NetLinkTrust
the fibre of a smart nation

NETLINK MANAGEMENT PTE. LTD.

(AS TRUSTEE OF NETLINK TRUST)

SUBMISSION TO

THE INFO-COMMUNICATIONS MEDIA DEVELOPMENT AUTHORITY

IN RESPONSE TO

SECOND CONSULTATION ON 5G MOBILE SERVICES AND NETWORKS

DATE OF SUBMISSION: 19 JUNE 2019

NetLinkTrust
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Table of Contents

NetLinkTrust
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STATEMENT OF INTEREST

I. NetLink Trust (managed by NetLink Management Pte. Ltd. as its trustee) ("**NetLink Trust**") designs, builds, owns and operates the passive fibre network infrastructure (comprising ducts, manholes, fibre cables and central offices) of Singapore's Next Generation Nationwide Broadband Network ("**NGNBN**").

II. NetLink Trust's nationwide network is the foundation of the NGNBN, over which ultra-high-speed Internet access is delivered throughout Singapore and its connected islands. The principal services offered by NetLink Trust are: (i) fibre connectivity to residential homes and non-residential premises; (ii) fibre connectivity to non-building address points; (iii) segment fibre connections; and (iv) non-fibre ancillary services (e.g. co-location of telecommunication equipment in central offices).

III. NetLink Trust holds a Licence to Provide Facilities-based Operations granted by the Info-communications Media Development Authority ("**IMDA**") on 22 September 2011 pursuant to Section 5 of the Telecommunications Act (Chapter 323). NetLink Trust is designated as a Public Telecommunication Licensee pursuant to Section 6 of the Telecommunications Act (Chapter 323).

IV. As a Dominant Licensee, NetLink Trust offers its services to all Requesting Licensees on terms and conditions that are non-discriminatory and in compliance with the Code of Practice for Next Generation Nationwide Broadband Network NetCo Interconnection ("**NetCo Code**") and Code of Practice for Competition in the Provision of Telecommunication Services ("**TCC**").

GENERAL COMMENTS

i. NetLink Trust welcomes this opportunity to provide our views and comments on IMDA's proposed 5G framework as set out in its Consultation Paper.

ii. NetLink Trust supports IMDA's vision for Singapore to have a thriving Digital Economy, where every business is a digital business, every worker is empowered by tech, and every citizen a connected citizen. 5G, with its ability to deliver higher speeds and connect more things with better reliability and lower latencies, will be an important enabler for advancing Singapore's economic competitiveness in the digital age.

iii. NetLink Trust has studied the various proposals for 5G put forth by IMDA in its Consultation Paper, and is pleased to submit herein our comments for IMDA's consideration.

iv. This submission focuses on questions that are, in NetLink Trust's view, pertinent to IMDA's ongoing consideration of an appropriate regulatory approach and framework for 5G, to realise IMDA's ambition for Singapore to be a global front-runner for innovation in secure and resilient 5G applications and services.

v. Unlike the previous mobile technology upgrade from 3G to 4G, 5G will be a major technological advancement from its predecessor. The investment to enable such advancement will be significant, while the commercial return from a 5G investment remains unclear given the nascent technology, where most of the potential use cases for 5G applications/services have yet to be tested for commercial viability in a real-life commercial deployment.

vi. The absence of a clear business case for 5G, coupled with spectrum constraint in the extended C-band, warrant proactive intervention by IMDA. A fundamentally different approach is needed to address the inherent challenges associated with the rollout of 5G technology.

vii. A Single Wholesale Network ("**SWN**") for 5G in Singapore, akin to the Next Generation Nationwide Broadband ("**NGNBN**") and designed to incorporate open and non-discriminatory access at the wholesale infrastructure level, ensures a cost-effective and efficient regulatory framework that meets IMDA's policy objective of maximising value of 5G for Singapore and its economy, and deliver maximum benefits and welfare to the consumers.

viii. Importantly, an SWN addresses the risk of Mobile Network Operators ("**MNOs**") lacking the commercial incentive to invest to roll out nationwide 5G networks quickly, thereby causing Singapore to lose out on the benefits that would otherwise accrue due to a fast and full rollout of the advanced capabilities of 5G technology.

ix. An SWN for 5G also removes the additional costs of duplication of network infrastructure which occur when multiple MNOs roll out their own networks, leading to cost savings.

