task Force recommends that the Government consider further land reforms, as per below:

- Amendments to state land laws and regulations to facilitate flexible use of agricultural, native; and reserve land for network facilities. Currently some states do not allow use of such land for telecommunications, while some states permit it but with costly conversion of entire plot of land.
- Identify and review restrictions on using utilities infrastructure for network (e.g. water, sewerage), fair pricing for access to infrastructure.
- Adoption of relevant provisions of the UK Digital Economy Act 2017, which sets out a comprehensive legal framework governing the relationship between private landowners and telecommunications operators. In the interest of facilitating speedy network rollout, the Act clearly sets out the rights and obligations of telecommunications operators and landowners in relation to the use of private land for network rollout. This includes, among other things, specifying that the rental rates to be charged by landowners are to be set at market rate and providing for the referral of disputes with landowners to court. Consideration is given to public interest in access to a choice of high-quality communications services.

5.2 Fit-for-Purpose Regulation

The Malaysian government is cognisant that the communications regulatory framework will need to be sufficiently flexible to address the emergence of new technologies and business models. Today, the Communications and Multimedia Act 1998 (CMA98) is a legislation enacted to provide for and to regulate the converging communications and multimedia industries. Taking 5G requirements forward, some aspects of the CMA98 and sectoral regulatory frameworks need to be updated to take advantage of 5G.

5.2.1 Robust Regulatory Framework to Ensure Sufficient Resources and Sustainable Investment

The 5G network is expected to differ from legacy networks implemented today in addition to higher capacity requirements on fiber transport to backhaul to support 5G sites. It will have significant impact on investments. It is therefore important that government policies support sustainable investment over the long-term. Some of key considerations are:

1. Investment assurance by having optimal spectrum allocation, timely spectrum availability, transparent spectrum assignment and award process, modest spectrum price, and sensible rollout terms, guided by regulatory best practices.
    - Develop and publish a provisional 5G spectrum roadmap every 3 years in periodic intervals.
    - Longer Spectrum Assignment period for at least 20 years to provide investment certainty and predictability.
    - Transparent spectrum management by having public spectrum release plans and transparency regarding current spectrum use. The information should be publicly accessible and showcase up-to-date registers over the most important spectrum licenses
    - Prioritise long-term socioeconomic benefits for spectrum use with optimal release of spectrum for 5G to prioritise usage and consider refarming.
        i. New spectrum bands based on Priority 1 and 2 as recommended in Section 5.2.
        ii. Prioritise usage of C-band spectrum as recommended in Section 5.3.
    - Optimal allocation of spectrum per Telecommunications Operator (Telco) to support effective operation of 5G and maximise 5G network quality.
        i. Nationwide spectrum allocation rather than geo-confined
        ii. Optimal spectrum blocks made available for all spectrum bands, as recommended in Section 5
        iii. Avoid interspersed spectrum allocation for verticals or different usage but operators can be permitted to make arrangements using their spectrum for verticals to build their own private 5G networks if necessary.
    - Consultative process when setting 5G spectrum prices and terms, with assessment taking into consideration total cost of ownership across various fees imposed and the cost of rollout obligation, etc.
        i. Avoid limiting the supply of 5G spectrum as scarcity can lead to excessive prices
        ii. Allocate 5G high-bands for free i.e. mmWave 5G spectrum
        iii. Set modest reserved spectrum price for low and mid-bands with no annual fee component

2. Impose light fee for point-to-point Apparatus Assignment for 5G
   - As current fees prescribed in the Spectrum Regulation Schedule imposes high fees for large bandwidth for Point-to-Point communications (including E-band), a light fee for conventional Point-to-Point band is recommended including for E-Band.

3. Government's support to deliver 5G infrastructure deployment in rural areas by way of Universal Service Provision (USP) funding.
   - To support 5G rollout in rural areas, 5G Task Force recommend for government funding via USP to be allocated in new rollout and upgrade sites towards 5G aside current technologies. These communities can now grasp the opportunities and economic benefits of next generation 5G technologies.
   - A continued network sharing approach in an open manner should be considered as part of the operating model for mobile operators in these areas to reduce the infrastructure costs noting the daunting investment required.

4. Partnerships with fiber providers to reduce the cost of fiberisation

   - The 5G Task Force expects that there will be heavy backhaul requirements to support the 5G network. Hence it will be important to collaborate with fiber providers to share the available fiber backhaul resources to allow for more cost-effective backhaul resources.
   - Fiber sharing in open manner will be critical. Importantly, the sharing model shall aim to mitigate infrastructure duplication while allowing competition to persevere.
   - In future, it will be important that MCMC's Mandatory Standard on Access Pricing (MSAP) also take into consideration the multi-fold bandwidth requirement of 5G transmission.

5. Partnerships with vertical industries in areas to be explored for 5G verticals:
   - In the areas of vertical industry development (outlined in Section 2), the respective private sectors can collaborate with Telcos for virtual private networks. Noting that spectrum will be a scarce resource, it will be important to ensure that its allocation for 5G can be efficiently utilised by way of partnerships to avoid a widely dispersed spectrum allocation.

6. Incentivise long-term investment by considering, for e.g., tax deductions and rollout incentive programmes:
   - Exemption of import duty and SST for importation of 5G network equipment.
   - Special tax deduction on amount incurred for 5G Stand Alone (SA) network fees.
   - Incentives for R&D investments incurred for 5G use case verticals.
   - Tax incentives for 5G capital investment e.g. last mile NFP incentive, accelerated capital allowances incentive.
   - Special tax incentive on amount spent migrating customers to 5G (i.e. equipment, backhaul, etc.).

7. Incentivise 5G use cases development across different public funding or partnership models:
   - Public funding to support 5G trials in development of use cases across verticals in pilot areas. For example, the UK government took this approach focusing on, among other things:
     i. Smart Tourism: testbed aims to deliver enhanced visual experiences for tourists using AR and VR technology in major attractions in Bath and Bristol, South West England.
     ii. Smart Manufacturing: testbed aims to increase industrial productivity through assisted maintenance using robotics, big data analytics and Augmented Reality over 5G in Worcestershire.
     iii. 5G Rural Integrated Testbed: focuses on trialling innovative use of 5G technology across a range of rural applications, such as smart agriculture, connecting underserved communities, using shared spectrum in the TV bands and a mix of local Internet Service Providers (ISPs) and self-provision.

   - As China is set to host the 2022 Winter Olympics, 5G is hoisted to be one of the key technology enablers to showcase China's achievement. Among the key initiatives are:
     i. Application: Provide incentives for companies to set up in Beijing, with focus areas on cybersecurity, AI, and entrepreneurship.
     ii. R&D: By 2022, Beijing's R&D institutes aims to own more than 5% of the patents in international 5G standards, focusing on the manufacturing sector.
     iii. Pilot Districts: The Fangshan district and China Mobile partnered to create an experimental area for self-driving vehicles.

8. Reclassification of electricity tariff from Tariff B (Low Voltage Commercial Tariff) to Tariff D (Low Voltage Industrial Tariff) for mobile infrastructure.

5.2.2 Robust Regulatory Framework to Support 5G Use Cases

Use cases for 5G especially across vertical industries are endless. There are currently nine verticals that are being assessed as outlined in **Chapter 3** which cuts across agriculture, digital healthcare, education, manufacturing, services & retail, Smart Cities, smart transport, banking & finance, and oil & gas. Noting the benefits of 5G in other sectors than telecommunications, it will be important to begin assessing sectoral regulatory settings needed across the identified verticals. As a starting point, the Ministry of Communications and Multimedia with MCMC and the 5G Task Force, initiated a workshop on the 27th of June 2019 to bring together engagement from across the government and industry.

The key common recommendations are:

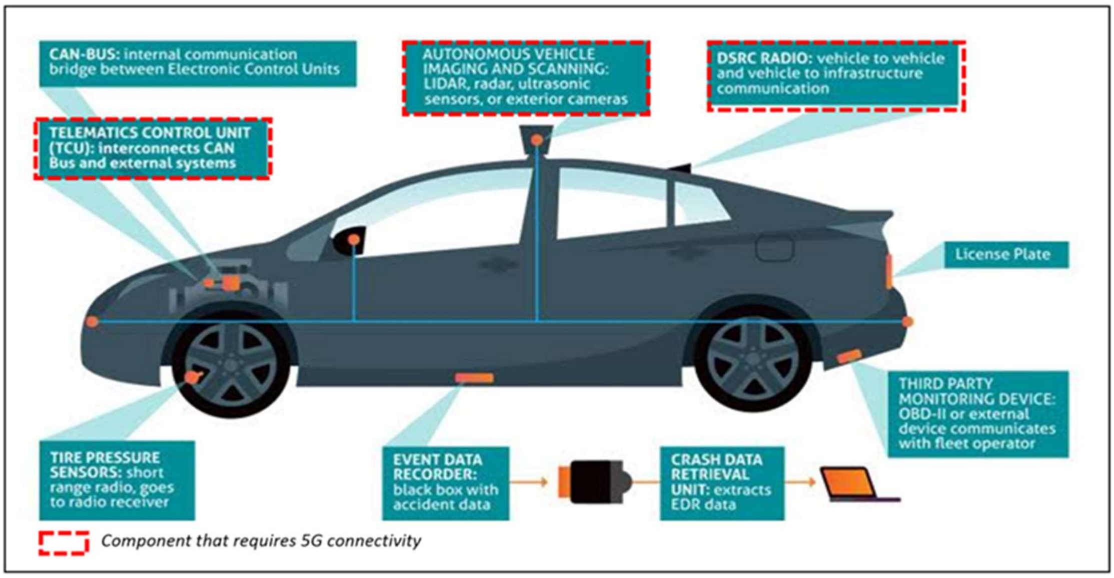
- Update current legislation in the relevant sectors to support and promote digitalisation, (4IR) and 5G technologies.
- Consider setting up a test bed within selected use cases to allow for regulatory sandboxes whereby credible arrangements for these use cases can be tested in a controlled environment and regulatory risks can be identified and managed with light regulations.
- Development of necessary guidelines catered to 5G requirements of the identified use cases as an initial reference point to support the respective Ministries in updating sectoral policies and regulatory frameworks.
- Monitor privacy and personal data protection requirements. If required, a code of practice can be recommended to Personal Data Protection Department (PDPD).
- Consider simplifying the existing requirements imposed in obtaining approvals and permits across multi-agency settings in future 5G deployment e.g., the approvals for rollout of drones and IoT implementation.

Further elaboration on some of the use cases' sectoral regulatory assessment is provided in the next page. A detailed list of recommendations is provided in **Appendix 5**. The initial recommendations are non-exhaustive and require further insights from respective Ministries that are the subject matter experts on their sectoral regulation.

5G Use Case and Sectoral Regulatory Assessment: Smart Transportation

1. Use Case Proposal

Develop the AACV technology by the utilisation of 5G connectivity.



AACVs need to communicate with multiple devices, vehicles and even with its surroundings in order to fetch data and undertake appropriate driving decision. There are four key components for a fully automated vehicle to be operated called Vehicle-to-Everything (V2X)

Vehicle-to-Vehicle (V2V)	**Allows two vehicles to communicate directly with each other.** Communication is facilitated by the Onboard Unit (OBU) and it was designed primarily to support safety-critical applications.
Vehicle-to-Infrastructure (V2I)	**Allows vehicles to communicate with the infrastructure.** Communication is facilitated by OBU and Roadside Unit (RSU) and designed primarily to support traffic efficiency applications.
Vehicle-to-Network (V2N)	**Allows vehicles to communicate with the internet and the cloud.** Communication is facilitated by cellular-based OBUs. It was designed to support safety and traffic efficiency applications.
Vehicle-to-Phone (V2P)	**Allows vehicles to communicate directly with mobile phones.** Communication is facilitated by the OBU and a compatible phone. It was designed primarily to support pedestrian safety applications.

2. Sectoral Regulatory Assessment

Regulatory Impediments

Impediments do not appear to be many. However it is important to have controls/policies/guidelines which are 5G friendly (e.g. spectrum availability, standards, QOS, liability, safety, data privacy, implementation a regulatory sandbox policy, coordination with state/local governments too.

Recommended next steps

Recommended Solutions	Key Actions	Timeline
1. Test bed: To finalise the test bed requirement	Malaysia Automotive Robotics and IoT Institute (MARii)	End of 2019
2. Policy: To develop Autonomous Vehicle Guidelines by MOT/FUTURISE and National Transport Policy	The Ministry of Transport (MOT), Futurise	End of 2019
3. Safety: • Type approval and safety standards that enable AACV use globally or at least in ASEAN countries. • Test bed to test the AACV followed by digital simulation and live on the road (within controlled environment) • Guidelines to be issued on safety standards.	MoT/Futurise/ MARii working together on AACV as part of the revised NTP.	After test bed
4. Spectrum: Consider possible spectrum for short-range and long-range requirements for V2I, V2V respectively	MCMC	To be confirmed
5. Liability: Different liability for different level of AACV • Level 3 and 4 with overriding options, liability possibly falls on the driver (private owned), if a service then the responsibility falls on the either Service Provider or Driver depending on cases • Level 5 – current proposal only for controlled environment. Liability falls on the Service Provider	MOT	After test bed
6. Privacy/PDP: Current provisions adequate; data user to protect the personal data collected. May want to consider Code of Practice once requirements are ready; can leverage from Test Bed (via MARii, Futurise)	KKMM/PDP	To be confirmed
7. QoS: Consider technical standards or codes for AACV to ascertain acceptable QoS	MCMC, Telcos	2020
8. Implementation challenge: Coordination on policy and regulation – fed and state, to operate AACV (e.g. special lanes, controlled environment etc)	KKMM, MCMC, other relevant ministries and local authorities	2021

5G Use Case and Sectoral Regulatory Assessment: Smart Manufacturing

1. Use Case Proposal

Software Applications	Equipment Readiness	Warehouse and Logistics Industries
- Engineering applications using high bandwidth for cloud computing - Manufacturing/Production monitoring using low latency and massive sensor communication - Enterprise solution with medium bandwidth and latency for decision-making	- Smart Grid with ultra-low latency to establish immediate adjustments in the power supply - Massive sensor communication for IoT devices as well as cameras	- RFID Tracking in warehouses for better stock count - Logistics application for high-quality goods that need special monitoring

2. Sectoral Regulatory Assessment

Regulatory Impediments

There do not appear to be many impediments. However, it is important to have controls/policies/guidelines which are 5G friendly (e.g. spectrum availability, standards, equipment imports, QOS and data privacy, implementation a regulatory sandbox policy, and guidelines for Private Virtual Network Operators (PVNO).

Recommended Next Steps

Recommended Solutions	Key actions	Timeline
1. Spectrum Policy and Harmonisation	**MCMC:** Standardised spectrum bands that also caters to IoT, especially Sub-1GHz band - High speed broadband for Manufacturing	2020
2. PDPA	**PDP Commissioner:** No more than necessary, Fit-for-Purpose rules	2020
3. Simplified QOS	**MCMC QOS:** Avoid application of consumer QoS to IoT – issued guidelines	2020
4. Adopt Regulatory Sandbox	**MITI/MIDA:** Consider a test bed area with light regulation to enable firms manage regulatory risks during testing stage, not defined yet. Owner to be determined.	2020

Recommended solutions (cont.)	Key actions (cont.)	Timeline (cont.)
5. Standards for Interoperability, Data Privacy Storage, Quality and Safety: Adopting 3GPP Standards	**MTSFB:** Adopt standards relevant to manufacturing (see list in **Appendix 5.5** and **Appendix 5.6**) **Department of Standards Malaysia:** Adopt international standards (IEC, ISO, 3GPP, ACIA standards, including Goose on 5G), when IEC to adopt 5G 3GPP/ITU specifications. This covers many manufacturing verticals and oil & gas.	Q2 2020 Ongoing
7. Robotics	**FMM/MCMC:** Produce guidelines to engage Telcos for the setup of Private Virtual Network Operator (PVNO)	Q1 2020
8. Smart Grid	**Energy Commission:** Update Energy Commission Grid Code for Peninsular Malaysia [Electricity Supply Act 1990 (Act 447)] Section CC6.6 **SPAN**: Update Water Services Industry (Water Reticulation and Plumbing) Rules 2014 **Oil & Gas:** ATEX requirements to be evaluated for 5G readiness. Owner to be determined (e.g.: Petronas)	2021

5G Use Case and Sectoral Regulatory Assessment: Smart Agriculture

1. **Use Case Proposal**

Drones for Precision Farming	Robotics Automation	Internet-of-Things (IoT) Sensors
- Remote sensing for precise agriculture, which would result in 5% Return of Investment (ROI) - Automated manual jobs such as pesticide spraying, and fertiliser application can help to speed up productivity by up to 30%	- Automation such as self-driving tractors is the answer to ageing farmers and labour shortages in our agricultural sector - Robotics automation in the agricultural sector will lower production costs and increase productivity	- IoT sensors provide crucial farming data such as moisture levels, pH, soil fertility, etc., in real-time. This allows for precise applications of fertiliser, water, etc., resulting in reduction of cost.

2. Sectoral Regulatory Assessment

Regulatory Impediments

Tedious approval for drone flight operating at beyond line of sight, complicated environmental assessment for placement of sensors - i.e. from JPS (*Jabatan Pengairan Saliran*) and JKR (*Jabatan Kerja Raya*), local municipal council etc. coexistence of licensed and unlicensed spectrum usage for IoT.

Recommended Next Steps

Recommended solutions	Key actions	Timeline
1. Establish one-stop-centre to access existing regulations and approval for rollout of drone, IOT, robotic automation.	Malaysia Productivity Council (MPC)	Ongoing
2. Implementation of existing policy (example: NFCP) on connectivity issues for agriculture sites (rural).	KKMM and MCMC	2019/2020
3. Establish sectoral policy that is technology neutral and friendly in agriculture sector to address the regulatory impediments. - Currently on going by Ministry of Economic Affairs ("MEA"), support from other Ministries required.	MEA, KKMM, Ministry of Agriculture, & Ministry of Prime Industries ("MPI")	2020
4. Civil Aviation Authority of Malaysia (CAAM) and Ministry of Transport (MOT) involvement to address the LOS (line of sight) update to allow Beyond Visual Line of Sight ("BVLOS") & to operate more than 20kg, CAAM require Private Pilot License ("PPL").	CAAM and MOT	To be identified
5. Update on types of pesticide allowed for drone spraying.	Lembaga Racun *(under Department of Agriculture)*	To be identified

5.3 Safe and Secure 5G

5.3.1 5G Security Standard

5G will enable substantial implementation of massive IoT devices and the evolution of IoT as a service, hence the security challenges brought by new services, architectures, and technologies may increase cybersecurity considerations: including the ability to detect threats, authenticate users, and practice good operations.

While 5G technology offers more robust and resilient networks with opportunity for more enhanced security requirements and evolution from earlier technologies, it is important to encourage a healthy cybersecurity ecosystem for safe and secure use of 5G networks. A guiding principal for a secure 5G network will be critical.

Global standards like the 3GPP Security Standard can be a good reference in ensuring that the Malaysian ecosystem adheres to stipulated security features. As mentioned, security drivers in both 4G and 5G share a same purpose, which is to ensure the confidentiality, integrity, and availability of networks and data. The 3GPP evolution too ensures continuous security enhancements to meet future service requirements.

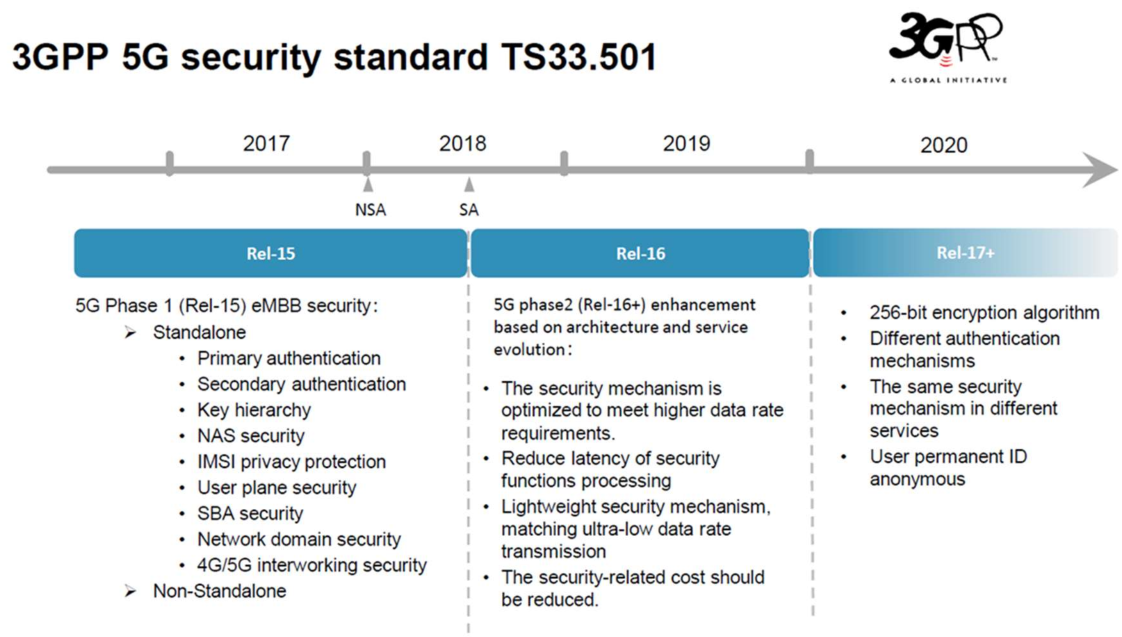


Figure 5.2: 3GPP Security Standard; Source: Huawei whitepaper 'Partnering with the industry for 5G security assurance'

The 3GPP has developed 5G Release 15 Security Standards (As mentioned in **Section 4.4.4**) and is developing the 5G Release 16 Security Standards to ensure that 5G consistently moves ahead at all technical levels, at the same pace as that of architecture and wireless standards. The Release 15 Standards have defined security architecture and standards for eMBB scenarios, covering Standalone (SA) and Non-Standalone (NSA) architecture. Based on the 5G Release 15 Security Architecture, 5G Release 16 and Release 17 standards will likely cover security optimisation for mMTC and uRLLC scenarios.

Secondly, the 5G system is designed to be resilient, secure and with capability to protect individuals' privacy. On top of state-of-the art encryption that is included in 5G, the trustworthiness of the 5G system is the result of the five properties as illustrated below, namely resilience, communication security, identity management, privacy, and security assurance. These properties make the 5G system a trustworthy platform that enables many new services to be created. More details can be found in Ericsson's White Paper titled: 5G security – enabling a trustworthy 5G system.

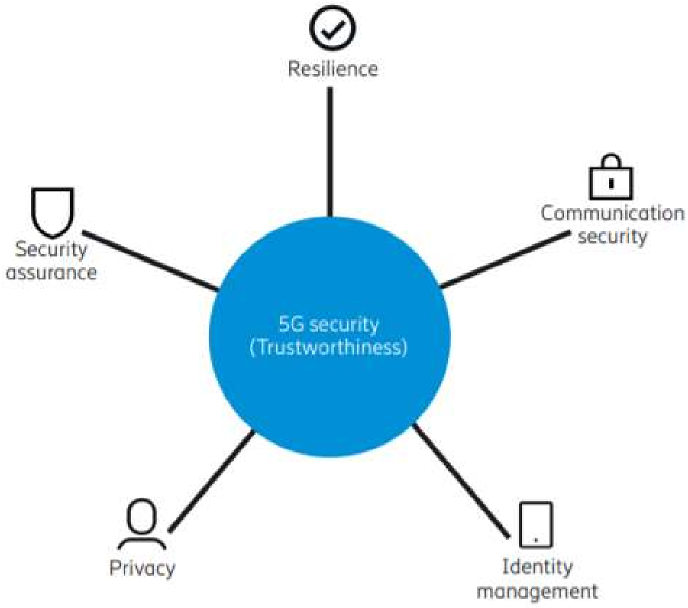


Figure 5.3: 5G Security Trustworthiness; Source: Ericsson

In summary, 5G systems offer end-to-end measures for privacy whereby:

- 3GPP 5G standards define that user IDs are encrypted during transmission over the air interface, and encryption and integrity protection are performed on end-to-end transmission channel to prevent personal data from being stolen or tampered with.
- User plane data protection: Both the air interface and transmission channel support encryption and integrity protection according to 3GPP standards.
- The following measures need to be taken when user identity data is collected during network O&M:
    i. All user operations must be authorised before collection.
    ii. Collected data is encrypted during storage and processing to prevent data breach. The data is automatically deleted upon expiry of the personal data storage period.
    iii. For boards returned to the manufacturer, a secure deletion mechanism is provided to avoid data breach during repair.
- Documentation must be provided to describe how network equipment handles personal data in compliance with privacy requirements.

In addition, it is important to note that an integrated 5G ecosystem will consist of multiple elements, including RAN, mobile core networks and non 3GPP access networks, with different types of user devices and IoT devices that are connected to the ecosystem, as below. (next page)

Security Layer	Vulnerability Topic	RAN			Core network			Transport			User devices		
		HW	SW	Sys	HW	SW	Sys	HW	SW	Sys	HW	SW	Sys
Services, Applications and Use cases	QoS	■	■	■	■	■	■	■	■	■			
	Access right to network slides	■	■	■	■	■	■	■	■	■			
	Vertical use cases											■	■
	Data confidentiality	■	■	■	■	■	■	■	■	■	■	■	■
	Service and application genuineness, safety and reliability										■	■	■
	Edge computing and service vulnerability				■	■		■	■				
Users and things	Device and connection genuineness		■	■		■	■				■	■	■
	Resource limitation of M2M devices										■	■	■
	Device identification for M2M and IoT					■	■						
Inter-networking	Operator models			■			■			■			
	Distributed core				■	■	■						
	Use of various RAN technologies	■	■	■		■	■	■	■	■			
	Separate ownership of RAN for rural and enterprise use cases	■	■	■		■	■	■	■	■			

Figure 5.4: Security Vulnerabilities of Various Elements

Therefore, on top of the 5G security standards, it is important to deliver robust security architecture by analysing several security layers of the system. Below are initial guiding steps across key stakeholders in Malaysia:

- The development of technical codes to ensure that Malaysia can meet up-to-date technical standards in relation to 5G security.
    - i. The technical codes will facilitate the establishment of cyber security assurance system ensuring secure services.
    - ii. The 5G Task Force recommends leveraging the expertise of Malaysian Technical Standards Forum (MTSFB), the Working Group on Security, Trust and Privacy, which comprises various cyber security experts from the private sectors and academia. It is targeted that the work 5G security technical code to be completed by end 2020.
- Leveraging on the expertise of National Cyber Security Agency (NACSA), to collaborate with MCMC and the private sectors (i.e. mobile operators, technology vendors etc) to develop a Standardised Minimum Security Assessment Checklist whereby it will clearly define responsibilities and standards towards ensuring secured 5G networks.
- The 5G Task Force opines that it is important for the government to promote solutions that enables cost-effective and adequate security for service providers and users as well as the balance in expectation of compromised network quality with security features.

5.3.2 5G Safety: Electromagnetic Field (EMF)

Another important aspect in 5G security is to ensure human safety from radio frequency radiation from 5G networks. Today, strict exposure limits for electromagnetic fields has been applied throughout 2G/3G/4G networks in line with the international standards. Extensive research has been performed by various parties to investigate whether mobile phones and mobile base stations present health risks, including in Malaysia. All reviews[20] conducted so far, indicated that its Electromagnetic Field (EMF) exposure level is below the limits recommended under ICNIRP EMF guidelines covering full frequency from 0 to 300GHz, and do not produce any adverse health effects.

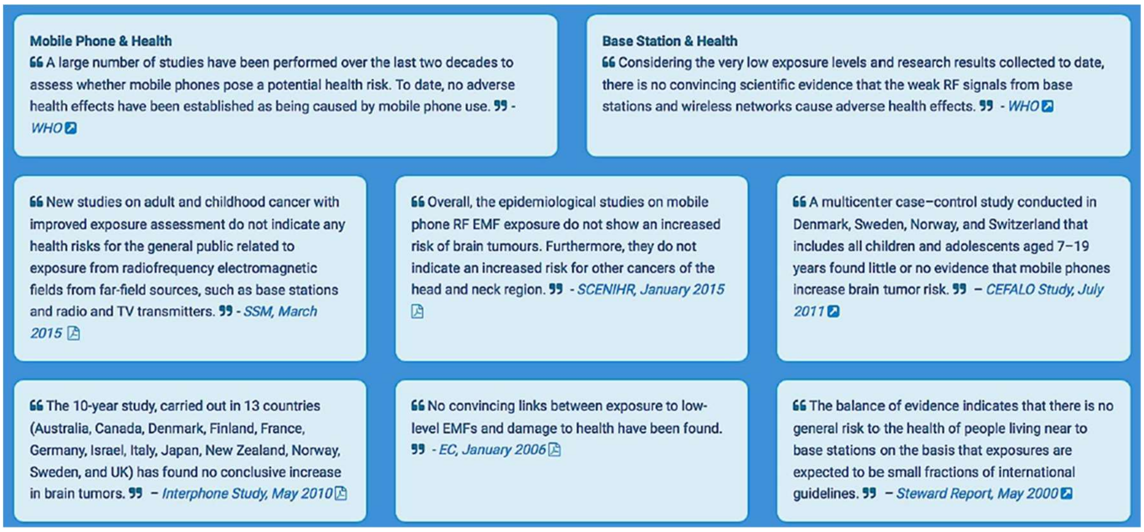


Figure 5.5: International Review on RF EMF Exposure; Source: Presentation by National 5G Task Force Advisor (Prof Dr Tharek Abdul Rahman), 12 March 2019

[20] Including a study by Universiti Teknologi Malaysia. Nov 2015. Wireless Industry Emission: Electromagnetic Field Monitoring and Analysis

RF EMF exposure limits for electromagnetic fields, ICNIRP limit

Frequency Band	ICNIRP Limit
3GHz < f < 10GHz	0.08 W/kg
10MHz < f < 3GHz	0.08 W/kg
10GHz < f < 10GHz	10 W/m^2
400GHz < f < 10GHz	2 W/m^2 - 10 W/m^2
f < 10GHz	10 W/m^2

The 5G Task Force recommends the development of technical codes in relation to "5G Technology and Human Exposure to Radio Frequency Electromagnetic Wave". The intention for the technical code is for mobile operator usage while deploying 5G networks in Malaysia to observe technical guidelines specific to RF EMF and profiles suitable for Malaysia. This technical code should leverage on existing standards for 2G to 4G and future 5G system from international standardisation bodies such as ITU so that Malaysia can best meets the up-to-date technical standards. Work for technical code on "5G Technology and Human Exposure to Radio Frequency Electromagnetic Wave" is slated for completion by the end of 2020.

Documents That Can Be Considered For 5G EMF Exposure

Documents That Have Been Released By ITU-T in Relation to EMF Exposure; Source: ITU

In addition to technical standards, it is important to conduct a technical study on 5G RF EMF exposure to assess long-term health risks in Malaysia, which considers the following:

- MCMC to invite an independent agency to undertake such study by conducting multiple on-site measurements wherever possible for free in order to gauge the RF EMF exposure levels of 5G network structures.
- The 5G Task Force believes that it is best to make full use of the upcoming 5G demonstrations in Langkawi for independent agencies to perform the said technical study.
- Separately, Telcos should perform its EMF simulations on aforementioned 5G use case scenarios to assess the EMF emission/exposure levels as well.

Finally, the 5G Task Force also recommends further improvements on the public's understanding of 5G and radio frequencies; an effort to be jointly undertaken by MCMC, Ministry of Health (MOH), Malaysian Technical Standards Forum (MTSFB), Consumer Forum of Malaysia (CFM) and the Telcos. While improving awareness among the Rakyat will be important, it is equally critical that the relevant government agencies collaborate in addressing the concerns that may arise among the public.

- It is important to establish Standard Operating Procedure (SOP) for consumer issues or any complaints regarding EMF at the local councils and local authorities, and best to be streamlined across (if possible).
- The 5G Task Force recommends that local councils and local authorities consider evidence-based requirements for complaints prior to any consideration to dismantle sites (e.g. EMF compliance supported by report from *Agensi Nuklear Malaysia* to substantiate).

5.4 Summary of Recommendations

The summary of Regulatory Working Group recommendations is as follows:

1. Regulatory Intervention to Support Sustainable Infrastructure-Building	2. Fit-for-Purpose Regulation	3. Safe and Secure 5G
Facilitating timely infrastructure deployment, via the following: a. Amendment to relevant legislations and guidelines - *Streamline policies on infrastructure planning and approval mechanism* - *Embed new infrastructure standards required by 5G* b. Coordination body at Federal Government and Local Government levels c. Ensuring open access policy to promote healthy infrastructure d. More access to government land, buildings, or assets and further land reforms	**Robust regulatory framework:** a. Sufficient resources and sustainable investment b. Partnership with fiber operators and vertical industries c. Public funding for 5G in rural areas d. Incentivise 5G use case development **Assessing sectoral regulatory conditions on 5G use case verticals**	**Ensuring safe 5G, by having:** a. Up-to-date technical standards on 5G EMF safety (by MTFSB) b. MCMC to invite independent agency for few on-site measurements for free in order to gauge EMF exposure levels c. Improvement on the public's understanding of 5G and EMF **Ensuring secure 5G by having:** a. Technical standards for 5G security by MTFSB b. Leveraging NACSA/MCMC and private sectors to develop a standardised minimum-security assessment checklist

6. Conclusion

This report from the 5G Task Force has outlined a holistic view and relevant recommendations in anticipation of 5G deployment in Malaysia for the consideration of the Government of Malaysia.

The 5G Task Force wishes to thank all ministries, agencies, and organisations from both public and private sectors within and outside of Malaysia, who have contributed immensely in producing this final report.

Appendix 1: Public Consultation Questions

No.	Question
Section 1: Business Case	
1	We seek views on optimising investment strategies for R&D (Research and Development) as 5G will enable new applications that will transform the way we live, work, and engage with our environment.
2	We seek views on the above recommendation that IoT is fuelling the need for massive connectivity of devices, and a need for ultra-reliable, ultra-low-latency connectivity over Internet Protocol.
3	We seek views on the above recommendation that it is important to have a reliable 5G network as this will help AR and VR applications evolve to the next level.
4	We seek views on the above recommendation to improve public safety in Malaysia's towns and cities, through the deployment of 5G wireless CCTVs to support authorities in ensuring public safety.
5	We seek views on the above recommendation, that the adoption of 5G private networks will benefit the Oil & Gas industry and the nation thus grant them permission to operate 5G network independently due to the nature of their business.
6	We seek views on the above recommendation that connected vehicles will increase transportation safety and improve the environment by leveraging 5G technology for massive machine communication.
7	We seek views on the above recommendation that the adoption of 5G-connected ambulance services can improve emergency medical care and the probability of better patient outcomes.
8	We seek views on the above recommendation that 5G technology will bring a positive impact on the agriculture sector and help to optimise resources.
9	We seek views on the above recommendation that 5G-supported AI and Data Analytics will be integrated and embedded into production systems and manufacturing environments to enhance and improve productivity.
10	We seek views on the above recommendation that 5G will enable Malaysians to communicate with their banks in a more secure and proper way
11	We seek views on the above recommendation that 5G-supported personalised advertisements and indoor GPS will enhance user experience

Section 2: Spectrum	
12	a. We seek views on the recommendation positioning 3.5GHz and 26GHz/ 28GHz as the Priority 1 spectrum bands for Malaysia's 5G deployment Are there any other spectrum bands that could be considered as Priority 1? b. We seek views on the proposed spectrum allocation timeline
13	We seek comments on the recommendation for 3.5GHz re-assignment and the interference mitigation approach for both local and cross-border scenarios
14	We seek comments on the recommendation that 26GHz/ 28GHz be allocated for 5G and the approach or limitations for each spectrum band
15	We seek comments on the proposal for Priority 2 spectrum bands
Section 3: Infrastructure	
16	We seek views on the likely radio deployment models for 5G in Malaysia including the degree of 'densification' to be expected in urban and rural areas
17	We seek views from the public on whether the list above captures the key challenges for 5G deployment, and proposed solutions (Note that regulatory and policy interventions to overcome some of these challenges are covered by separate questions in the Regulatory section)
18	We seek views on the suitability of different types of structures to support smooth 5G rollout in Malaysia including the level of street furniture deployment expected
19	We seek views on the likely timing and compelling use cases for Mobile/Multi-Access Edge Computing in Malaysia.
Section 4: Regulatory	
20	We seek views on the recommendations set out to ensure sufficient resources and promotion of sustainable investment. Are there any other important areas that should be considered by the government?
21	We seek views on the recommendation to facilitate timely infrastructure deployment, as 5G is expected to require additional infrastructure in new forms. Are there any other important areas that should be considered?
22	We seek views on the recommendation to ensure secure 5G implementation. Are there any other important areas that should be considered by the government?
23	We seek views on the recommendation to ensure safe 5G implementation. Are there any other important areas that should be considered by the government?
24	We seek views on the recommendation to assess the sectoral regulatory settings needed across the identified use cases verticals

Appendix 2: Use Cases (Business Case Working Group)

Appendix 2.1 Agriculture

Lead: Mr Mohd Kamal Arifin Ibrahim, Malaysian Palm Oil Council (MPOC)

Malaysia Gross Domestic Product (GDP) grew 4.5%[21] in the second quarter of 2018 which shows decline from the previous quarter at 5.4%. Both Agriculture; and Mining & Quarrying sectors contributed to this decline in GDP performance. The Agriculture sector consists of three sub-sectors; mainly Crops, Livestock and Fisheries. In 2017, the Agriculture sector has contributed RM96 billion or 8.2% to the national GDP. At 46.6% Oil Palm was them major contributor to our agricultural GDP followed by other types of Agriculture (18.6%), Livestock (11.4%), Fisheries (10.5%), Rubber (7.3%); and Forestry & Logging (5.6%).

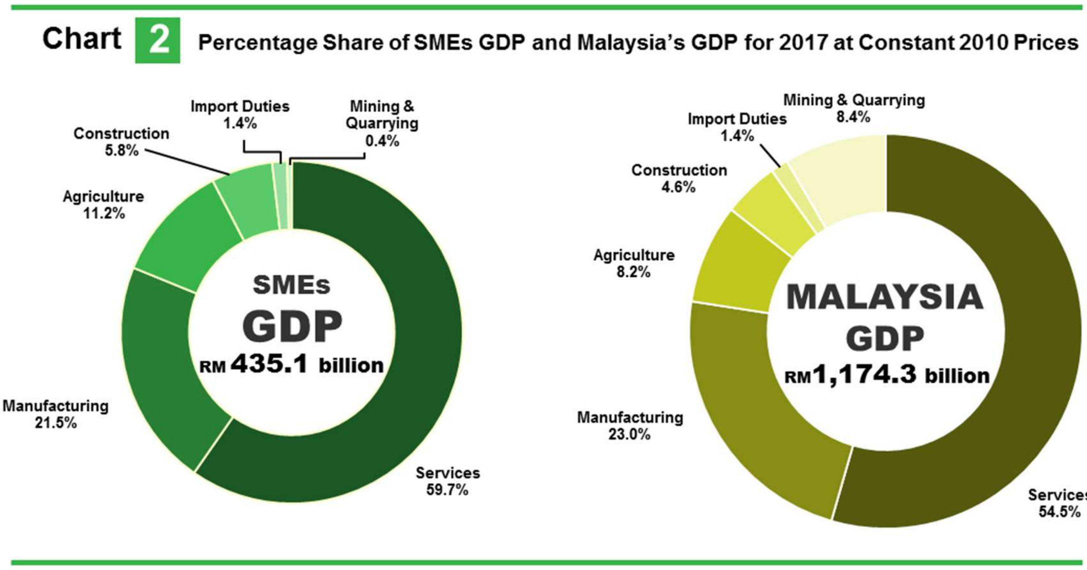


Figure A2.1: Percentage Distribution by Type of Economic Activity; Source: Department of Statistics

21 Department of Statistics Malaysia. As seen in Dec 2019. https://www.dosm.gov.my/v1/index.php

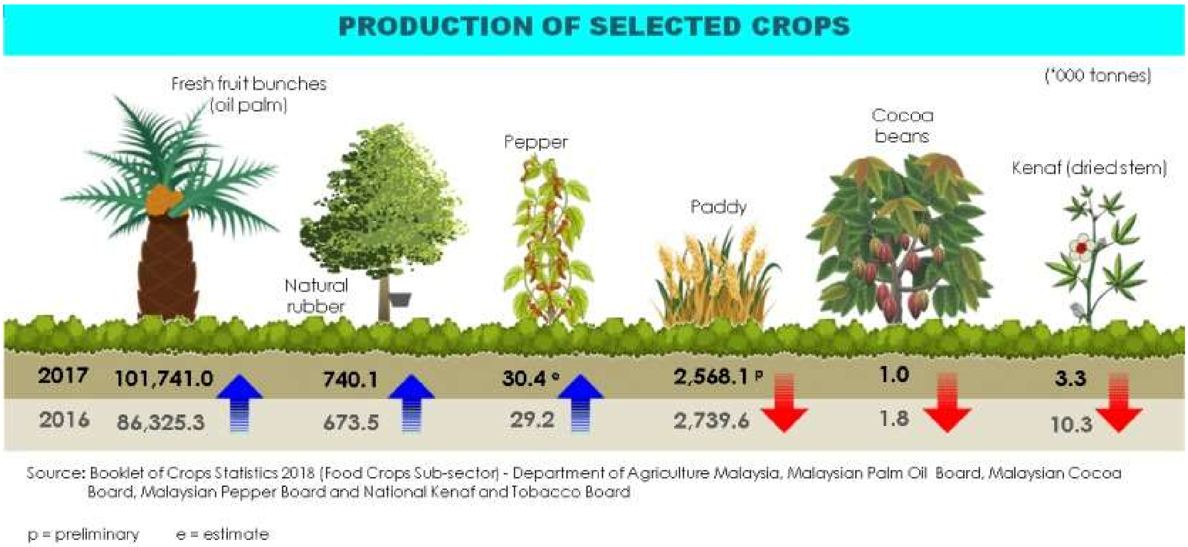


Figure A2.2: Production of Selected Crops

In 2017, a total of 33 Agricultural commodities were observed and 16 of them recorded Self-Sufficiency Ratios (SSR) of more than 100%. These selected Agricultural commodities were divided into three categories; Crops (Fruits and Vegetables), Livestock and Fisheries. Based on below SSR diagram, Fruit crops like Starfruit, Papaya, Jackfruit, Sweetcorn, Pineapple, Banana and Watermelon showcased more than 100% SSR. Other crops which retained more than 100% SSR include vegetables (Spinach, Lady’s Finger, Long Bean, Binjai, Cucumber and Tomato) Livestock (Chicken and Duck Egg) and Fisheries (Cuttlefish and Shrimp).