Allowing competitive build of nationwide 5G networks will lead to duplicated, dense small cell networks being rolled out nationwide. Such duplication of network infrastructure is not only highly inefficient and cost-ineffective; it is also highly disruptive to road users, businesses and the general public.

x. An SWN for 5G that leverages on the existing NGNBN infrastructure for its fibre backhaul requirements would further reduce costs on both networks (i.e. NGNBN and SWN) and improve speed of deployment – this would be beneficial for both fixed and mobile users.

xi. Adopting the SWN model for 5G will lead to increased retail competition. Unlike an SWN that operates exclusively at the wholesale level and offers equal and non-discriminatory access to wholesale inputs on its network, under IMDA's proposed Call-For-Proposal ("**CFP**") approach 5G wholesale customers would have to compete with their wholesalers (which are vertically-integrated MNOs) at the retail level, placing them at a competitive disadvantage vis-à-vis MNOs that own and operate the 5G network. This inevitably will lead to a lessening of competition at the retail level. In comparison, an SWN, being a neutral and independent wholesale-only network provider, is strongly incentivised to maximise the number of its wholesale customers since the wholesale-only network provider does not have its own retail arm, and therefore there is no conflict of interest to protect or treat its retail business preferentially.

xii. The successful rollout and implementation of the NGNBN, and the consequent development of a vibrant and competitive retail fibre broadband market, ensures that all end-users in Singapore can enjoy ultra-high-speed Internet access at fibre broadband prices that are highly competitive and affordable. Furthermore, under the Universal Service Obligation ("**USO**") NetLink Trust continues to provide fibre connectivity services to all existing and new physical addresses in Singapore. This universal fibre coverage for all residents and businesses, coupled with a highly developed and competitive retail fibre broadband market, eliminate any need for an alternative last-mile access in Singapore.

xiii. NetLink Trust's specific comments on IMDA's proposed CFP approach are detailed in the following sections.

xiv. In support of this submission, NetLink Trust appends herewith a position paper by Frontier Economics entitled *"Singapore 5G Position Paper"*, which was developed as part of an independent expert study commissioned by NetLink Trust to consider the factors that would be important to the successful deployment of 5G services in Singapore.

CHAPTER 3: PROPOSED REGULATORY POLICY AND FRAMEWORK FOR 5G DEPLOYMENT IN SINGAPORE

Question 5: IMDA would like to seek views, comments and suggestions on:

i) Whether Singapore should have two nationwide networks as a start given the considerations and trade-offs;

ii) The proposed 3.5 GHz lot sizes and spectrum packages;

iii) Whether 5G equipment would be able to support 3.5 GHz bandwidths in multiples of 50 MHz;

iv) The value, if any, in assigning the remaining 50 MHz restricted 3.5 GHz spectrum in the same assignment exercise as the unrestricted lots;

v) The proposed mmWave lot sizes and preferred band plan option; and

vi) The rank order preference of the 3.5 GHz spectrum package and mmWave lot combinations.

1. NetLink Trust concurs with IMDA's policy intent of having 5G networks that are capable of delivering full-fledged 5G functionalities and capabilities. However, NetLink Trust differs with IMDA on the specific approach that IMDA should adopt to achieve the intended policy outcome.

2. In this response to Question 5, NetLink Trust will first set out the benefits of equal access to wholesale inputs on the nationwide fibre network infrastructure, and its contribution to the competitive development of the info-communications sector. This will be followed by an elaboration of NetLink Trust's proposed regulatory approach to achieve IMDA's policy objectives for 5G.

Next Generation Nationwide Broadband Network

3. NetLink Trust designs, builds, owns and operates the passive network infrastructure of the Next Generation Nationwide Broadband Network ("**NGNBN**"). In 2008, the Government decided to adopt a three-layered industry structure for the NGNBN, and to couple this with Effective Open Access requirements through structural and operational separation. The Government deemed Effective Open Access through structural and operational separation as key to the achievement of a vibrant and competitive next-generation broadband market[1].

[1] Speech by Dr Lee Boon Yang, Minister for Information, Communications and the Arts, at media briefing for award of Next Generation National Broadband Network NetCo Request-For-Proposal, 26 September 2008: http://www.nas.gov.sg/archivesonline/speeches/view-html?filename=20080926987.htm

4. Importantly, through structural separation put in place by the then Info-communications Development Authority of Singapore ("**IDA**") at the foundational NetCo layer of the NGNBN industry structure, the NGNBN incorporates and entrenches Effective Open Access[2]. Relevant interconnection principles based on Effective Open Access, aimed at creating an info-communications ecosystem that assures open and non-discriminatory access to the NGNBN by all qualified persons, have been adopted and implemented by IMDA. These regulatory measures initiated by the Government remain key and instrumental to the successful development of a vibrant and competitive retail fibre broadband market.

5. The NGNBN has delivered significant tangible and intangible benefits to the nation. Singapore has climbed from the fifth to the first position in the World Economic Forum Networked Readiness Index since the NGNBN was launched in 2010. Singapore, through the NGNBN, has reached universal fibre coverage for all its residents and businesses. Fibre broadband prices for consumers in Singapore have remained competitive and affordable, and continue to compare favourably with other countries with widespread fibre rollout – for example, retail fibre broadband plans offering 1Gbps are available from as low as S$34/month. The NGNBN has brought about significant positive changes to Singapore's broadband market and the broader info-communications industry, as evident from the high degree of service innovation and competition in today's vibrant marketplace.

IMDA's Proposed Regulatory Approach for 5G

6. In its Consultation Paper, IMDA noted that the business case and economics of 5G remain unclear amongst most operators globally[3]. NetLink Trust agrees with this observation.

7. Indeed, the lack of clarity as to the potential demand for prospective 5G use cases has led to challenges in building a business case for investment in 5G. Coupled with the shortage of contiguous spectrum in the extended C-band in Singapore, NetLink Trust submits that it is urgent for IMDA to consider a fundamentally different approach to achieve its key policy objectives for 5G, namely[4]:

   (i) Maximise value of 5G for the economy and welfare for the consumers;

   (ii) Facilitate efficient allocation of scarce resources such as spectrum;

   (iii) Ensure that Singapore's 5G networks are designed to be trusted and resilient; and

   (iv) Support the growth of a vibrant telecommunication sector.

[2] Speech by Dr Lee Boon Yang, Minister for Information, Communications and the Arts, at media briefing for award of Next Generation National Broadband Network NetCo Request-For-Proposal, 26 September 2008: http://www.nas.gov.sg/archivesonline/speeches/view-html?filename=20080926987.htm

[3] Page 11, paragraph 26 of the Consultation Paper

[4] Page 19, paragraph 51 of the Consultation Paper

8. The twin challenges of uncertainty over the business case for 5G investment and spectrum constraint in the extended C-band warrant proactive intervention by the Government. In the same way that the Government drew up the blue-print for the NGNBN and played an instrumental role in ensuring its successful rollout and implementation, in order to achieve its vision for Singapore to become a global front-runner for innovation in secure and resilient 5G applications and services[5], IMDA may need to consider a structural change to the mobile industry and adopt a fundamentally different approach that addresses the inherent challenges associated with the rollout of 5G technology.

9. In its Consultation Paper, IMDA stated that facilities-based competition in the mobile market would continue to be key to ensure that players in the market have the incentive to invest in new technology, innovate and compete. NetLink Trust would respectfully disagree with IMDA for the following reasons:

   (i) As discussed above and in IMDA's Consultation Paper, there continues to be significant uncertainty around demand for potential new use cases. This inevitably has led to the absence of a clear business case for 5G; and

   (ii) The investment for 5G network rollout is expected to be substantial and significantly higher than that of 4G. It is also unclear as to whether Mobile Network Operators ("**MNOs**") would continue to play a significant role in the value chain of delivering innovative services and applications through 5G connectivity to end-users, or if they would operate as a conduit for transmitting third party data over their 5G networks.