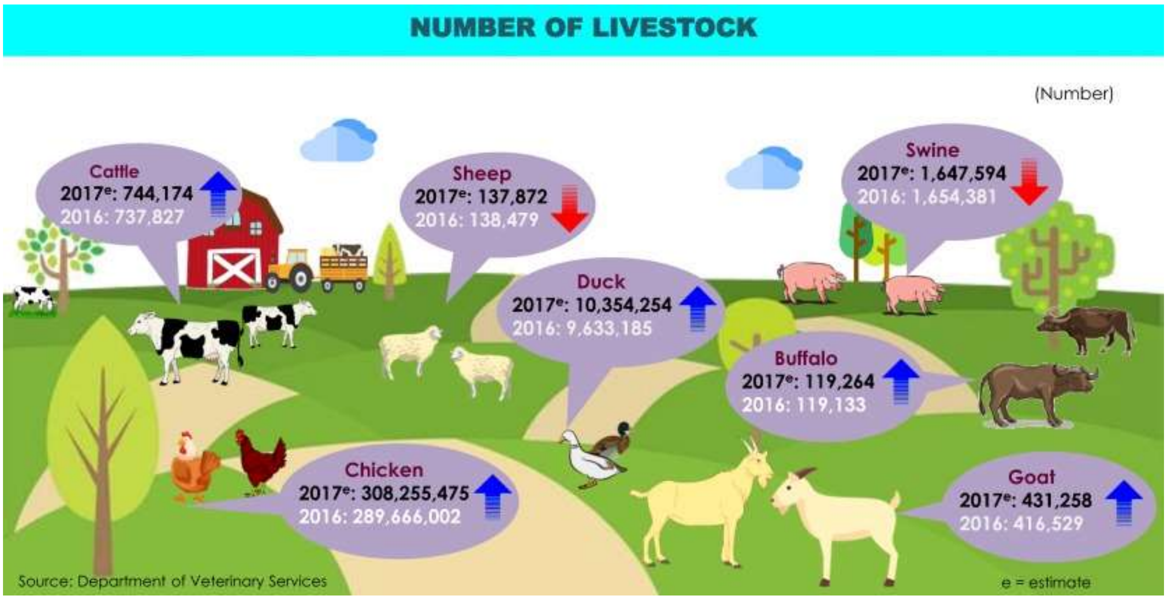


Figure A2.3: Number of Livestock

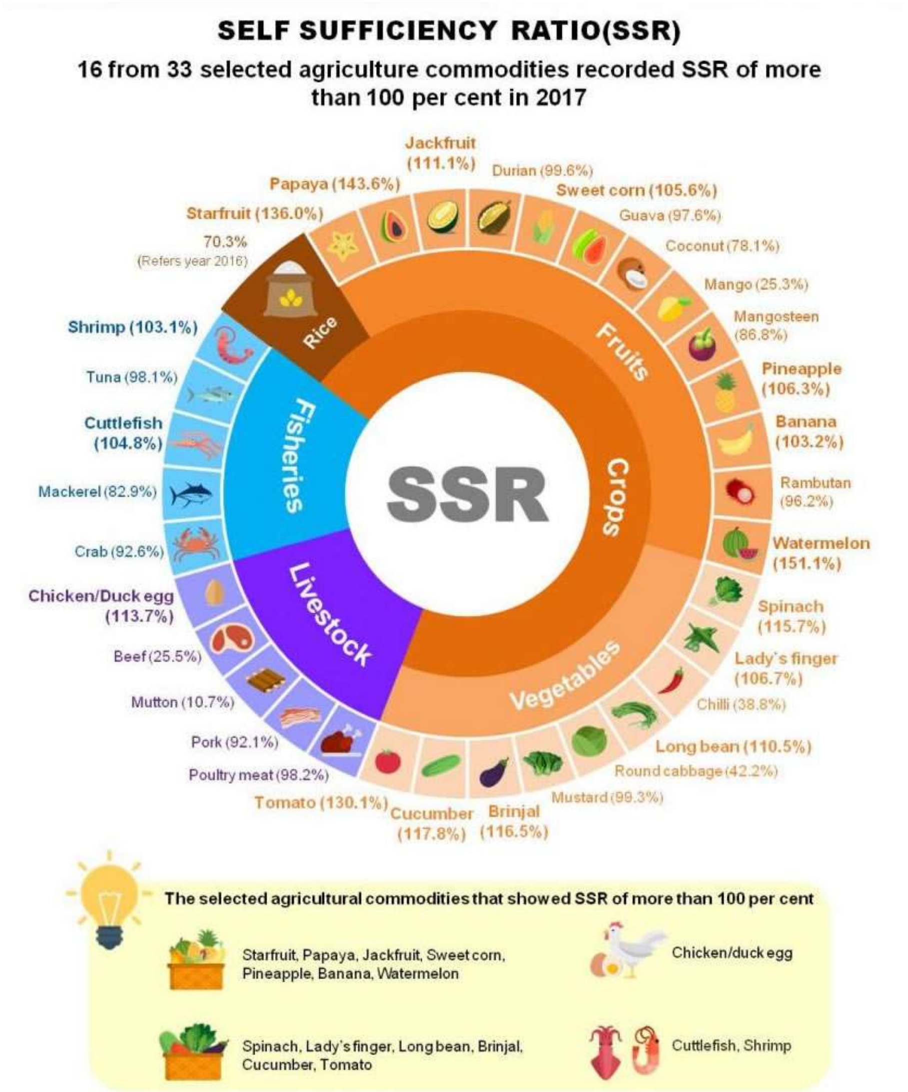


Figure A2.4: Self Sufficiency Ratio (SSR); Source: Department of Statistics Malaysia

Rice production is crucial in Malaysia as it is a staple food for the country. In 2018, 740,000 tonnes of rice were imported which cost about RM1.18 billion. Based on the 2017 SSR diagram, rice's SSR is still below 100%. The target is to increase rice production's SSR to 75%, within the next three or four years as set by minister. Adoption of digital solutions like data-driven precision farming may assist in rice production.

Apart from food crop, industrial crops like Palm (for oil) contributed almost half of agriculture's overall national GDP in 2017. The increase of production in 2017 resulted in 101,741.0 thousand tonnes of yield, a 17.9% increase from 2016. Studies shows that implementing technologies such as field monitoring application can increase yield production of oil palm as precision farming comes into play.

Implementing modern technologies in the Malaysian agriculture landscape can lead to several positive outcomes such as:

- Increase in profits and reduction in risk
- Enhanced efficiency at every stage in the agricultural value chain
- Reduced labour costs and eliminated wastage
- Creation new job opportunities in the agricultural sectors

The adoption of proposed smart farming techniques enabled by 5G in this business plan will result in an estimated 5% increase of yield/productivity for our agriculture segment, thus contributing RM9.6 billion to Malaysia's GDP.

Appendix 2.2: Banking & Finance

Lead: Ms Charmayne Ong Poh Yin, SKRINE

Banking, financial and insurance offerings ensures Malaysians are able to save, borrow and invest money to protect themselves from financial losses. The sector is also driven by a huge workforce, so there will always be a constant demand in various sectors.

With the evolution of technology and mobile communications, more banking and financial institutions (FI) are looking to enhance their digital presence. Currently, some of the most common activities conducted via online banking are account/ statement checking and fund transfers, but more Malaysians are expected to adopt online banking with the introduction of functions such as fixed deposit placement, account opening, online trading, etc. Whilst these functions may already be available with 4G, 5G will force the banks and financial institutions (as well as insurers) to rethink their services so that they can incorporate newer channels such as 5G-capable smartphones, wearables, IoT devices, AI-powered devices, and VR/AR.

Use Case 1: Digital Banking

1. **Banking the Unbanked**

   Due to the geographical diversity in Malaysia, access to financial institution branches presents a challenge to certain communities. According to the Global Findex Database 2017 by the World Bank Group, 85% of Malaysia's population aged 15 and above reported having an account at a financial institution. Among the respondents without such an account, 31% reported that the reason for not having one was that the financial institutions were too far away. Access to financial services must be more readily available to cater for the constant and growing need to transact, borrow, invest, and save money. Better access to financial services will then increase opportunities for Malaysians to grow their businesses, facilitate trade and improve financial literacy.

   The role of machine learning and advanced analytics will vastly increase with 5G's ability to handle this complexity. 5G with its advanced data analytics can allow innovations in credit scoring. Instead of relying on traditional credit information, solutions such as psychometric analysis, social media usage analysis and other novel Know-Your-Customer (KYC) methods can be used. Advanced data analytics can also allow them to develop new products based on predictive models that are more suitable for the rural community.

2. Improved digital banking experience

According to the Global Findex Database 2017[22], only 32% of the Malaysian population aged 15 and above reported using a mobile phone or the internet to access a bank or financial institution account. Furthermore, only 10% reported paying utility bills using a mobile phone.

With 5G, financial institutions will be able to leverage uRLLC and the eMBB capabilities of 5G to deliver a more seamless digital banking experience[23] to customers. This can include the opening of bank accounts, the use of e-wallets and more.

It is anticipated that common network issues that hinder existing technology such as connection time-outs or slow response times will be eliminated with 5G. This will encourage more customers to open bank accounts online, including the provision of necessary documents (e.g. National Identity Card or IC, Passport, relevant statements, etc.) digitally. This would greatly facilitate the banks in carrying out validation procedures such as KYC and Anti-Money Laundering (AML) procedures more quickly, e.g. conducting effective live KYC and AML procedures over video conferencing. Customers can also receive prompt and speedy updates on their applications.

With more connected smart devices and increased consumer spending via e-wallets, faster and more secure networks will allow financial institutions to perform real-time data analytics, which provides the customer with highly personalised content and curated offers. 5G-enabled real-time analytics will also effectively enable financial institutions to detect fraud cases quickly and implement early prevention.

To encourage the adoption of mobile banking and mobile payments, financial institutions can also leverage 5G to build and provide 'lighter' and more seamless mobile applications that can deliver the same or more financial services to the customers, eventually eliminating the need to download an application entirely. With the bulk of applications running on the cloud, financial institutions can also dramatically decrease the frequency of updates users are required to download.

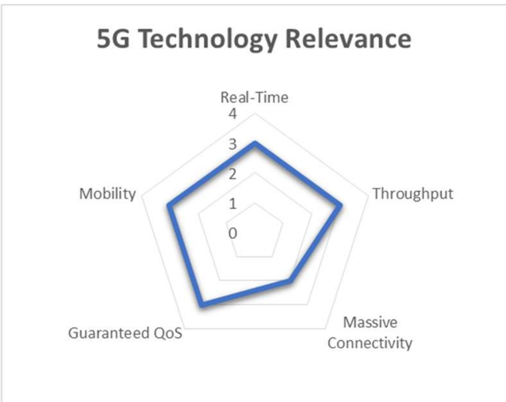


Figure A2.5: 5G Technology Relevance

[22] World Bank. 2017. https://globalfindex.worldbank.org/
[23] Institute for Development and Research in Banking Technology. 2019. https://www.idrbt.ac.in//assets/publications/Best%20Practices/2019/5G_2019.pdf

Use Case 2: Remote Teller

With 5G, banks can offer remote services to customers such as robo-advisors (AI-based financial or investment advisors with minimal human intervention) or digital connection with officers instead of face-to-face interaction, essentially allowing for services to be rendered 'anywhere', 'anytime'.

While this is already possible with 4G, a more streamlined video-conferencing[24] experience may have to wait until the 5G era.

Once customers are connecting digitally, a human could even help them with a complex problem using virtual reality. For example, a financial adviser could walk a client through complex asset allocations, with both looking at a dashboard[25]. VR and AR headsets are already available, but 5G is the only way they can be used smoothly on a mobile network and in conjunction with other network-enabled devices. High-speed bandwidth is required, otherwise latency in the experience would cause nausea. Furthermore, cloud services will allow these devices to be made thinner and smaller. Another use case for 5G is real-time language translation that could be embedded in an application for smartphones, tablets, PCs, or kiosks[26], which will facilitate dealings with international customers that pose language barrier issues.

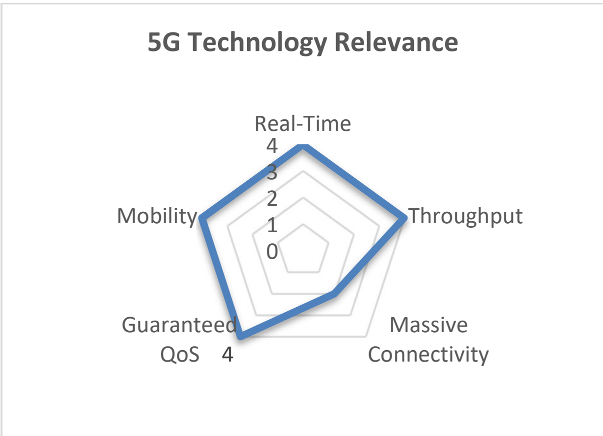


Figure A2.6: 5G Technology Relevance

[24] American Banker. Apr 2019. How 5G could shape the future of banking

[25] Lifewire. 2019. *5G Changes Everything*. https://www.lifewire.com/5g-use-cases-4261046

Use Case 3: Mobile Trading

5G's ultra-low latency and high bandwidth offer an opportunity for an essentially zero waiting times and seamless transactions. Orders placed can be executed at real-time speeds. Where fractions of seconds can make huge differences worth millions of dollars, 5G's ultra-low latency of 1ms will prove irresistible in mobile trading.

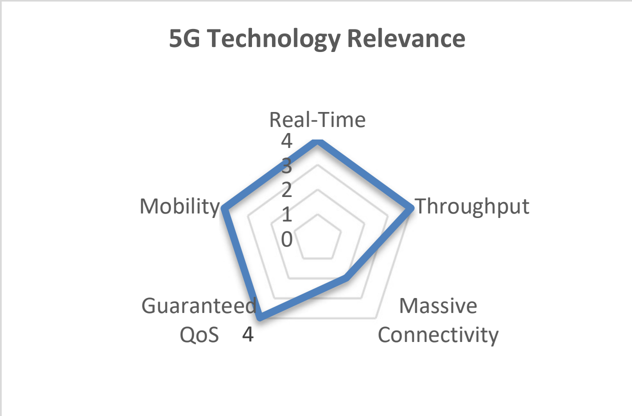


Figure A2.7: 5G Technology Relevance

Use Case 4: Insurance and Takaful

The long and complex information gathering process underwriters must go through before making decisions on risk acceptance has always a challenge, particularly for specialised industries such as engineering, commercial properties, etc. Moreover, poor quality information could lead to riskier approvals.

5G-enabled IoT devices can assist in providing real-time and higher quality information for underwriters when accepting risk or providing quotes. With uRLLC and eMBB, 5G-enabled risk prevention devices can feed large amounts of information in real-time. Examples include IoT enabled ovens that warn the customer of the likelihood of a fire, devices can track shipments in real-time, instant uploads of medical information from doctor's offices, and smart vehicles that send real-time accident information to companies. As wearable 5G-connected healthcare devices gain popularity, health insurers could offer "positive reinforcement" policies, where premiums would be reduced if a certain level of activity or fitness is maintained.

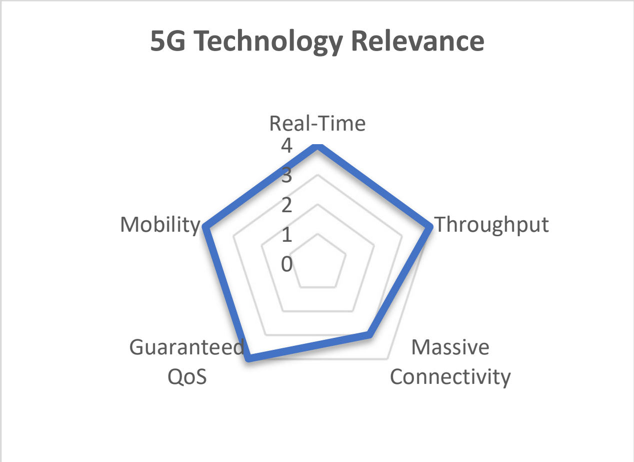


Figure A2.8: 5G Technology Relevance

2.2.5 Proposals to Encourage 5G Adoption

- Streamline regulatory conditions to facilitate 5G deployment.
- To adopt the PPP (Public Private Partnership) Model: Government and private funding—public/industry as end-user.

Appendix 2.3 Digital Healthcare

Lead: Ms Aida Basri, Collaborative Research in Engineering, Science & Technology (CREST)

Malaysia operates a two-tier healthcare system consisting of both a public-based universal healthcare system and a private healthcare system. Malaysia's healthcare market is expected to grow by 127% from RM56.3bil in 2017 to RM127.9bil in 2027[27]. Lowering healthcare costs and providing effective care for the masses are key concerns in the healthcare system. With the introduction of 5G, new efficiencies such as creating self-management capabilities, facilitating access to healthcare and minimising costs is expected.

2.3.1 5G Technology Drivers in Healthcare

Healthcare is a fast-expanding market that has introduced applications[28] that utilise sensor devices running on existing technologies such as Wi-Fi, Bluetooth, and low power related technologies. As this market matures, sensor-based applications will fuel the growth of Massive-Machine Type Communication (MMTC)[29]. The next wave of innovation—Tactile Internet[30] and Emergency Medical Services[31]—will spur the need for uRLLC in combination with high availability, reliability, and security.

Key 5G technology drivers in healthcare

a)Internet of Medical Things (IoMT) Devices

b)management of massive amount of data created by IoMT devices (wearables, implantable medical devices and smart sensing remote/in-house monitoring devices)

a)Tactile Internet

b)2-way interaction such as tele-diagnosis, tele-surgery and tele-rehabilitation places a special premium on millisecond level latency and immediate response times

a)Critical Healthcare Communications

b)remote monitoring of heart rate and blood glucose levels, temperature interworking with Quality of Service (QoS) mechanisms to reserve capacity for critical communication

a)Emergency Medical Services

b)remote medical treatment-assistant system enables ambulance services communicating back to nodal hospital with relevant patient information like high resolution images/videos in timely manner

[27] The Star. 2018. https://www.thestar.com.my/business/business-news/2018/12/04/malaysias-healthcare-market-to-reach-rm127pt9b-by-2027-says-fitch-research
[28] Berkeley Research Group & Qualcomm. 2017. *5G Mobile: Impact on the Health Care Sector*
[29] Ericsson, Huawei and Qualcomm. 2015. https://www.huawei.com/minisite/5g/img/GSA_the_Road_to_5G.pdf
[30] ITU-T. 2014. *The Tactile Internet*
[31] Big Data and Cognitive Computing. 2017. *A 5G Cognitive System for Healthcare*

1. **Data Analytics**
   Various parameters such as user location, services used, signaling information, and applications in use form a composite and large data[32] set which needs to be processed and handled. This gives rise to new models and use cases that range from data extraction, data formatting, storage, and presentation. Through data mining, feature extraction and data analysis, potential diseases could be screened in advance based on medical and health data collected by various IoMT in hospitals and home environments.

2. **Data Privacy and Security**
   Privacy and security[33] of patient data is of paramount importance and necessitates adoption of specialised mechanisms. Different levels of protection need to be applied to meet the various communication and security requirements of 5G use cases in healthcare.

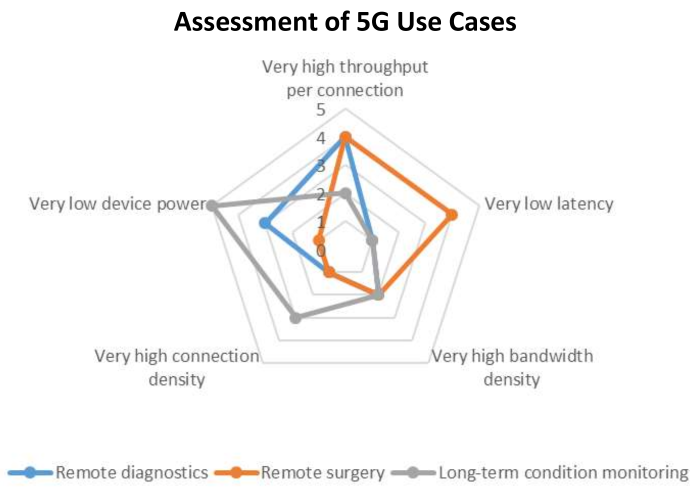


Figure A2.9: Wireless network requirements for future health applications; Source: GSA

2.3.2 Socio-Economic Impact

1. **Personalisation of healthcare**
   5G will usher in an era of personalised healthcare[34], empowering patients with the ability to better manage their health and medical conditions. Personalisation of healthcare can be both predictive and preventive[35], offering improvements in well-being and quality of life. It also offers cost savings and productivity improvements to both patients and healthcare providers.

2. **New business opportunities**
   Advances in health informatics, fueled by 5G, will facilitate a shift in the way healthcare is delivered and create new business opportunities. According to David J Teece (Haas School of Business, University of California), IHS calculated the "sales enablement" effect of 5G on sectors related to healthcare as follows: (next page)

[32] Institute of Electrical and Electronics Engineers. 2019. *The Path to 5G for Health Care*
[33] Cleveland Clinic Journal of Medicine. 2012. *Building an Innovative Model for Personalized Healthcare*
[34] 5G Americas Whitepaper. 2017. 5G Services & Use Cases
[35] 5G Infrastructure Association. 2015. *5G and e-Health*

Sales enablement due to use of 5G in healthcare industry, 2035 ($ billions)

A. Sales enablement in "use" sectors	US$ 253
B. Final vertical sales enablement % of healthcare industry sales	US$ 453 3.1%
C. Supply chain enablement	US$ 409
D. Total sales enablement from "Healthcare" 5G % of $ 12.3 trillion 5G sales enablement	US$ 1,115 9.06%

Figure A2.10: IHS Economics/IHS Technology

IHS calculates:

- US$253 billion for industries that process or add value to healthcare data. These industries include insurers, providers of data analytics and providers of cloud-based data services.
- US$453 billion in the healthcare vertical that includes hospitals, doctors, medical equipment manufacturers and the pharmaceutical sector.
- US$409 billion for the "supply chain". For example, increased sales of IoMT[36] devices also mean increased sales for semi-conductor companies.

These sales enablement calculations illustrate significant economy-wide impact from deployment of 5G in the healthcare vertical. These sales enablement calculations are, however, a substantial understatement of the true economic impact of 5G.

3. Research and Innovation

According to the 5G Infrastructure Association in Belgium, the following technical areas are predicted to be of particular interest in terms of research and innovation related to 5G use cases in healthcare:

- Improvement of massive MTC capacity in terms of density of connected objects per area and to extend indoor coverage and in rural areas.
- Improvement on latency to fulfil an upper latency bound limit to be usable for remote surgery.
- Reliability boost which can match existing wired solutions but also supersede them by e.g. using the inherent flexibility of 5G to improve reliability of mobile communication substantially.
- Energy consumption optimisation where advanced MIMO and beamforming techniques could help to focus the energy usage where it matters
- Security mechanisms related to identity management, privacy protection, and data encryption.
- Interdisciplinary and evidence-based trials of IoMT are required to ensure quality of design, appropriate recommendations on the use and data confidentiality. Meanwhile, development of human capital and fostering entrepreneurial spirit are essential elements to match technology innovation with societal and business challenges.

[36] International Journal of Education and Information Technologies. 2017. *Some new services and network architectures and educational results in the Internet of Medical Things (IoMT)*

Appendix 2.4 Education

Lead: Ms Norizan Harun, Ministry of Education (MoE)

Whilst this study is a business case study for 5G implementation, we should remind ourselves that benefits of mega-speed broadband as depicted by service provides has already been achievable via fibre optics technology which exists in our lives today. When it comes to education, mega-speed broadband alone doesn't complete the requirements, because hardware compatibility needs to be considered.

This report focuses on the impact of 5G should it be implemented, and the current standing of connectivity in Malaysia's government-based education infrastructure for higher education and schools. Whilst it is obvious that increase in speed and throughput of broadband will benefit the education sector, achieving it with a restricted budget is another issue altogether. Hence evolution of telecommunications technology has never been spelled out for education or consumership in most 5G use cases because the benefits is a given.

Therefore, this report executes a stock take of current infrastructure in place for government education facilities, the pain points that 5G could assist in reducing, and policies or regulations should 5G come into play in educational facilities.

2.4.1 Narrative

A study was conducted in Class 1 Farabi, SMK Putrajaya Precinct 16 (1) with the objective of discovering the pain points that may arise from applying digital education in Malaysia's secondary schools, especially in regard to connectivity. From this, the study should derive the potential gaps in connectivity that could be filled by 5G technology.

Environment & assumptions:

1. Bring Your Own Device (BYOD) Policy—students bring their own devices, opening possibilities of personal data plans.
2. No internet supply in classrooms.
3. Students' access within classroom parameters are governed by an MDM (Mobile Device Management) system.

Going down this route, if classes are not wired up by broadband fibre, perhaps private 5G will be the main source of high throughput connectivity for use of rich media content by students in the future.

With contemporary wireless setups via 4G LTE infrastructure, mass connectivity cannot be achieved, especially considering the entire school's student body will also use their personal data plans from the same ISP.

The current setup of telecommunication towers can only cater to laboratories and the staff room, but won't support classroom connectivity for the entire student body. In other words, current methods of internet supply were never designed for classroom connectivity and does not take into account mass connectivity for schools.

Moving ahead, the study committee suggests that for connectivity in secondary education, fiberisation will be the ultimate future-proof solution. However, due to costs of setting it up and the time constraints inherent in the fiberisation process, wireless technology that can bring substantial broadband throughput and mass connectivity, and 5G is pivotal in realising those needs.

Plans moving ahead require 5G technology to be built as a last-mile solution for broadband at schools so that cost for fiberisation can be relaxed, and so that ISP for 5G in and around school areas can be scheduled with a throughput to cater the needs of schools during the day, and perhaps for the public at night.

Should the current method in using Wimax and 4G LTE with limited mass connectivity is maintained, usage of data plans on mobile will not be realistic and efforts in encouraging connectivity in schools will be dampened.

Recommendations and Strategies Approaching 5G

1. **Policies and standards to ensure cybersecurity.**

   Where public schools are concerned, the government has a duty to protect the data of the youth that attend public education from any forms of vulnerability or manipulation. While security measures are put into place for physical exposure of school children, policies and standards must be considered when implementing digital and internet exposure at schools be it via fibre broadband, or 5G.

   The risk of digital exposure does not necessarily refer to vulnerabilities in just software alone, but more critically, may appear as spyware or tracking instruments that are placed directly into hardware and backbone infrastructure. As technology continues to improve at its rapid pace, the telecommunication backbone may require constant upgrades in performance and thus opening doors for data vulnerabilities. Policies and standards will have to be put in place to hinder any form of data phishing or spying in the education system.

   For example, sooner or later, school premises will be involved in 4G to 5G migration, and it is at this point that new hardware, backbone and transmitter infrastructure will have to be installed, potentially exposing institutions to vulnerability. Since data is so valuable for the development of big data and artificial intelligence, many parties, local and foreign, are willing to go that extra distance into the unethical line to acquire data.

   Therefore, some recommendations for 5G implementation for public education purposes are:

   - The government via agencies such as Ministry of Education, SIRIM, MCMC, and more to draft standards, tests as well as monitoring mechanisms to eliminate foreign components that allow storing and transmitting data outside of the norm of 5G backbone.
   - Government via agencies such as Ministry of Education, SIRIM, MCMC and Energy commission to draft standards and tests, for hardware which are implemented for schools be it for 5G compliances or other reasons.
   - Government to form policies that will take more control over installed telecommunication towers at schools—overcoming land and permit disputes with local authorities, resolve service provider conflict, and set up land or even backbone providers for telecommunication technology for 5G, as well as future generations.

2. **Standards and planning for connectivity at schools: Urban schools to use fibre broadband, remote schools to use data broadband (cellular).**

At a glimpse, 5G may bring cost benefits in rural areas, where fibre seems to be costly. The Ministry of Education's (MOE) position is that for longevity of broadband access for schools, it makes long-term sense to plan for fibre optics implementation. However, whilst fibre optics is far more challenging to install because of land permissioning complexity, and costly last-mile setups due to router cabling at schools—other solutions may be more sensible for school terrains which face fibre cabling issues.

Using telecommunication transmitters which have a longer-term expansion plans that are supported by 3GPP and IEEE such as 4G LTE or 5G can be seen as a more realistic approach. However, there are many factors that must be considered in these calculations, namely cost for bridging the network via towers to these less urban areas. In some very remote school locations, the possibility that Very Small Aperture Terminal (VSAT) comes into play is still unavoidable for now as it does not bring economic sense to implement even the bridging telecommunication towers to these areas. To ease these contributing factors, clear standards on how to approach a better throughput and mass connectivity should consider:

- Form aggregation standards for network solution providers—blending of fibre optics for WiFi, WiMax, 3G, 4G and 5G where suitable.
- Clear roadmap for the digitisation of classrooms and other school environments entering 5G era (5 – 15-year plan).

Appendix 2.5 Manufacturing & Process Industries

Lead: Mr Martin Mueller, Mawea Industries Sdn Bhd

Over the last five years, the Fourth Industrial Revolution (4IR) initiative gained momentum for its purpose of increasing production efficiency, create new business opportunities, and enable ubiquitous high data rate wireless connectivity for factories. In doing this, the main scope will be to achieve an optimised utilisation[37] of resources such as machinery, energy, real-time process data and human expertise. In fact, production cycles need to be drastically shortened to cater to very small, yet diverse production lots and fast changing customer requirements. However, the drawback of this solution is that short cycles bring new complexity and flexibility that is difficult to handle with current wired/wireless technologies. Therefore, new solutions in terms of communication technologies are required to cope with such requirements and guarantee more reliable and low latency performance.

Industrial automation can be divided into two categories:

Process Automation

Includes all applications that deal with monitoring and diagnostics of industrial elements and processes like heating, cooling, mixing, stirring and pumping procedures.

It is worth noting that these actions are generally tolerant of latency requirements (e.g. can be between 100ms and several seconds) since measured values change relatively slowly. However, there are sensors such as vibration sensors that require Ultra Low Latency data acquisition as the sampling rate can reach up to 20 kHz.

Factory Automation

Typical applications are those involving real-time control and monitoring of machines in the scope of enabling fast production and manufacturing.

Up until very recently, these types of applications only garnered interest from niche groups and thus, the mobility of objects/machines/users is limited or almost stationary. Hence, measurements and control commands need to be applied faster (less than 10ms) and apply fail-safe transfer of sensor and actuator signals.

[37] Institute of Electrical and Electronics Engineers. 2018. https://futurenetworks.ieee.org/images/files/pdf/applications/Factories-of-the-Future-Enabled-by-5G-Technology_030518.pdf

Use Case 1: Predictive Maintenance Using AI

Predictive maintenance is one of the key factors that manufacturers focus on to optimise their resources. This includes manpower, tools, spare parts, and material for the whole production environment.

One aspect is the sheer variety of IoT sensors, ranging from vibration sensors, temperature sensors, humidity sensors, etc. that can generate permanent data for analytical systems such as Manufacturing Operation Management (MOM) or Advanced Planning and Scheduling (APS). These systems have algorithms implemented that will optimise production and minimise downtime. Furthermore, low latency data communication between machines can be established.

The other area of consideration is the usage of high-density data, such as Ultra High Definition video streaming. By using Ultra High Definition (UHD) cameras connected to 5G, combined with machine learning algorithms, future maintenance can be better predicted for various applications.

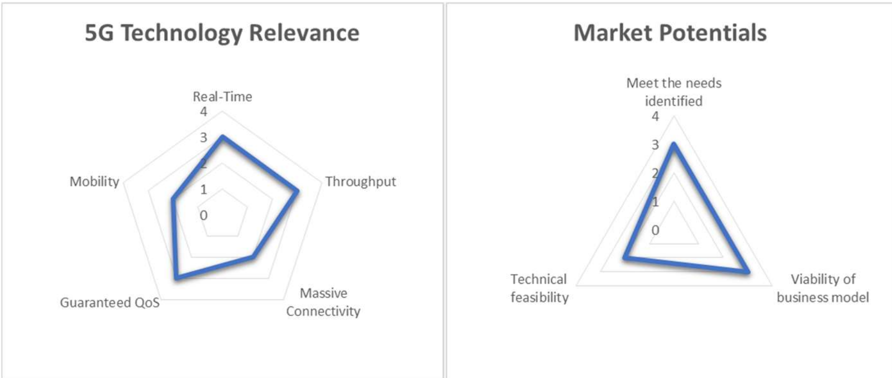


Figure A2.11: Predictive Maintenance

Use Case 2: Software Applications besides AI

Beside AI, two other software applications have been identified. Under this aspect, the complete infrastructure must be considered. Overall, we observe a tendency towards cloud applications which grants access to different business models in the industry, with great economic benefits for companies.

Use Case 3: Engineering Applications (CAD, CAM, and CAE) and Enterprise Solutions (ERP, PLM, APS and MOM)

As for engineering services, Computer-Aided Engineering (CAE), also known as Finite Element Analysis (FEA) requires high computational power and huge data transmissions between client and server. On the other side, Enterprise Solutions enable collaboration and allow companies to operate on a digital platform.

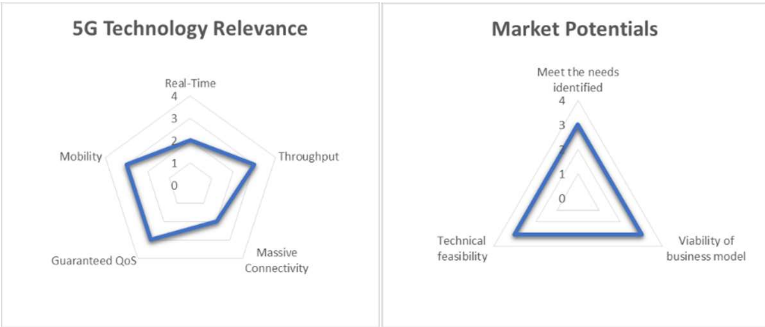


Figure A2.12: Engineering Applications

Use Case 4: Enhancing Utilities Infrastructure

As interest into 5G technologies and applications for manufacturing and process industries increases, there is a growing demand to develop and ensure enhancements in utilities infrastructure for the industrial sector.

Use Case 5: Managing Power Distribution Networks

Managing power distribution networks with an increasing amount of distributed energy resources and an increasing need of flexibility requires advanced technology for protection, control, and monitoring. 5G-powered uRLLC technology provides an affordable communication platform for deployment of these advanced technologies. Successful trials show that uRLLC technology can be applied to protect applications in medium-voltage distribution networks. It is of the utmost importance that severe faults are cleared immediately to keep the distribution network running, guaranteeing the safety of personnel, and avoiding damage to equipment.

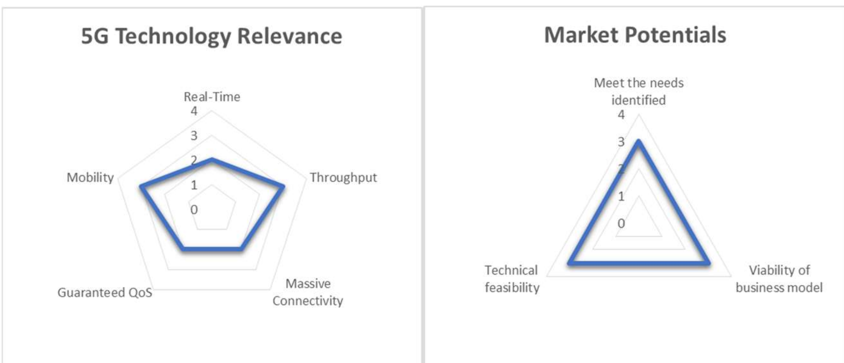


Figure A2.13: Managing Power Distribution Networks

Use Case 6: Warehouse and Logistic Industries

The warehouse and logistics industry form the backbone of the supply chain and recognised as the key for stimulating trade, facilitate business efficiency, and spur economic growth. It is also vital to the connectivity to the rest of the world and the nation's competitiveness.

Use Case 7: RFID tracking in Warehouse: Logistics Application

One of the major challenges in warehouse management is stock control[38]. Companies have to find a good balance between stock and minimising capital investment. Increasing traceability costs money, but overstocking binds valuable capital into the warehouse.

Logistics players like liners, freight forwarders, and hauliers are transporting large amounts of cargo daily, and much of the cargo actually require tight monitoring to ensure they are being transported safely, and with full compliance with technical conditions, the latter in reference to high value cargo and perishable cargo. Emerging IoT solutions with real-time location tracking and condition monitoring capabilities require high-speed and consistent data transfer to enable a continuous and granular way of tracking. Data transmission requires various types of data, such as GPS coordinates, temperature, humidity etc. to ensure that goods have been handled with care.

Figure A2.14: RFID tracking in Warehouse

[38] McKinsey. 2016. *Where machines could replace humans—and where they can't (yet)*

Overall Summary for the Manufacturing and Process Industry

Various use cases that are related to the sector of manufacturing and process industry demonstrate the benefits of having a 5G infrastructure in Malaysia. During these studies another important point has be discussed that has to be considered for 5G implementation. First of all, the specific use case has to be differentiated as either mobile or static. Many static use cases are solvable with fiberisation as the object is not moving. With that being said, there are static use cases that would incur too much fiberisation costs, and thus 5G would be a more economical solution. For mobile use cases, 5G is the way forward as it will provide fibre-like connectivity.

The differentiation between static and mobile must be made to better anticipate investments into fiberisation and the number of 5G sites that need to be set up.

The social effect that may arise from automation and digitisation is challenging to fully predict at the time of writing. Based on a research carried out by McKinsey Digital, many activities in different industry sectors technically hold the potential for automation. However, there are various constraints, such as technical feasibility, the costs to automate, the relative scarcity, skills necessary and cost of workers who might otherwise do the activity, the benefits (e.g., superior performance) of automation beyond labour-cost substitution and regulatory and social-acceptance considerations.

Appendix 2.6 Oil and Gas

Lead: Assoc Prof Dr Wong Peng Wen, Universiti Teknologi Petronas (UTP)

Oil and Gas is one of the core industries in Malaysia, contributing 18% of National GDP. Legacy oil and gas networks were not designed to support the high volumes of real-time data generated by massive Internet of Things (IoT) and Machine-to-Machine (M2M) systems with a high quality of service. Much of the equipment currently in use are either approaching or past end-of-life. The adoption of 5G technologies will enable the digital transformation of oil-fields resulting in improved operational efficiency, predictive maintenance, better workforce efficiency and safety, asset optimisation, and increased revenue. Real-time monitoring, and data analytics are crucial for the success of this industry, as efficiency and accuracy are highly valued in the oil and gas industry—perhaps more than any other industry. Small improvements in efficiency can make a notable economic difference. Profit generated in the oil and gas industry is dependent on prompt and accurate production of data. With massive IoT integration, oil production can be captured in real-time through embedded sensors, and the right automation of data communications systems enables companies to gather information from assets anywhere and make informed decisions.

Use Cases in Upstream & Downstream Examples:

Use Case 1: Enhanced Exploration & Production Performance

5G enables big data transfers from distant remote locations to an Integrated Operation Center which facilitates a collaborative working environment for instant and precise decision-making. Seismic, drilling, and production data can be instantaneously shared across various disciplines, which allows for application of cost optimum methods in delivering the hydrocarbon. For example, companies can adapt their drilling and chemical injection strategies after observing real-time down-hole drilling data from production wells. According to Bain & Company[39], this level of visibility can help oil and gas companies improve production by 6% – 8%. The figure can be translated into increased revenue of US$1.05 billion[40].

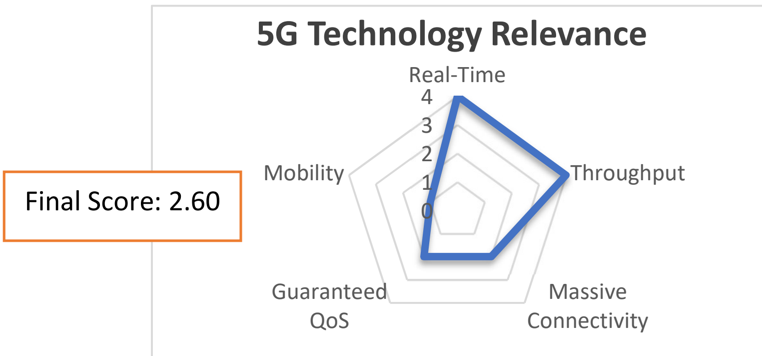


Figure A2.15: 5G Technology Relevance of Enhanced Exploration Use Case

[39] Bain & Company. 2014. *Big Data Analytics in Oil and Gas*

[40] Department of Statistics Malaysia. As Accessed in 2019. https://www.dosm.gov.my/v1/

Use Case 2: Enhanced Plant Performance & Efficiency

5G technology offers plants high network availability, enabling personnel and/or devices in the field to have constant connectivity with people and assets while they are working out in the field. Plants will be able to use real-time and historical data for predictive analysis to improve operational efficiency and productivity. This can be achieved through big data and analytics to detect anomalies and predict previously unforeseen machine upsets.

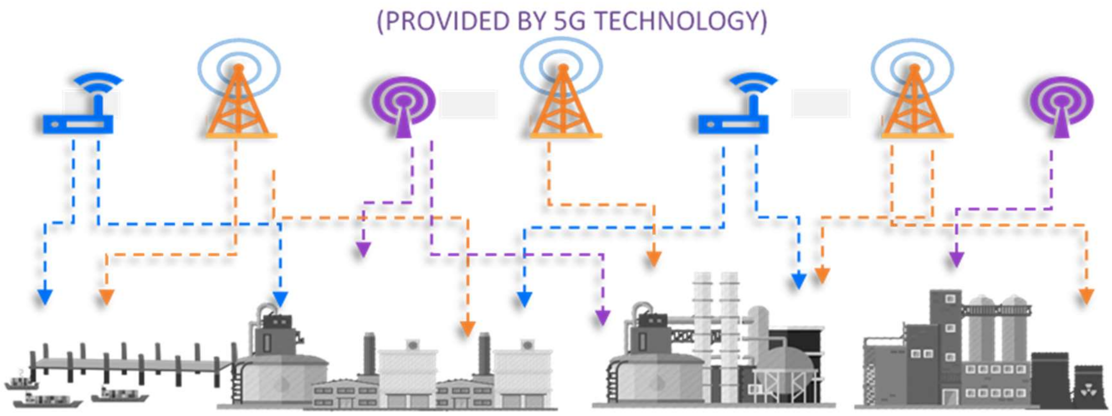


Figure A2.16: 5G Network for Collaborative Environment.

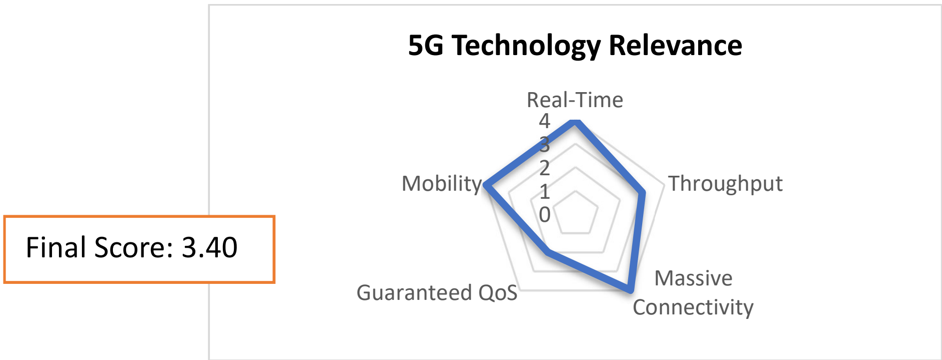


Figure A2.17: 5G Technology Relevance of Enhanced Plant Performance and Efficiency Use Case

Use Case 3: Remote Platform Monitoring and Control

Real-time monitoring and mobile inspection of systems, devices, and processes, especially in remote and dangerous areas can be enabled with 5G. Safety is perhaps the largest industry concern, both internally and externally. Massive IoT can lessen risks taken by identifying potential issues before they become actual problems or safety hazards. Remote troubleshooting means more consistent and efficient regulation of oil rigs and reduced human intervention. This also means less travel and reduction of potentially dangerous work for personnel.

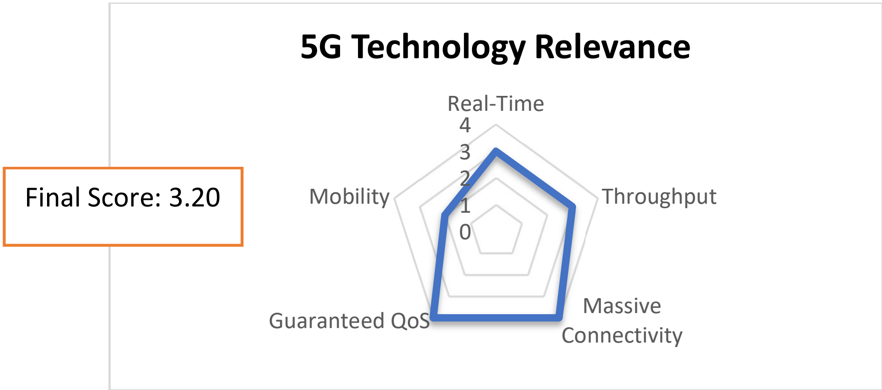


Figure A2.18: 5G Technology Relevance of Remote Platform Monitoring and Control Use Case

Use Case 4: Health Safety Environment in Real-Time

Real-time monitoring of environment stress conditions, video streaming, and facial recognition for security enforcement are ways to determine human activity and assets digitally via 5G. This includes CCTV monitoring for different hazardous areas, video streaming and on-body sensor devices to monitor the health condition of personnel in a company. Applicable to both onshore and offshore platforms.

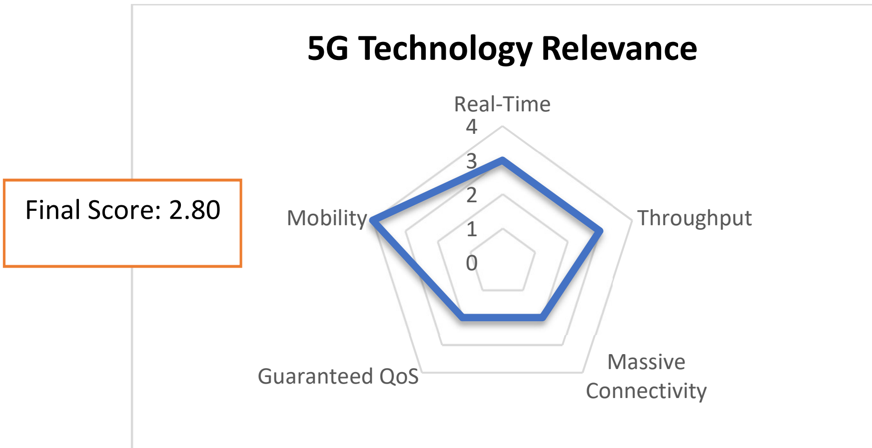


Figure A2.19: 5G Technology Relevance of HSE Use Case

Use Case 5: Smart M2M and Predictive Maintenance

Current processes are limited to passive monitoring with human intervention. Transmission of machine data for process automation with big data analytics will drive fast decision-making, reduce downtime, and increase production yield. This will also transform the company from schedule-based maintenance to condition-based maintenance and hence reduces intervention, frequency of checking, and costs incurred.