10. Taken together, these valid commercial concerns and considerations appear to run counter to the belief that facilities-based competition would be the appropriate regulatory approach for the 5G market. NetLink Trust respectfully holds the view that IMDA's proposal for Singapore to have two nationwide 5G standalone networks might not be feasible or sustainable.

Single Wholesale Network

11. IMDA may wish to consider an alternative proposal that would more appropriately mitigate the commercial risks arising from the uncertainties and challenges around the business case for 5G.

12. A Single Wholesale Network ("**SWN**") for 5G in Singapore, akin to the NGNBN and designed to incorporate open and non-discriminatory access at the wholesale infrastructure level, ensures a cost-effective and efficient regulatory framework that would fulfil IMDA's policy objective of maximising value of 5G for Singapore and its economy, and deliver maximum benefits and welfare to the consumers.

13. In NetLink Trust's view, an SWN addresses the risk of MNOs lacking the commercial incentive to invest to roll out nationwide 5G networks quickly, thereby causing Singapore

[5] Page 14, paragraph 35 of the Consultation Paper

to lose out on the benefits that would otherwise accrue due to a fast and full rollout of the advanced capabilities of 5G technology.

14. By relying on an SWN to roll out the underlying network infrastructure for 5G, IMDA could potentially remedy issues which arise when applying the existing model of network competition (i.e. facilities-based competition). Key among these concerns is that competing MNOs may lack the incentives to maximise coverage quickly, resulting in inadequate, or slow deployment of certain capabilities of 5G technology.

15. As IMDA acknowledged in its Consultation Paper, a nationwide 5G standalone network will require a denser network of small cells in order to overcome the limited propagation characteristics of the millimetre wave ("**mmWave**") spectrum. In this respect, an SWN that is solely appointed to roll out and operate the underlying network infrastructure for 5G avoids the inefficient and costly duplication of fibre network infrastructure nationwide, a scenario which would have been unavoidable under IMDA's proposed Call-For-Proposal ("**CFP**") approach (whereby at least two MNOs would be required to roll out their own dense networks of small cells nationwide).

16. Under this proposed regulatory approach, the SWN will be the sole appointed network infrastructure provider to design, build, own and operate a nationwide 5G standalone network. As with the case of the NGNBN, equal and non-discriminatory access to wholesale inputs on this network will support the development of a competitive market at the retail level, where traditional retailers of mobile services (including existing MNOs) operate alongside providers of 'vertical' applications that target specific market segments.

17. An SWN for 5G removes the additional costs of duplication of network infrastructure which occur when multiple MNOs roll out their own networks, leading to cost savings. Allowing competitive build of nationwide 5G networks will lead to duplicated, dense small cell networks being rolled out nationwide. Such duplication of network infrastructure is not only highly inefficient and cost-ineffective; it is also highly disruptive to road users, businesses and the general public.

18. To elaborate, the proposed CFP approach will result in traffic disruptions (including slower vehicular speed) to road users, pedestrians and businesses due to roadworks by MNOs and their contractors when laying their ducts and cables underground to extend their networks to 5G cell sites nationwide, and when they install their cables and network equipment on lampposts, bus stops and other street furniture. The amount of civil engineering works will increase and traffic disruptions will intensify due to the need for more road lane closures and/or road diversions. In comparison, an SWN avoids the inefficient and highly disruptive rollout of duplicated networks of small cells across Singapore.

19. Furthermore, given the limited outdoor public spaces in Singapore, it would likely be a challenge to identify sufficient sites that are suitable for MNOs to install their network equipment, to accommodate the rollout of at least two nationwide 5G networks (where each will be built with dense small cells). Lampposts and street furniture may not be

sufficiently robust to sustain equipment from multiple MNOs. An SWN, which avoids the duplication of network equipment and infrastructure at small cell sites (as shared antenna and equipment could be deployed for all small cells), is ideally placed to address such site limitations and constraints. In addition, the disruption to the public in relation to the deployment of 5G small cells would be minimised if only one provider needs to deploy equipment.