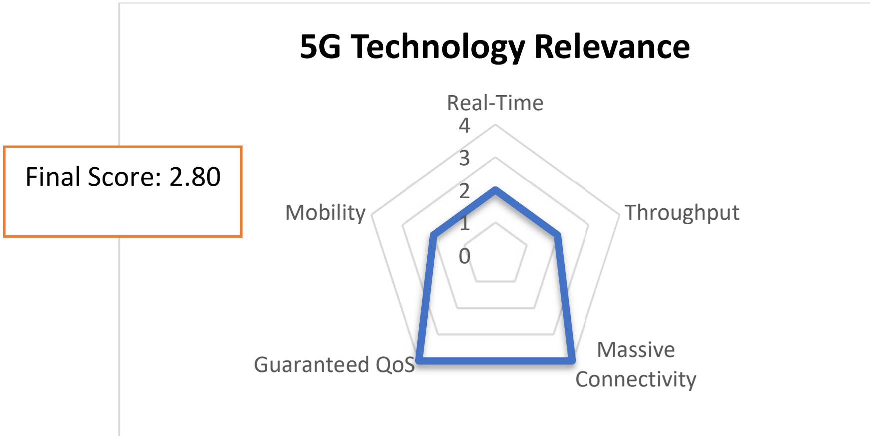


Figure A2.20: 5G Technology Relevance of Smart M2M And Predictive Maintenance Use Case

Business model

- Private network: Localised network for industry
- Niche Operator: Industry as end-user

1. Private to invest in the infrastructure with incentive (tax/reinvestment)
2. Government to facilitate by providing necessary support and assistance (e.g. License-free spectrum)

❑ Preliminary assessment indicated that;

a) 5G technology relevance: 2.96

b) Market potentials: 3.0

Notes:
4 - Very High
3 - High
2 - Moderate
1 - Low
0 - Not at all relevant

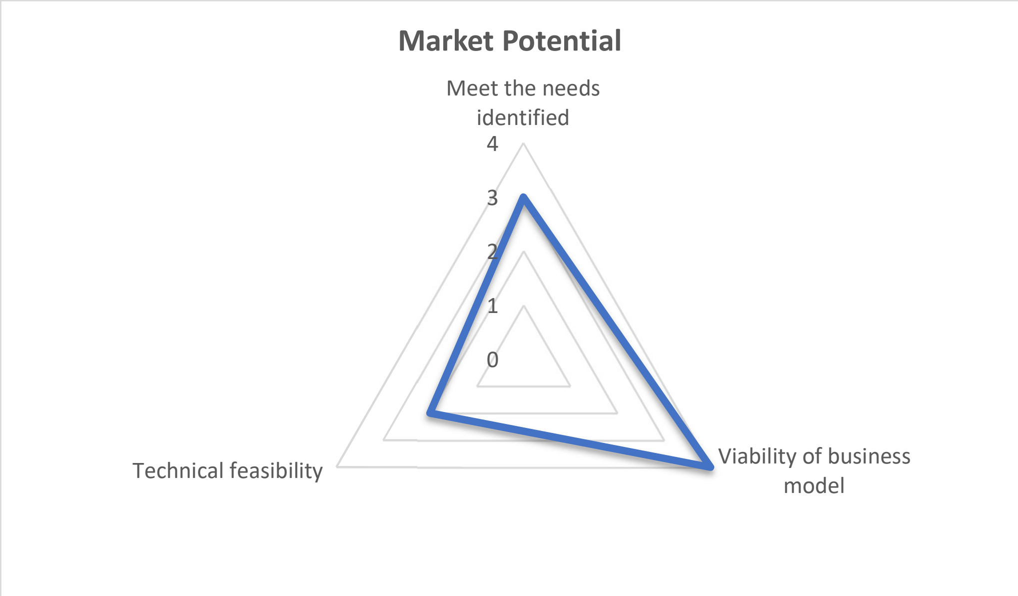


Figure A2.21: Overall Market Potential Assessment

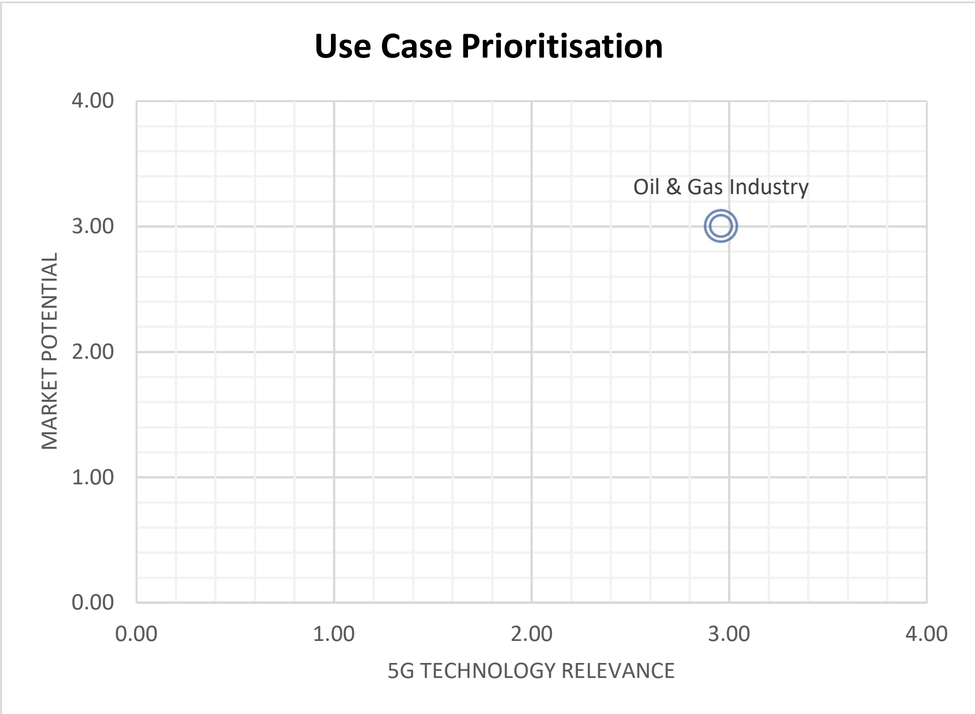


Figure A2.22: Use Case Assessment

Appendix 2.7 Retail & Services

Lead: Mr Khairuddin Yahaya, Malaysian Administrative Modernisation and Management Planning Unit (MAMPU)

For the third quarter of 2018, the Malaysian retail industry achieved an encouraging growth rate of 6.7%, compared to the same period in 2017[41], which performed above market expectations. The Malaysia Retail Chain Association (MRCA) expects retail sales to grow by 5% in 2019 in line with the nation's gross domestic product (GDP) growth[42].

Customers today are more sophisticated and by having faster round-the-clock connection, retail transactions will grow, as well as demand customised customer experience. Over the past decade, marketers have demonstrated their ability to react, innovate, and adapt to new technology to improve customer experience: Nevertheless, there's still room to improve for the retail and services industries in terms of customer growth, and this could be done by solving their connectivity needs especially using FWA (Fixed-Wireless Access) to rural and remote areas and enabling the proliferation of digital services.

Significance of 5G in Retail and Service Market Segment

Therefore, 5G has the potential to reduce time to market, provide greater outreach to customers, reduce energy, and waste and optimise deliveries of products and services in the retail industry. 5G may open the door for endlessly customisable merchandise, drone delivery, virtual reality dressing rooms, and augmented reality experiences at home or in-store.

5G can also make personalisation more seamless for retailers and customers alike. Using facial recognition technology, IoT devices can alert in-store sales clerks that a customer is a VIP or help to provide recommendations based on their recorded preferences. That same customer could then exit the store without reaching for their wallet because their payment information is on file in the system.

Of course, more digital interactions with consumers mean far more customer data for retailers to collect and leverage. If they don't have a customer analytics infrastructure in place now, they will have a difficult time keeping up in the near future. A centralised system and customer intelligence technology will equip retailers with the means to respond to customers faster, and with more targeted and personalised messages.

In a nutshell, the three key characteristics of 5G drive the growth of Retail & service segment

- **eMBB:** Improves customer experience by delivery high definition media and content by retailers. Improves speed, security of online transactions.
- **mMTC and uRLLC:** enables IoT and new devices to enhance ecommerce, using smart speakers like Alexa or Google Home, payment gateway devices on top of smartphone apps for online purchases.

[41] The Edge Markets. 2018. Retail Group Malaysia ups nation's retail sales growth forecast

[42] Malay Mail. 2018. *Malaysian retailers target 5pc retail sales growth in 2019.* https://www.malaymail.com/news/money/2018/11/27/malaysian-retailers-target-5pc-retail-sales-growth-in-2019/1697498

Use Case 1: Broadband and Media Everywhere

Broadband and Media Everywhere covers rich interactive work, media and entertainment applications on the cloud or reality augmentations (both centralised and distributed).

Proposed 5G features to enable Broadband and Media Everywhere are outlined in below Table:

Enablers	Characteristics
5G radio	- Improved beam forming - Massive MIMO - Carrier aggregation - New high frequency spectrum
5G core network	- QoS supports consumer's profile - Roundtrip latency in 1 ms range - Cloud based flexible deployment of media services - Network slices all optimised for mobile broadband and media delivery

Use Case 2*: Indoor Location Service*

The global indoor location market size is expected to grow from US$7.11 billion in 2017 to US$40.99 billion by 2022, at a Compound Annual Growth Rate (CAGR) of 42.0% during the forecast period[43].

Hassle-free navigation, improved decision-making, and increased adoption of connected devices are boosting the growth of the indoor location market across the globe based on the assumption that business users spend 80% of their working hours indoors, which generated 70% of indoor data services. However, nearly 50% of users are unsatisfied with the perceived indoor experience[44]. Therefore, the need to have massive deployment of AP's in an indoor environment, indoor localisation is possible, along with 5G wireless signature ID and IoT sensors integration

The addition of 5G technology to an existing network architecture can cross-pollinate new technologies, such as personalised digital signage, augmented reality, virtual reality, and video and pattern recognition of shoppers' interactive mobile, will facilitate targeted advertising, public safety surveillance, indoor navigation ala Waze/Google maps inside buildings in shopping malls, public areas, and transportation hubs.

[43] Markets and Markets. Oct 2017. *Indoor Location Market worth 40.99 Billion USD by 2022* https://www.marketsandmarkets.com/PressReleases/indoor-location.asp

[44] Light Reading. 2018. *Digitalization: Key to 5G Indoor Success.* https://www.lightreading.com/huawei-mobile-world-congress/digitalization-key-to-5g-indoor-success/a/d-id/740922

Use Case 3: Smart Energy Savings

Malaysia will have close to 700 shopping malls with total net rentable area of 170 million sq. ft. by end of 2019, which equates to 11BWh (or RM4.24B@38.53sen kWh)[5], on the assumption that average energy consumption for such centres is about 300kWh per square meter, and they generate high levels of Co2 emissions and waste.

Therefore, 5G enables massive wireless sensor deployment to measure temperature, humidity, air quality, electrical power usage in shopping malls. Smart energy management solutions can be deployed to optimise energy usage and provide savings while ensuring tenants' comfort and safety. With big data analytics, the mall traffic data collected can be aggregated and analysis to predict shoppers' traffic, behaviour and optimised comfort and reducing wastage.

Consideration Constraints

As with any new technologies, there will be early and late adopters due to many factors. By connecting many IoT devices to the internet, there is a risk of hacking or security issues of data privacy issues. Massive deployment of base stations or access points, especially on private properties might have legal and environmental implications.

The 5G management and orchestration strategies for Retail & service segments are as follows:

- Congestion handling per subscriber/service or based on usage
- Dynamic allocation of resources according to traffic variation
- Reduce load on transport links and central processing units

Appendix 2.8 Smart City

Lead: Mr Robert Tai Chiang Vun, Malaysian Industry-Government Group for High Technology (MIGHT)

Globally, urbanisation is increasing. The United Nations estimates that in 2014, 54% of the world's population is residing in urban areas, a number projected to increase to 66% by 2050. In Malaysia, 74% (2014) of Malaysians are now living in urban areas, which is projected to increase to 86% by 2050[45]. This rapid rate of urbanisation is placing tremendous strain on city infrastructures and urban communities. In addressing these challenges, the United Nations is calling for countries to pursue smarter and more sustainable practices in developing their towns and cities. Smart and sustainable city is now an integral part of the larger UN sustainable development goals initiative, which serves as a benchmark for many countries, including Malaysia. An important element of a smart and sustainable city is public safety. In Malaysia, public safety has been and will continue to be an area of priority for policymakers and the public at large. In the last two national plans (RMKe10 and RMKe11), public safety was clearly a focus area that needed to be addressed and improved upon. Rightfully so, as statistics on public safety still presents a dismal picture of Malaysia's public safety track-record in 2017 (DOSM).

[45] United Nations. *2014. World Urbanization Prospects*

An effective approach in addressing public safety for towns and cities is video surveillance. Video-based surveillance provides the authorities with an effective means to monitor activities within their municipalities, such that incidences can be managed in a timely and effective manner. CCTV has also been shown to deter crimes from occurring, with up to 40% effectiveness. Cities like London and New York have pursued the advantages of video surveillance for many years, with reasonable success. The following sections shall outline two plausible use cases on public safety in smart cities that capitalises on the 5G network's inherent features of high-bandwidth and ultra-reliability.

Use Case 1: Fixed-Location CCTV via 5G Network

The proposed use case is to leverage on the 5G mobile network as the backbone for a large-scale deployment of low-cost and low-power 5G enabled CCTV cameras across a given town or city. The huge volume of video data generated by these "Internet of CCTVs" will be processed by edge computers located near to the observation points and organised in geographically distributed clusters. These edge clusters are then connected back to the 5G core network to reach the Government's central command (or monitoring) center (see **Figure A2.23**).

Each edge cluster, consisting of mobile edge computing (MEC) functionalities and a pool of 5G connected CCTV cameras, is responsible for performing real-time video analytics (with artificial intelligence) to autonomously identify abnormal incidences, such as traffic accidents, robbery in progress, and other suspicious activities. Upon detecting such activities, the affected video feed will be escalated to the central command center for further investigations and remedial actions.

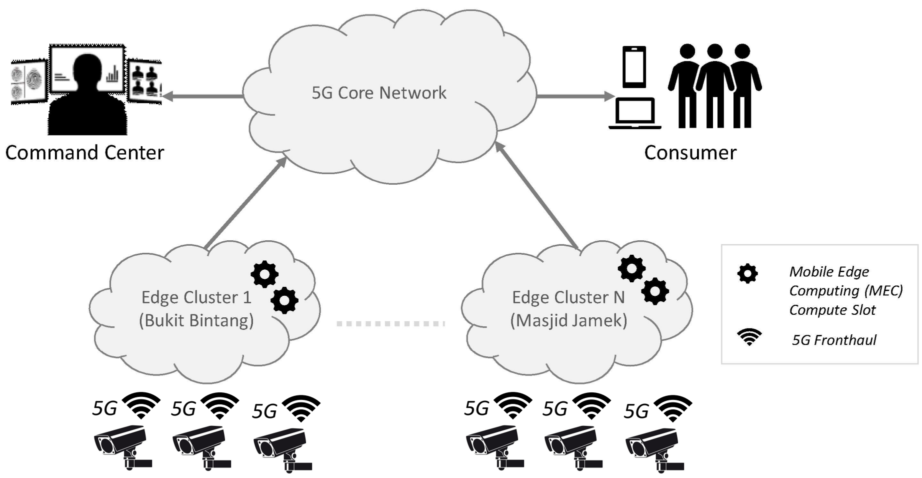


Figure A2.23: Distributed CCTV Video Analytics (Logical) Infrastructure

There are various advantages of such systems, including

1. Rapid deployment of 5G enabled CCTVs in a massive scale to increase both indoor and outdoor CCTV coverage.
2. Ultra-high definition video streams—up to 4K resolution—for accurate face recognitions.
3. Rapid re-deployment of CCTVs from one crime hot-spots to another, to combat crime displacement.
4. Mobile 5G body-cams could enable law enforcement officers to document crimes on-the-spot.
5. The MEC's autonomous incidence detection feature could reduce the manual workload of monitoring video feeds, thus freeing up human operators to focus on more important tasks, such as incidence coordination and investigations.

However, there will be various challenges that must be addressed in deploying the proposed system, including:

1. The maturity and accuracy of AI technology used in incidence detection
2. The extremely high bandwidth required for massive deployment of high-resolution video feeds.
3. Concerns regarding intrusions into the individual privacy
4. The protection of personal data captured via CCTVs

Nevertheless, implementation of the proposed use case can be done in phases, starting with the massive deployment of 5G enabled CCTVs connected directly to existing central command centers operated by the authorities. The inclusion of MECs for automated incidence detection could be implemented in subsequent phases, when the underlying technologies (such as AI.) becomes more mature and reliable.

The proposed business model is a Public Private Partnership (PPP) arrangement, whereby the private sector (MNOs or ASPs) will provide the government with last-mile CCTV connectivity as a service. Fronthaul CCTV infrastructure investments and maintenance will be borne by the private sector, while the government will commit to leasing the usage of these CCTV video streams on a per-channel or per-cluster basis (see **Figure A2.24**). The proposed common API approach will allow for multiple private sector vendors (MNOs and MVNOs) to participate in providing the 5G enabled CCTV video streaming services to the government, thus increasing competitions for better service and ensuring a level playing field for all interested parties.

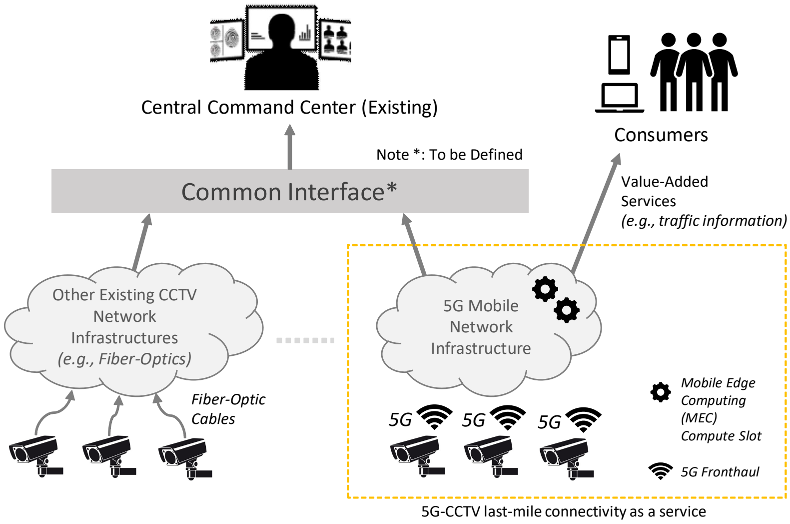


Figure A2.24: Business Model Of 5G-CCTV Last-Mile Connectivity as A Service

This PPP approach could be a win-win situation for both the private sector and the government, whereby MNOs can fully capitalise on their excess bandwidth at night by providing CCTV surveillance services to the government. On the other hand, the government can achieve high CCTV coverage with minimal capex investment and rapid deployment. But most importantly, the ultimate beneficiary will be the general public, as a safer living environment can be established and be better maintained.

Use Case 2: Mobile Drone Surveillance via 5G Network

In widening the areas covered by video surveillance for public safety[46], aerial surveillance could be an invaluable tool. This is achieved through the adoption of unmanned aerial vehicles (UAV)[47], commonly known as drones[48]. Drones fitted with cameras and sensors can provide real-time aerial surveillance of emergency situations for better control, precise intelligence gathering, comprehensive situational awareness, and more informed decision-making.

The proposed use case is to utilise drones as an aerial surveillance platform to facilitate the upholding of public safety and for other purposes such as traffic control. A fleet of unmanned drones equipped with high-definition cameras and other useful sensors can be deployed in targeted areas. These drones will be programmed to autonomously traverse a pre-determined flight path for surveillance. As these drones patrol their pre-determined path, real-time video (and audio) surveillance information will be captured and transmitted back to the central command center for further processing and analysis, via the 5G network. When a security threat or an emergency situation is detected (either autonomously by an AI server or manually by a surveillance operator), an alert will trigger calling for the dispatchment of law enforcement officers to attend to the detected incident.

[46] The Economist Intelligence Unit. 2017. *Safe Cities Index 2017: Security in a rapidly urbanising world*
[47] Strategic Defense Intelligence. 2015. he Global UAV Market 2015 - 2025 (sample)
[48] Multiple Drone Solutions. 2018. Applications: Law Enforcement. http://www.mdsuav.co.za/lawenforcement.html

When necessary, operators at the command center could also override the autonomous navigation of the subject drone, and pilot it manually. This will allow authorities at the command center to maneuver the drone into the most optimum surveillance position to manage a detected incident. As such, when working in concert with ground-based CCTV surveillance cameras, aerial drone surveillance could expedite the deployment of ground personnel, provide better and informed decision making, and improve the overall safety of towns and cities.

In view of the need for high-bandwidth video streaming and transmission through a mobile platform, a 5G mobile network would be the ideal backbone for the deployment of unmanned drones for aerial surveillance. The eMBB feature of the 5G network should provide sufficient sustained bandwidth for these video streaming requirements, while the uRLLC feature could provide the reliable connection required to pilot the drone manually and autonomously.

Besides the transmission of video signals, the 5G mobile network is also crucial in enabling swarm technologies which would allow for a pool of drones to autonomously operate within a confined airspace without colliding with each other. Swarm technology enables individual drones to communicate with each other so that they know each other's position to avoid a collision. As such, a highly reliable communication network is necessary to ensure that these drone-to-drone communications are uninterrupted and operates with minimal latencies. Again, 5G's uRLLC feature would be ideal in this case.

However, the deployment of autonomous drones in an urban environment may pose many impediments that needs to be addressed, such as:

1. Regulation on co-sharing of the airspace with other aerial vehicles.
2. May be challenging for 5G fronthaul to provide reliable 3D coverage that extends beyond ground level to reach the drones' operating altitude (at approximately 150m).
3. The need for accurate virtual 3D mapping of the environment that these drones operates in.
4. Technical difficulties for drones to fly in adverse weather conditions.

The business model for drone surveillance will be similar to the "Fixed-Location CCTV via 5G Network" use case outlined earlier. The proposed business model is a Public Private Partnership (PPP) arrangement, where the private sector will invest into the necessary drones and network infrastructure, which is then leased to the government long-term. That said, the cost elements will be very different from a fixed-location CCTV network, as drones are more complex to operate, and the business risk is much higher. As such, a cost-benefit analysis will need to be conducted to gauge the commercial viability of this use case.

Appendix 2.9 Smart Transportation

Lead: Mr Mohammad Zaim Azyze, Malaysia Automotive, Robotics & IoT Institute

Currently, the global trend is transforming the automotive industry towards mobility, meaning to offer better solutions for people and goods mobility while at the same time creating new services within the value chain. Therefore, the government through the Ministry of International Trade and Industry (MITI) and its agency, Malaysia Automotive, Robotics and IoT Institute (MARii) have carried out strategic studies on benchmarking automotive policy globally which aims to identifying emerging technology in the automotive industry in relation to mobility. This strategic study benchmarked existing policies of developing countries with reference to the developed countries in terms of energy consumption, trade, Gross Domestic Product (GDP), mobility and technology.

2.9.1 National Automotive Policy 2019 (NAP 2019)

NAP 2019 maintains and enhances the NAP 2014 framework through three directional thrusts and three strategies that introduce new technological elements which will assist the development of local automotive industry, in line with the global automotive industry trends. NAP 2019 considers future technology development inputs and improve existing NAP 2014 by introducing new elements such as Next Generation Vehicle (NxGV), Mobility as a Service (MaaS), and 4IR. The framework of NAP 2019 is illustrated as in **Figure A2.25**[49]:

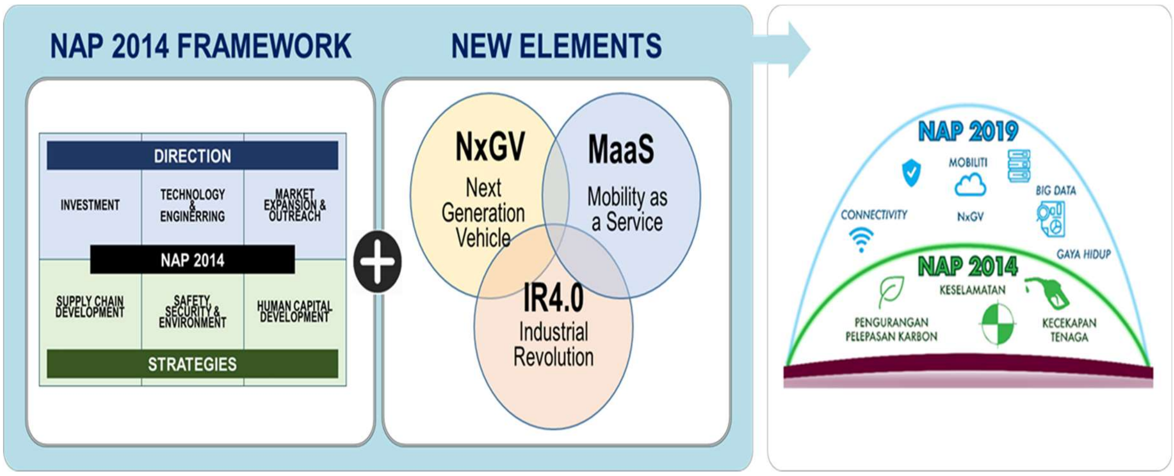


Figure A2.25: Framework of NAP2019.

[49] *MARii. 2019. National Automotive Policy (NAP) 2019 (Under review)*

2.9.2 Next Generation Vehicle (NxGV)

NxGV is classified as a vehicle that meets the definition of Energy Efficient Vehicle (EEV) classifications and is enhanced with Intelligent Mobility applications that enables the vehicle to connect to the internet and become smarter and more efficient. The vehicle technology is classified according to five levels of automation level as shown in the **Figure A2.26**[50].

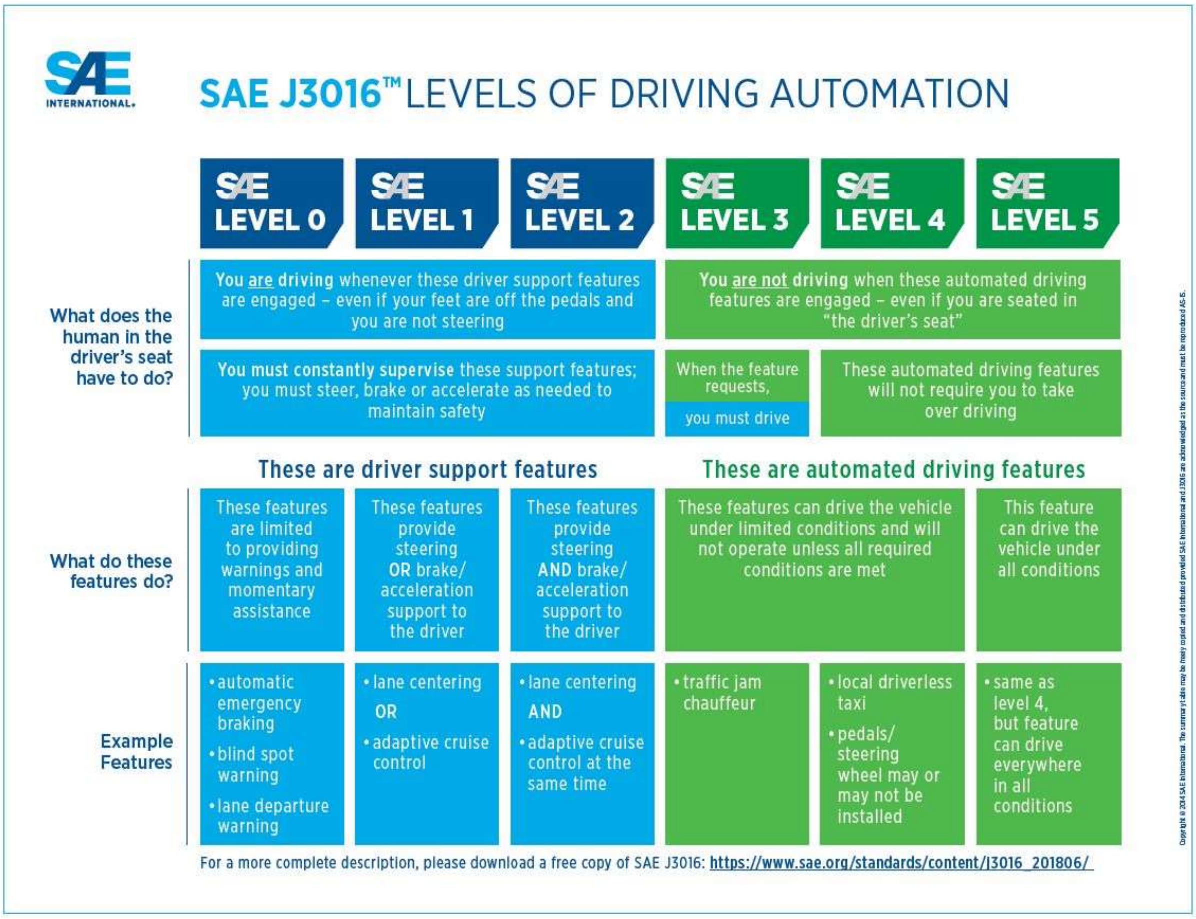


Figure A2.26: Automation Level Based on SAE.

2.9.3 Business Case: Automated, Autonomous and Connected Vehicle (AACV)

Automated, Autonomous and Connected Vehicle (AACV) or simply autonomous vehicle (AV), including "self-driving" autonomous vehicles, has the potential to improve the lives of billions of people and transform mobility as we know it. It could enable a safer, more efficient, accessible, and ecologically friendly means of transport.

Addressing first, the safety aspects, a study from McKinsey & Company found that AVs could potentially reduce up to 90% in driving fatalities by using AV due to a key fact; computers are so much better drivers than error-and-distraction-prone humans[51]. In the USA alone, this translates to about 30,000 lives saved each year and up to US$190 billion in annual savings from healthcare costs associated with accidents. This adds up to 10 million lives saved globally each decade.

[50] *Society of Automotive Engineer (SAE). 2018. Level of Driving Automation.*

[51] BEC Crew, Science Alert. 2015. *Driverless cars could reduce traffic fatalities by up to 90*

AACV combined with car-sharing services could save up to 90% on fuel consumption, mainly through "right-sizing" the vehicle required for each task. By right-sizing each vehicle for each trip, the needless transportation of tons of steel could be dramatically reduced from today's highly wasteful default driving situation. The concept of "right-sizing" is then expanded to enable the Mobility as a Service (Maas) as introduced in the NAP 2019. Right-sizing can also be useful for ride-hailing services like Uber and Lyft, further increasing the efficiency of our entire transportation system while at the same time creating new services for the people within the ecosystem.

AACV Implementation Landscape via 5G Connectivity

AACV senses their surroundings with techniques such as radar, LIDAR, GPS, odometry, and computer vision. Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage. AACV control systems are capable of analysing sensory data to distinguish between different cars on the road, which is very useful in planning a route to the desired destination. **Figure A2.27** illustrates the critical components for AACV.

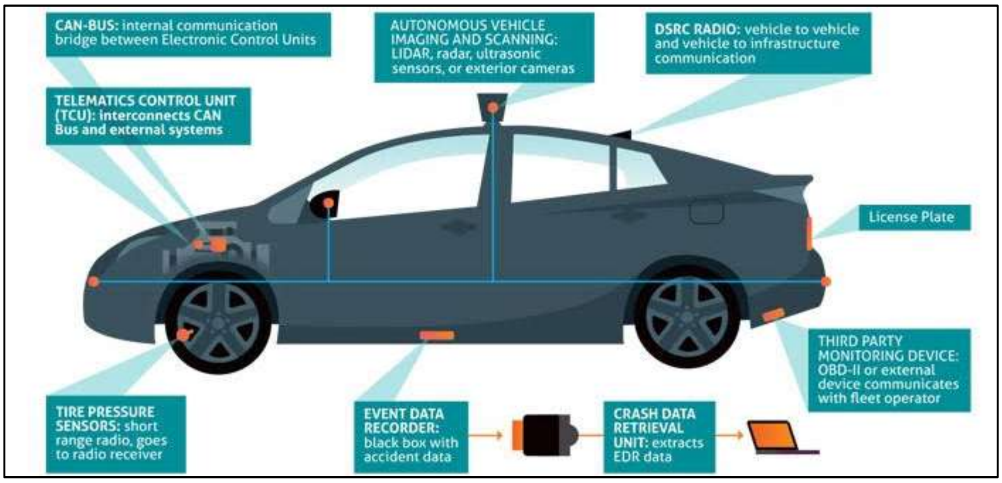


Figure A2.27: Critical components of AACV

AACV uses any of several different communication technologies to wirelessly communicate with the driver, other cars on the road (V2V), roadside infrastructure (V2I), other network telecommunication (V2N), smart devices (V2P) with bikes, pedestrians, and others[52]. For safety and automation, connectivity should be bi-directional between vehicles and the infrastructure, meaning communication happens in two directions. The Vehicle-to-Everything (V2X) ecosystem—V2V, V2I, V2N and V2P is illustrated in the **Figure A2.28**:

[52] Frost and Sullivan. 2018. Global Automotive Vehicle-to-Everything (V2X) Communication Market

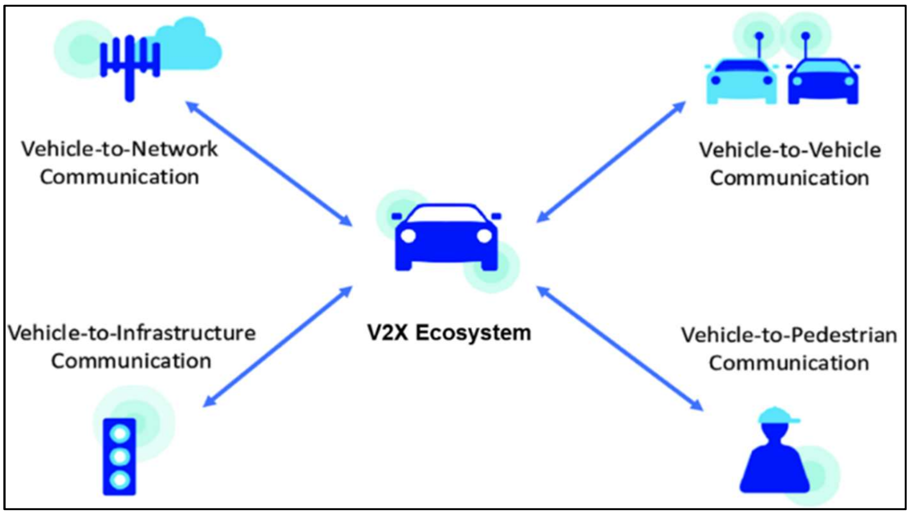


Figure A2.28: V2X Ecosystem

2.9.4 Challenges and Recommendation for 5G Adoption

The development AACV requires real-time data and information from the surroundings as well as the vehicle localisation (navigational mapping). 5G connectivity could be twice as fast as dedicated short-range communications devices. 5G is able to address demanding and high-bandwidth applications that enable AACV. Other challenges are issues with security, privacy, data analytics, and aggregation due to an abundance of data associated with the vehicles. The increasing of technical complexity of vehicles makes them more prone to "bugs" and other system malfunctions that can effectively immobilise an AACV—issues on devices interoperability.

Therefore, the V2X ecosystem has been identified a key focus during the designated test bed that will incorporate of 5G connectivity. The test bed is crucial in determining best practices or code of conducts in accordance to Malaysia's domestic conditions for its communication protocol, interoperability, signal interference, etc. The test bed must be designed in a way that simulates real-world driving attributes as illustrated in **Figure A2.29**.

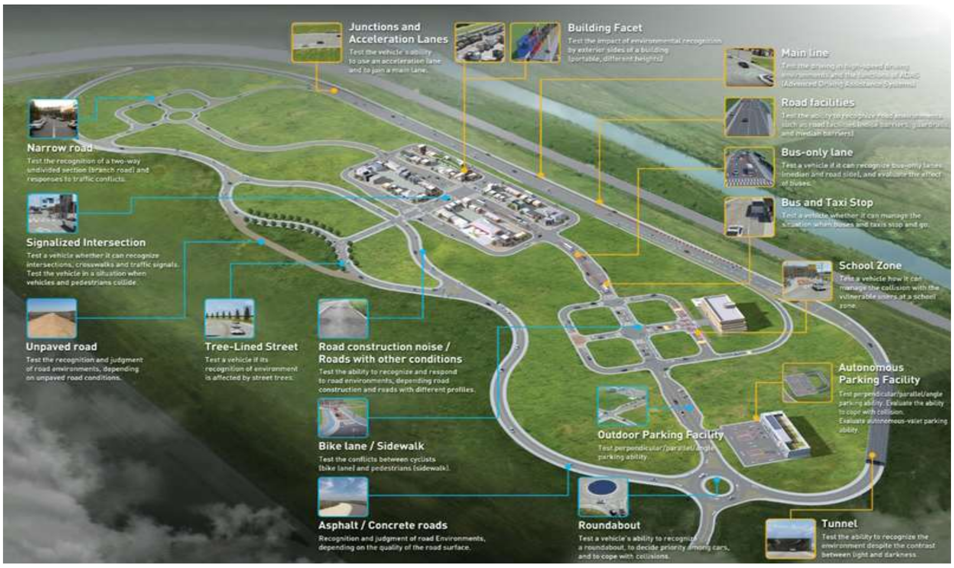


Figure A2.29: Autonomous Vehicle test bed; Source: Korea Automobile Testing & Research Institute (KATRI)

Appendix 3: MIER Report

An Economic Impact Analysis on the Implementation of 5G Services in Malaysia for the Malaysian Communications and Multimedia Commission

Abbreviations and Acronyms

AI	Artificial Intelligence
AR	Augmented Reality
ASEAN	Association of Southeast Asian Nations
B2B	Business-to-Business
B2C	Business-to-Consumer
BCAR	The Bureau of Communications and Arts Research (Australian Government)
BCG	Boston Consulting Group
BCWG	MCMC 5G Task Force's Business Case Working Group
BDA	National Big Data Analytics Framework
C2C	Customer-to-Customer
CAGR	Compound Annual Growth Rate
CCTV	Closed-Circuit Televisions
CGE	Computable General Equilibrium
DFTZ	Digital Free Trade Zone
DOSM	Department of Statistics Malaysia
DTAP	Digital Transformation Action Plan
ECG	Electrocardiogram
EMR	Electronic Medical Records
EU	European Union
FTTH	Fibre-To-The-Home
GDP	Gross Domestic Product
GNI	Gross National Income
GPT	General Purpose Technology
GSM	Global System for Mobile Communications
HIC	High Income Country
IBM	International Business Machines Corporation

ICT	Information and Communications Technology
i.e.	*id est*
INSEAD	*Institut Européen d'Administration des Affaires*
IoT	Internet of Things
IP	Internet Protocol
IT	Information Technology
KADA	Kemubu Agricultural Development Authority
KPI	Key Performance Indicator
LA	Local Authorities
LMC	Lower Middle Income Country
LIC	Lower Income Country
LTE	Long-Term Evolution
M2M	Machine to Machine
MARDI	The Malaysian Agricultural Research and Development Institute
MARii	Malaysia Automotive, Robotics and IoT Institute
MATRADE	Malaysia External Trade Development Corporation
MCMC	The Malaysian Communications and Multimedia Commission
MDEC	The Malaysia Digital Economy Corporation Sdn Bhd
MEA	The Ministry of Economic Affairs
MENA	Middle East and North Africa region
MFP	Multifactor Productivity
MIDA	Malaysian Investment Development Authority
MIER	Malaysian Institute of Economic Research
MIMO	Multiple-Input and Multiple-Output
MIMOS	Malaysia’s National Applied Research and Development Centre
MITI	The Ministry of International Trade and Industry
MMS	Multimedia Messaging Service

mMTC	Massive Machine Type Communications
MMRF	Monash Multi Regional Forecasting Model
MOA	The Ministry of Agriculture and Agro-based Industry
NFCP	The National Fiberisation and Connectivity Plan
NGO	Non-Governmental Organisation
NTT	Nippon Telegraph and Telephone
OECD	The Organisation for Economic Co-operation and Development
Pikom	The National ICT Association of Malaysia
PMU	Project Management Unit
POS	Point-of-Sales
PPP	Public-Private Partnership
PSAP	Public Safety Answering Point
PwC	PricewaterhouseCoopers
QoS	Quality of Service
RFID	Radio-Frequency Identification
R&D	Research and Development
RM	Malaysian Ringgit
ROI	Return on Investment
RTT	Real-Time Text
SEM	Emergency Medical System of Catalonia
SFA	Stochastic Frontier Analysis
SIM	Subscriber Identity Module
SMECorp	SME Corporation Malaysia
SMEs	Small and Medium-sized Enterprises
SMS	Short Message Service
SOP	Standard Operating Procedure
SSB	Services Sector Blueprint
STEM	Science, Technology, Engineering and Mathematics

TC	Technical Committee
UAE	United Arab Emirates
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
UNDP	The United Nations Development Programme
UMC	Upper Middle Income Country
URLLC	Ultra Reliable Low Latency Communications
UHB	University Hospitals Birmingham National Health Service Foundation Trust
US	United States
US$	United States Dollar
V2I	Vehicle-to-Infrastructure
V2N	Vehicle-to-Network
V2P	Vehicle-to-Physical
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VoIP	Voice over Internet Protocol
VR	Virtual Reality
WEF	World Economic Forum

1. Introduction

1.1 Network Technology Evolution from 1G to 5G

It took a mere 40 years for 5G to avail itself. The journey started in 1979, when Nippon Telegraph and Telephone (NTT) launched 1G in Tokyo[i]. Even though 1G technology was expensive and has notable drawbacks, such as poor coverage, low sound quality, no roaming support between various operators and no compatibility, among others; Motorola's DynaTAC, one of the first approved 1G mobile operators in the United States (US) (in 1983), saw themselves garnering 20 million global subscribers by 1990[ii].

The launch of 2G under the Global System for Mobile Communications (GSM) standard in Finland (in 1991) saw massive adoption by both consumers and businesses[iii]. With 2G, Short Message Services (SMS) and Multimedia Messaging Services (MMS) sent via phones, for the first time, in addition to voice-based system of 1G[iv].

By the time 3G was rolled out in 2001, 3G's increased data transfer capabilities, which is four (4) times the speed of 2G, saw services such as video conferencing, video streaming and voice over IP (VoIP)[v] being issued and used, as well as having access to the world wide web[vi].
The Long-Term Evolution (LTE) 4G standard, the current standard, was rolled out in Stockholm, Sweden and Oslo, Norway in 2009. Although it provides fast mobile web access which facilitates high definition videos, pictures and high-quality video conferencing[vii], it is not inclusive of wearable devices with artificial intelligence (AI) capabilities. Further comparison on the key differentiators and weaknesses of 1G to 4G, is as listed in Table 1.1:

Generation	Primary services	Key differentiator	Weakness (addressed by subsequent generation)
1G	Analogue phone calls	Mobility	Poor spectral efficiency, major security issues.
2G	Digital phone calls and messaging	Secure, mass adoption	Limited data rates – difficult to support demand for internet/e-mail.
3G	Phone calls, messaging, data	Better internet experience	Real performance failed to match hype, failure of WAP for internet access
3.5G	Phone calls, messaging, broadband data	Broadband internet, applications	Tied to legacy, mobile specific architecture and protocols.
4G	All-IP services (including voice, messaging)	Faster broadband internet, lower latency	Data intensive service which requires high bandwidth and low latency, thereby stressing legacy backhaul links.

Table 1.1: Key Differentiators Between Technology Generations
Source: GSMA (2014)[viii]

The performance of mobile broadband technology has transformed society and industry by enabling a very high degree of innovation[ix]. Figure 1.1 compared the theoretical limits on the downlink speeds of the various networks since 3G, while Table 1.1 presents the key differentiators between these networks.

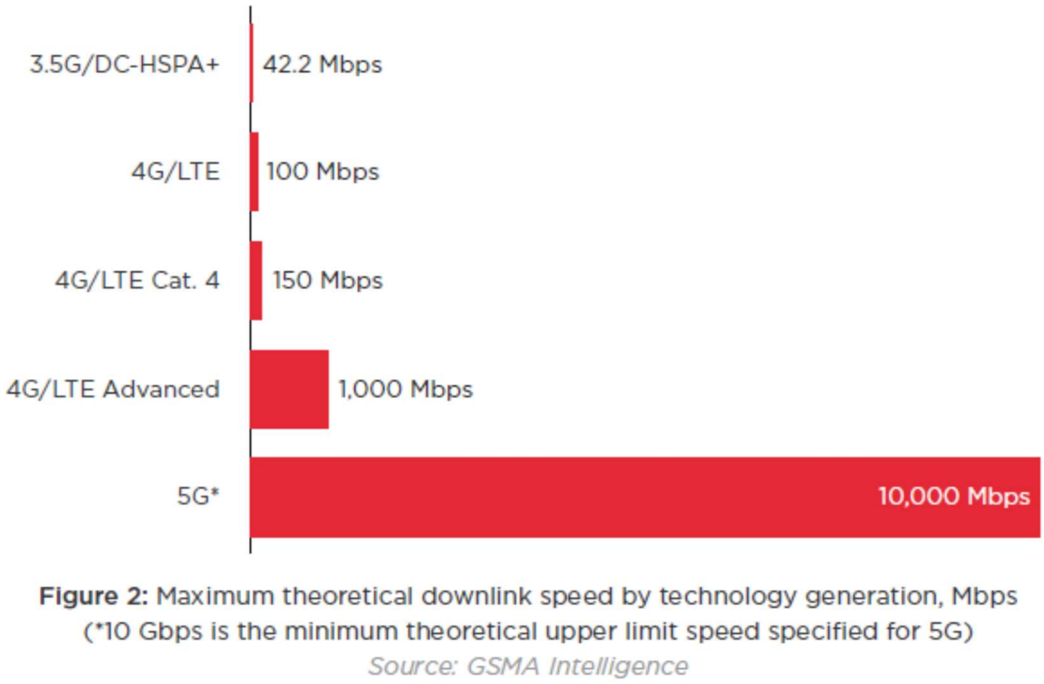


Figure 1.1: Maximum Theoretical Downlink Speed by Technology Generation
Source: GSMA (2014)[x]

While many countries are currently offering versions of the 4G standard for wireless broadband communication, 5G has been in development for the past few years due to the demand for connectivity to better enable the Fourth Industrial Revolution (4IR) technologies, as 5G offers enhanced mobile broadband, massive Internet of Things (IoT) and low latency. [xi]

1.2 Impact on Malaysia

The soon to be issued 12th Malaysia Plan 2021-2025[xii] anchors the three (3) development dimensions of the Shared Prosperity Initiative[xiii], which includes Empowerment of 5G, Local Authorities (LA), and Communities[xiv]. This is an effort to advance the preceding 11th Malaysia Plan's aim of becoming a high-income nation, in addition to the new aim of also protecting and promoting the social well-being of its citizens.

As the mobilisation of 5G falls under the facet of Social Re-Engineering, it is inferred that the enablement of connectivity drives both economic growth[xv] and economic development[xvi]. This assumption concurs with the previous findings of both the Department of Statistics Malaysia (DOSM) and the National ICT Association of Malaysia (Pikom), published in 2018.

Based on the collated data, DOSM found that 18.7 per cent of the economy is contributed by the Information and Communications Technology (ICT) sector in 2017, recording a significant jump from 16.5 per cent in 2010[xvii]. Pikom's ICT Strategic Review 2018/2019 Report also noted that in 2017, the ICT industry has contributed RM247.1 billion to the economy, equivalent to 18.3 per cent of Malaysia's Gross Domestic Product (GDP) of that year[xviii].

Henceforth, it is imperative to consider further investment into telecommunications infrastructure, as it is hypothesised that the improvement of Malaysia's economy will depend upon the development of the communications and multimedia sector (i.e. digital communications).

The economic effects of digital communications could manifest in several ways[xix]. Firstly, like any infrastructural investment, the effects of the physical construction projects have both forward and backward linkages to the economy [xx], including new jobs creation. Secondly, there will be rise in productivity for both businesses and users, particularly in terms of time-saving and efficiency; leading to improvements in multifactor productivity (MFP)[xxi]. Thirdly, the augmented use of the technology by consumers increases real household income[xxii].

Thus, as 4IR (with 5G) is expected to transform the economy and improve quality of life, a clear policy framework for 5G deployment will be critical. This is because the required capital expenditure to roll out 5G infrastructure, could be significant.

For example, a 5G cell using 20GHz has a radius of approximately 85 meters compared to approximately 294 meters radius for a 3.5GHz cell[xxiii]. As presented in Figure 1.2, this suggests that almost a dozen 20GHz cells are required to cover the area of one 3.5GHz cell. Hence, expenditure will escalate in terms of acquiring equipment. Additionally, more real estate will be required for base stations.

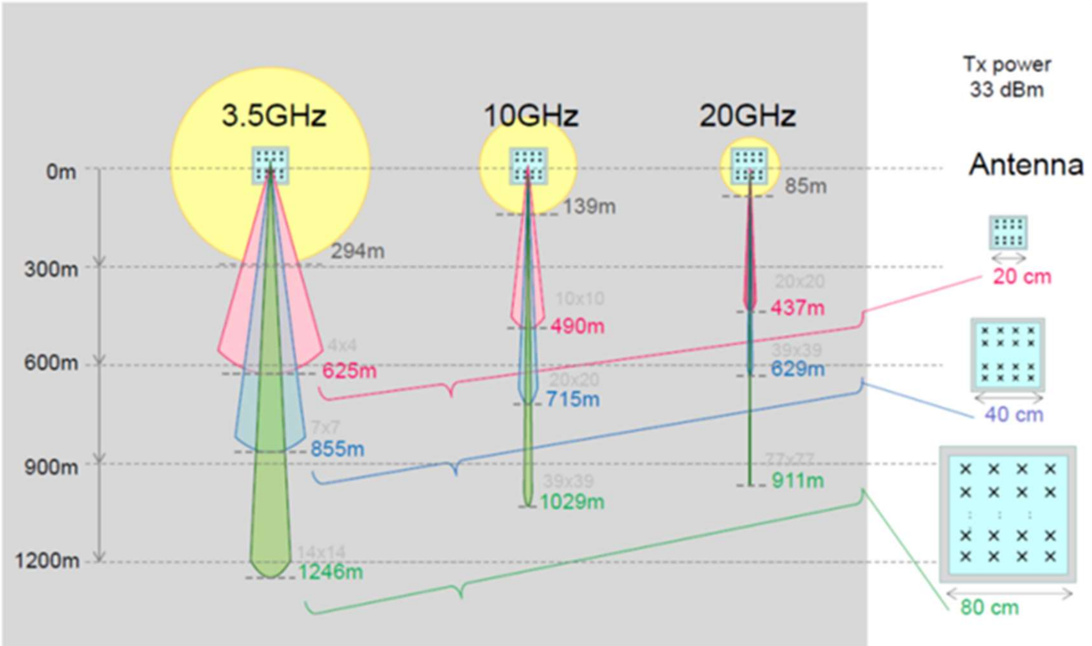


Figure 1.2: Massive MIMO: Coverage Extension; Source: Nakamura (2014)[xxiv]

1.3 Enablers

5G is expected to enable and propel Industry 4.0 technologies, such as Massive IoT[xxv]. IoT is defined as "a system of connected devices that gather data"[xxvi]. It connects with the internet or local networks to generate analytics, and (in some cases) based upon these data or analytics, adapt its responses[xxvii]. As it has implications on almost all sectors of the economy, businesses especially those in high income countries (HICs), quickly capitalised on this opportunity.[xxviii]

Therefore, as 5G is able to support and transmit more data at a faster rate as well as low latency in comparison to 4G LTE, the IoT could have a total (global) potential economic impact of US$3.9 trillion to US$11.1 trillion (about RM16 trillion to RM45 trillion) by 2025[xxix]. Consequently, if Malaysia is able to roll out 5G by 2025, it may be possible for Malaysia to have a slice of this economic pie.

IoT is already acknowledged as one of Malaysia's key tools in driving economic growth as it is emphasised in several national policies and initiatives, such as the National Big Data Analytics Framework (BDA) (2015)[xxx], National IoT Strategic Roadmap (2015)[xxxi], National IoT Framework[xxxii], Malaysia's Industry 4WRD: National Policy on Industry 4.0 (2018)[xxxiii], the soon to be unveiled National Automotive Policy (NAP) (2019)[xxxiv], and the National Artificial Intelligence Framework[xxxv]. Therefore, it is evident that the Malaysian government is aware of the exponential potential of the IoT, and ergo, the digital economy.

According to the World Bank Group[xxxvi], in 2015, "...17.8 per cent of Malaysia's GDP was attributed to the digital economy, of which 13.1 per cent was from the ICT sector. This is much higher than the average 5.4 per cent of total value added attributed to the Organisation for Economic Co-operation and Development (OECD) countries' ICT sectors in 2015. If Malaysia's ICT sector is approximated using the OECD's industry classifications and definition, it still accounted for 9.7 per cent of GDP in 2015". Hence, with 5G, it is expected to catalyse the growth of the sectors encompassing Malaysia's digital economy. The sectors encompassing Malaysia's digital economy is detailed as Table 1.2.

Component		OECD	Malaysia
Information and Communication Technology (ICT) Sector	Commonalities	ICT manufacturing; software publishing; telecommunications; computer programming, consultancy, and information and related activities	
	Differences		ICT wholesale and retail trade; Content and media activities; Other ICT services such as repair of machinery, E&E and optical equipment; Installation of industrial machinery and equipment, etc.
e-commerce	Commonalities	Wholesale and retail sectors	
	Differences	A broader measure can be derived, which includes all sectors across the economy for which data are available	The broader approach is used, comprising all sectors across the economy for which data are available

Table 1.2: The Sectors in Malaysia's Digital Economy Versus The OECD
Source: the World Bank (2018)[xxxvii]

This technological evolution (i.e. 5G) is anticipated to create new and additional job opportunities, as it needs extensive support for its implementation, maintenance and securitisation. Figure 1.3 displays the estimated bandwidth and latency requirements of the various 5G network use cases.

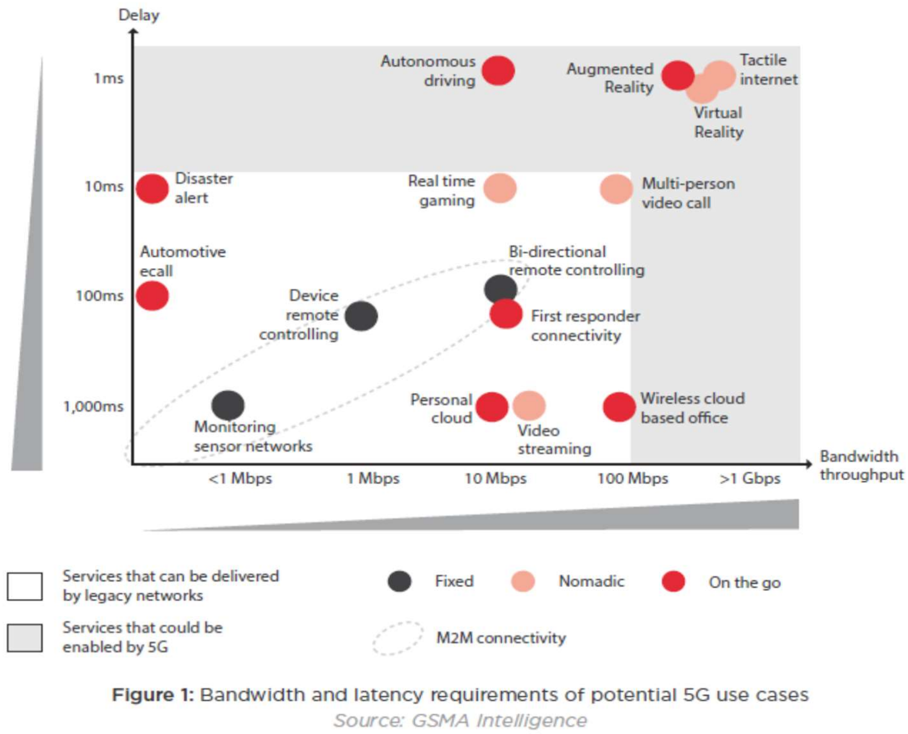


Figure 1.3: ***Expected Bandwidth and Latency Requirements of Potential 5G Use Cases***
Source: GSMA (2014)[xxxviii]

Previous studies employed different methods and data sets to examine the impact of the deployment of advanced technologies (i.e. 5G, mobile technologies adoption, broadband internet, information and communication technologies and other General Purpose Technologies (GPTs) on productivity.

GSMA (2019a)[xxxix] found that mobile technologies and services generated US$3.9 trillion of economic value in last year (4.6 per cent of GDP) globally, a contribution that will reach US$4.8 trillion (4.8 per cent of GDP) by 2023. Further ahead, 5G technologies are expected to contribute US$2.2 trillion to the global economy over the next 15 years. For the Asia Pacific region, mobile technologies and services in this region generated US$1.6 trillion of economic value (5.3 per cent of GDP) in 2018. And this contribution will surpass US$1.9 trillion by 2023 as countries increasingly benefit from the improvements in productivity and efficiency brought by the increased adoption of mobile services.

Moreover, 5G technologies are expected to contribute almost US$900 billion to the region's economy over the next 15 years; with sectors such as manufacturing, utilities and professional services standing to benefit the most[xl].

Currently, identified in the Mid-term Review of The 11th Malaysia Plan, Malaysia has four (4) persistent economic concerns[xli]:

a. complex regulatory framework,
b. low productivity,
c. the reliance on low-skilled foreign workers, and
d. low technology adoption.

The Mid-Term Review[xlii] also noted that per capita income is expected to reach only RM47,720 or US$11,700 in 2020, which is well below the minimum threshold for Malaysia to be considered a high-income nation. The minimum threshold to be considered as a high-income nation is to have a minimum Gross National Income (GNI) per capita of US$12,055, which is set by the World Bank.[xliii]

To overcome these challenges, the government has identified the following three (3) priority areas, namely[xliv]:

a. strengthening sectoral growth and structural reform,
b. accelerating innovation and technology adoption, and
c. providing quality infrastructure.

Mindful employment of 5G as a GPT could play a significant role in addressing the above challenges, by helping Malaysia leapfrog other countries that are presently ahead of us in some of our strategic economic sectors.

1.4 Technology, Telecommunications and Economic Growth

One of the characteristics of high-income economies is their high rate at which they assimilate new technologies. Schumpeter (1934)[xlv] made the case for technology as the propellant of 'long-run economic growth'[xlvi]. This is done by promoting competition among industry players, and through innovation. This argument was further developed by other researchers, such as Nelson and Winter[xlvii], who theorised on the impact of creative accumulation[xlviii] through Research and Development (R&D).
MFP[xlix] is the highest when capital intensity has rapidly grown[l]. As a result, the embodiment of new technologies in new capital goods contributes positively to long term economic growth[li]. Therefore, we can credit the rise in productivity principally to technological transformation[lii][liii].

The invention of the internet and the investment in telecommunications is viewed as an important driver of economic growth. This is evident by the rapid rise of the Tiger Economies[liv], namely Singapore, South Korea, Taiwan and Hong Kong (China). Technology has played an important role in enabling these countries to catch up with advanced countries[lv].

The development of telecommunications technology has shortened the relative distances for consumers, governments and all sectors of business, while offering lower transaction costs. Greater market penetration also offers increasing returns to scale. Investment in communications technology and infrastructure promotes economic growth and national competitiveness[lvi].

In comparison to poorer countries, HICs gain more investing in telecommunications. According to the World Bank[lvii], the lowering of costs and productivity gains from broadband in a high-income country with an average of 10 broadband subscribers per 100 inhabitants would raise per capita GDP by 1.2 per cent per annum.

Therefore, middle income and low-income countries may need to invest significantly if they also want to realise the growth effects experienced by richer countries[lviii]. Failure to invest sufficiently and to create a sufficient mass of user penetration, will result in unequal development in technologies among countries.

1.5 Descriptive Statistics

There are presently no data available on 5G infrastructures as it is still in the stage of initial deployment. However, data related to legacy telecommunications technologies are available. The postulations made in this section are based on what is presently known on the correlations that fixed broadband, fixed telephone and mobile cellular have with economic growth.

While fixed telephones have been in use for some time, the penetration of fixed broadband and mobile cellular have been a more recent phenomenon. By studying the growth of these technologies, and their association with economic development, we can draw inferences on the potential opportunities that 5G could offer the Malaysian economy.

The Descriptive Statistics presented in Table 1.3 below infers the relationship between penetration of fixed broadband, fixed telephone and mobile cellular, with the income cohort of countries. Malaysia is classified as an upper middle-income country (UMC) by the World Bank classification regime; the other classifications being high income countries[lix] (HICs), lower middle income countries (LMCs) and low income countries (LICs). The table shows tabulations of three (3) years, namely 2002, 2010 and 2017, and the mean and median of each telecommunications technology and the GDP per capita per country income groups are displayed.

The installed base (or number) of fixed telephone subscriptions in HICs was at its peak nearing 2002, when the median was 46.8 subscriptions per 100 people in the country. By 2010, the median fell to 42.3, and then to 34.7 by 2017.

For UMCs, the median for fixed telephone subscriptions was 12.9 per 100 people, and this median rose to 16.5 in 2010 before declining to 15.8 in 2017.

The medians for LMCs and LICs were only at 3.7 and 0.5 per hundred people in 2002. These rose marginally to 4.4 and 0.7 respectively in 2010, before also declining to 4.2 and 0.4 respectively in 2017.

Conversely, the subscriptions for mobile cellular have been rising steadily between 2002 and 2017. The medians in 2002 were 62.6, 13.4, 3.0 and 0.9 per hundred people for HICs, UMCs, LMCs and LICs respectively. By 2017, the medians were 126.9, 107.2, 91.7 and 58.2 subscriptions per 100 people respectively.

The patterns of fixed telephone and mobile cellular subscriptions amongst different groups of countries (divided by their income level) provide several pointers. Firstly, the richer the country, the more likely they are to invest early with a larger budget in new communication technologies. As a result, HICs have a head start in creating critical mass users of its network, which in turn provides these countries increasing rates of return.

Secondly, by 2017, the subscription rates of fixed telephony have declined across all country groups. On one hand, LMCs and LICs, which have had very low penetrations in 2010, declined further by 2017. The medians of HICs and UMCs also declined during this period.

On the other hand, mobile cellular subscriptions rose rapidly between 2002 and 2017. Even poorer countries were having reasonably developed mobile cellular infrastructure. The decline in fixed telephone subscription coupled with the rise in mobile cellular subscriptions suggests that mobile cellular has become a substitute for fixed telephone lines.
The above also indicates that poorer countries have bypassed the high investment in fixed telephone infrastructure and leapfrogged into investing in mobile cellular technology. This has enabled poorer countries, to a certain degree, catch up with rich countries in the past decade.

In 2002, fixed broadband was only starting to gain traction in the HIC, which had a median of 2.5 subscriptions per 100 people in the country. Fixed broadband then expanded rapidly in these countries to a median of 23.3 subscriptions per 100 people in 2010, and 30.7 subscriptions per 100 people in 2017. The other countries have been consistently lagging. The UMCs only signed up 4.3 subscriptions per 100 people in 2010, rising to 10.9 in 2017, while the LICs only had 0.2 subscriptions per 100 people in 2017.

HICs developed their respective fixed broadband infrastructures and subscriptions at a faster rate than lower- and middle-income countries. As a result, the HICs have been able to benefit the most from the development of the internet-based technologies and various marketplaces. The digital economy has become ever more skewed in favour of the HICs.

However, just like in the case of fixed telephone, other countries like Malaysia can reduce the digital divide with respect to HICs by leapfrogging fixed broadband technologies by investing in 5G technologies. The latter can be carried out by leveraging existing mobile cellular infrastructure.

Year 2002	Fixed telephone subscriptions (per 100 people)		Mobile cellular subscriptions (per 100 people)		Fixed broadband subscriptions (per 100 people)		GDP per capita (constant 2010 US$)	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
High income countries	46.4	46.8	60.5	62.6	3.9	2.5	34,457	30,385
Upper middle income countries	15.7	12.9	15.6	13.4	0.3	0.1	5,131	4,824
Lower middle income countries	5.2	3.7	4.7	3.0	0.01	0.01	1,571	1,340
Low income countries	0.8	0.5	1.4	0.9	0.04	0.01	533	476

Year 2010	Fixed telephone subscriptions (per 100 people)		Mobile cellular subscriptions (per 100 people)		Fixed broadband subscriptions (per 100 people)		GDP per capita (constant 2010 US$)	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
High income countries	41.5	42.3	123.8	119.9	23.4	23.3	39,308	33,692
Upper middle income countries	17.6	16.5	97.8	96.5	5.6	4.3	6,775	6,310
Lower middle income countries	7.6	4.4	69.9	69.1	1.17	0.43	2,024	1,891
Low income countries	1.0	0.7	37.0	36.5	0.1	0.04	611	575

Year 2017	Fixed telephone subscriptions (per 100 people)		Mobile cellular subscriptions (per 100 people)		Fixed broadband subscriptions (per 100 people)		GDP per capita (constant 2010 US$)	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
High income countries	34.4	34.7	135.0	126.9	30.0	30.7	39,179	33,790
Upper middle income countries	15.6	15.8	113.0	107.2	11.7	10.9	7,358	6,952
Lower middle income countries	5.8	4.2	96.5	91.7	3.2	1.9	2,405	2,160
Low income countries	0.7	0.4	67.6	58.2	0.4	0.2	708	671

Table: Figure *1.3: Descriptive Statistics*

***Source: Calculated by MIER based on the World Bank (2019)*[lx]**

As abovementioned, to be classified as a HIC, the minimum Gross National Income (GNI) per capita threshold set of the World Bank is US$12,055 (RM51,607)[lxi]. The GNI per capita by Malaysia in 2018 was RM43,086, which is approximately US$10,043. It is expected to increase to RM47,720 by 2020[lxii]. Malaysia is therefore not far from meeting the HIC threshold.

Figure 1.4 below compares the GDP per capita of Malaysia with the Tiger Economies, selected Association of Southeast Asian Nations (ASEAN) countries, and the mean of UMCs. Malaysia has consistently been performing better than the average UMC[lxiii] during the 1992 to 2017 period. Malaysia has also been performing better than many other Southeast Asian nations, namely Thailand, Indonesia, Vietnam and Philippines.

However, the Tiger Economies have been forging ahead of Malaysia. While the Malaysian GDP per capita grew by 128 per cent between 1992 and 2017, South Korea, which is the "Tiger" closest to Malaysia in economic terms, have had its per capita GDP grow by 169 per cent.

The other countries, such as Hong Kong, Japan and Singapore grew by 88 per cent, 23 per cent and 134 per cent, respectively. The end result is that the Malaysian economy did not converge with the Tiger Economies. Though the Malaysian economy grew faster than some of the "Tigers", the gap between Malaysia's GDP per capita against the others has only risen.

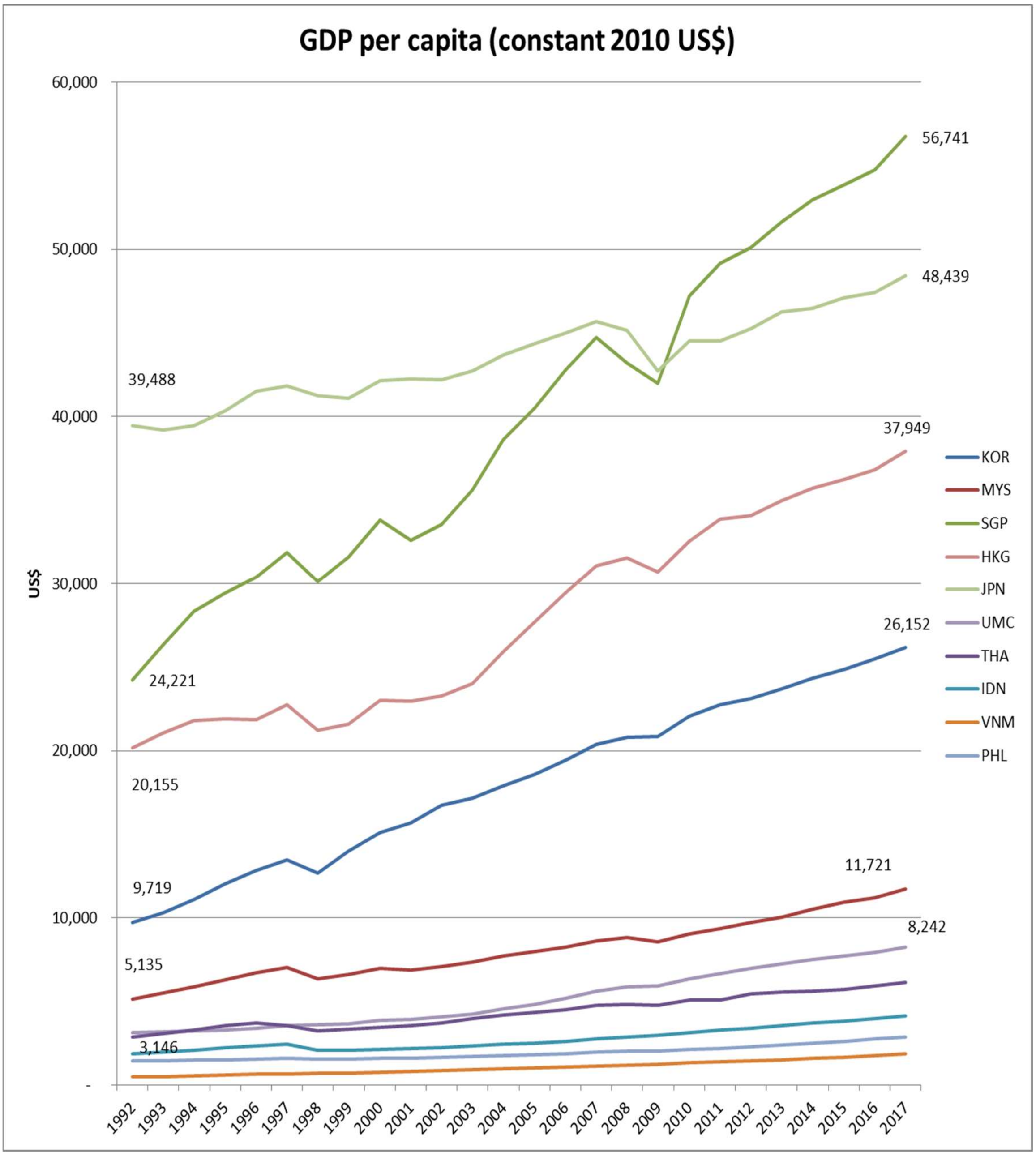


Figure 1.4: Comparison Of Per Capita GDP
Source: Calculated by MIER based on the World Bank (2019)[lxiv]

From year 2000 onwards, the growth rate of mobile cellular subscriptions has been rapid (see Figure 1.5 below). Except for Hong Kong, which had an exceptionally high subscription rate of 250 users per 100 people, the rest of the countries in this comparison have above 100 users per 100 people.

Malaysia experienced a significant decline in mobile cellular subscriptions between 2014 and 2017. This decline can be explained by the propensity of subscribers in reducing the number of Subscriber Identification Module (SIM) registered per user account[lxv].

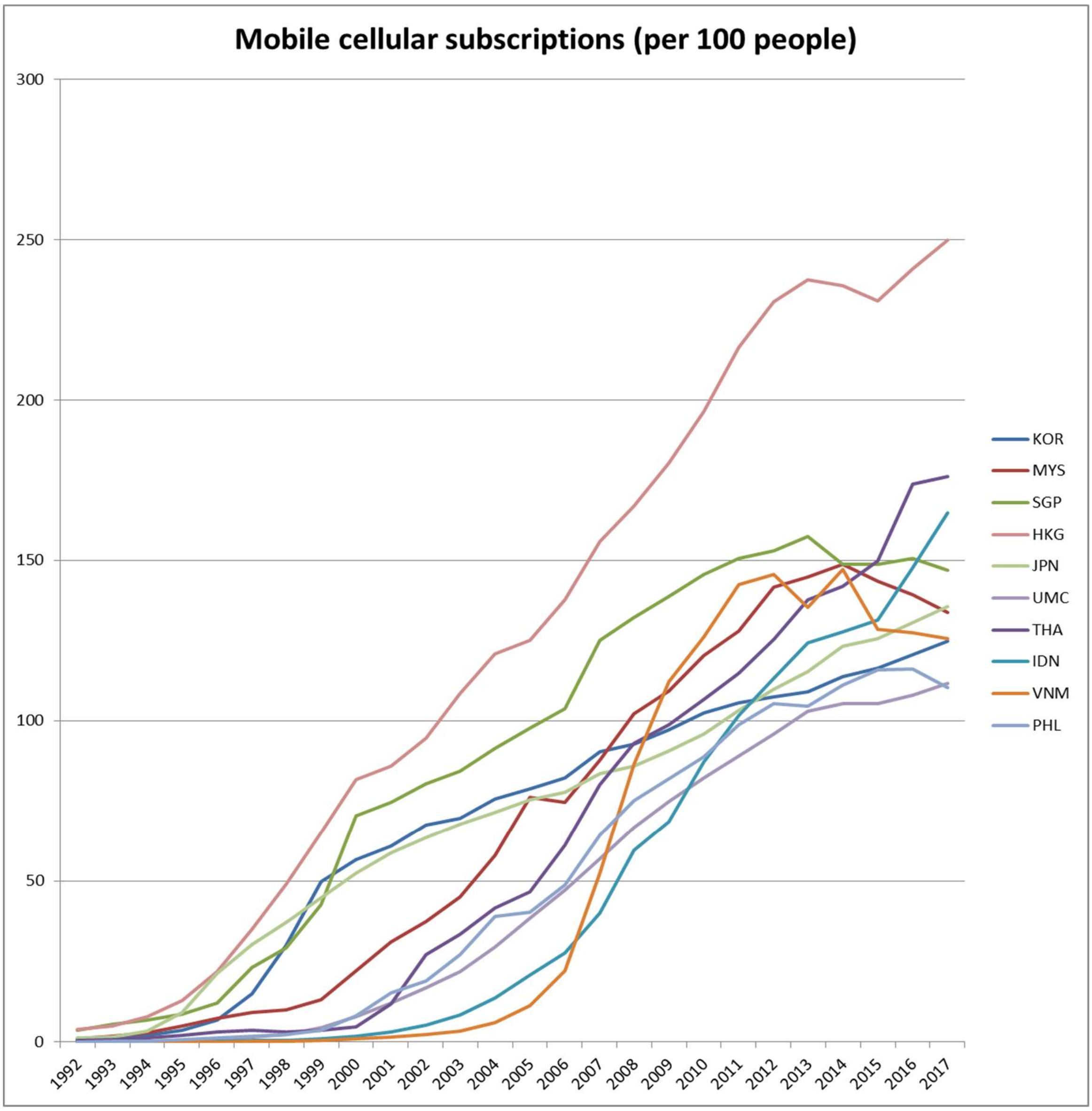


Figure 1.5: Comparison Of Mobile Cellular Subscriptions

Source: Calculated by MIER based on The World Bank (2019)

Between 2014 and 2017, single SIM subscriptions increased to 68.0 per cent from 62.3 per cent, up by 5.7 percentage points. Within the same period, double SIM subscriptions reduced 3.6 per cent. The same trend was observed among subscribers with more SIM in 2014 as well. Furthermore, from 1st June 2017, MCMC revised the subscribers' registration process, which includes limiting each customer to five (5) Prepaid SIM cards per service provider[lxvi].

Upon analysis of Malaysia's uptake of fixed broadband in comparison to other countries, the country is lagging when compared to most others. Only Indonesia and the Philippines registered below Malaysia, with 2.4 and 3.2 subscribers per 100 people. While Malaysia had 10 subscribers per 100 people by 2012, it had since reduced to 8.5 subscriptions in 2017.

It is also noted that there is a fall in subscribers per 100 people in Malaysia between 2015 and 2017. There were 10.0, 8.7 and 8.5 subscribers per 100 users in 2015, 2016 and 2017, respectively. In 2015, there were 2.8 million fixed broadband and 27.8 million cellular broadband subscriptions in Malaysia[lxvii]. These subscriptions fell to 2.6 million and rose to 35.3 million subscriptions respectively, in 2017.

As fixed broadband and cellular broadband are possibly substitutes, a portion of the reduction in fixed broadband subscriptions could have been compensated by the increase in mobile broadband subscriptions. The significant monthly cost of having subscriptions for both services also could have compelled some users to terminate their fixed broadband and rely solely upon their mobile broadband subscription.

Thailand and Vietnam have surged ahead to 11.9 and 11.8 subscribers respectively in 2017. Nevertheless, the mean for UMC's rose to 21.1 subscribers.

The subscription rate for fixed broadband in Malaysia have consistently lagged behind the Tiger Economies. By the time Malaysia achieved one (1) subscriber per 100 people in 2004, Korea, Hong Kong, Japan and Singapore have had 25, 22, 15 and 12 subscribers respectively. In 2017, the latter four countries had 41.6, 31.6, 31.8 and 25.8, respectively. Therefore, as per the graph in Figure 1.6, in comparison to these fixed broadband subscriptions, Malaysia has lagged behind in fixed broadband roll-out.

The Figure 1.7 plots GDP per capita against mobile cellular subscriptions, while Figure 1.8 plots GDP per capita against fixed broadband subscriptions, respectively. While Malaysia has largely followed the HICs in mobile cellular subscription rates, the same cannot be said with regards to fixed broadband subscriptions.

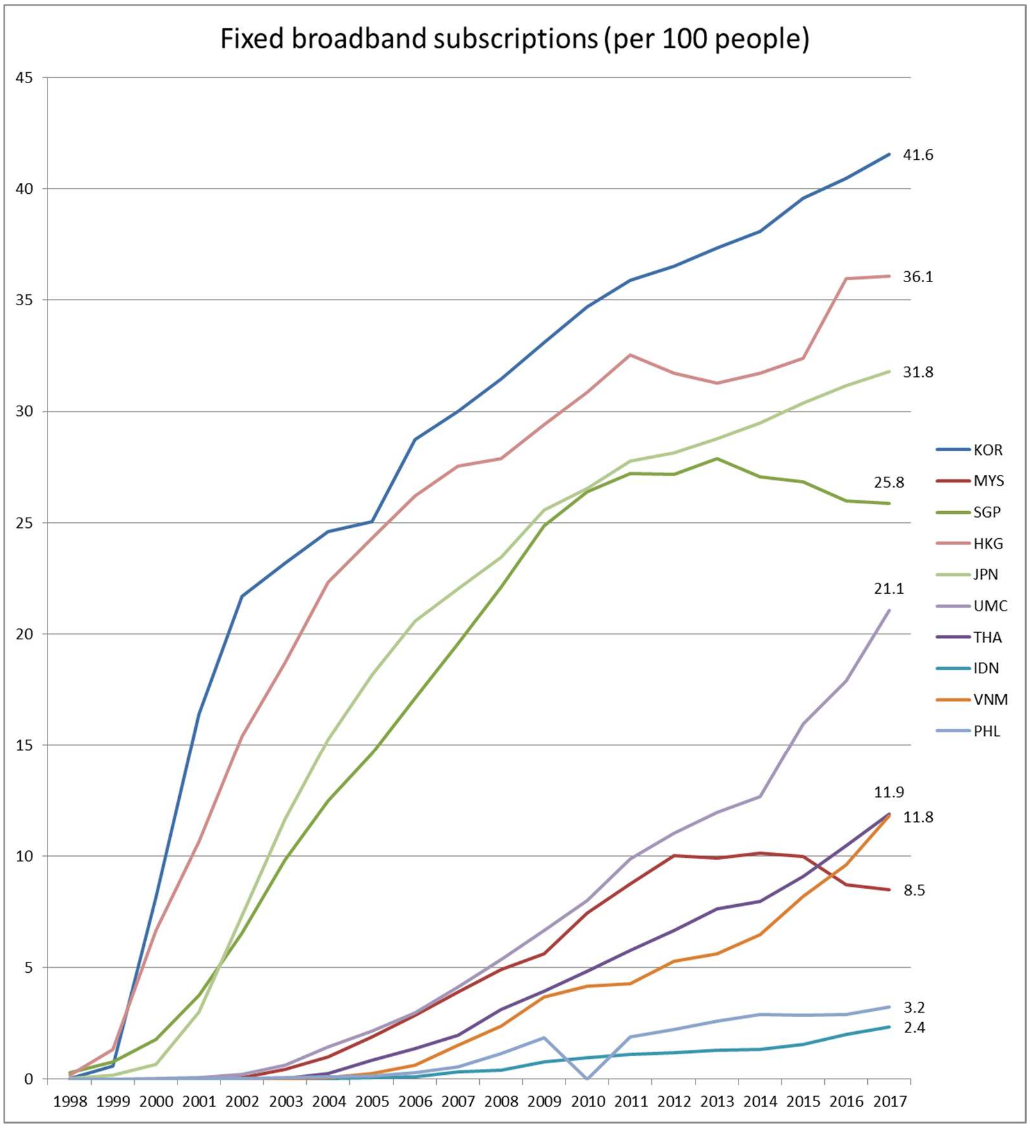


Figure 1.6: Comparison of Fixed Broadband Subscriptions
Source: Calculated by MIER based on the World Bank (2019)
Note: Each plot on a graph represents a year.

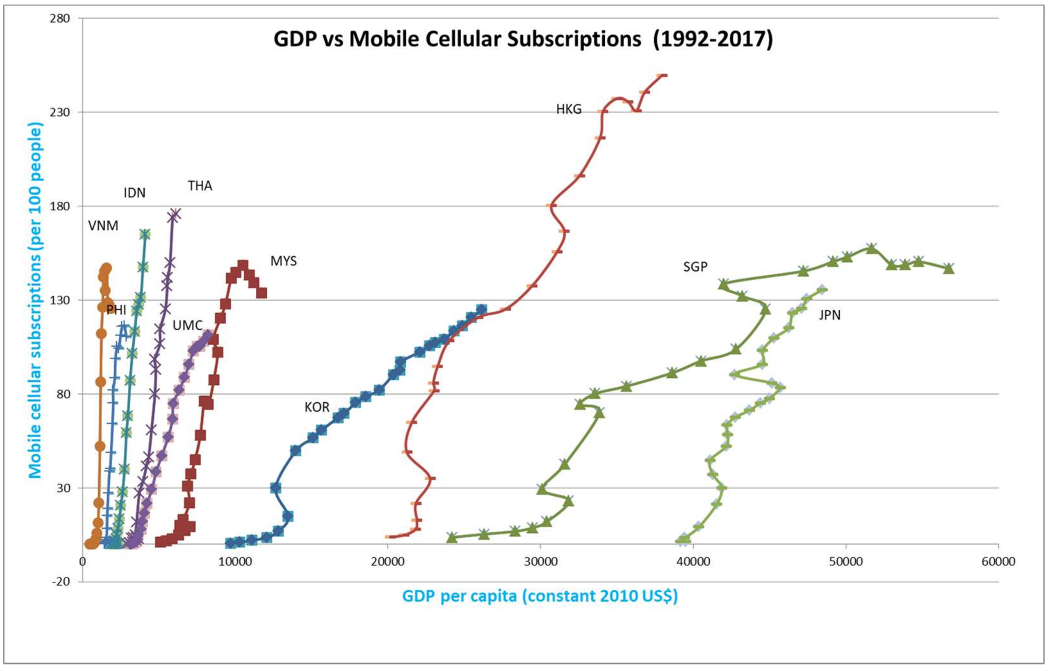


Figure 1.7: Mobile Cellular Subscriptions vs. GDP (1992-2017)
Source: Calculated by MIER based on the World Bank (2019)
Note: Each plot on a graph represents a year

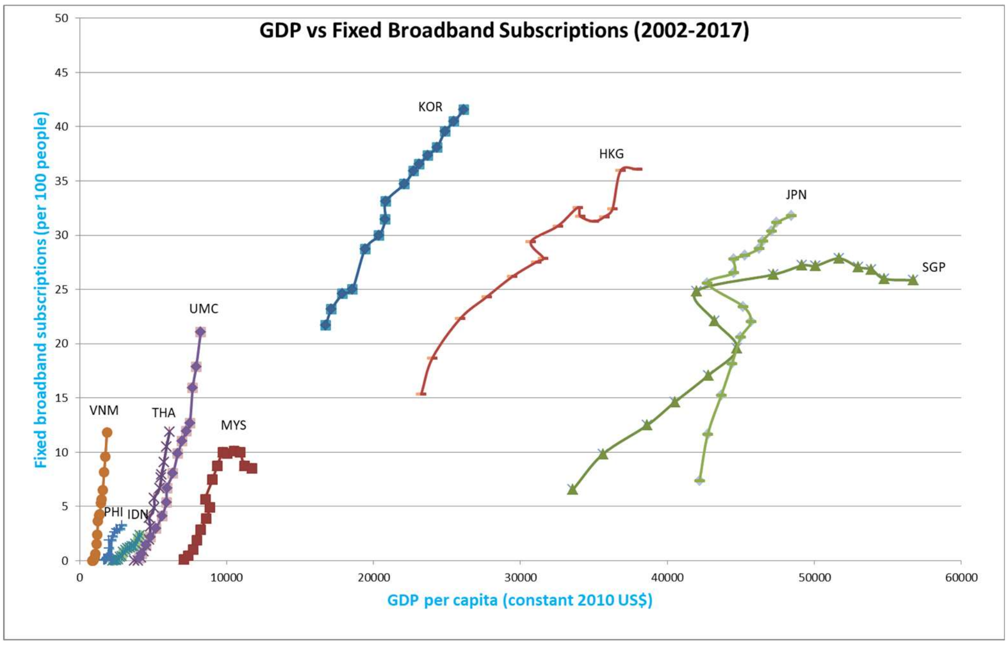


Figure 1.8: Fixed Broadband Subscriptions vs. GDP (2002-2017)
Source: Calculated by MIER based on the World Bank (2019)
Note: Each plot on a graph represents a year

1.6 Summary

From the many studies conducted worldwide, it is evident that the communications infrastructure of HICs have consistently been better developed than other countries. This strongly suggests that countries like Malaysia, in order to achieve high income status, must also invest significantly in this sector if Malaysia aims to achieve economic convergence as a HIC.

HICs such as Singapore, South Korea, and Sweden have announced their 5G targets. Malaysia's National Fiberisation and Connectivity Plan (NFCP) has the following targets, relevant to the future implementation of 5G technology[lxviii]:

a. Entry-level fixed broadband package at one (1) per cent of GNI by 2020.
b. Gigabits availability in selected industrial areas by 2020 and to all state capitals by 2023.
c. 100 per cent availability for premises in state capitals and selected high impact areas with a minimum speed of 500Mbps by 2021.
d. 20 per cent availability for premises in sub-urban and rural areas with up to 500Mbps by 2022.
e. Fibre network passes 70 per cent of schools, hospitals, libraries, police stations and post offices by 2022.
f. Average speed of 30Mbps in 98 per cent of populated areas by 2023.
g. Improve mobile coverage along the Pan Borneo Highway upon completion

It was also announced in August 2019 that the RM21.6 billion was approved for expenditure for the next five (5) years (2019 to 2023) under the NFCP, to ensure its roll out has 98 per cent baseline coverage in inhabited areas by 2023 with a minimum bandwidth of 30Mbps[lxix]. 5G technology will also be introduced as part of the NFCP to provide Malaysians with a sustainable, comprehensive, high-quality and affordable digital connectivity.

2. Macro-Economic Impact of 5G Network Deployment

2.1 Background

To reiterate the previous Chapter, this latest network technology has yet to be rolled-out. Thus, due to the uncertainty on the quantum of investment needed to enable 5G, the scope and scale of benefits resulting from the new technology, it is highly difficult to quantify the most accurate productivity and economic impact of the enablement of this technology.

A detailed literature review[lxx] below shows that the Growth Accounting Approach, Dynamic Computable General Equilibrium (CGE) Model and the Input-Output Economic Impact Model are the mainstream methodologies used in earlier literatures to study the impact of the deployment of advanced technologies on productivity[lxxi].

There are a few studies which have examined the macro-economic impact of 5G-network deployment, including GSMA (2019a, 2019b)[lxxii][lxxiii], BCAR[lxxiv] and IHS[lxxv]. Here, the Australian study[lxxvi] was referenced because it is the only existing study which provides a clear forecasting model on the impact of 5G on a specific country, with a clear assumption framework on the possible required investment for 5G.
Calculated using the Growth Accounting Approach, BCAR's (2018)[lxxvii] benchmark study found that the GDP per capita of Australia could be raised by around US$8,400 per person by 2050 (based on 2015 to 2016 prices) in the most favourable economic circumstance[lxxviii]. In the least favourable circumstance[lxxix], the GDP per capita could be raised by a modest US$1,900 by 2050 (based on 2015 to 2016 prices).

In another benchmark study, employing the 5G Sales Enablement Model, IHS Markit Global Link Model together with the Input-Output Economic Impact Model, IHS[lxxx] showed that 5G will enable a global economic output of US$12.3 trillion in 2035. This is almost equivalent to United States' (US) total consumer spending in 2016; exceeding the combined spending of consumers in China, Japan, Germany, the United Kingdom (UK) and France, in 2016.

This study also showed that 5G deployment will fuel sustainable long-term growth to global real GDP. From 2020 to 2035, the total contribution of 5G to real global GDP will be equivalent to an economy the size of India – currently the seventh largest economy in the world. Consequently, the global 5G value chain will generate US$3.5 trillion in output, and support 22 million jobs in 2035.

When it comes to GDP growth, the previous roll out of 3G showed notable increase in GDP per capita. Based on the econometric analysis of mobile data from 96 developed and developing countries from year 2008 to 2011, Deloitte, GSMA and Cisco (2012)[lxxxi] observed a 0.15 per cent increase in GDP per capita growth after substituting only 10 per cent of the available 2G network with 3G. Upon econometric analysis on data gleaned from Cisco's Visual Networking Index (VNI) Index[lxxxii], this study also found that the that doubling of mobile data use led to a 0.5 per cent increase in GDP per capita each year, from 2005 to 2010.

When it comes to MFP growth, it was found that there is a link between mobile telecommunications penetration and MFP growth[lxxxiii]. This study also applied the Stochastic Frontier Analysis (SFA)[lxxxiv] to data from 74 countries, and also concluded that if these countries had a 10 per cent higher mobile penetration between 1995 and 2010, MFP[lxxxv] would have increased by 4.2 percentage points.

According to the econometric analysis of the contribution of mobile telecommunications to productivity growth in Australia, the findings of Gruber and Koutroumpis (2011)[lxxxvi] indicated that productivity growth increased by 0.28 per cent per annum in Australia over years 1990 to 2008, in comparison to 0.31 per cent in Nordic countries (Finland, Norway and Sweden), 0.30 per cent in the UK, 0.24 per cent in US, and 0.18 per cent in Canada during the same period.

In Europe, Micus Management Consulting GmBH (2008)[lxxxvii] found that productivity experienced a 0.29 per cent growth from 2004 to 2006, and business services enjoyed the highest annual improvement (0.58 per cent) while the manufacturing sector rose only 0.14 per cent. These findings were based on data from the Community Survey on ICT Use in Enterprises (2004 to 2006) for Europe[lxxxviii] and the estimation of the macro-economic broadband-related productivity improvement[lxxxix].

The increase in mobile device usage has also led to increased labour participation via mobile devices. Deloitte (2016)[xc], by applying the dynamic CGE model[xci], found that this also led to an increase of US$8.9 billion of real GDP between 2008 and 2015.

With the application of Dynamic CGE Model of the Australian economy with the Monash Multi Regional Forecasting Model (MMRF), Allen Consulting Group (2010)[xcii] found that MFP rose by 0.07 percentage points when household internet connectivity in Australia increased by 20 per cent.

Moreover, Allen Consulting Group (2002)[xciii] found that productivity also enjoyed a 0.32 per cent increase due to the 6.3 per cent cost savings from broadband internet.[xciv] By applying the cross-country regression with data from OECD countries, Bean (2000)[xcv] showed that the uplift in ICT investments in Australia contributed 0.12 percentage points to MFP growth in the

1990s. In the same year, Toohey (2000)[xcvi] documented that the Information Technology (IT) industry contributed 0.75 per cent per annum to the Australian productivity growth. This was also calculated using the Growth Accounting Approach.

2.2 Methodology

Growth Accounting Approach is a procedure used in economics to measure the contribution of different factors to economic growth and to indirectly compute the rate of technological progress, measured as a ‘residual’, in an economy.

It decomposes the growth rate of an economy’s total output, which is due to the increase in the ‘contributing amount’ of the factor used, usually the increase in the amount of capital and amounts of inputs, or a measure which can be defined as technological progress.

This technique has been applied to study most economies in the world. A common finding of this methodology is that observed levels of economic growth cannot be explained by changes in the capital stocks in the economy, or population and labour force growth rates. Hence, in line with the assumption of Robert Solow[xcvii]’s model, the Solow residual, it is concluded that technological progress plays a key role in the economic growth of nations, or the lack of it. The model is further discussed in Appendix A.
Therefore, in this study, with this approach, it is assumed that output growth in the Malaysian economy is based on labour input growth, capital input growth and MFP.

This approach can help us to estimate the potential effect on MFP with the introduction of 5G in Malaysia. It does so by assuming different changes to investment and output growth. By deriving the effects of 5G network roll out on MFP, the result can then be used to assess its potential effect on GDP per capita (further details of this methodology are as per Appendix A).

As previously mentioned, there is uncertainty on the extent and scope of 5G’s impact on the economy. One of the biggest uncertainties is the cost needed to enable 5G, especially infrastructure costs (of building the network), the cost of acquiring the spectrum, and how much will it cost businesses and consumers to gain access to 5G (such as purchasing new 5G-compatible equipment). In this study, we endeavour to overcome this uncertainty by modelling three (3) different scenarios: low cost/investment, medium cost/investment, and high cost/investment.

Based on a literature review on the cost of building 5G networks[xcviii], BCAR's (2018)[xcix] benchmark study concluded that the cost of building the network could vary between US$2 billion to US$27 billion. They examined potential low, medium and high cost scenarios in their modelling, as indicated below:

a. Low Cost assumes that there would be:

   i. US$5 billion investment in non-dwelling construction and US$0.5 billion in Research and Development (R&D) for the Information, Media and Telecommunications Sector (reflecting the cost of building the network) over the next five (5) years (i.e. US$1 billion per year. US$5 billion equalled to 1.4 per cent of Malaysia's total GDP in 2018)

   ii. A five (5) per cent increase in investment in electrical and electronic equipment across all industries (reflecting the cost of purchasing new 5G-enabled equipment)

b. Medium Cost assumes that there would be:

   i. US$10 billion investment in non-dwelling construction and US$1 billion in R&D for the Information, Media and Telecommunications Sector (reflecting the cost of building the network) over the next five years (i.e. US$2 billion per year. US$10 billion equalled to 2.8 per cent of Malaysia's total GDP in 2018).

   ii. A 10 per cent increase in investment in electrical and electronic equipment across all industries (reflecting the costs of purchasing new 5G-enabled equipment).

c. High Cost assumes that there would be:

   i. US$25 billion investment in non-dwelling construction and US$2.5 billion in R&D for the Information, Media and Telecommunications Sector (reflecting the cost of building the network) over the next five (5) years (i.e. US$ 5 billion per year. US$ 25 billion equalled to 7 per cent of Malaysia's total GDP in 2018).

   ii. A 20 per cent increase in investment in electrical and electronic equipment across all industries (reflecting the costs of purchasing new 5G-enabled equipment).

The results of these three (3) different scenarios will be compared to the 'baseline' case, where no change is made to the investment.

In this study, the relevant series were forecasted to generate productivity estimates up to 2050. Output growth and labour input growth for each industry, and productive capital stock growth for each asset in each industry, were forecasted using the average annual growth rate from 1985 to 2018, with existing data from the World Bank database and Department of Statistics of Malaysia (DOSM). The forecasting is based on the assumption that the investment on 5G will end in the year 2025. This means that the results obtained under this forecasting model will change if continuous investment on 5G in Malaysia is made from 2025 onwards.

2.3 Findings

Table 2.1 shows the results of the impact of 5G network technology deployment on the total GDP per annum for three (3) different cost scenarios relative to the baseline case.

In the least favourable circumstance, where investment is low (i.e. US$1 billion per year), the total GDP in 2030 and 2050, respectively, would be 0.0489 per cent and 0.1441 per cent higher than the baseline. (See Table 2.1)

In the most favourable circumstance, where investment is high (i.e. US$5 billion per year), the total GDP in 2030 and 2050, respectively, would be 0.1066 per cent and 0.2977 per cent higher than the baseline. (See Table 2.1). Although we are aware of that the NCFP will invest RM21.6 billion for broadband infrastructural projects in Malaysia, the justifications for the high investment assumption – RM100 billion over a five (5)-year period, includes (but not limited to) investments on broadband infrastructural projects. It also includes (but not limited to) other economic activities, such as investment by telecommunications service providers, investments by businesses for 5G use case implementation, purchase of 5G handset by consumers and so on. By taking above mentioned possible needed investment into consideration, therefore it is decided that for the rest of this study, Malaysia will follow the high investment scenario over the five-year period.

The result for the Malaysian case here seems positive, relative to the findings from the worldwide IHS study[c] and Australian BCAR study[ci], it was found that the difference in GDP growth rate for Malaysia with 5G deployment versus without 5G deployment, is quite close to IHS's findings. The results from earlier studies will be discussed in detail in the next paragraph.

For example, for the 2020 to 2035 period, IHS[cii] forecasted that global real GDP will grow at an average annual rate of 2.9 per cent with the deployment of 5G, while global real GDP will only expand at a slower pace of 2.7 per cent per annum, without the deployment of 5G. In other words, global real GDP growth rate would be 0.2 per cent lower without 5G deployment. Conversely, BCAR (2018)[ciii] showed that in the scenario of high cost, longer output effect and instant timing, an additional 0.20 per cent and 0.23 per cent will be added to the GDP growth rate of Australia in 2030 and 2050, respectively.

Figure 2.1 (a), (b), (c) illustrates the changes in total GDP between the three (3) different scenarios and baseline cases, brought by 5G network technology deployment.

	Effect on Total GDP (per annum) to 2030	Effect on Total GDP (per annum) to 2050
Low Cost	0.0489 per cent	0.1441 per cent
Medium Cost	0.0617 per cent	0.2485 per cent
High Cost	0.1066 per cent	0.2977 per cent
IHS (2017)	0.2 per cent	
BCAR (2018)	0.2 per cent	0.23 per cent

Table 2.1: The Impact of 5G Network Technology Deployment on Total GDP (p.a) for Three Different Cost Scenarios Relative to the Baseline

Notes: 1) our estimation is based on data from the World Bank database and DOSM; 2) the effects shown are relative to the baseline case, where long-run productivity growth is assumed to continue through to 2050 (under our estimation); 3) the result of IHS'[civ] worldwide study is based on the forecasted period of 2020-2035; 4) the result of BCAR's (2018)[cv] study on Australia, is based upon the most favourable scenario – high investment assumption.

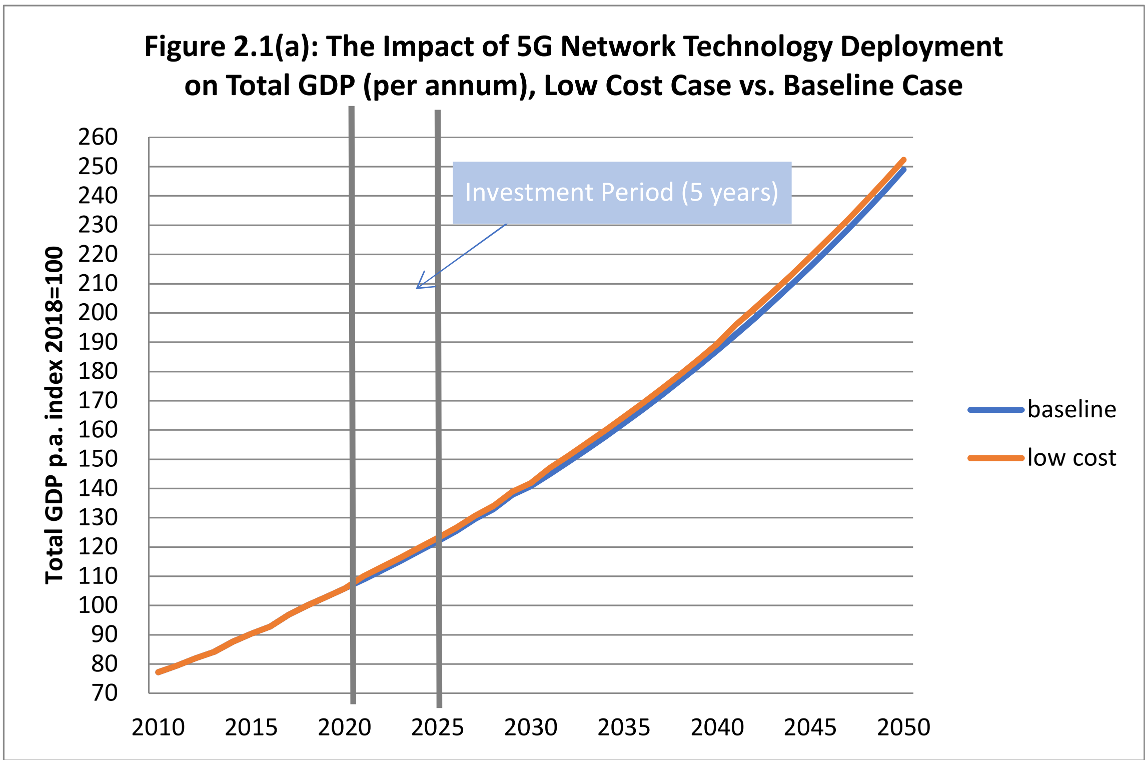


Figure 2.1 (a): The Impact of 5G Network Technology Deployment on Total GDP (per annum), Low Cost Case vs. Baseline Case; Source: Estimated by MIER

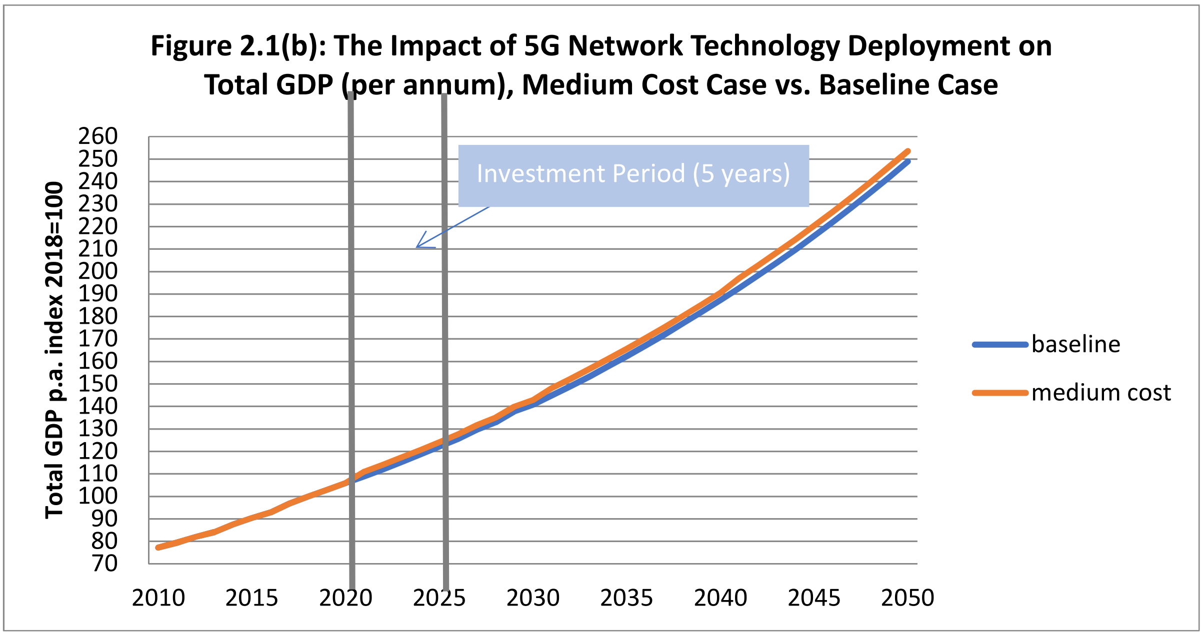


Figure 2.1 (b): The Impact of 5G Network Technology Deployment on Total GDP (per annum), Medium Cost Case vs. Baseline Case; Source: Estimated by MIER

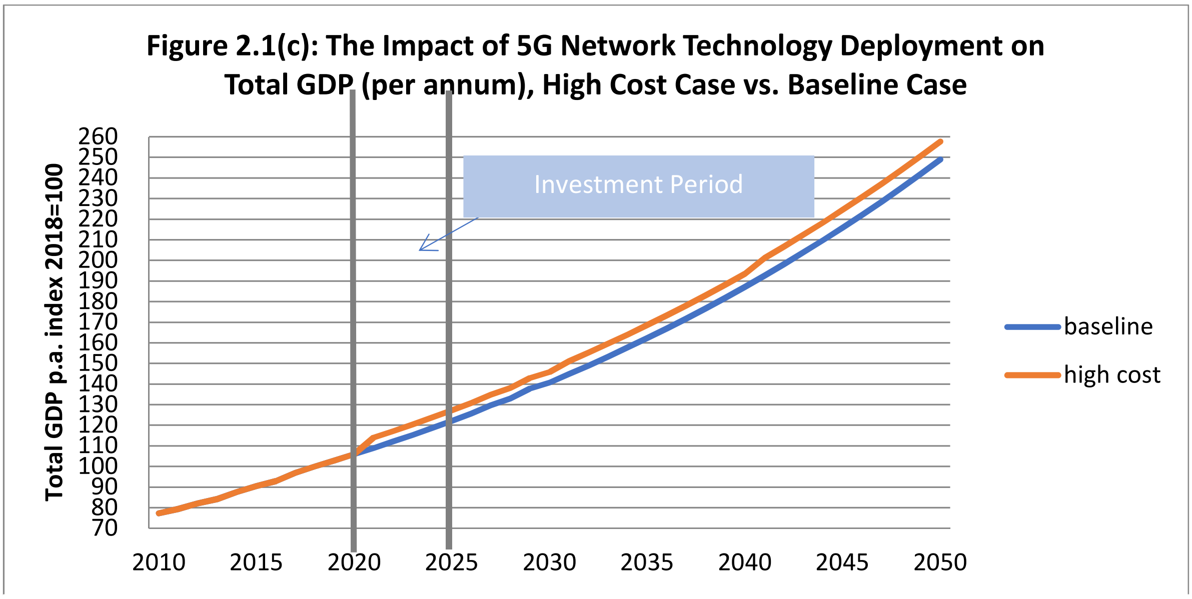


Figure 2.1 (c): The Impact of 5G Network Technology Deployment on Total GDP (per annum), High Cost Case vs. Baseline Case; Source: Estimated by MIER

Figure 2.2 shows the contribution from the deployment of 5G network technology to GDP per capita in Malaysia. In the most favourable circumstance, where the cost is high (i.e. US$5 billion per year), the GDP per capita are US$1559.6 and US$5071.9 higher than the baseline case (without any change to the investment) in 2030 and 2050 (based on 2017-2018 prices[cvi]).

In the least favourable circumstance, where cost is low (i.e. US$1 billion per year), the GDP per capita are US$385.7 and US$1201.2 higher than the baseline case (without any change to the investment) in 2030 and 2050 (based on 2017-2018 prices). In other words, the 5G network technology deployment will yield an additional US$5071.9 per capita by 2050 in the most favourable circumstance, in comparison to an additional US$1201.2 per capita by 2050 in the least favourable circumstance.

The above findings show that our results are consistent with previous literatures. As expected, the deployment of 5G network has a positive effect on productivity and economic growth in Malaysia. If we look into the trend in the economic benefit/impact (in terms of the additional GDP growth rate and the additional GDP per capita) brought by 5G deployment, it shows that this benefit/impact is initially rather small, but it grows increasingly larger as the term prolongs. This indicates that productivity benefit will offset the cost of building the 5G network in the earlier stage over the investment period, which is in line with the fact that new technologies usually takes time to mature. This means that the positive effect of 5G deployment on the Malaysian economy is not immediate or obvious upon roll out. However, it becomes significant around the year of 2030 (i.e. five (5) years later, after high investment) if an additional GDP growth rate at 0.1 per cent was added to the threshold. In addition, if a comparison was made with the results across different investment models, it is apparent that additional investments can both bring further short-term benefits and long-term benefits.

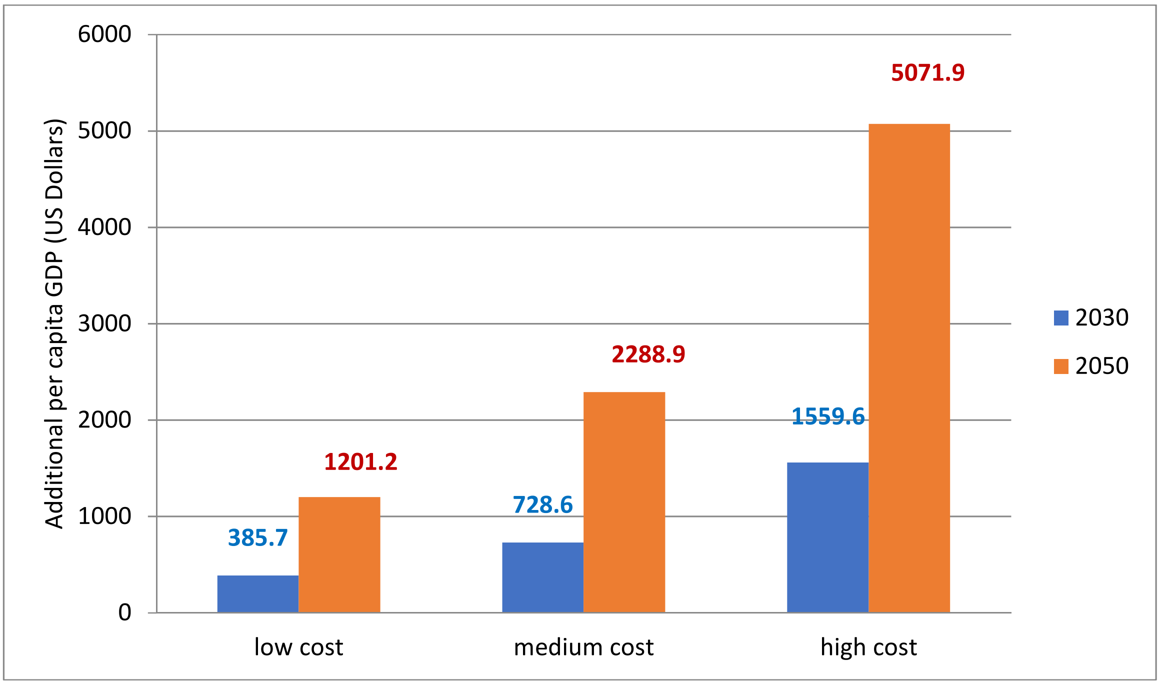


Figure 2.2: The Impact of 5G Network Technology Deployment on GDP per capita – Additional GDP per capita in 2030 and 2050.
Source: Estimated by MIER

Notes: 1) our estimation is based on data from the World Bank database and DOSM; 2) the effects shown are relative to the baseline case, where long-run productivity growth is assumed to continue through to 2050 (under our estimation).

2.4 Limitations

First, besides the uncertainty on the investment required to enable 5G and the estimated benefits accrued from 5G, there are two (2) other possible uncertainties that were not included in the analysis of this study, due to limited time and data unavailability during this economic modelling:

a. certainty could not be made on whom will use 5G and when – especially given the expectations of this technology, which is expected to enable a wider range of new goods and services in comparison to previous generations of mobile technology.
b. certainty could not be made on the timing of 5G deployment – it is not clear how long it takes to build the network, nor how quickly the technology will be taken up. These two uncertainties could be the additional focus of further studies.

Second, in this study, MIER's forecasts are based on these assumptions:

a. there is no long-run change in the structure of the economy, such as the value-added shares, gross operating surplus shares and so on;
b. relative prices between different capital goods do not change.

Therefore, as there are structural changes[cvii] occurring over the forecast period, this analysis will not truly reflect the change in MFP with 5G, as modelled. The true effect could be more of less than what the growth accounting might suggest. This includes any structural changes that 5G itself might drive.

Third, in this current modelling regarding 5G, any 'dynamic' or 'behavioural' responses were not incorporated by firms. For example, an increase in productivity caused by 5G could be expected to change the allocation of resources in the economy, which in turn would have a further impact on productivity. Therefore, in further studies, especially studies on specific sectors or industries, the Dynamic CGE Model is suggested to be used to evaluate the productivity and income impact of 5G on different sectors.

Fourth, although Growth Accounting Approach is a useful tool, it cannot tell the full story on how 5G will affect people's lives and work in differentiated sectors, such as Digital Healthcare. Therefore, a more qualitative approach is required to have a better understanding on the impact of 5G Network Technology Deployment in these different sectors.

3. Micro-Economic Impact of 5G Network on Selected Verticals and Use Cases

3.1 Introduction

The information and telecommunications industry have been both an enabler of technological innovation as well as economic growth. It is estimated that around 35.13 per cent of the world's population today own a smartphone and 63.4 per cent of mobile phone users have access to the internet from it[cviii]. These numbers are predicted to increase at a rapid pace. Even in Malaysia, as per the Malaysian Communications and Multimedia Commission (MCMC)'s Hand Phone Users Survey 2017[cix], smartphone usage rate increased from 68.7 per cent in 2016 to 75.9 per cent in 2017 – a 7.2 per cent growth.

Amongst UMCs, Malaysia belongs the group with above median level of telecommunications penetration. Malaysia's current challenge is not just to grow faster than the other UMCs, but to become a HIC.

Hence, there is a need to adopt relevant technological advances, such as 5G, at a rapid pace. The adoption of 5G telecommunications in Malaysia, in collaboration with other ubiquitous technologies, can contribute towards development in at least the following ways:

a. **Complement other technologies**
   Technologies very rarely support users in isolation. They often have two-way causation with other technologies i.e. where technologies support the expansion of one another. 5G telecommunications is extremely collaborative with other Industry 4.0 technologies.
b. **Compete and complement fixed networks**
   On one hand, 5G may be viewed as a substitute for fixed broadband among end-users. On the other hand, the demand for 5G services to support new services, will create a demand for fixed broadband. This is because 5G is a last mile solution, and is therefore dependent on fixed networks, which is part of the telecommunications backhaul. Hence, an increase in demand for data bandwidth will also invariably lead to greater traffic on fixed broadband networks.
c. **Creation of new services, business innovations and new job opportunities**
   The expansion of fixed broadband technology has converged of all communications services, from analogue to digital transmission, from a multitude of transmission protocols to internet protocol (IP), as well as the integration of fixed, nomadic and mobile networks[cx]. This has created new services such as Voice over Internet Protocol (VOIP) and Internet Protocol television (IPTV), which created opportunities for new businesses and new jobs.
d. **Increase labour productivity**
   Higher network speed will enable workers to operate from any location. Greater flexibility in this could increase business efficiency as it offers firms a larger labour pool for hire, while allowing the firms to reduce office overhead[cxi].

e. Promotes GDP growth

When a comparison was made between communication technologies, the World Bank (2016)[cxii] study found that the highest contribution by penetration towards GDP was by fixed broadband, followed by mobile subscriptions, and finally fixed telephony. This suggests that the possibility for 5G network penetration could contribute to the GDP more than other technologies. An econometric study concluded that a 10 per cent increase in fixed broadband penetration increases GDP growth by 1.21 per cent in developed countries, and by 1.38 per cent in developing countries[cxiii].

f. Socioeconomic benefits

A 2013 study analysed data from 290 municipalities in Sweden and showed that fibre-to-the-home (FTTH) broadband deployments promoted statistically significant socioeconomic benefits, including population growth and better job opportunities in the municipalities served by those networks[cxiv]. 5G deployment will likely provide similar socioeconomic benefits. Furthermore, a study by OECD[cxv] found that increasing broadband speeds from 4Mbps to 8Mbps led to an increase of household income by US$122, while increasing the speed to 24Mbps resulted in a larger increase in household income. Other benefits includes reduction in both travel costs and carbon footprint.

3.2 Sectoral Analysis

As previously stated, the introduction and applications of 5G is expected to transform the way Malaysians live and work, as well as Malaysia's economy. However, the economic benefits accrued are heavily dependent on how this technology is used or deployed.

According to the MCMC 5G Task Force's Business Working Group (BCWG)[cxvi], nine (9) key verticals were found to benefit the most from this technology: (1) Smart City (2) Smart Transportation (3) Digital Healthcare (4) Agriculture and (5) Retail & Services (6) Manufacturing, (7) Oil and Gas (8) Education and (9) Banking and Finance.

However, all key verticals will be addressed except for Education, and Banking and Finance, as it is deemed that the former's use cases should be rolled out when 5G is available in both rural and urban Malaysia, to ensure that all Malaysian students have equal access. For the latter, the current mobile and online applications for this sector are still accessible on 4G LTE – therefore, it is deemed best to improve its existing financial platform first before making it 5G-enabled. Further limitations pertaining these two (2) verticals will be further discussed in the final section of this Chapter.

3.2.1 Smart City

As per the second quarter of 2019, Malaysia houses an estimated 32.48 million people, a 0.6 per cent increase from the second quarter of 2018 (32.38 million)[cxvii]. The most densely populated state in Malaysia is Selangor (an estimated 6.53 million people), followed by Sabah (an estimated 3.9 million people) and Johor (an estimated 3.76 million people)[cxviii].

As urban agglomeration increases, its accompanying issues, such as congestion, pollution and inefficient deployment of urban services such as public transportation will likely be major contributors to the decrease in quality of life of urban dwellers. Thus, it is crucial to adopt 'smart' technologies to address and mitigate the challenges of urbanization[cxix].
To address these challenges, Malaysia has issued several policies and initiatives, including state-driven initiatives, such as:

a. The National Urbanization Policy (NUP) (2006),[cxx] which states that urban development must be steered towards, among others, the creation of an environment that offers peaceful community living, and improved quality of life and living standard,

b. The Second National Urbanisation Policy (NUP 2) (2016),[cxxi] which was issued to address rapid urban growth and technological advances for cities, as well as to further the aims and goals of the NUP,

c. The Smart Selangor Blueprint, which posits that economic growth and innovation is the product and outcome of seamless interaction between hardware (tech infra) and community[cxxii], and

d. The Cyberjaya Smart Low Carbon City Action Plan 2025, which acts as a guide to improve quality of life in Cyberjaya while establishing an environmentally responsible and sustainable approach to development (i.e. "low carbon")[cxxiii].[cxxiv]

Based on Deloitte's 2015 report[cxxv], smart cities were stated to have numerous socioeconomic benefits, including faster reaction to public safety threats, as indicated in Figure 3.1. Hence, as one of the primary issues for Malaysia is the improvement of public safety, use cases focusing on public safety were chosen as it is in line with Malaysia's national plans (11th and 12th Malaysia Plans)[cxxvi][cxxvii], and to address Malaysia's 2017 Crime Index. This is important because the Federal Territory of Kuala Lumpur alone recorded 3,999 violent cases (18.7 per cent) and 9,483 property cases (12.1 per cent), from a total of 99,168 nationwide crime cases that year[cxxviii]. Thus, with 5G, coupled with a fixed broadband network, it could lower the risk of public safety by intensifying the adoption of these smart technology applications[cxxix].

Figure 3.1: Socioeconomic Benefits of Smart Cities.

Source: Deloitte (2015)[cxxx]The BCWG has identified two (2) use cases to address the issue of public safety: city-wide Closed-Circuit Televisions (CCTVs) and Drone Surveillance.

a. CCTVs

The deployment of large-scale, low-cost, and low power 5G-enabled CCTV cameras across a town or city could assist law enforcement personnel in monitoring incidences more effectively, without it being labour intensive. These 5G-enabled CCTV cameras will be able to perform real-time video analytics (with AI) to identify abnormal incidences or suspicious activities such as traffic accidents and robbery; and immediately alert the central command centre for further action[cxxxi].

b. Drone Surveillance

Aerial surveillance (i.e. drones) could assist in ensuring public safety as well as traffic control. As it works in tandem with CCTVs, it could provide accurate and real-time surveillance, facilitate decision-making, and improve the overall deployment of law enforcement personnel to ensure public safety[cxxxii].

However, there may be challenges in its initial implementation, such as the level of accuracy of detection using AI, as these technologies are still being refined. Nevertheless, there are countries which have implemented these technologies, albeit without AI.

Globally, 120 major cities have employed CCTVs to ensure public safety, and eight (8) out of the top 10 most surveilled cities are in China[cxxxiii]. By 2022, China is anticipated to have one (1) public CCTV per two (2) persons[cxxxiv]. However, Comparitech.com's research found little correlation between the number of CCTVs and crime rate[cxxxv], which concurs with the studies of London's civil rights group Big Brother Watch[cxxxvi] and the Scottish Government[cxxxvii]: it is has little impact on crime reduction, although it does help law enforcement personnel in solving crimes.

When it comes to drones, it was found that 347 United States police, sheriff, fire and emergency response units have acquired drones between 2009 and 2017, and the acquisitions shows no sign of slowing down.[cxxxviii] The benefits of using drones are also quite extensive, including but not limited to:[cxxxix]

a. Alleviating Manpower: "Drones can capture and store hi-resolution recording footage, freeing up officers to do other work during an investigation."[cxl]
b. Traffic Collision Reconstruction: "The combination of drones and 3D mapping software allows investigators to quickly and efficiently create a 3D rendering of the actual crash site instead of manually recreating from ground photos and manual measurements."[cxli]
c. Crowd Monitoring: "Drones allow officers to monitor crowds and scan for potential threats. In the event of an attack or threat, the drone can also be used to follow a person through a crowd safely and quickly. Police can also use the video footage to get a description of the perpetrator."[cxlii]

   At present, drones in low-altitude airspace are well served by the current mobile networks. With 5G, the ultra-low latency and large bandwidth could provide "...more efficient and effective mobile connectivity for large-scale drone deployments with more diverse applications."[cxliii]

   Currently, 5G!Drones[cxliv] is testing a project called "Unmanned Aerial Vehicle Vertical Applications' Trials Leveraging Advanced 5G Facilities", with the ultimate objective of designing, implementing and running trials of UAV use cases on top of a 5G infrastructure provided and addressing contemporary 5G challenges. The project took off on 1st June 2019 and it is a part of the 5G Infrastructure Public Private Partnership (5G PPP), a joint initiative between the European Commission and European ICT industry. Four (4) use cases are being tested, namely, Unmanned Aerial Vehicle (UAV) Traffic Management, Public Safety / Saving Lives, Situation Awareness, and Connectivity during crowded events. 20 companies from eight (8) countries across the European Union (EU) are taking part in this project, which will last 36 months.

3.2.2 Smart Transportation

The automotive industry plays an important role towards enabling Smart Cities[cxlv]. As indicated in the 2019 Smart Cities Index, 'transport and mobility' is noted as a as a critical ranking parameter[cxlvi], because traffic congestion and lack of mobility are two of the biggest challenges the cities of today, face.

Therefore, the National Automotive Policy (NAP) 2019 aims to improve the existing NAP 2014 by adding another dimension – it considers the development of future technologies by introducing new elements such as Next Generation Vehicle (NxGV), Mobility as a Service (MaaS), and Industrial Revolution 4.0 (IR4.0), which addresses the issues aforementioned.[cxlvii] [cxlviii]

Hence, the MaaS concept recognises the need to integrate various types of services and transport (such as public transport services and private vehicles) into an efficient, and centralized (single platform), mobility service as illustrated in Figure 3.2. Thus, MaaS can be seen as an augment of urban services offered by smart cities.

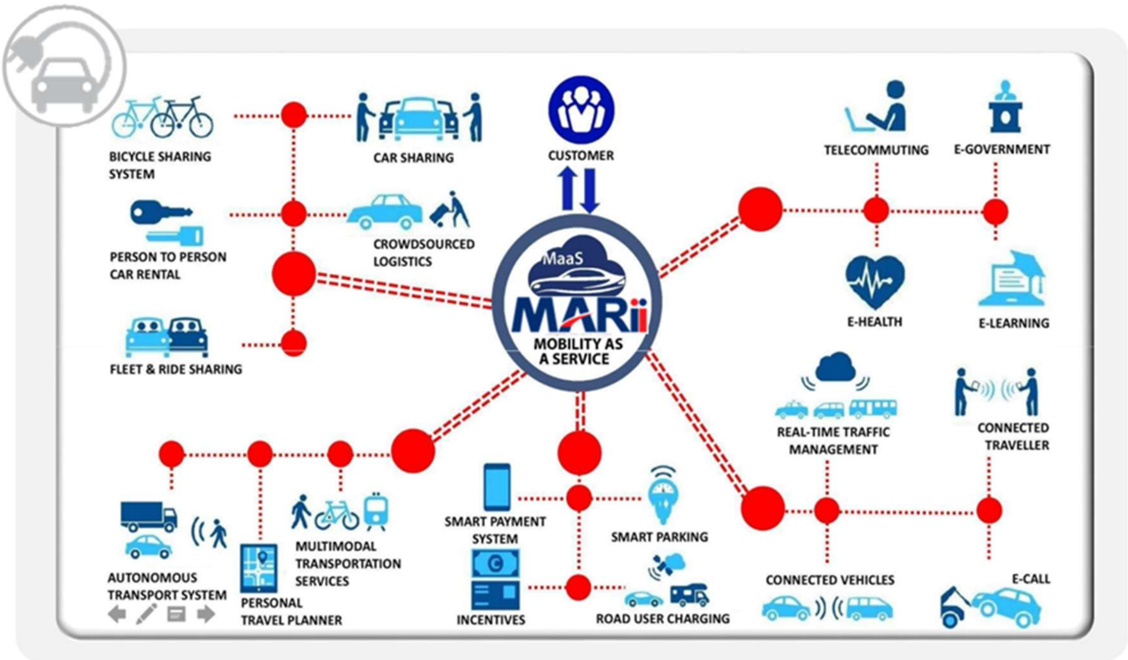


Figure 3.2: The MaaS Ecosystem; Source: BCWG Mid-Term Report (2019)[cxlix]

Automated/Autonomous and Connected Vehicle (AACV) or autonomous vehicle (AV) could enable a safer, more efficient, accessible and ecological means of transport. With the availability of a large bandwidth and low latency network, such as 5G, these vehicles will use several communication technologies to "…wirelessly communicate with the driver, other cars on the road (V2V), roadside infrastructure (V2I), other network telecommunication (V2N), smart devices (V2P) and with bikes, pedestrians or others (V2X)"[cl].

The enablement of 5G network could also shoulder the volume of data (i.e. video feed) transmitted from the dashboard camera to a centralised server, which is useful in gathering information regarding road conditions[cli].

Other developed nations in Europe have begun testing AACVs and AVs. For example, French car manufacturer Groupe PSA has tested its cars on expressways in Europe, covering 170,000 kilometres, and nearly 10,000 kilometres in China[clii]. In January 2019, Groupe PSA also became the first French car manufacturer to be authorised to test autonomous driving on open roads in China (Chongqing)[cliii]. Currently, driving assistance functions are already available on several of the Group's models: the Peugeot 208, 308, 2008, Traveller, the new Peugeot 3008, the Citroën C4 Picasso, the C3, and the SpaceTourer in Europe, and the Peugeot 4008 and the Citroën C6 in China[cliv].

3.2.3 Digital Healthcare

According to Fitch Solutions Macro Research[clv], Malaysia's healthcare market is expected to grow from RM56.3 billion 2017 to RM127.9 billion in 2027, a 127 per cent increase. Hence, unsurprisingly the government increased the budget for healthcare to RM29 billion in 2019, which is a 7.8 per cent increase from the 2018 allocation. Therefore, the current healthcare budget makes up almost 10 per cent of the total national budget[clvi].

Though there is an increased allocation in the healthcare budget, with 5G, the BCWG expects that it will bring cost-minimizing efficiencies, such as self-management capabilities which facilitates access to healthcare, due to its larger bandwidth, larger data rate and low latency[clvii]. Thus, four (4) key 5G technology drivers are identified[clviii]:

a. Internet of Medical Things devices: such as wearables, implantable medical devices and smart sensing remote/inhouse monitoring device;
b. Tactile Internet: such as 2-way interaction remote healthcare and robotics, which requires millisecond latency and immediate response times;
c. Critical communications: such as remote health monitoring with Quality of Service (QoS) mechanisms, such as blood sugar, electrocardiogram (ECG), and temperature;
d. Emergency medical services: such as connected ambulance services, which communicates to the hospital staff with real-time data.

As emergency medical services are deemed most necessary to be executed first, one of the use cases proposed is for a 5G-connected ambulance service – an ambulance equipped with multiple medical technologies, and advanced communication and multimedia services such as voice, SMS text, Real-Time Text (RTT), video clips, audio clips, graphics, pictures and real-time video, location determination, with the appropriate emergency services network and the appropriate PSAP (Public Safety Answering Point)[clix], as well as remote surgery.

5G-enabled ambulance would benefit emergency first responders as assistance can be rendered immediately before transporting the patient to healthcare facilities. This is especially beneficial when there are mass gatherings (such as a marathon or a fire incident in a high-density area)[clx].

For example, in Spain, to demonstrate how 5G could impact the healthcare sector, the government of Catalonia and the Emergency Medical System of Catalonia (SEM), in collaboration with several private entities[clxi], are set to roll out a 5G-enabled ambulance which is able to receive specialised remote real-time high definition video support over a 5G network, while transporting a patient. Soon, it will be fitted with vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) capabilities, to ensure access to clearer roads to the hospital.[clxii]

In the UK, medical staff from University Hospitals Birmingham National Health Service Foundation Trust (UHB) and telecoms engineers from telecoms provider BT Group PLC have conducted a demonstration, where a paramedic is able to assist in an ultrasound scan in a 5G-connected ambulance. This ultrasound scan was guided by a clinician, who is situated in the hospital.[clxiii] Hence, with the support of 5G-enabled technologies such as this, shorter time would be spent on diagnosing patients and the number of patients visiting the emergency departments would also be reduced; which in turn reduces pressure/demand on hospital occupancy and ambulance usage.[clxiv]

In terms of remote surgery, this use case is also deemed to be beneficial especially for rural Malaysians, which comprises 7.3 million people. Of which, 3.1 million reside in 46 remote districts, including Sabah and Sarawak[clxv]. As the rural population has reduced access to adequate medical facilities and staff, 5G will enable pop-up surgery tents or mobile operation theatres to be set up to conduct remote surgeries, due to its low latency. For example, China has successfully conducted its first remote brain surgery for a patient based in Sanya, Hainan, conducted by a surgeon in Beijing – about 3,000 kilometers away.[clxvi]

Nevertheless, as both use cases requires transmission and storage of large amounts of data, it is recommended for a unified e-health platform to be implemented first. This is because e-health platforms are required to store an immense amount of data in order to offer services such as a unified clinical data repository and conduct remote monitoring of pre and post-surgical patients, as well as collecting real-time data of multiple clinical indicators[clxvii clxviii]. For example, 'iCare', an Electronic Medical Records (EMR) system already used in the UAE, holds almost half a million electronic medical records. It allows doctors to instantly access critical patient information (online), including their medical history, blood type and use of prescription drugs, without depending on other hospitals or clinics to release their details[clxix].

3.2.4 Agriculture

The sector of agriculture – consisting of food crops (i.e fruit and vegetables), industrial crops (i.e oil palm and rubber), livestock and fisheries – remains as one of the most important contributor to Malaysia's economy via provision of employment and earnings to farmers, manufacturers and consumers[clxx].

According to Malaysia's Ministry of Agriculture and Agro-based Industry (MOA), the gross output of agriculture for the year 2017 was RM91.2 billion, an 11.1 per cent increase in contrast to RM73.9 billion in 2015 - contributing about 8.2 per cent to Malaysia's GDP in 2017.[clxxi] In 2018, the total export of agricultural goods amounted to RM67 billion (6.7 per cent of total exports)[clxxii], while for the months of January to July 2019, exports of agricultural goods amounted to RM37.11 billion, constituting 6.5 per cent of Malaysia's total exports[clxxiii].

As there are farmers and fishermen in Malaysia whom are smallholders, this means that these smallholders are considered as part of the 2.7 million Malaysians within the B40 category[clxxiv]. As the lowest income group, the B40 records a mean monthly income of RM2,848[clxxv clxxvi clxxvii]. Furthermore, MOA's statistics recorded that in 2004, 70 per cent of farmers were over the age of 45 and 45 per cent over the age of 55. Today, the numbers are even less, as there is permanent migration of rural youths to the cities[clxxviii]. Additionally, agricultural land which can be cultivated for food crops, is projected to decrease 2.2 per cent from 870,000 hectares in 2010, to 825,000 hectares in 2020[clxxix]. Hence, if these issues are not mitigated, Malaysia will not be able to cope with the demand for its own agri-produce, such as rice, beef and vegetables – which poses a threat to Malaysia's food security[clxxx].

According to the Food and Agriculture Organization of the United Nation (FAO)'s 2018 report[clxxxi], it stated that the world population is expected to grow by over a third, or 2.3 billion people, between 2009 and 2050. Thus, this means that the market demand for food sees continuous and exponential growth – with cereals, both as food and animal feed is projected to reach about 3 billion tonnes by 2050, from today's nearly 2.1 billion tonnes[clxxxii]. In the context of Malaysia, Malaysia's population growth rate of 1.1 per cent or 356,400 in 2018

(32.4 million population)[clxxxiii] which is projected to increase to 35.8 million by 2020, this will also cause a rise in demand for food in Malaysia.

Commodities	'000 Hectare			Average annual growth rate (%)		
	2010	2015	2020	10 MP		11MP[1]
				Target 1	Achieved	
Industrial commodities						
Rubber	1,020.4	1,087.6	1,197.6	2.2	1.3	1.9
Oil palm	4,853.8	5,480.0	5,672.0	1.9	2.5	0.7
Cocoa	20.1	18.2	23.4	8.4	1.4	5.2
Pepper	14.2	16.3	18.3	4.0	2.8	2.3
Subtotal Industrial commodities	**5,908.5**	**6,602.1**	**6,911.3**	**2.0**	**2.2**	**0.9**
Agrofood commodities						
Paddy	444.3	394.2	368.2	-2.4	-2.4	-1.4
Vegetables	39.3	38.4	45.7	2.4	-0.4	3.5
Fruits	239.4	203.1	206.9	-0.5	-3.2	0.4
Coconut	105.7	85.8	77.6	-3.4	-4.1	-2.0
Fisheries[2]	33.8	46.8	116.6	4.0	6.8	20.0
Others[3]	7.1	9.6	10.2	5.2	6.4	1.1
Subtotal Agro-food	**869.6**	**777.9**	**825.2**	**-1.4**	**-2.2**	**1.2**
Total land use	**6,778.1**	**7,380.0**	**7,736.5**	**1.4**	**1.9**	**0.7**

Table 3.1: Average Annual Growth Rate of Malaysia's Agricultural Commodities
Source: MOA (2019)

Therefore, to ensure that Malaysia's agricultural sector maintains its growth, is able to cope with the domestic and international demand for food, and that farmers are able to be breach into the M40 category, technological intervention such as the implementation of Industry 4.0 agricultural technology, may be necessary.

Henceforth, MOA's Strategic Plan 2019-2020 was issued, detailing five (5) main objectives to be addressed[clxxxiv]: food security, rural economic development, and the implementation of Industry 4.0 technology, among others, to guarantee continuous opportunity for farmers, in terms of job creation and poverty alleviation.

To ensure the promotion and the application of technology in line with MOA's Strategic Plan, the enablement and access of 5G is important to deliver the MOA's plans of developing and implementing Industry 4.0 agritechnologies[clxxxv], such as an integrated IoT monitoring and control system, advanced planting system technology, lighting technology for open cultivation, and vertical self-watering systems**.** This is because the 5G network has a bigger bandwidth, and it is about 100 times faster than 4G, making it ideal to transmit information from remote sensors and drones or automate farming processes[clxxxvi].

As the 5G network could ensure faster connectivity with low latency, it could also support MOA's prediction that faster internet penetration rate across the country encourages the widespread use of smart mobile devices among farmers and fishermen. Hence this could allow an online national agribusiness database accessible via a smartphone to be established, which could collate, report, and analyse[clxxxvii] real-time data.

In the EU, with 5G, farmers whom experimented with digital farming technologies have seen productivity gains of up to 20 per cent. For example, KPN successfully tested a precision farming application in a test farm in Drenthe, the Netherlands, using 5G. There, drones were used to take accurate pictures for potato cultivation and transmitting it to KPN headquarters in real time. Usually, the process will take two (2) days to complete. This has also led in a spike in productivity for farming[clxxxviii].

According to the BCWG[clxxxix] the use cases for Malaysia are identified as follows:

a. Drones for precision farming
b. Farming data sensing and analysis
c. Robotics automation

Drones for precision farming is seen as the primary Industry 4.0 technology to be implemented, as this helps reduce labour intensity of farming in Malaysia. By automating pesticide and fertilizer application using drones, a farmer will be able to oversee a larger area, which would require large manpower without drones. This could potentially cause a 30 per cent increase in productivity, as it is also time-efficient, resulting in 5 per cent ROI[cxc]. With 5G, drones will be able to collect and process terabytes of data on moisture levels or the pH[cxci] levels of soil, among others, per day using IoT sensors.

This assumption concurs with the findings of the Australian Government's Working Paper[cxcii] on the impacts of 5G on productivity and economic growth, stating that 5G is likely to improve efficiency in producing and delivering goods and services, for "...faster download speeds and lower latency will make cloud computing more effective and allow for better collection and analysis of Big Data that can lead to real-time decision making."

A potential testbed area for the aforementioned drones would be the granary areas under the Kemubu Agriculture Development Authority (KADA). This is because KADA's average paddy yield is among the lowest among the granaries in Malaysia (only 3.86 tonne per hectare), even though it is the second largest planted area[cxciii]. Moreover, the results of a study conducted by the Economic and Social Science Research Centre of The Malaysian Agricultural Research and Development Institute (MARDI) shows that these farmers are receptive towards new technologies – the paddy farmers at KADA has a 92.4 per cent acceptance rate of new technologies, and 96.3 per cent agree that precision farming technology will increase yield[cxciv]. Therefore, this means that this potential testbed could have a higher rate of success.

This potential drone testbed could also be executed in conjunction with an existing IoT-based paddy monitoring and advisory system called e-PADI, which has been successfully tested [cxcv]. The e-PADI system was developed by students and researchers from University Malaysia Perlis. Furthermore, with any implementation of new technology, the upskilling of the potential users is recommended to ensure the technology is deployed and used correctly, as well as offering financial assistance to facilitate the initial phase of implementation.

3.2.5 Retail and Services

Across all sectors, 98.5 per cent of businesses established in Malaysia are SMEs.[cxcvi] As of 2018, it was recorded that 89.2 per cent of SMEs in Malaysia are of the Services sector[cxcvii], and retail forms a part of the Services sector[cxcviii].

The SMEs' contribution to Malaysia's GDP in 2018 was 38.3 per cent (RM521.7 billion of Malaysia's total GDP of RM1.36 trillion) recording a rise from 37.8 per cent in 2017. This is led by expansion in the services and manufacturing sectors as SMEs exports grew[cxcix].

To transform Malaysia into a knowledge-intensive and services-driven economy, the Services Sector Blueprint (SSB) was launched in 2015 to overcome key barriers that may hinder the growth of the services sector (which includes SMEs). The four (4) policy levers to overcome the potential barriers to the development of the services sector are[cc cci]:

a. Internationalisation – increase service providers and export reach;
b. Investment Incentives – promote transparent and merit-based incentive delivery;
c. Human Capital Development – produce, attract and retain skilled talents
d. Sector Governance Reform – adopt efficient and facilitative approach, positive to sector growth.

To future-proof existing businesses and further expand market access for SMEs, Malaysia's National eCommerce Strategic Roadmap was launched in 2016, to emphasis on e-commerce

as one of the key drivers of the economy; in which its adoption could contribute more than RM170 billion to the Malaysian economy by 2020.[ccii]
With these policies in place, DOSM (2018) recorded an increase in e-commerce's contribution to the economy from RM37.7 billion in 2010 to RM85.8 billion in 2017, with an average CAGR of 12.5 per cent. In 2017, the e-commerce to GDP share is at 6.3 per cent[cciii]. Furthermore, according to DOSM (2019), the GDP contribution of SMEs rose from RM491.6 billion in 2017 (37.8 per cent share of the GDP) to RM521.7 billion in 2018 (38.3 per cent share of the GDP)[cciv].

This surge in GDP contribution is likely due to the increase in smartphone penetration in Malaysia, which infers that its users are utilising digital applications for businesses and transactions. Therefore, the BCWG's choice of e-commerce as a use case, is in line with the government's initiatives and interventions.

By utilising applications such as e-payment, social media and mobile point-of-sales (POS) systems via smartphones, these technologies are seen to help SMEs transform their operations, by cutting back cost of advertising, maintenance cost of a physical space, labour cost, and logistics cost.

As these digital tools and platforms promotes direct engagement with customers, several Deloitte reports[ccv] [ccvi] [ccvii] found that it can deliver a range of benefits across financial, operational and market dimensions, such as revenue growth, improved profit margins, expanded market reach, reduced capital expenditures, and improved customer data through 'customer segmentation' – being able to determine specific needs of each demography of consumers.

For example, in China, 60.53 billion e-payment transactions were conducted in 2018, with a transaction value reaching US$41.51 trillion (around RM 173.4 trillion)[ccviii]. In terms of GDP contribution, China's mobile ecosystem contributed around US$750 billion (about RM3.14 trillion) in 2018.[ccix]

One of China's major third-party mobile and online payment platform, Alipay, now accounts for 54 per cent of China's e-commerce market. Although it was first created by Alibaba Group to support their main business, it now does not only function as a form of payment transaction, but also a multi-sided platform that involves users, merchants, platform providers and social media[ccx].

Alipay has enabled merchants to bring their POS system into direct engagement with consumers and has allowed consumers to go not only cashless, but also card-less. It is used by all tiers of sellers, from night market operators to shopping malls, while buyers get to access their e-payment account instantly from their mobile phones.[ccxi]

Figure 3.3: The Ecosystem of Alibaba; Source: China Internet Watch (2014)[ccxii].

As noted by the BCWG's report[ccxiii], e-commerce platforms are gaining traction in Malaysia, with various B2C, C2C and B2B e-commerce platforms such as Lazada, Aliexpress, Shopee, Zalora, and 11Street being established. Hence, with 5G, due to its ultra-low latency, it could transform the way businesses operate as more consumers develop confidence in online transactions.[ccxiv]

With 5G, GSMA's The Mobile Economy China 2019 report forecasted that China will be leading other 5G markets with 460 million 5G connections, accounting for 28 per cent of its total connections, by 2025. In terms of economic contribution, China's mobile ecosystem is also forecasted to grow to US$870 billion (around RM3.63 trillion) by 2023, from US$750 billion in 2018 as previously mentioned.[ccxv]

Hence, in order for Malaysia to spur exponential growth with 5G, e-commerce retailers could tap into existing initiatives such as the Digital Free Trade Zone (DFTZ) to drive exports of Malaysian SMEs via e-commerce. This initiative is a collaborative effort between MITI, MATRADE, and SMECorp; led by MDEC. Via this initiative, e-commerce retailers will be thoroughly guided from the initial onboarding to exporting.

The DFTZ, as of today, has successfully assisted about 2,000 SMEs registered on the platform to export various products to countries such as Italy, Poland, Ghana, South Africa, China and the United States[ccxvi]. With 5G's ultra-low latency, it could eliminate cross-border customer frustration in terms of delayed order processing and payment, especially in developed countries that has begun beta-testing or rolling out 5G.

Upskilling the existing workforce is also required to complement the adoption this technology. Hence, the creation of new jobs is expected, which could well exceed the SSB's forecast, in which "…the services sector is expected to grow at 6.8 per cent per annum and contribute 56.5per cent to the GDP in 2020 and provide 9.3 million jobs."[ccxvii]
Moving forward, 5G could enable the adoption or establishment of Amazon GO cashierless convenience stores in Malaysia, with their "Just Walk Out" concept – a combination of mobile app, AI and facial recognition by Quick Response code scanning at the entrance that link's customer's profile to its data base and deduct the cost of their purchases accordingly. Once shopping is done, an e-receipt will be sent to the customer along with their purchase history. [ccxviii]

5G could also enable the most advanced machine learning, AI and data analytics to gauge trends and predict future interest of customers; enabling retailers to suggest brands to customers and innovate products based on accurate customer data.[ccxix] Furthermore, Augmented Reality (AR) could also be implemented to enhance the shopping experience. For example, in the UAE, Dubai-based tech firm Mall.Global, is set to launch a digital mall in 2020. This mall will offer more than 2,500 brands, featuring immersive technologies such as virtual reality (VR), augmented reality (AR), and artificial intelligence (AI), as well as the usage of cryptocurrency.[ccxx]

3.2.6 Oil and Gas

Contributing a large percentage (20-30 per cent) to the national GDP, this sector is certainly one of the core industries of Malaysia[ccxxi]. However, many legacy networks were not designed to support high volume of real-time data generated by M2M (machine-to-machine) and massive IoT systems. Thus, digitization, enabled by the adoption of 5G, is predicted to transform the industry, leading to better workforce efficiency and safety, asset optimization and revenue.

According to World Economic Forum, this sector seeks to leverage new development in digital technologies to unlock a value of 1.6 trillion by 2025 [ccxxii]. Major energy companies such as Aramco, British Petroleum and Statoil are now spearheading enhanced exploration program by digitalization to benefit from 5G's low latency allowing reliable and uninterrupted reception and management of data from a wide range of sensors within a near-shore offshore structure network [ccxxiii]. Oil and gas companies now utilise live data received from production plants to better facilitate drilling plans, among others. This is also driven by 1) improved cost of data by a factor of 1,000; 2) cost of data processing improved by a factor of 60; 3) cost of sensors improved by a factor of 50; 4) cost of bandwidth improved by a factor of 40 [ccxxiv].

Data collected from offshore platforms, however, are concentrated mainly on single platforms[ccxxv]. Multiple-vessel (also known as multiple-platform) interaction does not provide enough data to be tested due to a few issues such as (a) adverse conditions within specific offshore environments, (b) long distances between the nodes, (c) dependence of the system on the main power supply network, (d) latency/bandwidth limitation on communication network, and (e) cybersecurity issues [ccxxvi]. The forthcoming 5G connectivity suggests that in the near future, these firms will be able to use real-time live and historical data to assist them in streamlining operational costs and encourage higher productivity [ccxxvii]. Under the current method, explorations are based on communicating via a number of expensive satellites which requires individual links. It is not only costly (up to US$15,000 to run every month), but it also omits the importance of large scope of data transmission, and mainly focuses on voice communication only within very limited range[ccxxviii].

A platform can generate between one (1) or two (2) terabytes per day [ccxxix]. This large-file transmission is usually compressed, and its transmission takes a while to be completed. This results in data being stored for a long time in the vessel's data centre before it reaches the main data centre.

5G is also beneficial to remote communication. Doosan, a Korean engineering firm, uses 5G in their excavator project; where it enables remote operation of a 40-tonne crawler excavator in South Korea from a booth in Munich, Germany. They are also now able to identify hazardous situations derived from real live data, without the intervention of onsite personnel by using remote platform monitoring[ccxxx].

Hence, the crucial aspect in migrating the existing technology to 5G would be to enable the industry to fit their vessels with effective instruments that has lower power consumption, but high throughput. The need is greater now as more data is being generated from offshore platforms to be transmitted back to the headquarters/main data storage centre. As summarized by Wu et al[ccxxxi], there is (a) need for smart monitoring instruments with less power requirement, higher accuracy, ability for synchronization, and applicable in a variety of sensor types and ideally on fiber-optic sensors, and a (b) need for efficient wireless communication network that allows multi-measurement acquisition and real time data exchange between different offshore structures and between offshore structures and third parties (i.e. port authorities) [ccxxxii].

This will lead to an overall investment across the industry, to trigger the implementation of 5G. Currently, the focus is still on upgrading 4G infrastructure to support future installation of 5G, as the technology is built upon 4G infrastructure rather than being a complete departure[ccxxxiii].

In 2017, Malaysia's oil and gas sector produced a gross output of RM139 billion, paid RM6.9 billion in wages and salaries, and maintained fixed assets worth RM313 billion[ccxxxiv]. Petroliam Nasional Berhad, the firm acting as the custodian for Malaysia's oil and energy resources, would gain tremendous benefit from the implementation of 5G. This technology will assist in streamlining their operations, making it more cost effective and thus, generating more revenue for the firm and the country. Thus, as the data accrued on Malaysia's oil and gas reserve is sensitive in nature, it is highly recommended for this firm to have their own spectrum.

3.2.7 Manufacturing

Manufacturing is identified as a vertical because it is a major contributor to Malaysia's GDP; about RM79 billion in the second quarter of 2019 in comparison to RM76 billion in the first quarter of 2019[ccxxxv]. Therefore, the plan is to have a well thought out strategy to cope with the requirements of new technology, which means guaranteeing reliable performance and low latency.

Industrial automation is important as it provides the advantages of improving productivity and quality while reducing errors and waste, increasing safety, and adding flexibility to the manufacturing process. This is because industrial automation yields increased safety, reliability, and profitability[ccxxxvi]. According to BWCG (2019)[ccxxxvii], this is to be divided into two sub-categories: Process Automation and Factory Automation. Thus, three (3) use cases are identified for this vertical: 1) Process Automation 2) Massive Sensor Automation and 3) Logistic Application Tracking.

Factories of the future will make use of cyber-physical systems in large numbers and wireless connectivity to support and connect the entire manufacturing supply chain[ccxxxviii]. This is only achievable if the infrastructure is supported by an extensive wireless telecom infrastructure that allows machinery interactions and information exchange.

For Factory Automation, equipment readiness is a vital aspect. Growing interest in 5G technologies and application will net a demand to develop and ensure hardware is updated accordingly to the advances in applications and system[ccxxxix]. This can be observed from the use case of managing power distribution network as it demands an increasing amount of distributed energy resources; at the same time requiring more flexibility for protection, control and monitoring. Ericsson has been testing the implementation of 5G via establishing a 5G Factory, an IoT Factory and a Digital Factory in three (3) separate location: Estonia, China and Sweden. Developing and implementing the first 5G and Industrial IoT systems in a real manufacturing environment allows this new wave of tech enablers to reach maturity more rapidly. If it yields positive results, Ericsson intends to implement it worldwide[ccxl].

5G would also enable URLLC[ccxli], allowing machines to communicate and interact within a specified distance. It also includes new security features which benefits industry deployment, creating a seamless workflow process that boosts productivity; lowering the turnover of manual labour and reducing operational costs. One of the near-term benefits is the reduced usage of cable. Leveraging 5G wireless network brings down the cost of hardware and labour, since cables typically comes with high installation fee[ccxlii]. Furthermore, with the implementation of 5G, existing 4G-supported technologies will be enhanced in terms of application. This could lead to the spearheading of new technologies on smart manufacturing in the near future, and this in turn creates demand for manpower along with the need to upskill the workforce[ccxliii].

In terms of massive sensor communication, with 5G, manufacturing can now be optimized, safety enhanced and a better prediction for industrial maintenance. An example of this will be the usage of ultra-high definition cameras combined with machine learning algorithms that is predictive of the next future maintenance cycle[ccxliv].
As for Malaysia, 5G could bring significant change to two (2) use cases: Process Automation and Logistic Application Tracking.

As for Process Automation, the usage of Radio-Frequency Identification (RFID) tracking is becoming common in warehouses. Thus, many handheld devices are being used to inventorise tracked data. 5G will enable the existing system to improve its accuracy by eliminating errors due to slow uploading of information or overlapping of data. As demand for automated tracking grows, with 5G, a much larger amount of data could be relayed and processed immediately[ccxlv].

Another use case would be Logistic Application. The adoption of 5G, enhanced by IoT devices, could offer a host of new functions to these firms. Real-time tracking of packages with 5G connectivity, low latency, high speed and wide availability would overall enhance and improve the logistic experience, as millions of devices would be able to connect at the same time[ccxlvi]. Logistic companies rely heavily on the driving history of their vehicles and the behaviours of drivers. Hence, 5G and IoT together will allow live tracking to be conducted (to pinpoint the exact location of a vehicle), therefore ensuring that both the driver and goods are safe and in transition.[ccxlvii].

3.3 Limitations

These verticals are by no means exhaustive, as it is keeping in line with the verticals identified by MCMC's 5G Taskforce's Business Case Working Group Mid Term Report.

Education was removed from the list of verticals as it is deemed that it could have sociological ramifications, if the deployment of digital educational technology for both schools and institutions of higher learning is not rolled out synchronously across the urban and rural areas. As per the Shared Prosperity Initiative of the upcoming 12th Malaysia Plan, as it seeks to reduce the economic gap between the rural and urban areas, it is of concern that the staggered (i.e. urban first, rural last) implementation of the use cases of this vertical could entrench the existing educational, digital, and economic divide. Nevertheless, this warrants further study as the verification of these assumptions are necessary.

In terms of Banking and Finance, countries which have rolled out 5G, such as the UAE, has seen significant improvement in banking or financial transactions and has tremendously eased the usage of other financial technologies (FinTechs) such as Peer-to-Peer Lending, Equity Crowdfunding, and Telematics, among others. Thus, as the FinTech industry in Malaysia is burgeoning, in light of 5G, the implementation of regulatory technology (RegTech) or cybersecurity mechanisms for FinTechs could warrant further study, perhaps via the Fintech Regulatory Sandbox Framework established by the Central Bank of Malaysia.

Two (2) other potential vertical that warrants further study is the Defence and Aerospace sector, as 5G could lend significant impact to the development and innovation of this sector.

4. Recommendations for 5G Network Deployment based on Socioeconomic Benefits

4.1 Introduction

To reiterate Chapter 1, the economic effects of digital communications are realised in several ways[ccxlviii]. Together with Industry 4.0, 5G can transform the economy and improve quality of life. However, as the required capital expenditure is significant, a clear policy framework for 5G deployment that drives innovation, promotes entrepreneurship, and makes productive use of knowledge will be critical for Malaysia to gain the full benefits of the digital economy.

4.2 5G Contribution to the Economy (2021-2025)

It is estimated by 2034, 5G would generate US$2.2 trillion (RM9.2 trillion) in global GDP, of which US$212 billion (RM884 billion) will be for the Asia Pacific region, and governments are expected to collect US$588 billion (RM2.5 trillion) in tax revenue[ccxlix]. China expects 5G to stimulate US$500 billion (RM2.452 trillion) in technology sector growth between 2019 and 2024[ccl].

As the Government is keen to achieve a “robust, pervasive, high quality and affordable digital connectivity”[ccli] through the NFCP, it is anticipated that private entities too would be very interested to benefit from Malaysia’s 5G development. This should result in a high investment scenario for 5G in Malaysia where RM 100 billion will be invested economy-wide over the initial five (5) years. The estimates in this chapter follows the high investment model presented in Chapter 2.

As displayed in Figure 4.1, it is estimated that there will be approximately 2.1 million mobile 5G subscriptions in Malaysia by 2025, with an estimated penetration of 6.6 mobile 5G subscriptions per 100 people.

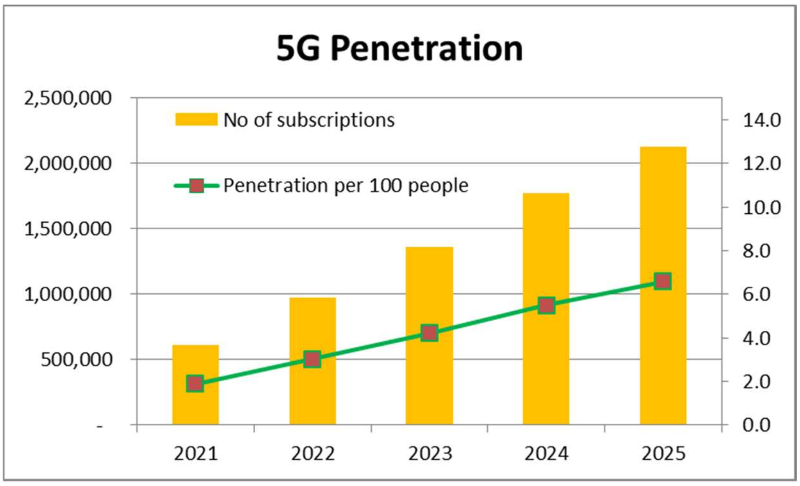


Figure 4.1: 5G Subscription and Penetration, 2021-2025; Source: Estimated by MIER

5G related economic activities are estimated to contribute an additional RM12.7 billion to the GDP between 2021 and 2025. As displayed in Figure 4.2, the marginal contribution to the GDP for 2025 alone is expected to be valued at RM5.3 billion. The share of 5G, and 5G-enabled Industry 4.0 activities in the Malaysian GDP is expected to continuously rise in the subsequent years.

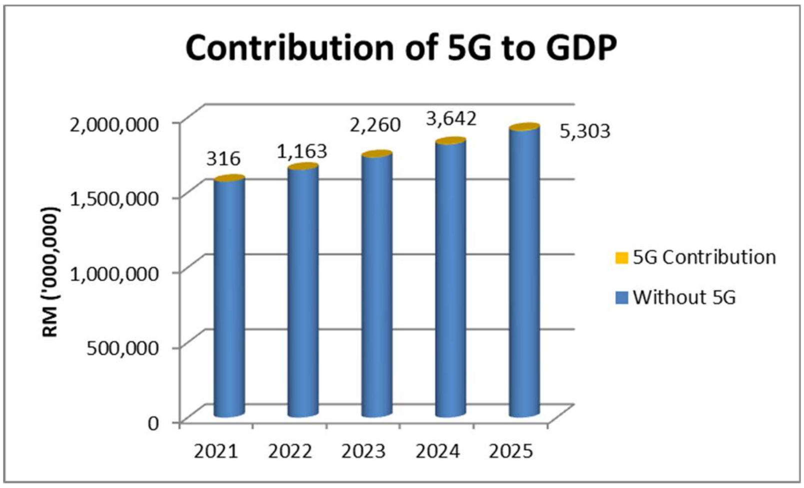


Figure 4.2: Contribution to GDP, 2021-2025: Source: Estimated by MIER

It is anticipated that the average salaries and wages for the new jobs created by 5G deployment will be similar to that received by skilled telecommunications workers. Job losses amongst Malaysians due to 5G connected activities is expected to be minimal during this period, and these too should be predominantly frictional in nature. There are two principal reasons for this inference: 1) The Chinese 5G programme does not expect major breakthroughs during this time in AI applications, which could be a threat to many high skilled jobs [cclii]; 2) As one of objectives of the 2018's Digital Transformation Action Plan (DTAP) is to reduce the dependence on low-skilled foreign labour, the Malaysian government's policy would be tilted in favour of replacing unskilled foreign labour with Malaysian labour that is skilled in the new technologies.

The estimates for new job creation by the roll out 5G use cases between 2021 and 2025 are displayed in Figure 4.3[ccliii]. Between 2021 and 2025, almost 39,000[ccliv] new jobs will be created, with almost 40 per cent of the jobs made available in 2025.

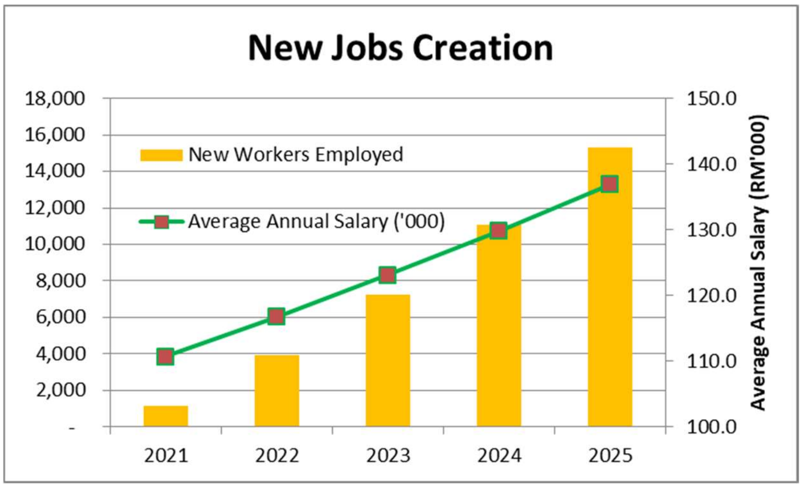


Figure 4.3: New Job Creation, 2021-2025; Source: Estimated by MIER

4.2.1 Effect of higher economic growth

This study is based on the assumption that the GDP of Malaysia will grow at a rate of 4.9 per cent per annum. If the economy grows at the faster rate, it will be accompanied by a higher rate of adoption of 5G and Industry 4.0 technologies. Figures 4.4, 4.5 and 4.6 present the estimated effects of GDP growth rates at 6 per cent and 8 per cent respectively on 5G penetration, GDP contribution and new job creation. It can be observed that 5G penetration, GDP contribution and new job creation grow at an increasingly higher rate when the economy expands at a faster rate. There are several factors that would explain this:

a) Increases in the aggregate demand for goods and services will lead to an increase in the supply of goods and services. This results in higher demand for the production and supply of goods and services;
b) Households will have a positive outlook towards the future, thereby increasing spending;
c) New products and services will need to be developed to meet rising customer demand;
d) Government policy can influence the level of 'technological intensity'[cclv] that businesses employ;
e) Firms will also have greater access to capital to invest in new technologies.

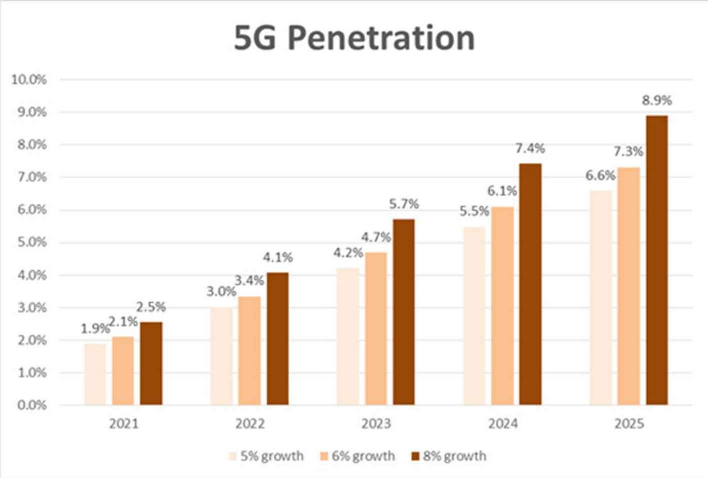


Figure 4.4: 5G Penetration under Different Growth Scenarios 2021-2025; Source: Estimated by MIER

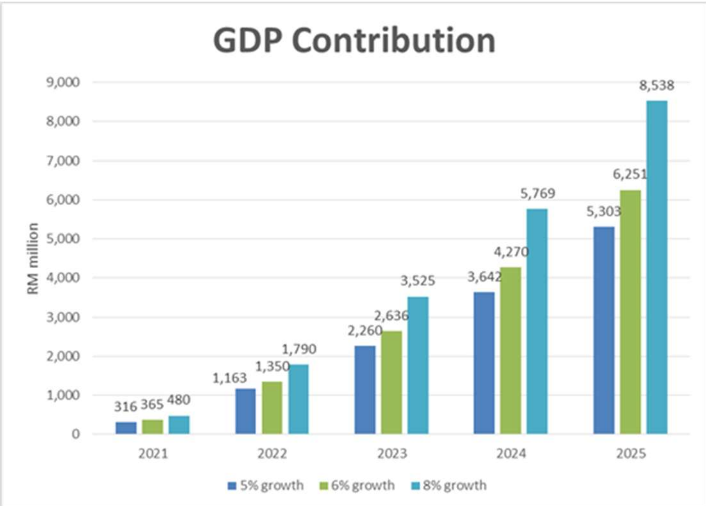


Figure 4.5: Contribution to GDP under Different Growth Scenarios, 2021-2025; Source: Estimated by MIER

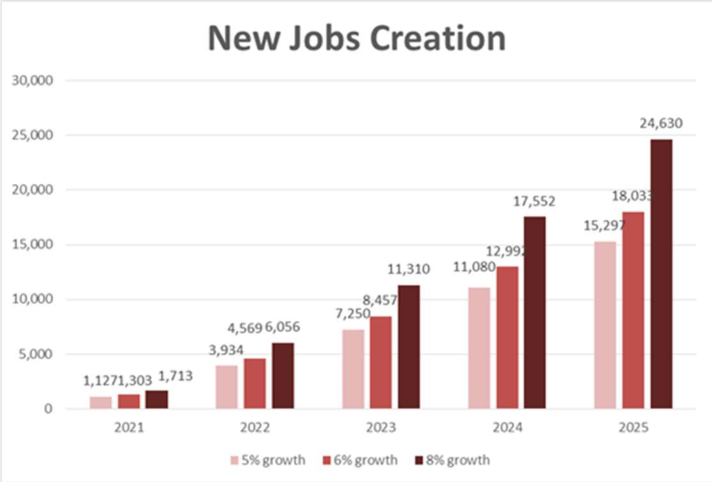


Figure 4.6: New Jobs Creation under Different Growth Scenarios, 2021-2025; Source: Estimated by MIER

4.3 Socioeconomic Benefits of 5G

5G deployment can bring some positive impact to quality of life. The improved quality of life provided by better healthcare, education, transportation, consumer experience, environment and smarter cities will enable Malaysians to be more productive, for a longer period of time as life expectancy increases.

Among the use cases for digital healthcare will be geared towards improving wellbeing and preventing illness. The convergence of the life sciences and physical sciences coupled with the connectivity and better data management that 5G provides, should also make healthcare more affordable.

Better traffic management, reduced congestion, energy efficiency, better logistics and improved public safety are among the benefits of living in smart cities. Improved connectivity will allow firms to hire the most suitable workers irrespective of their location as it will become less important for workers to present themselves at the workplace.

Utilities and other services at the local council will be more efficiently managed, therefore saves costs for the consumer and reduces carbon footprint. Social, environmental and other sustainability benefits will also increase as the awareness and educational level of citizenry increases.

As connectivity improves, the rural areas will begin to enjoy the benefits of 5G, such as better education, improved healthcare and greater employment opportunities. The yield from livestock and farming will also increase as the IoT devices will provide useful data for precision farming. Drones will also be used for a variety of tasks, thus increasing farmers' income.

The introduction of 5G to the retail and wholesale sector would improve customer experience while increasing customer loyalty and retail sales. AR, VR, personalised digital signage, video and pattern recognition, interactive mobile apps and e-sports will be drivers of innovation in this area.

4.4 Negative Social Effects

While there are significant social and economic benefits from the roll out of 5G, the government also needs to address the social issues that are also likely to be aggravated. Smartphone addiction could increase, resulting in decrease in productivity, increased financial distress, health problems and other social issues.

4.4.1 Online Gaming

Many of the current cloud-based mobile games require data download exceeding 1GB. The current 4G LTE networks takes more than five (5) minutes to download 1GB of data. Furthermore, the high latency of 4G networks makes the experience when playing such games inconsistent. As a result, many gamers prefer to play from home via their fixed broadband. With 5G, AR and VR could further increase ubiquitous online gaming, leading to gaming addiction; due to its nature of providing an immersive experience.

4.4.2 Online Gambling

Once latency issues are resolved by 5G networks, online gambling will become more accessible to players. Gamblers can now play online casino games or make bets at great convenience, higher security and at astonishing speed. Gamblers, much like the gamers, can also use VR and AR headsets to further enhance their gambling experience. Workers might be distracted from their responsibilities, thereby adversely impacting their efficiency and productivity. If unchecked, such behaviour could also lead to an increase in incidences of financial distress.

4.4.3 Abuse of Social Media

With 5G, social media firms will invest heavily in immersive technologies such as virtual reality and augmented reality. Video streaming capabilities will also reach new heights. Social media users are likely to invest even more time on their favourite platforms. While social media has many benefits, but studies have also shown the adverse effects on the users. These include the increased risk of internet addiction[cclvi], increasing the risk of mental health[cclvii], and the erosion the user's self-esteem through unfavourable social comparisons[cclviii].

4.5 Policy Challenges in 5G Implementation

The advent of new technologies provides the opportunity for economic growth; more so with GPTs such as 5G, which is expected to disrupt businesses and work culture. Hence, there would be challenges that would require great attention.

4.6 Effects on Labour Market and Income Inequality

Just as how computerisation made switchboard operators obsolete, autonomous cars may make taxi obsolete. A McKinsey & Company's report estimated that more than 22 per cent of jobs in Malaysia could be lost due to automation and AI between 2016 and 2030[cclix].

Approximately 400,000 Malaysians commute to Singapore daily for work[cclx]. The educational attainment of 55.4 per cent of these workers is *Sijil Pelajaran Malaysia* (SPM) or equivalent or less[cclxi], which means the majority of these workers are blue-collar workers. As similar job losses also occur in Singapore, this cohort would be at risk of being unemployed.

These workers may need to switch occupations and learn new skills, which will result in a major shift in the labour market. This will also create downward pressure on median wages[cclxii], which will then increase income inequality[cclxiii].

Leipziger et al (2016) explained that inequality rises as a result of two forces; firstly, due to the increasing gap between payment to capital and payment to labour, and, secondly, due to the increasing gap between high and low wage earners[cclxiv]. This can be mitigated by adapting our educational and reskilling programmes to create a labour force that can fill the new jobs being created.

There are about 1.8 million[cclxv] registered foreign workers in Malaysia, which most of them are labourers. In 2010, the agriculture and plantation sector, the construction sector, the services sector, the wholesale and retail sector, and the hospitality sector employed 32 per cent, 14 per cent, 12 per cent, 11 per cent and seven per cent of the total foreign labour, respectively[cclxvi].

DTAP provides a structured approach to digitally transform businesses. One of the objectives of the programme is to reduce the dependence on foreign labour[cclxvii]. The large contingent of foreign workers constitutes a significant challenge in relation to the implementation of DTAP. Firstly, the availability of "cheap" labour does not incentivise businesses to invest in productivity related technologies. Secondly, once the relevant technologies are implemented, many of the foreign workers would be left unemployed.

The Government needs to prepare plans for the deportation of foreign workers once their services are no longer required. If the foreign labour issue is not addressed, it might become a barrier to the adoption of 5G use cases across the verticals. Nevertheless, the less our economy is dependent on low-skilled foreign labour, the more competitive the economy will be[cclxviii].

4.7 Recommendations

5G will be a key enabler to not just to achieve faster economic growth, but to also improve productivity, salaries and wages, household income and the quality of life in Malaysia. Through the successful development of the various use cases, it will transform our systems of production, management, security and governance, in its entirety.

Conducting a detailed analysis of the impact of 5G on the respective verticals is not within the scope of this paper. An economic cost-benefit analysis, which encompasses the economic, social and environmental aspects of the various 5G implementation strategies, and its contribution to the respective verticals, would provide the Government invaluable inputs in 5G and Industry 4.0-related policies.

In terms of financing, a Public-Private Partnership (PPP) channel would be most conducive towards further promoting the economic, social and environmental benefits to be accrued by 5G and Industry 4.0. The private sector, specifically the presently active telecommunications service providers, will be more inclined to invest in the urban areas as they are more likely to receive a high ROI. For the rural areas, where the ROI will be lower, the government could take the lead in rolling out 5G infrastructure.

The focus of policy initiatives until recently has been on Industry 4.0, with the latter being listed as the first item on the list of new sources of growth in the 12th Malaysia Plan. While 5G will neither design smart cities nor smart factories, but it will provide exciting new operating models especially with regards to the Industry 4.0 use cases. Hence, 5G should be given more attention from a policymaking perspective.

The participation of state governments is important in enabling 5G driven innovations. Besides providing real estate for the installation of base stations, the active interest by the policymakers would create an environment that is conducive to the development of local infrastructure and incentives that would encourage the expansion of the aforementioned use cases in the respective states.

4.7.1 Small and Medium Enterprises (SMEs)

In 2017, SMEs contributed 37 per cent of the country’s GDP and they employed 66 per cent of total employed workforce[cclxix]. A host of Industry 4.0 technologies that will be facilitated by 5G at the workplace, such as wireless factories, real-time predictive maintenance, increasing data flow, greater unification of the supply chain, and autonomous guided vehicles, which will increase the productivity of the SMEs. As SMEs have limited financial resources, the Government should play an important role in providing the former with easier access to technology, worker upskilling and financial resources.

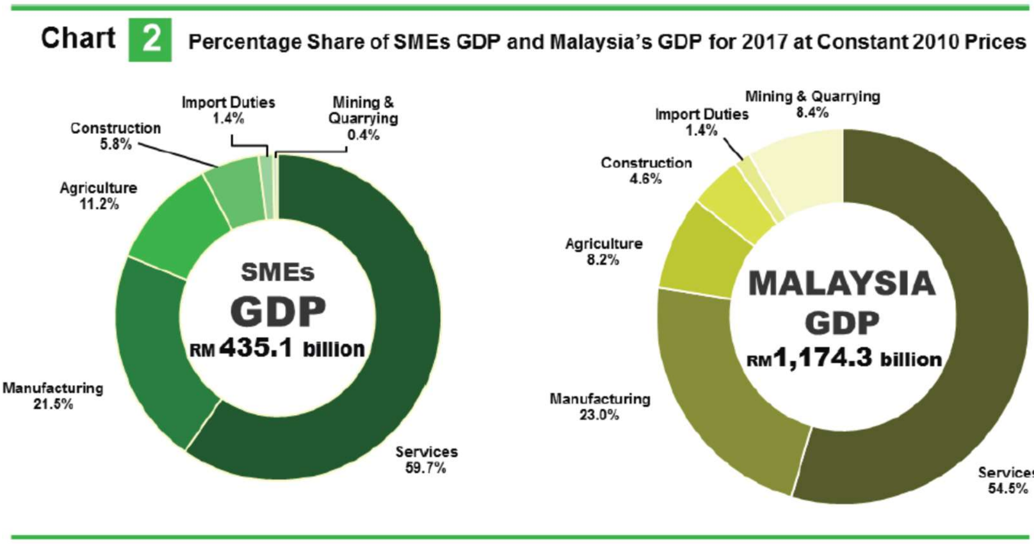


Figure 4.7: Percentage Share of SMEs GDP and Malaysia's GDP for 2017 at Constant 2010 Prices; Source: DOSM (2018)[cclxx]

4.7.2 Education and Upskilling

Malaysia can compensate for job losses by upskilling workers with higher technical skills, including complex problem solving. As global consumption is expected to increase by US$23 trillion (RM96 trillion) between 2015 and 2030, new jobs will be created[cclxxi]. However, workers will have to acquire skills that will provide them with a competitive advantage over the machines. The education and skills training system needs to adapt to changes in the labour market, where there will now be greater demand for individuals who are critical thinkers and complex problem solvers.

While many workers would be displaced by 5G leveraged technologies, the use cases will demand for workers with new skillsets. While the required skill specifics are unclear at present, there will be rising demand for: 1) business process experts to help refine the use cases; 2) workers with wide-ranging cloud, privacy, miniaturisation, supply chain, safety and security capabilities; 3) highly skilled STEM[cclxxii] professionals with skills in radio frequency (RF) technologies, mobile and platform programming, including the IoT[cclxxiii].

Our education system needs to be transformed to be more relevant to meet the future demand of the labour market. The House of Lords Select Committee on AI report[cclxxiv] suggested that the new school curricula should integrate computing skills with the arts and humanities as the latter two will hone the students' creative, contextual and analytical skills. Furthermore, the report also adds that the more knowledgeable an individual in the subjects of STEM, the more likely the individual will appreciate the effects of the new technologies.

This is in line with the Malaysian government's planned interventions, such as identifying the required skills needed by the industries, mainstreaming of technical and vocational education and training (TVET), reducing dependency on low-skill foreign worker and cultivating entrepreneurial culture in Malaysia[cclxxv].

4.8 Deployment Strategy

If maximising economic returns is the objective of the government, then a 5G deployment strategy similar to that of China should be followed. China's strategy is to first deploy 5G to the first-tier cities where the respective population exceeds one million people[cclxxvi]. Subsequently, deployment is carried out in the lower-tier cities, and finally the rural areas. About 90 per cent of the 5G base stations in China are deployed in big cities due to the concentrated demand for 5G technologies[cclxxvii].

If the objective is to achieve a combination of economic, social and environmental benefits, then a deployment strategy similar to that of the EU could be employed[cclxxviii]. As such, 5G should also be deployed in rural areas where fixed broadband services are inadequate, so that ICT-dependent industries could be promoted in these areas as well[cclxxix].

The 700MHz band is one of the 5G pioneer bands in Europe, where it is expected to become available for 5G by 2020. This layer allows large area coverage with outdoor-to-indoor penetration, supports massive machine type communication (mMTC), and supports ultra-reliable – low latency communication (URLLC). However, it only requires a moderate investment on existing 800/900MHz grids. Malaysia could also utilise the presently unallocated 40MHz on low band 700MHz layer for quick 5G deployment in the country. Hence, it is important to understand how the infrastructure and associated cost base will evolve in the future[cclxxx].

5. Conclusion

The Growth Accounting Approach predicts that a sustained investment in 5G over the next five (5) years will provide the economy with long term growth impetus. The estimates forecasted that by investing strategically in 5G, Malaysia's GDP will increase by a total of RM12.7 billion, and almost 39,000 new jobs will be created over the first five (5) years.

The initial social and economic benefits from the development of 5G might be low. However, with continuous investment, the maturation of technology (related to new use cases), and their subsequent deployment will lead to a rise in productivity and greater economic activity, coupled with higher household income. It is important for the government to promote 5G related R&D investments by firms to increase the technological intensity of Malaysian products and services.

MIER recommends for MCMC to evaluate in detail multiple investment scenarios before finalising the 5G deployment strategy. An ineffective strategy may lead to a poor ROI, increased unemployment and/or rising inequalities across the country.

Appendix 3A: Technical Derivation of the Growth Accounting Approach

The total output is an economy is modelled as being produced by various factors of production, with capital and labour being the primary ones in modern economies (although land and natural resources can also be included). This is usually captured by an aggregate production function.

$Y=F(A, K, L)$

Where Y is the total output, K is the stock of capital in the economy, L is the labour force (or population) and A is a "catch all" factor for technology, role of institutions and other relevant forces which measures how productively capital and labour are used in production.

Standard assumptions on the forms of the function F(.) is that it is increasing in K, L, A (if you increase the number of factors used you get more output) and that it is homogeneous of degree one, or in other words that there are constant returns to scale (which means that if you double both K and L you get double the output). The assumption of constant returns to scale facilities the assumption of perfect competition which in turn implies that factors get their marginal products:

$dY/dK = MPK = r$

$dY/dL = MPL = w$

Where MPK denotes the extra units of output produced with an additional unit of capital and similarly, for MPL. Wages paid to labour are denoted by w and the rate of profit or the real interest rate is denoted by r. Note that the assumption of perfect competition enables us to take prices as given. For simplicity we assume unit price (i.e. P=1), and thus quantities also represent values in all equations.

If we totally differentiate the above production function, we get:

$dY=F_A dA+F_k dK+F_L dL$

where F_i denotes the partial derivative with respect to factor I, or for the case of capital and labour, the marginal products. With perfect competition this equation becomes:

$dY=F_A dA+ MPK_d K+MPLdL=F_A dA+rdK+wdL$

If we divide through by Y and convert each change into growth rate, we get:

$dY/Y=(F_A A/Y)(dA/A)+(rK/Y)*(dK/K)+(wL/Y)*(dL/L)$

or denoting a growth rate (percentage change over time) of a factor as $g_i=di/i$ we get:

$g_Y=(F_A A/Y)*g_A+(rK/Y)*g_k+(wL/Y)*g_L$

Then rK/Y is the share of total income that goes to capital, which can be denoted as α and wL/K is the share of income that goes to labour, denoted by 1-α. This allows us to express the above equation as:

$gY=F_A A/Y*g_A+\alpha*g_K+(1-\alpha)*g_L$

In principle the term α, g_Y, g_K and g_L are all observable and can be measured using standard national income accounting methods (with capital stock being measured using investment rates via the perpetual inventory method). The term $F_A A/Y * g_A$ however is not directly observables as it captures technological growth and improvement in productivity that are unrelated to changes in use of factors. This term is usually referred to as Solow residual or total factor productivity growth. Slightly rearranging the previous equality, we can measure this as that portion of increase in total output which is not due to the (weighted) growth of factor inputs:

$SolowResidual = gY-\alpha*gK-(1-\alpha)*g_L$

Another way to express the same idea is in per capital (or per worker) term in which we subtract off the growth rate of labour forth from both sides:

$SolowResidual=g_{(Y/L)} – \alpha*g_{(Y/L)}$

Which states that the rate of technological growth is that part of the growth rate of per capita income which is not due to the (weighted) growth rate of capital per person.

Appendix 3B: List of Interviewed Organisations or Individuals

Name	Organization
Khairuddin Yahaya ICT Consultant (Network Management) Consultancy Division	Malaysian Administrative Modernisation and Management Planning Unit (MAMPU)
Yong Meng Keet Senior Manager Unit Trust	Eastspring Investments Berhad
Wong Mee Len Deputy Director Department of Market Research and Intelligence	The Malaysian Communications and Multimedia Commission (MCMC)
Dr. Yoong Siew Wai Senior Manager National Strategic Initiatives	National Applied R&D Centre (MIMOS)
Mohd. Kamal Arifin Ibrahim CCU Manager	Malaysian Palm Oil Council (MPOC)
Norizan Harun Undersecretary Information Management Division	Ministry of Education Malaysia (MOE)
Noorizam Kassim Senior Principal Assistant Secretary Information Management Division	Ministry of Education Malaysia (MOE)
Faiz Al-Shahab Managing Director and Co-Founder	Xentral Methods Sdn. Bhd. (e-sentral)
Jacob Lee Chor Kok Council Member Chairman, FMM Selangor Branch Chairman, FMM Industry 4.0 Committee	Federation of Malaysian Manufacturers (FMM)
Toh Kean Chung Systems Delivery – Channels & Development	OCBC Bank (Malaysia) Bhd (OCBC Bank)
Aida Basri Program Director Digital Healthcare, Internet of Things (IoT)	Collaborative Research in Engineering, Science & Technology (CREST)

Anuar B. M. Isa Telecomm TP Radar Surveillance and Security System "RS3" Project Group Technical Solutions (GTS) Technology & Engineering Division	Petroliam Nasional Berhad (Petronas)
James Lai Chairman	Malaysia Internet-of-Things Association (MyIoTA)
Za'im Azyze Senior General Manager Information Technology Development	Malaysia Automotive, Robotics and IoT Institute (MARii)
Muhammad Farhan Mohd Suhaimi Executive Strategy & Policy Development Division	Malaysia Automotive, Robotics and IoT Institute (MARii)
Robert C. V. Tai Senior Principle Analyst 1	Malaysian Industry-Government Group for High Technology (MiGHT)
Mohd. Mazlan Ab Rahman Special Officer to the Chairman of KADA	Kemubu Agricultural Development Authority (KADA)
Raja Segaran Head, Strategy and Research Corporate Strategy	Malaysian Digital Economy Corporation Sdn Bhd (MDEC)
Mohd Mokhtar Daud Manager, Business Environment. Enabling Ecosystem	Malaysian Digital Economy Corporation Sdn Bhd (MDEC)
Jeffrey Parsons Chairman and Chief Executive Officer	E-Health in Motion, UAE
Marwan Ksibati Consultant	E-Health in Motion, UAE
Toh Kean Chung Systems Delivery – Channels & Development	OCBC Bank (Malaysia) Bhd (OCBC Bank)

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[xi] Ibid.
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Appendix 4: Spectrum For 5G Deployment in Malaysia

4.1: 5G Private Network Drivers

The cellular technology that is required for the deployment of private network for verticals should evaluated based on the drivers (LMR modernisation or industry digitalisation), coverage area, and number of networks.

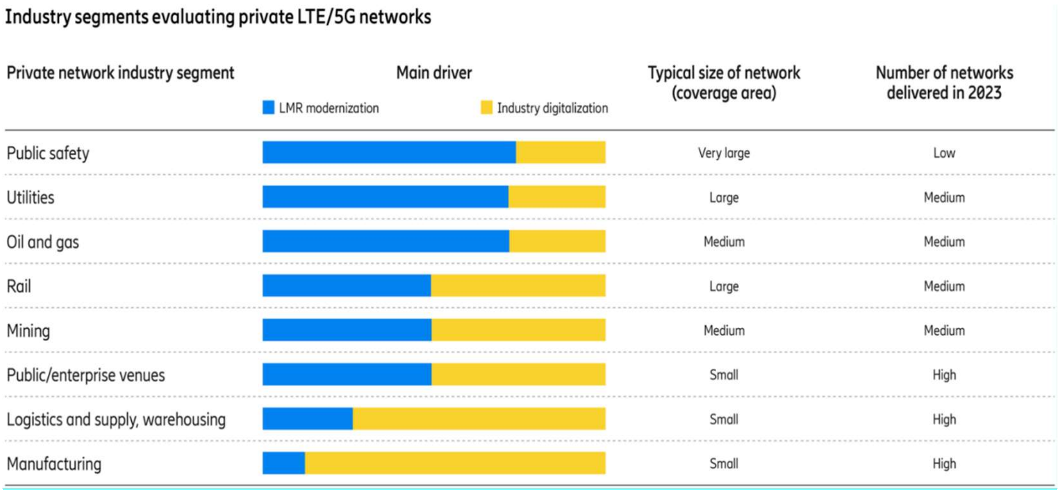


Figure A4.1: Private Network Drivers; Source: Ericsson Mobility Report June 2019

4.2 Mobile traffic in South East Asia and Oceania

Mobile traffic in South East Asia and Oceania will grow at least 7x from 2018 to 2024

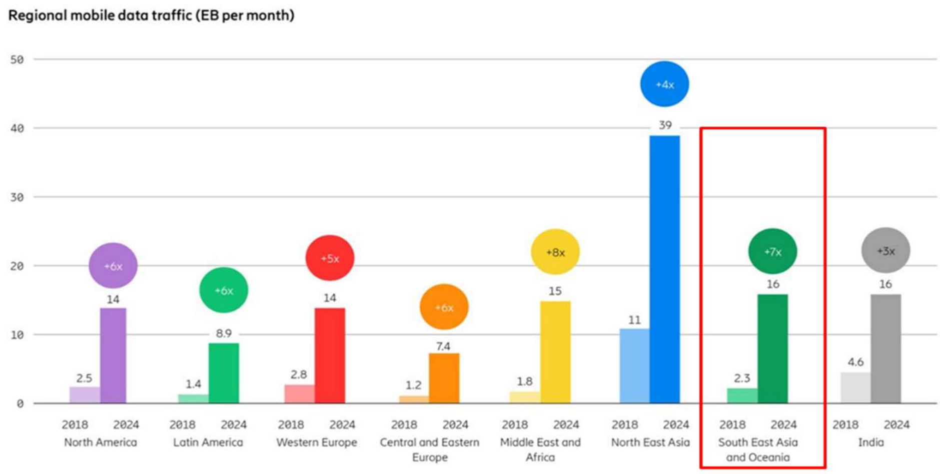


Figure A4.2: Mobile data traffic; Source: Source: Ericsson Mobility Report June 2019

4.3 Potential Interference Risks to FSS System

A 5G Base Station in the 3.5GHz band which is located near or in direct Line-Of-Sight (LOS) with an antenna dish of FSS system may saturate the latter. The saturation occurs at the Low-noise Block Downconverter (LNB) of the FSS system. When the LNB is driven into saturation, it ceases to amplify the wanted weak satellite signals in a linear fashion thus decreasing the conversion gain significantly. **Figure A.3** and **Figure A4.** show the out of band saturation caused by high level signals in the 5G transmitter that causes severe interference towards the FSS.

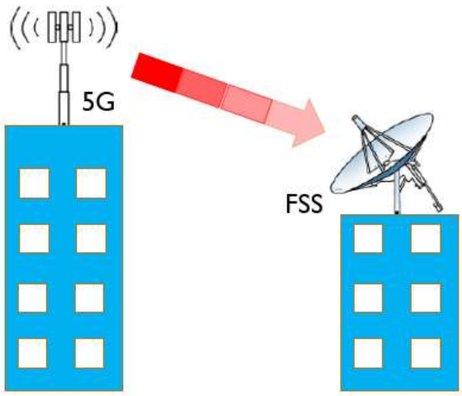


Figure A4.3: Receiver blocking in FSS due to 5G out of band emission

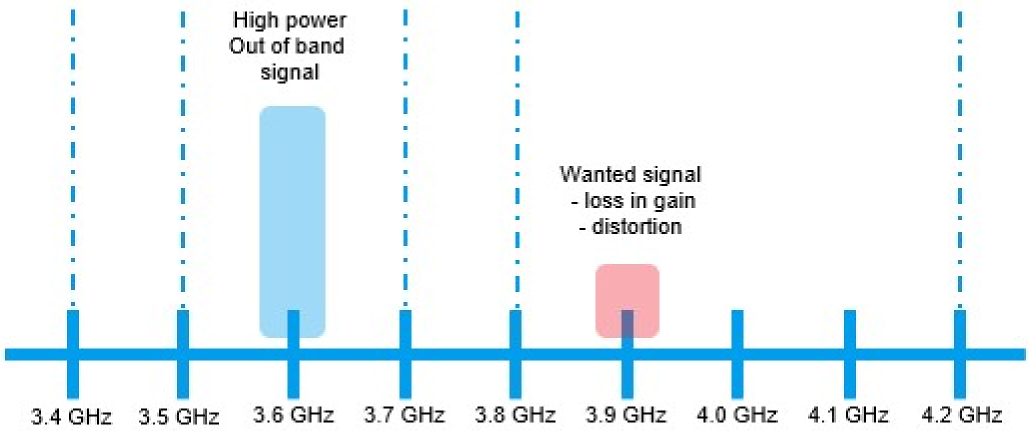


Figure A4.4: Saturation Caused by High Signal in the 5G Band

In 5G NR terminology, the frequency ranges below and above up to 40MHz of an NR signal operating band (equivalent to channel bandwidth) are defined as the NR spurious emissions. Spurious emissions stemming from an NR signal in the 3.5GHz band can straddle across the 3.4 – 3.8 and 3.8 – 4.2GHz bands. In the context of the Proposed Re-Allocation, only spurious emissions traversing the 3.8 – 4.2GHz band, which will become interference to FSS signals, will be considered and analyzed for mitigation. Such unwanted spurious emissions will manifest as background noise in the 3.8 – 4.2GHz frequency band and reduce the signal to noise ratio of the FSS systems as well. **Figure A4.5** and **Figure A4.6** show the In-band Interference caused by spurious emissions of mobile signals traversing the allocated FSS frequency range.

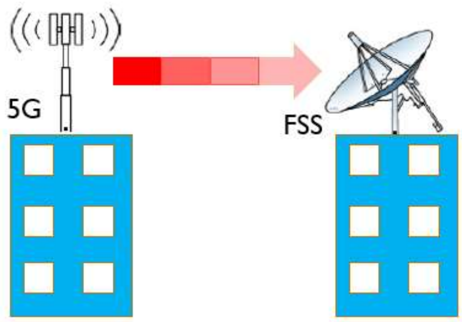


Figure A4.5: Spurious Emissions Caused By 5G Base Station

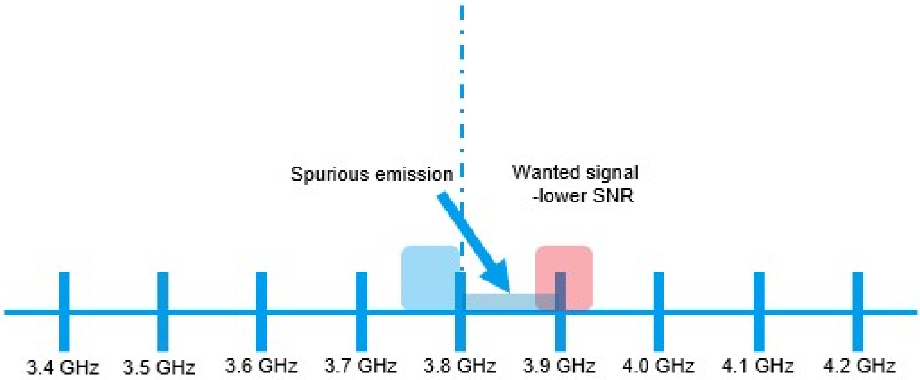


Figure A4.6: Spurious Emissions in The FSS Spectrum Range

Inherently, intermodulation distortion is caused by nonlinearities of the active radio frequency of the FSS system. For example, two Base Station signals of frequencies around 3.5GHz and 3.7GHz at the FSS receiver input would generate the product of third-order intermodulation interference at 3.9GHz as in-band interference to the desired FSS signal. **Figure A4.7** and **Figure A4.8** show the interference from intermodulation products generated in FSS system.

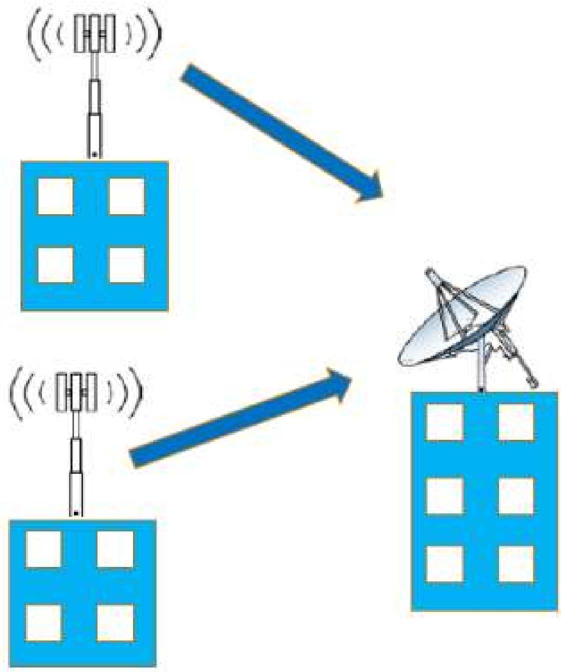


Figure A4.7: Intermodulation Interference From 5G Base Station to the FSS

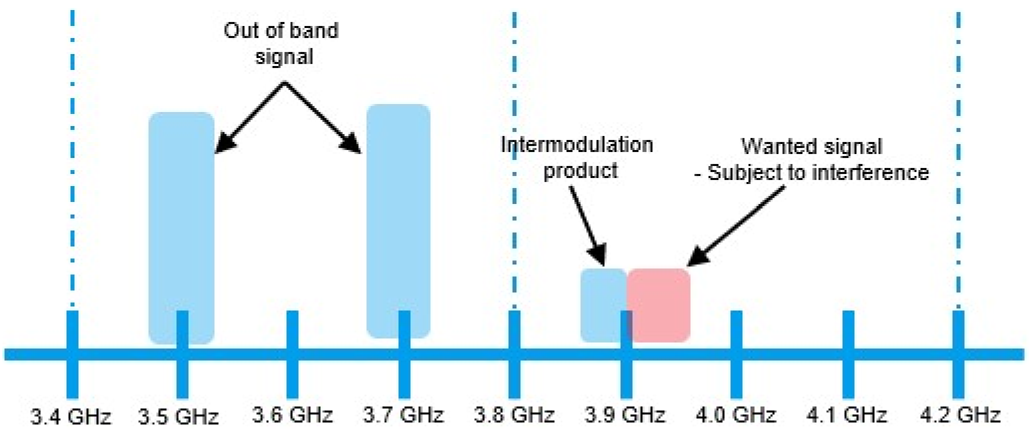


Figure A4.8: Intermodulation Interference in The FSS Spectrum Range

4.4 Global Reference on Coexistence Scenarios

Case	Spectrum Identified for IMT	Incumbent Services	Mitigation Solution	Supporting Regulatory Policy
Hong Kong	3400MHz – 3700MHz	TT&C earth stations maintained at 3400MHz – 3405 MHz SMATV, EFTNS, SPETS, TVRO relocate from 3400MHz – 4200MHz to 3700MHz – 4200MHz	TT&C: identification of restriction zones of ~10 x 20 km^2 (as in the reallocation statement) Other earth station receivers: - Guard band 100MHz (i.e. 3600MHz – 3700MHz) - More blocking resilient LNB/filters (55 dB suppression for signals below 3.6GHz) - IMT Base Station location/ RF parameters optimisation	**Relocation notice and technical specification requirements issued in advance to incumbent licensees for advance planning:** - Incumbent system upgraded with appropriate mitigation measures conforming to new technical specifications requirement will be protected from harmful interference - Any subsequent new deployment of EFTNS, SPETS and SMATV shall conform to the new technical specifications, catered to the local radio environment before installation at a particular location **Subsidy procedure to be administered by government:** - Subsidy of HK$20K per SMATV to be paid by successful bidders. - Upgrade cost of other earth stations will not be compensated.

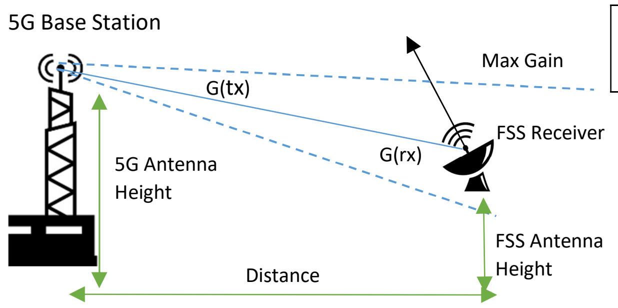
Figure A4.9: Summary of Reference on Mitigation Solution from Other Countries (Part 1); Source: Spectrum Working Group

Case	Spectrum Identified for IMT	Incumbent Services	Mitigation Solution	Supporting Regulatory Policy
China	3300MHz – 3400MHz	Radiolocation	Limited to indoor use	**Coordination to be administered by local regulator if there is interference found**
	3400MHz – 3600MHz	TT&C earth stations, SMATV, EFTNS, SPETS, VSAT maintain at 3400MHz – 4200MHz *Note: incumbent operating at 3400-3700 MHz is the minority*	Scenario 1 - Adjacent-channel co-existence scenario (incumbent operating at 3700 – 4200 MHz) : - If LNA/LNB for earth stations working at 3700 – 4200MHz is upgraded to meet the technical requirements, the coordinated separation distance is 100m*; otherwise, 2km*. -IMT Base Station location/RF parameters optimization, shielding net Scenario 2 - Adjacent-channel co-existence scenario (incumbent operating at 3600 – 3700MHz): - If LNA/LNB for earth stations working at 3600-3700MHz, the coordinated separation distance is 4km* Scenario 3 - Co-channel co-existence scenario (incumbent operating at 3400-3600MHz) : -Coordinated separation distance is 42.5km*. **coordination distance is only for reference from theoretical analysis, not mandatory requirement.*	**New applications of 3400 – 3700 MHz satellite station will not be approved** **Technical requirement notice issued in advance to incumbent licensees for advance planning:** - The LNA/LNB of the installed satellite earth stations at 3700-4200 MHz shall conform to the technical specifications **Coordination procedure are administered by local regulator when conflicts arise between mobile and FSS operators** **Subsidy procedure administered by government** - Upgrade cost of LNA/LNB to be covered by mobile operators

Figure A4.9: Summary of Reference on Mitigation Solution from Other Countries (Part 2); Source: Spectrum Working Group

4.5 Analysis Model and Assumption

The path loss between 5G Base Station and FSS Station is calculated using formula below:



P(rx) = P(tx) + G(tx) – CL(tx) – L(FS) + G(rx) – CL(rx)

P(rx) = FSS receive max allowable input power
P(tx) = Output power of 5G BTS
G(tx) = 5G BTS transmit antenna again
G(rx) = FSS receive antenna gain
CL(tx) = cable loss 5G Base Station 90dB in AAU case)
CL(rx)= cable loss FSS receiver (assume 1dB in analysis)
L(FS) = Path Loss

Figure A4.10: Analysis Model for Path Loss Between 5G Base Station and FSS Station; Source: Spectrum Working Group

Assumptions:

1. Two different propagation models are being considered in the study, i.e. Free-space for Line-of-Sight (LOS) scenario and 3GPP Uma for Non-Line-Of-Sight (NLOS) scenario.

   Free-space Loss **LOS** : L(FS) = 32.4 + 20 log (f) +20log (d)

   Where:

   f = frequency in MHz
   d = distance in km

   3GPP Uma:

   NLOS :

   $PL_{3D\text{-}UMa\text{-}NLOS} = 161.04 - 7.1 \log_{10}(W) + 7.5 \log_{10}(h) - (24.37 - 3.7(h/h_{BS})^2) \log_{10}(h_{BS}) + (43.42 - 3.1 \log_{10}(h_{BS}))(\log_{10}(d_{3D})-3) + \text{k3} \log_{10}(f_c) - (3.2 (\log_{10}(17.625))^2 - 4.97) - 0.6(h_{UT} - 1.5)$

2. 5G Base Station technical specification assumptions:

5G Base Station parameters	Values
Bandwidth (MHz)	100
Transmit power (dBm)	53
Antenna gain (dBi)	24 / 19 (24dBi is max. gain, i.e. worst case)
Maximum out-of-band blocking interference (dBm/MHz)	-15
Noise factor (dB)	3.5
ACLR (dBm/MHz)	-47

The parameters above are based on commonly available 5G products in the market now. ACLR specification of -47 dBm/MHz @ 100MHz out-of-band is commonly found in the market. If 5G Base Stations can be designed to meet -47dBm/MHz @ 50MHz out-of-band, similar levels of interference apply.

Interference from IMT 5G User Devices (UE) was not considered in this study.

3. FSS receiver technical specification assumption:

Satellite earth station (see ITU –S.465)	Satellite receiving station
Antenna gain (dBi) (1.8m diameter)	35 (typical scenario)
Feeder loss (dB)	1 (7/8 feeder: 20 m)
Receiver noise level (dBm/MHz)	-112.7 (10*LOG(KTB))
Interference noise threshold ratio I/N(dB)	-12.2 (ITU-RS.1432-1)
Noise figure (dB) @ Noise temperature 100 K	1
Allowable interference level (dBm/MHz), I **- Spurious interference requirement**	-124.9 (I/N= I-N = -124. 9 - (-112.7) = -12.2)
Receiver Max input Signal Level(dBm) **- Saturation Level/ blocking interference requirement**	-60 (ITU-R S.2368; and based on assumption main interference contribution is from 5G BS)
BPF Filter Suppression (dB)	55
Sidelobe Envelope Gain (dBi)	$G = 32 - 25 \log \varphi$ dBi for $\varphi_{min} \leq \varphi < 48°$ $= -10$dBi for $48° \leq \varphi \leq 180°$

4. The antenna gains G(tx) and G(rx) is subject to following factors:

    - Height of both antennas
    - Downtilt and azimuth of 5G antenna
    - Uptilt degree and azimuth of FSS antenna

Typically, all IMT Base Station will apply down-tilt. FSS receivers in Malaysia served by MEASAT satellites operating at 91.5E, typically have FSS up-tilt angles that range from 58-degrees, at worst-case scenario (Sandakan) to 77 degrees, at best-case scenario (Klang Valley).

In this analysis, 24dBi maximum (worst-case) and 19dBi antenna gain (typical case considering 5G antenna is not pointing directly to the FSS receiver's main beam) of the 5G Base Station is assumed. Furthermore, -10dBi FSS antenna gain is assumed, as typically, the FSS receiver's side-lobe is pointed at the 5G Base Station directly.

Analysis Results

Based on these assumptions, the following is the path loss requirement (dB) for both Spurious and Blocking interference:

Spurious Interference			
Adjacent-channel interference	**gNB-> satellite earth station** **Tx gain= 19dBi**	**gNB-> satellite earth station** **Tx gain = 24dBi**	**Remarks**
Spurious power (dBm/MHz))	-47	-47	A
Receiver noise level (dBm/MHz)	-112.7	-112.7	B
Receiver interference noise threshold I/N(dB)	-12.2	-12.2	C
Maximum single-site interference (dBm/MHz)	-124.9	-124.9	D(D=B+C)
Maximum interference of multiple sites (dBm/MHz) 4 sites is being considered	-130.9	-130.9	E(E=10*log(10^(D/10/4)
Transmit antenna gain (dBi)	19	24	F (worst case-scenario)
Satellite Feeder Loss (dB)	1	1	H
Receive antenna gain (dBi)	-10	-10	G (The 5G has an off-axis angle for the satellite ground station)
Spurious isolation Path Loss (dB) -single site	85.9	90.9	Y(Y=A-D+F+G-H)
Spurious isolation Path Loss (dB) - multiple site	91.9	96.9	Y(Y=A-E+F+G-H)

Blocking Interference			
Adjacent-channel interference	**gNB-> satellite earth station Tx gain= 19dBi**	**gNB-> satellite earth station Tx gain= 19dBi**	**Remarks**
Transmit power (dBm)	53	53	M
Allowed blocking power at the receive end (dBm)	-60	-60	N
Filter suppression (dB)	55	55	O
Transmit antenna gain (dBi)	19	24	P
Receive antenna gain (dBi)	-10	-10	Q
Satellite Feeder Loss (dB)	1	1	H
Blocking isolation Path Loss (dB) without Rejection Filter	121	126	S=M-N+P+Q-H
Blocking isolation Path Loss (dB) with Rejection Filter 55dB	66	71	S=M-N-O+P+Q-H

Using the free-space model for LOS and the 3GPP Uma model for NLOS, the separation distance requirements between 5G Base Station (assumed height =30m) and FSS receiver (assume height = 5m) is as follows:

	Spurious Interference				**Blocking Interference**			
	Single site; Tx gain 19dBi	**Multiple site;** Tx gain 19dBi	**Single site;** Tx gain 24dBi	**Multiple site;** Tx gain 24dBi	**Without Rejection Filter;** Tx gain 19dBi	**With Rejection Filter 55dB;** Tx gain 19dBi	**Without Rejection Filter;** Tx gain 24dBi	**With Rejection Filter 55dB;** Tx gain 24dBi
Path Loss, dB	85.9	91.9	90.9	96.9	121	66	126	71
Isolation Distance (model: Free-space LOS), meter	135	270	240	480	7690	14	13675	24
Isolation Distance (model: 3GPP Uma NLOS, urban), meter	50	70	65	95	400	15	530	20
Isolation Distance (model: 3GPP Uma NLOS, suburban), meter	68	95	90	130	550	21	720	28

Once FSS receiver is upgraded with 55dB rejection filter:

- In Line-Of-Sight (LOS) scenario, based on typical 5G Base Station gain of 19dBi and FSS receiver gain of -10dBi, the isolation requirement is 135m and 270m for single and multiple (4) 5G sites deployment respectively.
- In Non-Line-Of-Sight (NLOS) scenario, based on typical 5G Base Station gain of 19dBi and FSS receiver gain of -10dBi, the isolation requirement is 70m and 95m for urban and suburban respectively in multiple (4) 5G scenario.

4.6 Proposed Tests and Corresponding Field Test Plan

4.6.1 Proposed Test Plan

The test plan for the coexistence study is based on the three scenarios in which the interference can occur between the 5G Base Station and the FSS receiver:

1. Receiver blocking (out of band power saturation caused by 5G Base Station)
2. Spurious emissions in the FSS spectrum range
3. Intermodulation products generated in FSS system by multiple 5G Base Stations

For the (1) receiver blocking and (2) spurious emissions test, the test will be conducted in the field based on the baseline parameters stated set in the theoretical study. This will require the 5G Base Station to be set up to emulate the amount of out of band emission from 5G Base Station as well as the height, antenna angle and distance from the FSS receiver as concluded from the theoretical study. The receiver blocking and spurious emission characteristics are then measured and the performance of the FSS receiver will be characterized to determine the quality of the Satellite receive signal to match the expected performance as shown from the theoretical study. Variation of parameters will also be considered in the Field Test.

For the intermodulation measurement, it is proposed for the test to be conducted in a lab environment. To emulate worst case intermodulation interference from multiple 5G Base Station, two signal generators will be set up to transmit a simulated 5G signals and operate at the highest frequency channel in the 3.4GHz – 3.8GHz. A TV generator will also be included in the test setup to generate the lowest frequency channels for each satellite service as used by the FSS receiver. The performance of the FSS receiver can then be measured at the FSS receiver unit as well as with a spectrum analyser to check for the level of intermodulation interference that the FSS receiver receive from multiple 5G Base Stations.

Field Test Setup

Field tests can be conducted in a testbed environment, where the test can leverage the existing network structure to deploy 3.5GHz 5G Base Stations for interferences in the area. The resources required for the Field Test are summarized below.

1. 5G Base Station
2. FSS receiver
3. Signal Analyser
4. Receive Filter (the specification as concluded from the theoretical study)

Apart from the resources mentioned above, the test requires the participation of a project manager, site location leads, and equipment test leads. The responsibilities that these individuals need to uphold are summarised in **Figure A4.11**:

Resource	Responsibility
Project Manager	To coordinate the overall test, manage resources and prepare all the permit as required for the test.
Site Location lead	Ensure site readiness, logistics and availability; and setup for Field Test. Actual number of sites may scale down depending on the outcome of Lab Test.
Equipment test lead	Ensure equipment readiness, logistics, availability, setup and configuration for Field Test
Documentation lead	To record measurement results and prepare the test report.

Figure A4.11: Responsibilities of Respective Manpower Identified for Field Test

The following is a scenario of the Field Test:

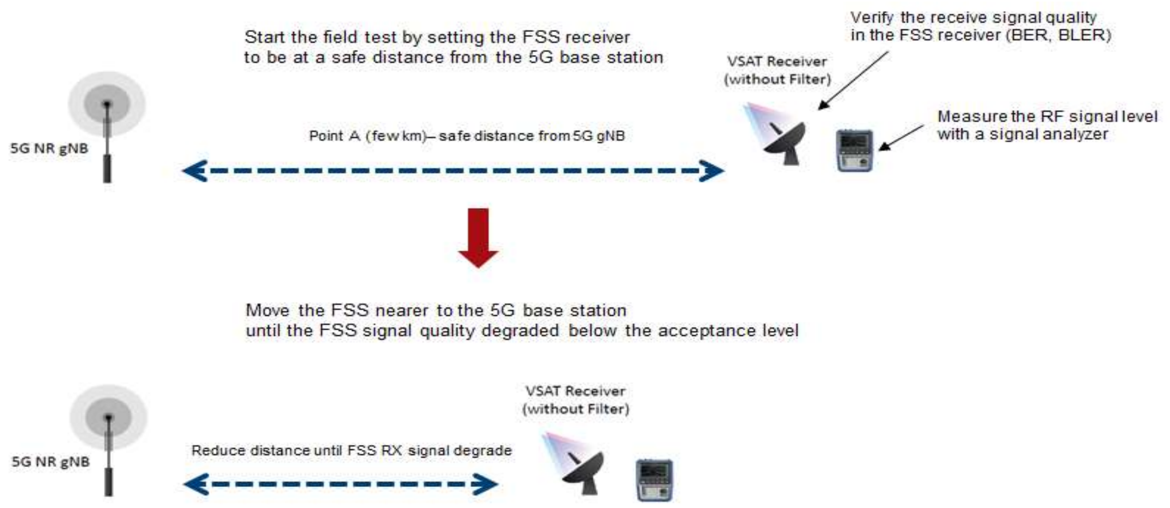


Figure A4.12: The Field Test Setup Scenario (Part 1)

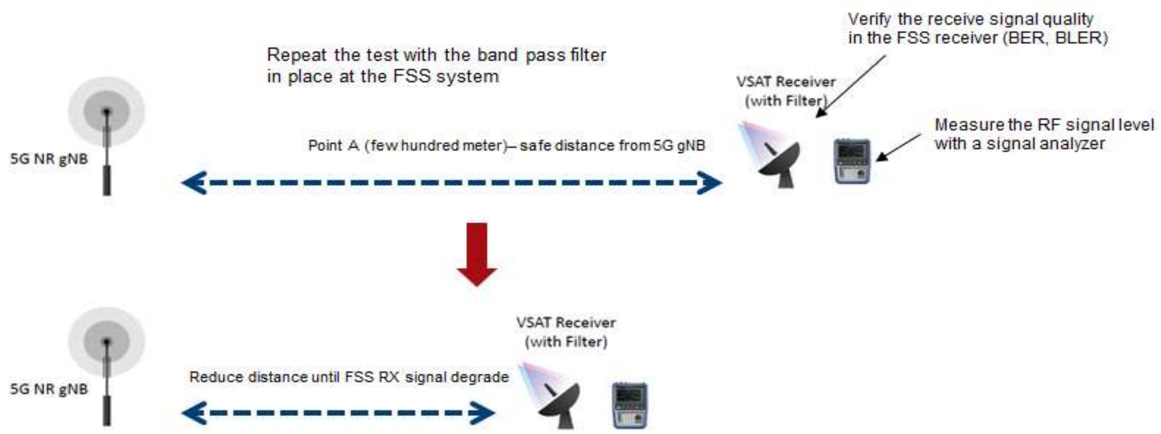


Figure A4.12: The Field Test Setup Scenario (Part 2)

The variations of parameters required of the 5G Base Station are summarised in the test matrix shown in **Figure A4.13**. For the antenna tilt, it is recommended that the test begins with reference to co-location LTE site antenna (1800MHz as reference).

No	5G Base Station Operating Frequency (MHz)	FSS Receiver Operating Frequency (MHz)	Guard band (MHz)	ACLR (dBm/MHz)	Filter Selection
Test 1	OFF	3700 -4200	100	-47 (subject to manufacturer's design)	Type A
Test 2	3500-3600	3700 -4200	100	-47 (subject to manufacturer's design)	Type A
Test 3	3500-3600	3700 -4200	100	-47 (subject to manufacturer's design)	No Filter
Test 4	OFF	3650 -4200	50	TBC (subject to manufacturer's design)	Type B
Test 5	3500-3600	3650 -4200	50	TBC (subject to manufacturer's design)	Type B
Test 6	3500-3600	3650 -4200	50	TBC (subject to manufacturer's design)	No Filter

Figure A4.13: 5G Base Station and FSS Receiver Parameter Variation for The Field Test

For each of the Test item above, there are other parameters/scenario variations that can be introduced, e.g.: 5G Base Station output power, azimuth/tilt, different environmental factor (LOS, NLOS) etc.

Type A Filter specifications	Frequency Range	Signal suppression
Passband	3.7GHz – 4.2GHz	<0.4 dB
Stopband (left)	3.0GHz – 3.6GHz	>55 dB
Return Loss	3.7GHz – 4.2GHz	>11.5 dB
Insertion Loss	3.7GHz– 4.2GHz	<0.2 dB

Type B Filter specifications	Frequency Range	Signal suppression
Passband	3.65GHz– 4.2GHz	<0.4 dB
Stopband (left)	3.0GHz – 3.6GHz	>55 dB
Return Loss	3.65GHz – 4.2GHz	>11.5 dB
Insertion Loss	3.65GHz – 4.2GHz	<0.2 dB

During the Field Test, the 5G Task Force proposes that FSS receives 3.7GHz – 4.2GHz instead of 3.8GHz – 4.2GHz due to:

- Filter with passband range 3.7GHz – 4.2GHz is easily available in the market.
- Current commercial 5G Base Stations are mostly designed to work at optimum levels when 5G operates within 3.4GHz – 3.6GHz with FSS operating at 3.7GHz – 4.2GHz; or with 5G operating at 3.6GHz – 3.8GHz with FSS operating at 3.9GHz – 4.2GHz. Other frequencies will necessitate equipment with special customisations.

The Field Test results will still be applicable in other frequency ranges, as long as the 5G Base Station is designed to meet the required ACLR, and filter is designed to meet 55dB rejection gain at the corresponding stop band.

Lab Test

Figure A4.14 shows the setup for testing a typical FSS receiver for intermodulation interference.

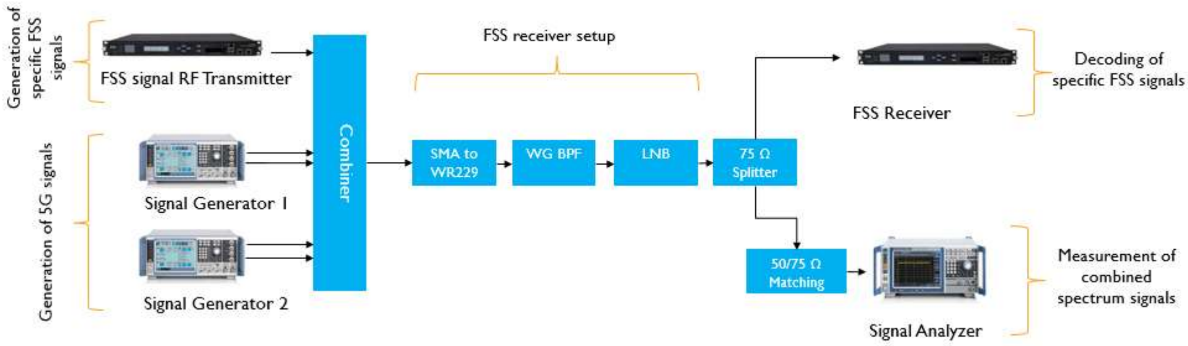


Figure A4.14: The Intermodulation Lab Test Setup with FSS Receiver

In gauging the performances of typical FSS receivers, the performance metric used was the maximum mobile signal power (i.e. interference power). The power level of the interfering signal was increased progressively until a point where the receiver system cannot successfully decode the received signal which set forth the most stringent of decoding requirements. This power level was referred as the "maximum tolerable mobile signal power". The power of the interfering signal was probed at the signal analyser and the FSS receiver whereby the reading corresponded to power input to the FSS receiver system. The measurements and equipment used for that purpose during the intermodulation interference test is listed in **Figure A4.15**.

Equipment	Function
Signal Generator 1	To generate input signal (5G)
Signal Generator 2	To generate input signal (5G)
FSS Signal RF Transmitter	To generate input signal (FSS)
FSS Receiver	To decode FSS receive signal
Signal Analyzer	To analyse FSS receiver signal
LNB	Part of the FSS receiver system
Band pass filter	To suppress the interference signal

Figure A4.15: Equipment Required in The Lab Test

Deliverables and Test Schedule

The deliverables of the Field Test include:

- One skeleton proposal within 2 weeks from the commencement of the Field Test
- One final report submitted over 5 stages and completed within 6 months from the commencement of the test
- Bi-weekly progress reports

The overall schedule of the Field Test is depicted below.

	Month	1	2	3	4	5	6
Item	Task Description						
1	Preparation for field test						
2	Field Test						
3	Reporting						

Figure A4.16: The Field Test Overall Schedule

4.6.2 Field Test Plan for 5G And FSS Co-Existence Study
Spectrum Working Group (SWG)

1. Background

The proposed deployment of the 5G Base Station adjacent to the incumbent's receiver in the re-allocated C-band spectrum is expected to generate interference towards the incumbent's receiver system. The 5G Task Force recommends a segregated approach in allocation of the C-band, whereby allocating 3.4–3.8GHz to the mobile service and the remaining spectrum to be re-allocated to FSS, with a guard band (which to be determined) in between the two services. Based on the analysis, an initial total of 100MHz for limited 5G use (indoor and selective outdoor when there is no interference issue with incumbent service) and 400MHz (general use) is proposed to be allocated for 5G deployments.

Due to the technically sensitive nature of FSS operation within the 3.5GHz band, there is potential harmful frequency interference between 5G system and FSS system that operate in co- or adjacent band. **Figure A4.16** illustrates this whereby FSS earth stations receiving signals in the 3.5GHz frequency band can be interfered by the 5G Base Station and mobile terminals.

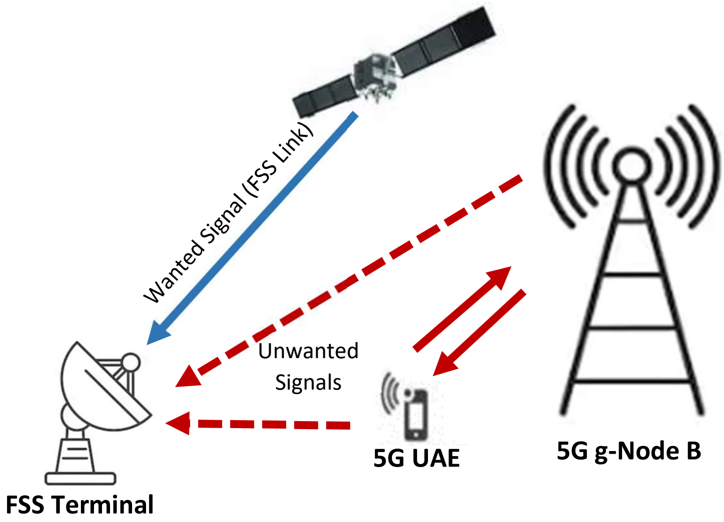


Figure A4.17: Potential Interference Scenario from 5G to FSS

The 5G Task Force is proposing a quantitative evaluation on the technical feasibility of co-existence between 5G and FSS, by conducting theoretical study, lab test and Field Tests at selected locations and provide recommendation on the mitigation required.

Among others, this technical study could specify the necessary guard band, emission power limits, separation distance, and mitigation required for the co-existence of 5G and FSS. These techniques are proposed based on global best practice, to be verified by theoretical study and field trial as these techniques would be used as the interference mitigation approach for both local and cross-border scenario.

2. Potential interference risks to FSS system

A 5G Base Station in the 3.5GHz band which is located near or in direct Line-Of-Sight (LOS) with an antenna dish of FSS system may saturate the latter. The saturation occurs at the Low-noise Block Downconverter (LNB) of the FSS system. When the LNB is driven into saturation, it ceases to amplify the wanted weak satellite signals in a linear fashion thus decreasing the conversion gain significantly. **Figure A4.18** and **Figure A4.19** show the out of band saturation caused by high level signals in the 5G transmitter that causes severe interference towards the FSS.

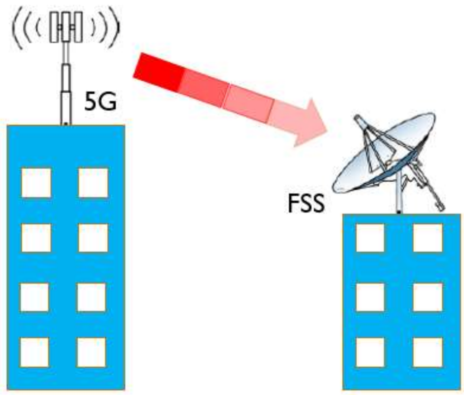


Figure A4.18: Receiver blocking in FSS due to 5G out of band emission

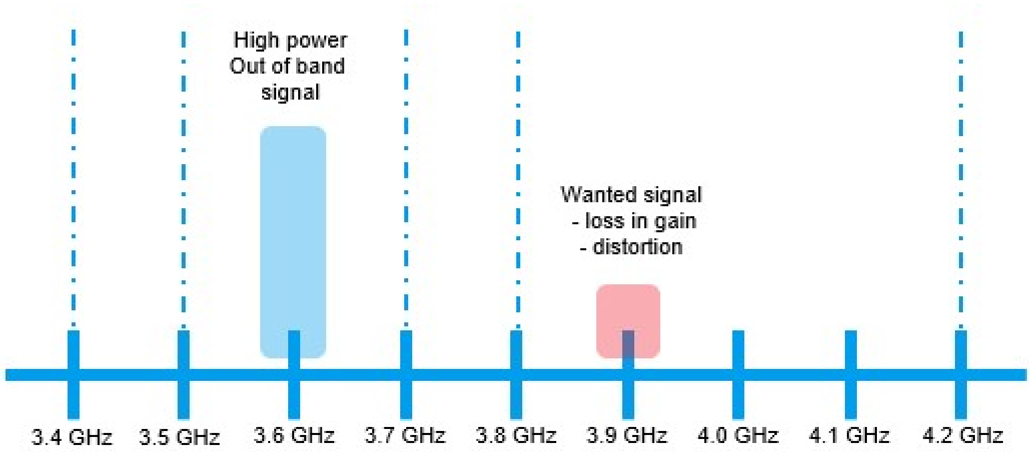


Figure A4.19: Saturation caused by high signal in the 5G band

In 5G NR terminology, the frequency ranges below and above up to 40MHz of a 5G signal operating band (equivalent to channel bandwidth) are defined as the NR spurious emissions. Spurious emissions stemming from a 5G signal in the 3.5GHz band can straddle across the 3.4–3.8 and 3.8–4.2GHz bands. In the context of the Proposed Re-Allocation, only spurious emissions traversing the 3.8–4.2GHz band, which will become interference to FSS signals, will be considered and analysed for mitigation. Such unwanted spurious emissions will manifest as background noise in the 3.8–4.2GHz frequency band and reduce the signal to noise ratio of the FSS systems as well. **Figure A4.18** and **Figure A4.19** show the In-band Interference caused by spurious emissions of mobile signals traversing the allocated FSS frequency range.

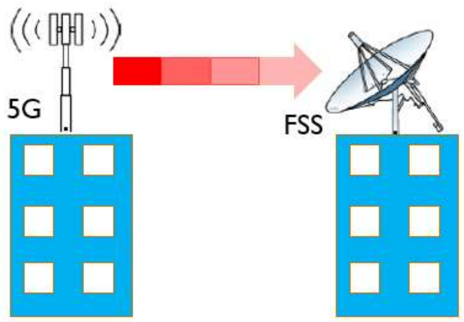


Figure A4.20: Spurious emissions caused by 5G Base Station

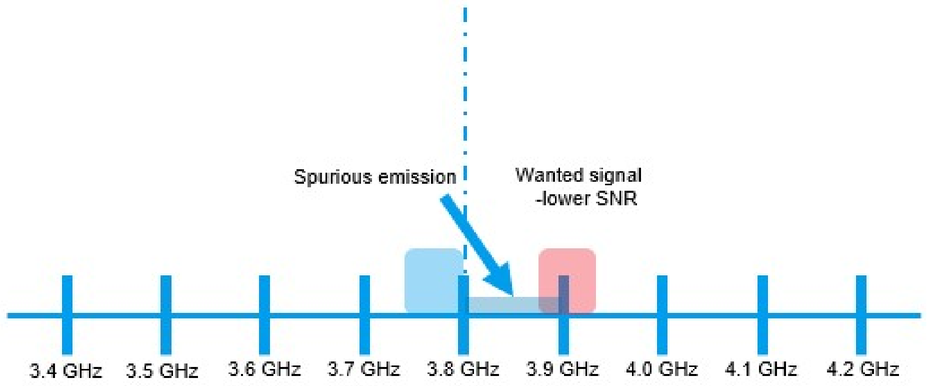


Figure A4.21: Spurious emissions in the FSS spectrum range

3. Test Objective

The Field Tests' objective to determine the isolation distance reference between 5G Base Station and FSS receiver based on the variation of parameters below:

I. Guard band (GB) between 5G and FSS receiver
II. Bandpass filter requirement for FSS receiver
III. Horizontal and vertical reference angles
IV. Environment factor, i.e. Line-Of-Sight (LOS) for Rural, Non-Line-Of-Sight (NLOS) for Suburban (e.g.: trees), Non-Line-Of-Sight (NLOS) for urban (e.g.: buildings)

4. Test Equipment and Tools

The equipment required for the Field Test are shown in Table 1. The equipment is required for transmitting the 5G signal and decoding the FSS signal. The 5G Base Station specifications are listed in Table 2. The 5G specifications are based on currently available equipment for the test.

The Field Test will have a scenario in which a band pass filter is required to be added at the FSS receiver to mitigate the interference. There are two type of filters required, one for the 100MHz guard band (type A), and the other is for 50MHz guard band (type B). The band pass filters specifications for type A and type B are shown in Table 3 and Table 4 respectively.

The FSS receiver specifications used in the Field Test will be based on FSS service provider equipment. However, a guideline on the specifications based on the ITU S.465 is listed in Table 5 for reference.

Table 1: The equipment required for the Field Test

Equipment	Function
5GNR Base Station	To transmit 5G signal (output power 200W, antenna gain 24dBi, 64T64R)
FSS Receiver	To receive Satellite signal
FSS Decoder	To decode Satellite signal Quality
Spectrum Analyser	To measure RF power at the receiving end

Table 2: The 5G Base Station specifications

Parameters	Values
Bandwidth	100MHz
Transmit power	53 dBm
Antenna gain	24 / 19 dBi
Maximum out-of-band blocking interference	-15 dBm/MHz
Noise figure	3.5 dB
ACLR	-47 dBm/MHz

Table 3: Type A Filter Specifications

Parameters	Frequency range	Values
Passband insertion loss	3.7GHz – 4.2GHz	<0.2 dB
Lower stop band	3.0GHz – 3.6GHz	>55 dB
Higher stop band	4.3GHz – 5.5GHz	>63 dB
Return loss	3.7GHz – 4.2GHz	>11.5 dB

Table 4: Type B Filter Specifications

Parameters	Frequency range	Values
Passband insertion loss	3.65GHz – 4.2GHz	<0.2 dB
Lower stop band	3.0GHz – 3.6GHz	>55 dB
Higher stop band	4.3GHz – 5.5GHz	>63 dB
Return loss	3.65GHz – 4.2GHz	>11.5 dB

Table 5: FSS receiver specifications as per ITU S.465

Parameters	Values
Antenna gain (1.8m diameter)	35 dBi (typical scenario)
Feeder loss	1 (7/8 feeder: 20 m)
Receiver noise level	-112.7 dBm/MHz (10*log(*k*TB))
Interference noise threshold ratio I/N	-12.2 dB (ITU-R S.1432-1)
Noise figure @ Noise temperature 100K	1 dB
Allowable interference level –spurious interference requirement	-124.9dBm/MHz
Receiver Max input Signal Level	-60dBm
Sidelobe Envelope Gain	$G = 32 - 25 \log \varphi$ dBi for $\varphi_{min} \leq \varphi < 48°$ $= -10$dBi for $48° \leq \varphi \leq 180°$
Band pass filter suppression	55dB

5. Test Parameters

The test parameters are derived on the independent variables (test factor) and the required corresponding measurement results (test response), which will be taken at each test point. Table 6 shows the test factor and Table 7 shows the test matrix response to be measured at each test points.

Table 6: The Field Test Factor

Factors	Unit
5GNR Base Station Power	dBm
Distance separation	m
Antenna elevation	°
Antenna tilt	°
Guard band	MHz

Table 7: The Field Test Matrix Response

Response
FSS Data Link (Eb/No)
FSS Data/Video Link (C/N)
Video Quality (pixilation)
Video Quality (black on air)
5G UE RSRP
5G UE SINR
Receive Spectrum Power

6. Test Setup

The test setup of the Field Test is based on three scenarios. The first scenario will be based on Line-Of-Sight (LOS) for rural areas, while second scenario is based on Non-Line-Of-Sight (NLOS) for sub-urban areas; and the third scenario is based on Non-Line-Of-Sight (NLOS) for urban areas (e.g.: buildings). From these three scenarios, the test will vary the relative isolation distance between the 5G Base Station and FSS receiver, the horizontal antenna tilt, and the vertical antenna tilt.

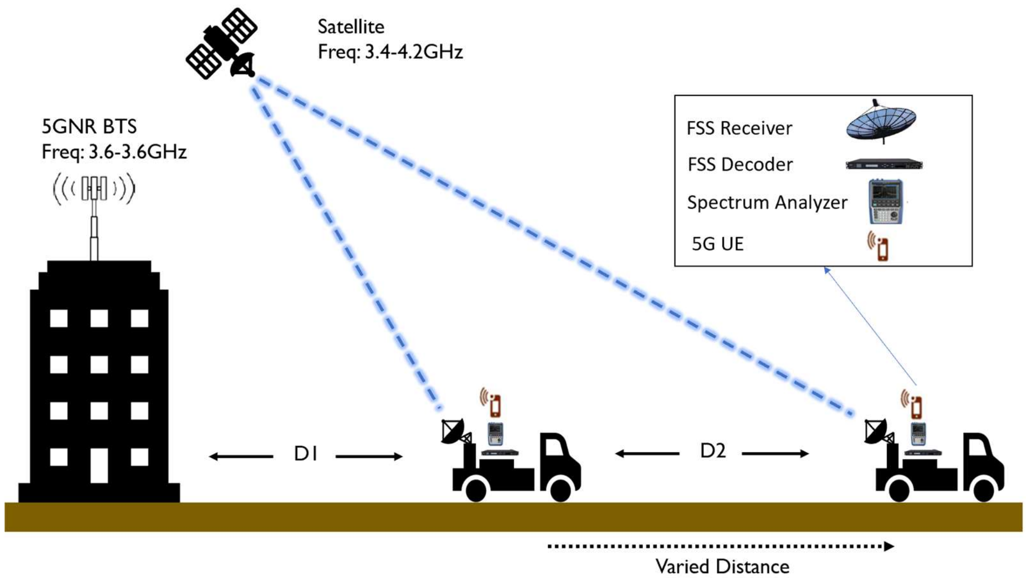


Figure A4.22: Varying the distance

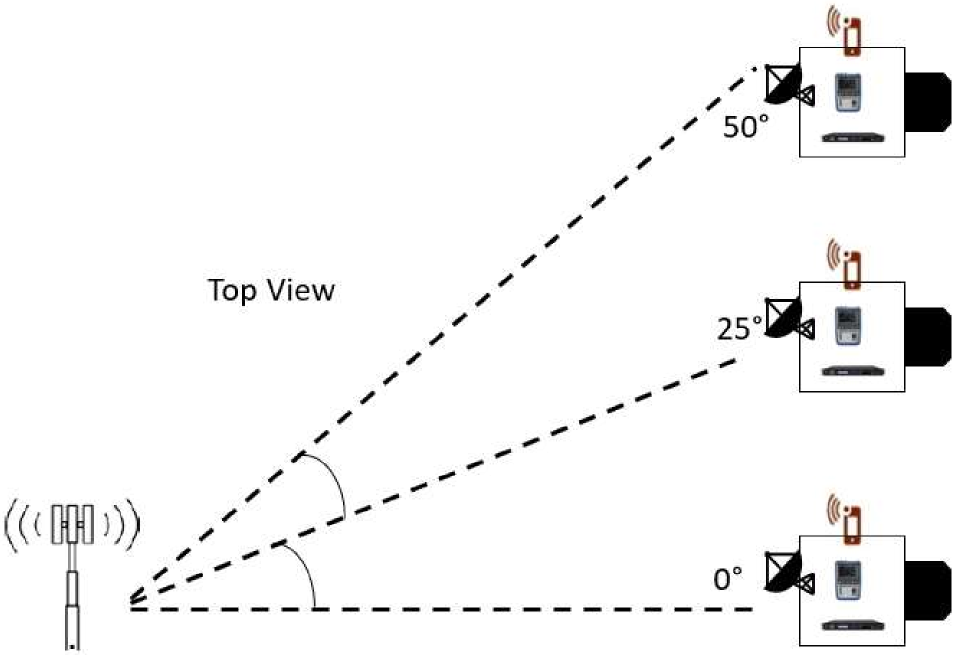


Figure A4.23: Varying the Antenna Tilt

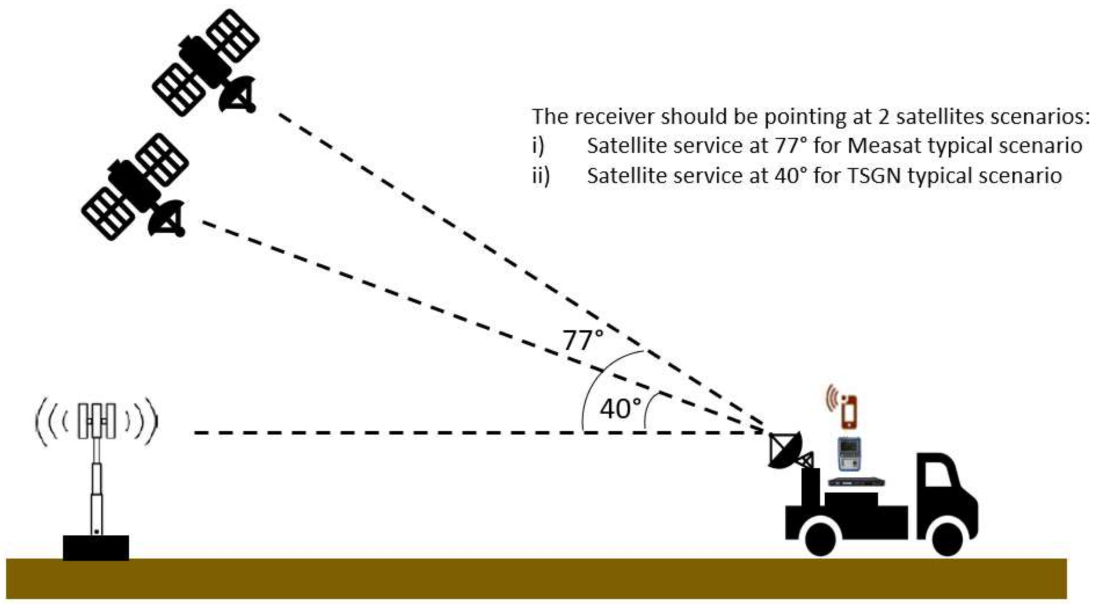


Figure A4.24: Varying the Antenna Elevation

7. Field Test Procedure

The Field Test is based on the test parameters and test setup of **Figures A4.22 and A4.24**. Due to current limitations of the Base Station, frequencies are limited to 3400MHz – 3.6MHz, as opposed to the 5G Task Force recommendation of 5G frequencies 3400MHz – 3800MHz. For the scenarios of all the transmitters transmitting from 3400MHz – 3800MHz altogether, a theoretical calculation is to be made based on the results of this Field Test to gauge the additional impact. Further tests on the 5G Base Station for frequencies up to 3800MHz can be conducted in the future once the Base Stations operating at this frequency range is available.

The test flow of **Figure A4.25** to **Figure A4.27** summarises the Field Test process. The test is first set up for guard band of 100MHz, in which the Base Station is transmitting at 3500MHz – 3600MHz, and the FSS receiver is set to receive the signal at 3700MHz. This is followed by the guard band of 50MHz, in which the Base Station is transmitting at 3500MHz – 3600MHz, and the FSS receiver is set to receive the signal at 3650MHz. The variation of distance is selected based on the test scenarios.

Figure A4.25 shows the test flow of Line-Of-Sight (LOS) in a rural scenario; **Figure A4.26** shows the test flow for Non-Line-Of-Sight (NLOS) a sub-urban scenario, and **Figure A4.27** shows the Non-Line-Of-Sight (NLOS) in an urban scenario. Test scenario 1 – 12 shows the step by step procedures of the test procedure.

(see next page)

Figure A4.25: The Line-Of-Sight (LOS) Scenario for Rural Environments

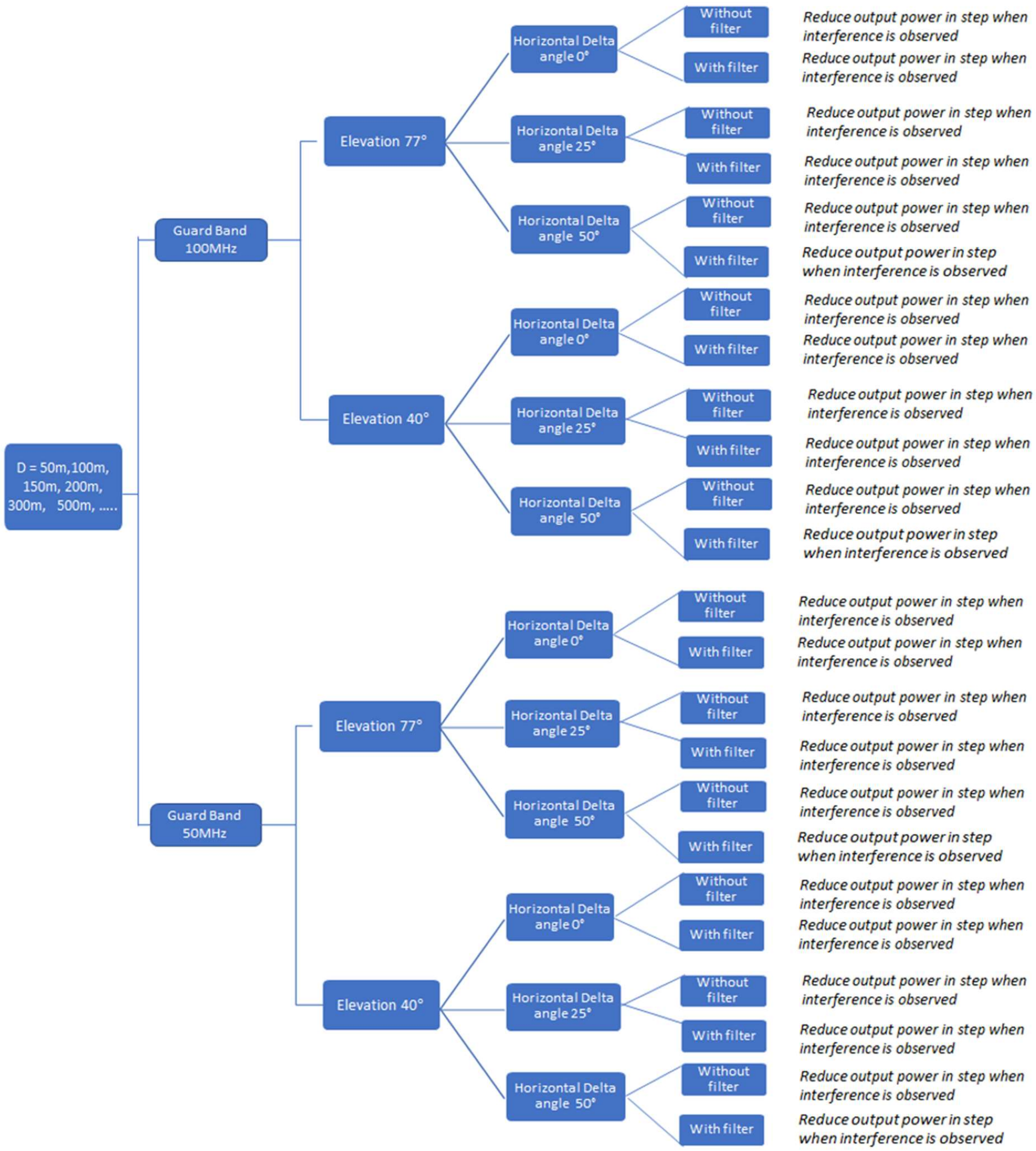


Figure A4.26: The Non-Line-Of-Sight (NLOS) Scenario for Sub-Urban Environments

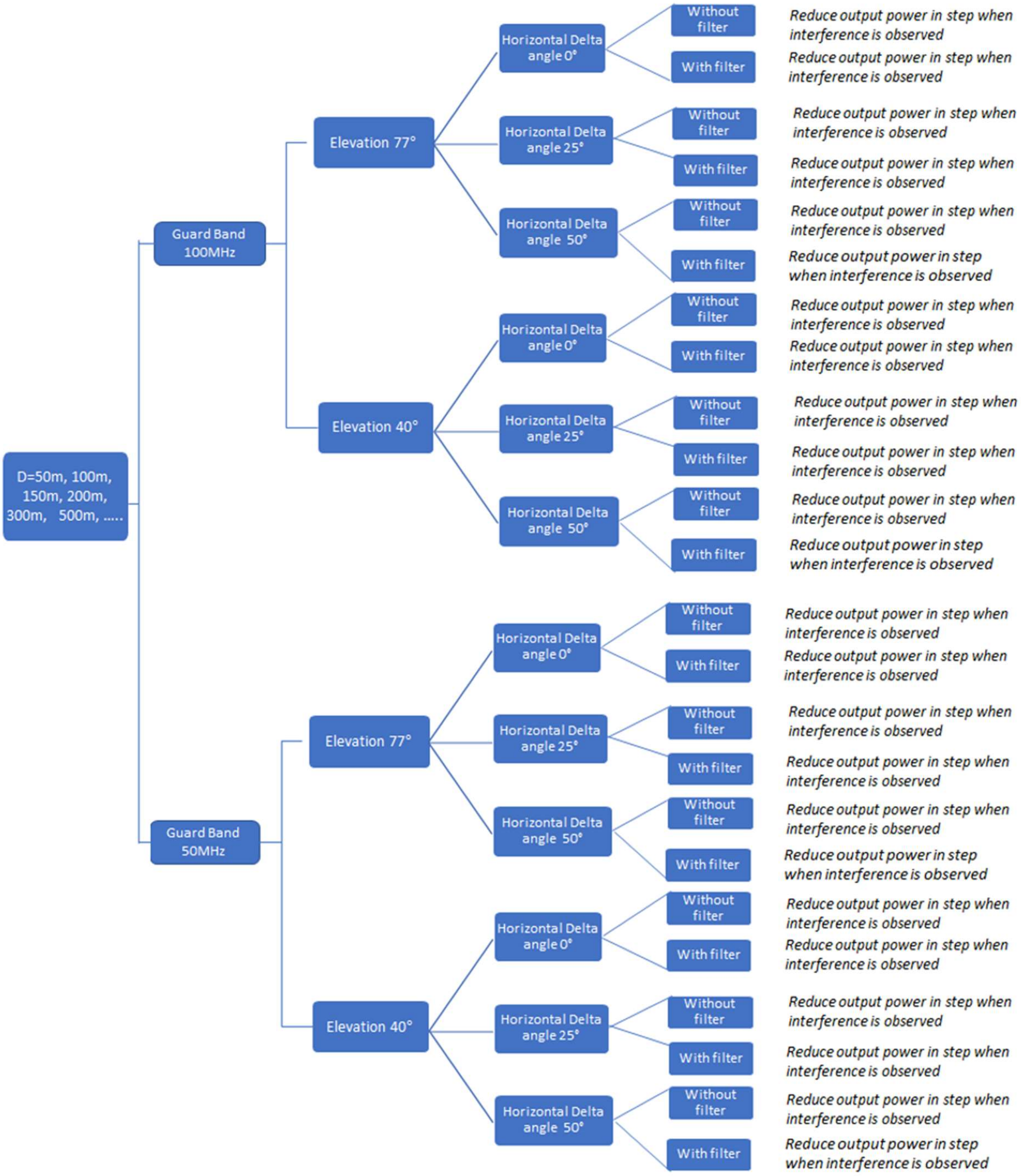


Figure A4.27: The Non-Line-Of-Sight (NLOS) Scenario for Sub-Urban Environments

Test No	**1**
Test Description	- LOS scenario - 100MHz Guard band - FSS receiver elevation angle =77° - 5G Base Station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3700MHz - Initial Distance D=50m.
Test Procedure	1. Set the distance as D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, install the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In horizontal delta angle 0°, scenario 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 200m, 500m, 1km, 2km. Repeat Step 3 to10.

Test No	**2**
Test Description	- LOS scenario - 100MHz Guard band - FSS receiver elevation angle =40° - 5G Base Station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3700MHz - Initial Distance D=50m.
Test Procedure	1. Set the as distance D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, installed the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In a horizontal delta angle 0° scenario, 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 200m, 500m, 1km, 2km. Repeat Step 3 to10.

Test No	**3**
Test Description	- LOS scenario - 50MHz Guard band - FSS receiver elevation angle =77° - 5G Base Station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3650MHz - Initial Distance D=50m.
Test Procedure	1. Set the distance as D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, installed the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In a horizontal delta angle 0° scenario, 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 200m, 500m, 1km, 2km. Repeat Step 3 to10.

Test No	**4**
Test Description	- LOS scenario - 50MHz Guard band - FSS receiver elevation angle =40° - 5G Base Station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3650MHz - Initial Distance D=50m.
Test Procedure	1. Set the as distance D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, installed the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In a horizontal delta angle 0° scenario, 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 200m, 500m, 1km, 2km. Repeat Step 3 to10.

Test No	**5**
Test Description	- NLOS scenario (suburban) - 100MHz Guard band - FSS receiver elevation angle =77° - 5G Base station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3700MHz - Initial Distance D=50m.
Test Procedure	1. Set the as distance D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, installed the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In a horizontal delta angle 0° scenario, 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 150m, 200m, 300m, 500m. Repeat Step 3 to10.

Test No	**6**
Test Description	- NLOS scenario (suburban) - 100MHz Guard band - FSS receiver elevation angle =40° - 5G Base Station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3700MHz - Initial Distance D=50m.
Test Procedure	1. Set the as distance D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, installed the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In a horizontal delta angle 0° scenario, 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 150m, 200m, 300m, 500m. Repeat Step 3 to10.

Test No	**7**
Test Description	- NLOS scenario (suburban) - 50MHz Guard band - FSS receiver elevation angle =77° - 5G Base Station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3650MHz - Initial Distance D=50m.
Test Procedure	1. Set the distance as D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, installed the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In a horizontal delta angle 0° scenario, 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 150m, 200m, 300m, 500m. Repeat Step 3 to10.

Test No	**8**
Test Description	- NLOS scenario (suburban) - 50MHz Guard band - FSS receiver elevation angle =40° - 5G Base Station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3650MHz - Initial Distance D=50m.
Test Procedure	1. Set the distance as D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, installed the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In a horizontal delta angle 0° scenario, 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 150m, 200m, 300m, 500m. Repeat Step 3 to10.

Test No	**9**
Test Description	- NLOS scenario (urban) - 100MHz Guard band - FSS receiver elevation angle =77° - 5G Base Station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3700MHz - Initial Distance D=50m.
Test Procedure	1. Set the distance as D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, installed the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In a horizontal delta angle 0° scenario, 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 150m, 200m, 300m, 500m. Repeat Step 3 to10.

Test No	**10**
Test Description	- NLOS scenario (urban) - 100MHz Guard band - FSS receiver elevation angle =40° - 5G Base Station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3700MHz - Initial Distance D=50m.
Test Procedure	1. Set the distance as D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, installed the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In a horizontal delta angle 0° scenario, 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 150m, 200m, 300m, 500m. Repeat Step 3 to10.

Test No	**11**
Test Description	- NLOS scenario (urban) - 50MHz Guard band - FSS receiver elevation angle =77° - 5G Base Station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3650MHz - Initial Distance D=50m.
Test Procedure	1. Set the distance as D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, installed the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In a horizontal delta angle 0° scenario, 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 150m, 200m, 300m, 500m. Repeat Step 3 to10.

Test No	**12**
Test Description	- NLOS scenario (urban) - 50MHz Guard band - FSS receiver elevation angle =40° - 5G Base Station frequency = 3500MHz – 3600MHz - FSS receiver frequency ≈ 3650MHz - Initial Distance D=50m.
Test Procedure	1. Set the distance as D=50m 2. Set the horizontal delta angle to 0° (both antennae pointing directly) 3. Turn off 5G Base Station, record the measurement matrix 4. Turn on the 5G Base Station at 200W transmit power, record the measurement matrix 5. If the measurement matrix shows no interference, then filter is not required 6. If the measurement matrix shows interference, installed the filter at FSS receiver and record measurement matrix 7. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 100W and record the measurement matrix 8. If the measurement matrix still shows interference, then reduce 5G Base Station transmit power to 50W and record the measurement matrix 9. If the measurement matrix still shows interference, move the truck until the horizontal delta = 25°, repeat step 2-8. 10. If the measurement matrix still shows interference, move the truck until the horizontal delta = 50°, repeat step 2-8. 11. In a horizontal delta angle 0° scenario, 5G transmit power 200W, and with filter installed at FSS receiver, if the measurement matrix shows interference, increase the Distance D to 100m, 150m, 200m, 300m, 500m. Repeat Step 3 to10.

4.6.3 Field Test Results Template

The Field Test results template was summarised in Tables 8 to 13. Each test scenario will be based on the LOS/NLOS (sub-urban)/NLOS(Urban) conditions, and for different guard bands (GB). For the 100MHz guard band, the FSS receiver is set at 3700MHz whereas for the 50MHz guard band the FSS receiver is set at 3650MHz. The Base Station frequency range is from 3500MHz – 3600MHz.

Table 8: Field Test template for LOS and 100MHz GB scenario

Distance (m)	FSS Antenna Elevation (°)	FSS to 5G Antenna tilt (°)	Eb/N0	C/N	Video Quality (pixilation)	Black on Air	5G UE RSRP	5G UE SINR	Receive Spectrum Power
50	77	0							
		25							
		50							
	40	0							
		25							
		50							
100	77	0							
		25							
		50							
	40	0							
		25							
		50							
500	77	0							
		25							
		50							
	40	0							
		25							
		50							
1000	77	0							
		25							
		50							
	40	0							
		25							
		50							
2000	77	0							
		25							
		50							
	40	0							
		25							
		50							

Table 9: Field Test template for LOS and 50MHz GB scenario

Distance (m)	FSS Antenna Elevation (°)	FSS to 5G Antenna tilt (°)	Eb/N0	C/N	Video Quality (pixilation)	Black on Air	5G UE RSRP	5G UE SINR	Receive Spectrum Power
50	77	0							
		25							
		50							
	40	0							
		25							
		50							
100	77	0							
		25							
		50							
	40	0							
		25							
		50							
500	77	0							
		25							
		50							
	40	0							
		25							
		50							
1000	77	0							
		25							
		50							
	40	0							
		25							
		50							
2000	77	0							
		25							
		50							
	40	0							
		25							
		50							

Table 10: Field Test template for NLOS (sub-urban) and 100MHz GB scenario

Distance (m)	FSS Antenna Elevation (°)	FSS to 5G Antenna tilt (°)	Eb/N0	C/N	Video Quality (pixilation)	Black on Air	5G UE RSRP	5G UE SINR	Receive Spectrum Power
50	77	0							
		25							
		50							
	40	0							
		25							
		50							
100	77	0							
		25							
		50							
	40	0							
		25							
		50							
150	77	0							
		25							
		50							
	40	0							
		25							
		50							
200	77	0							
		25							
		50							
	40	0							
		25							
		50							
300	77	0							
		25							
		50							
	40	0							
		25							
		50							
500	77	0							
		25							
		50							
	40	0							
		25							
		50							

Table 11: Field Test template for NLOS (sub-urban) and 50MHz GB scenario

Distance (m)	FSS Antenna Elevation (°)	FSS to 5G Antenna tilt (°)	Eb/N0	C/N	Video Quality (pixilation)	Black on Air	5G UE RSRP	5G UE SINR	Receive Spectrum Power
50	77	0							
		25							
		50							
	40	0							
		25							
		50							
100	77	0							
		25							
		50							
	40	0							
		25							
		50							
150	77	0							
		25							
		50							
	40	0							
		25							
		50							
200	77	0							
		25							
		50							
	40	0							
		25							
		50							
300	77	0							
		25							
		50							
	40	0							
		25							
		50							
500	77	0							
		25							
		50							
	40	0							
		25							
		50							

Table 12: Field Test template for NLOS (urban) and 100MHz GB scenario

Distance (m)	FSS Antenna Elevation (°)	FSS to 5G Antenna tilt (°)	Eb/N0	C/N	Video Quality (pixilation)	Black on Air	5G UE RSRP	5G UE SINR	Receive Spectrum Power
50	77	0							
		25							
		50							
	40	0							
		25							
		50							
100	77	0							
		25							
		50							
	40	0							
		25							
		50							
150	77	0							
		25							
		50							
	40	0							
		25							
		50							
200	77	0							
		25							
		50							
	40	0							
		25							
		50							
300	77	0							
		25							
		50							
	40	0							
		25							
		50							
500	77	0							
		25							
		50							
	40	0							
		25							
		50							

Table 13: Field Test template for NLOS (urban) and 50MHz GB scenario

Distance (m)	FSS Antenna Elevation (°)	FSS to 5G Antenna tilt (°)	Eb/N0	C/N	Video Quality (pixilation)	Black on Air	5G UE RSRP	5G UE SINR	Receive Spectrum Power
50	77	0							
		25							
		50							
	40	0							
		25							
		50							
100	77	0							
		25							
		50							
	40	0							
		25							
		50							
150	77	0							
		25							
		50							
	40	0							
		25							
		50							
200	77	0							
		25							
		50							
	40	0							
		25							
		50							
300	77	0							
		25							
		50							
	40	0							
		25							
		50							
500	77	0							
		25							
		50							
	40	0							
		25							
		50							

4.6.4 List of Abbreviations, Acronyms, Initials and Symbols

φ	Antenna Sidelobe angle
°	Angle in degree
5G	Fifth generation cellular network technology
5GNR	5G new access radio technology
64T64R	64 RF Transceiver Channels: 64 Transmit and 64 Receive
ACLR	Adjacent Channel Leakage Ratio
B	Bandwidth
BTS	Base Station
C/N	Carrier-to-noise ratio
dBi	Decibel isotropic
dBm	power ratio in decibels (dB) with reference to one milliwatt (mW)
dB	Decibel
Eb/No	Normalised signal to noise ratio, or signal to noise per bit
FSS	Fixed Satellite Service
GHz	Gigahertz
g-NodeB	5GNR Base Station
I/N	Interference-to-noise ratio
ITU-R	International Telecommunications Union Radiocommunications Sector
k	Boltzmann constant (1.380649×10^{-23} Joule/K)
K	Kelvin (base temperature unit)
LNB	*Low-noise block downconverter*
LOS	Line-of-sight
log	Non-Line-of-sight
m	Meter (length unit)
MHz	Megahertz
NLOS	Non-Line-Of-Sight
RF	Radio Frequency
RSRP	Reference Signal Receive Power
SINR	Signal-to-noise plus interference ratio
T	Temperature
UE	User Equipment
W	Watt (power unit)

Appendix 5: Sectoral Regulations (5G Use Cases)

5.1 5G Use Case and Sectoral Regulatory Assessment: Digital Healthcare

1. Use Case Proposal

Key Drivers for 5G	Description
Internet of Medical Things (IoMT): Amalgamation of medical devices and applications that connect to healthcare IT systems using networked technologies	Management of data created by IoMT devices - Consumer health wearables/remote patient monitoring - Tracking patient health parameters in-transit
Tactile Internet: Telediagnosis, telesurgery, telerehabilitation	- Remote physical examination by palpation (examination by touch) - Command motion of a tele-robot at the patient's location - Receive audio-visual information and critical haptic feedback
Critical communications: Monitoring of blood sugar, ECG, temperature, etc. - To support massive number of connections per square meter while maintaining the requisite Quality of Service (QoS) - To monitor progress of treatment remotely in real-time	Remote Monitoring - Sensors and wearable devices - Big data – public health monitoring Remote Healthcare - Individualised consultations, treatment, and patient monitoring - Video conferencing and tele-presence, sensors, smart pharmaceutical
Emergency medical services: - Rescue and services pre-hospital emergency - Ambulance communicating back to hospital	m-Health - Advanced wearable diagnostic devices - Remote medical treatment-assistant system Data Analytics - User location, services used, signalling information and applications - Disease screening in advance - Accessing and checking of patient data

2. Sectoral Regulatory Assessment

Recommended solutions	Key actions	Timeline
1. Test bed: To finalise the test bed requirement	MOH	End of 2019
2. Online healthcare services framework: MOH with other partners in healthcare	MOH	Started (5 years)
3. Develop Guidelines on wearables and sensors (for telehealth products, wellness)	MOH, Digital Health Malaysia, Manufacturers	2020
4. Review of the Medical Devices Act for 5G applications	MOH, Medical Device Authority	2020
5. To review requirements on Telemedicine Act, whereby doctors offering telemedicine; (i) must endeavour to provide the same quality and standard of care as in-person medical care, (ii) have the necessary expertise to provide the remote guidance, (iii) take reasonable care to ensure confidentiality of medical information shared through technology and ensure compliance with the relevant laws on personal data.	MOH, Malaysian Medical Council	2020
6. Review PDPA to enable Telehealth/Telemedicine	KKMM	2020
7. Review Medical Devices Act to accommodate 5G IoMT devices	MOH	2020
8. Review Private Healthcare Facilities and Services Act 1998 - prescribe the minimum standards [s107(jj) regulations on ambulance]	MOH	2020
9. Emergency Medicine and Trauma Services Policy (Ambulance)	MOH	2020

5.2 5G Use Case and Sectoral Regulatory Assessment: Retail and Services

1. Use Case Proposal

Business Case	Implementation Scenario	Suitable Business Cases
Broadband & Media	- Rich interactive work, media, and entertainment retail-based content; - Retail based applications in the cloud or reality augmentations (both centralised and distributed); - Personalised digital advertising (instead of static) based on the individual location; - Enhanced digital signage with live interaction	- E-sports - Live streaming - Entertainment - Advertisement - Unified Communications (Video Conferencing)
Indoor Location Services & Smart Energy Savings for Malls	- Hassle-free navigation, improved decision-making, and increased adoption of connected devices. - Deployment of sensors to better manage energy consumption, reducing Co2 emissions and waste.	- E-Tourism - Airport - Parking lot - Shop lots

2. Sectoral Regulatory Assessment

Regulatory Impediments

Impediments viewed on piracy and privacy issues to accommodate retail-based contents in the context of 5G.

Recommended next steps

Recommended solutions	Key actions	Timeline
1. Copyright issues on the next stepping stone of energy consumption; - To minimise disruptive effects on existing market, talents, artistic work.	MDTCA	tbc
2. Privacy - Who are the data processors? - Consumer protection: Can consumers trust these data processors.	PDP	tbc

5.3 5G Use Case and Sectoral Regulatory Assessment: Smart City

1. Use Case Proposal

CCTV feeds for local authorities will come from the private sector, by leveraging on the private sector's 5G network infrastructure. Video feeds will be captured through (1) static CCTVs and (2) mobile drones.

2. Sectoral Regulatory Assessment

Regulatory Impediments

Impediments viewed on harmonisation of regulations in the permitting for flying drones, and data management/privacy matters.

Recommended next steps

Recommended solutions	Key actions	Timeline
1. Harmonising the regulations for flying permit (drones) Location, pilot, flight details need to be documented and registered with JUPEM *Note: Same proposal as per "Recommended Solutions #1 for Sectoral Regulatory Assessment on Smart Agriculture"*	CGSO, JUPEM, CAAM, PDRM, Armed forces, MCMC State and local authorities	18 months
2. Study of *Akta 171* Local Government on provision of CCTV installation, operation, and management	KPKT	12 months
3. Centralised data to manage the geospatial to avoid inconsistent geospatial info. - Need to standardise geospatial information through coordination with various authorities, to ensure integrity and accuracy. No such coordination exists today. - Current system from the authority is not 5G ready to acquire geospatial data. - Drone mapping: 3D mapping of physical world and 3D mapping of 5G signal strength	JUPEM	12 months
4. Recommendation to standardise by-laws on CCTV implementation across local councils	KPKT	18 months
5. Privacy Managing video feeds, storage, and processing of CCTV to avoid infringing PDPA; data user (i.e. local authorities to be aware and responsible of risks)	PDP	tbc

5.4 5G Use Case and Sectoral Regulatory Assessment: Smart Education

1. Use Case Proposal

Driver	Enabler	5G Requirement
- Digital learning - Remote teacher training - Remote auditing and monitoring	***Smart classroom*** - Augmented Reality - Virtual Reality - Devices to support digital learning ***Digital content*** - Media rich content - Digital TVET	- Large bandwidth - Low latency - High connection reliability

2. Sectoral Regulatory Assessment

<u>Regulatory Impediments</u>
Impediments viewed on:

- Bring Your Own Device (BYOD) Policies, currently established at individual school, PIBG levels.
- Accreditation process for vocational certification (*Jabatan Pembangunan Kemahiran*) to be reviewed to do away with physical-only training
- Review on Guideline for "*Tugas-tugas Guru*"

<u>Potential recommended next steps</u>
In addition, further view/assessment from experts in MOE will be required to provide guidance on sectoral regulatory assessment in 5G use cases pertaining to the Smart Education sector.

Recommended solutions	Key actions	Timeline
1. To revise *Surat Pekeliling Bill 2/2018 KPM 100-1/7/2 Jilid 5 (3)* on *Garis Panduan Perlaksanaan Dasar Murid Membawa Peranti Peribadi Ke Sekolah Kementerian Pendidikan Malaysia.*	MOE	2020
2. To develop a policy that is: - Flexible enough to cater for various target groups' needs. For example, JKM to allow flexibility for disable student to use computer during exam but currently not allowed by MOE requirements. - Teacher/student presence in classroom	MOE	2020
3. To review the current human capital competencies and infrastructure readiness	MOE	2020
4. To develop new policy or guideline for digital content creation in MOE as the current one is conventional	MOE	2020

Aside from the aforementioned sectoral regulatory assessments, initial sectoral regulatory assessments were already made for Oil and Gas sector, together with PETRONAS (via UTP). It was concluded that there were no regulatory impediments at this stage. However, if required, experts from the Oil and Gas sector, may make further assessments.

5.5 Manufacturing: Robotics (Assessment Areas)

Use Case Description: Robotics/Warehousing in Manufacturing

Current Malaysian Regulatory Context:
- Standard Radio System Plan (SRSP) for spectrum bands are generic and do not have IoT-specific provisions; and
- Malaysian Standards do not have provisions for IoT or 5G:
  - "2005 Agreement on The ASEAN Harmonised Electrical and Electronic Equipment Regulatory Regime", a Mutually Recognised Agreement (MRA), does not cover 5G.

Amendments Required:
- Amend SRSP for the designated spectrum bands to include provisions for IoT use (spectrum, power emission) as applicable;
- Department of Standards Malaysia to adopt appropriate international standards (IEC, ISO, 3GPP standards, including Goose on 5G), when IEC to adopt 5G 3GPP/ITU specifications;
- SIRIM Equipment Type Approval Process: certification to be based on specifications instead of model or brands;
- MRA to include 5G equipment to speed up important processes; and
- Manufacturing organisations to engage Telcos for the setup of Private Virtual Network Operator (PVNO) that should provide more reliable cellular services/5G for manufacturing services.

Key stakeholders:
RWG (lead PIC): Maxis
BCWG: FMM
Authorities: SIRIM and/or MITI/MIDA/MDEC

International Regulations Impacting Manufacturing
- Adopt the Following Standards:
  - *International Telecommunications Union Radiocommunication Sector (ITU-R), "Minimum requirements related to technical performance for IMT-2020 radio interface(s)", Report ITU-R M.2410-0 (11/2017), November 2017;*
  - *3GPP specifications for MMTC and uRLLC (including CMTC): follow Release 15 and Release 16 standards;*
  - *3GPP TR 22.804, "Study on Communication for Automation in Vertical domains";*
  - *3GPP TS 23.501, "System Architecture for the 5G System";*
  - *3GPP TR 22.821, "Feasibility Study on LAN Support in 5G,";*
  - *3GPP TS 22.104, "Service requirements for cyber-physical control applications in vertical domain";*
  - *3GPP TS 22.261, "Service requirements for the 5G system";*
  - *3GPP TR 22.830, "Feasibility Study on Business Role Models for Network Slicing";*
  - *3GPP TR 22.889, "Study on Future Railway Mobile Communication System";*
  - *IEC 61907, "Communication Network Dependability Engineering, 2009"; and*
  - *IEC 62657-1, "Industrial Communication Networks – Wireless Communication Networks – Part 1: Wireless Communication Requirements and Spectrum Considerations".*

5.6 Manufacturing: Smart Grids (Assessment Areas)

Use Case Description: Smart Grids in Utilities, Electricity & Water as Examples

Current Malaysian Regulatory Context:

- "2005 Agreement on The ASEAN Harmonised Electrical and Electronic Equipment Regulatory Regime" does not cover 5G;
- The Energy Commission's "Grid Code for Peninsular Malaysia [Electricity Supply Act 1990 (Act 447)] Section CC6.6 Communications Plant and Apparatus" currently refers to traditional telecommunications and is typically self-provided; and
- The National Water Service Commission's (SPAN) "Water Services Industry (Water Reticulation and Plumbing) Rules 2014" has generic provisions for Supervisory Control and Data Acquisition System (SCADA).

Amendments Required:

- Update relevant regulatory documents for 5G and Smart Grids (see Energy Commission Code and Water Services Industry Rules above);
- For energy, grid owners should be permitted to engage Telcos as their Private Virtual Network Operator (PVNO);
- For energy, to cater for uRLLC with specific standards for different network parts (e.g. Grid access communication network, etc.); and
- MRA to include 5G equipment to speed up import processes

Key stakeholders:
RWG (lead PIC): Maxis
BCWG: ABB, Mawea
Authorities: Energy Commission, KKMM, SPAN, and the Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC)

International Regulations:

- The Council of European Energy Regulator (CEER)'s Report on Smart Technology Development made preliminary recommendations;
    - *Page 20 of the report states that, "CEER will work along with other relevant authorities, and possibly other organisations, on cybersecurity, data privacy, interoperability and monitoring".*
- 3GPP Release 16 has specifications for MMTC and uRLLC (including CMTC).

Amendments Required:

- To adopt 3GPP Release 16 when firmed up:
    - *MTSFB to adopt Code for Smart Grids based on 3GPP specifications;*
    - *SIRIM to adopt IoT Equipment Type Approval; and*
    - *Amend* SRSP.