Potential Synergies with NGNBN

20. As discussed in the preceding sections, a single neutral SWN would reduce the costs of 5G deployment while enabling a faster and less disruptive rollout of network coverage nationwide. Conceivably, this speed and cost advantage would place Singapore well ahead of other economies as the global front-runner for innovation in 5G applications and services, in the same way that the NGNBN had been architected to deliver the promised long-term benefits to consumers and businesses in Singapore.

21. Through the NGNBN, NetLink Trust has implemented a dense fibre network throughout Singapore. An SWN for 5G could leverage on this foundational passive infrastructure layer, which already has extensive nationwide reach to all of Singapore and its connected islands, for its fibre backhaul requirements for the delivery of 5G applications and services to consumers, businesses and public entities.

22. Apart from speed of deployment, an SWN for 5G that leverages on the existing NGNBN infrastructure could also reduce costs, and this would be beneficial for both fixed and mobile users.

23. To elaborate, an increase in demand for services on the NGNBN will translate to a lower unit cost of provision, as the overall user base will have grown larger thereby allowing the costs of building, operating and maintaining the underlying network infrastructure to be shared by a bigger base. An SWN for 5G that leverages on the NGNBN has the effect of enlarging the overall user base for the latter. This in turn leads to a lowering of the unit cost of provision for both the NGNBN and SWN. Fixed and mobile users, and more generally consumers and businesses in Singapore, will therefore benefit from an SWN that leverages on the NGNBN for its fibre backhaul requirements due to the inverse correlation between demand and unit cost as explained above.

Increased Retail Competition with Effective Open Access

24. As discussed above, an SWN for 5G would lead to a better outcome than that envisaged under IMDA's proposed CFP approach (whereby at least two MNOs would be required to roll out their own 5G networks).

25. A neutral and independent wholesale-only network provider clearly has more incentives to maximise the number of its wholesale customers as compared to a vertically integrated operator, since the wholesale-only network provider does not have its own retail arm which it would be incentivised to treat preferentially. An SWN is by design structured to benefit from greater competition at the retail level – i.e. through promoting entry of new

market entrants at the retail level so that the number of users on its wholesale network grows and its cost structure becomes more efficient progressively as competition at the retail level intensifies.

26. While IMDA has proposed a framework for the provision of 5G wholesale services under the CFP approach[6], NetLink Trust is concerned that such a proposal would not work in practice given the clear conflict of business interests within an MNO that operates both as a wholesaler of network access, as well as a retail service provider that competes with its wholesale customers.

27. In this regard, NetLink Trust would refer IMDA to an interview in 2018 in which an executive of an MNO commented on the sustainability of the Mobile Virtual Network Operator ("**MVNO**") business model, as follows:

> *"Speaking at a recent analyst briefing, new [StarHub] CEO Peter Kaliaropoulos said the broad strategy which will help the telco prepare for external threats, will be proposed to the board for approval. With the addition of new competitors, Kaliaropoulos also revealed that the* ***MVNO (mobile virtual network operator) business model do not last beyond a few years on average as incumbents adjust their business structures and marketing plans accordingly to mitigate new competition.*** *(Emphasis added)"* [7]

28. The above sums up the challenges and limitations of IMDA's proposal (under the CFP approach) to require MNOs to offer wholesale access to their eventual 5G networks. To reiterate, MNOs are vertically integrated operators and they each own and operate a retail business that competes with their wholesale customers. Unlike an SWN that operates exclusively at the wholesale level and offers equal and non-discriminatory access to wholesale inputs on its network, under IMDA's proposed CFP approach 5G wholesale customers would have to compete with their wholesalers at the retail level, placing them at a competitive disadvantage vis-à-vis MNOs that own and operate the 5G network. This inevitably will lead to a lessening of competition at the retail level, to the detriment of consumers and businesses.

29. Notably, the possibility of there being only one 5G network under IMDA's proposed CFP approach was recently acknowledged by an MNO, which cited the absence of a clear business case to "effectively monetise" a 5G investment:

> *"**While the 5G mobile network will benefit frontier applications such as self-driving cars and virtual-reality content streaming services in the future, there are currently hardly any immediate ways for industry players to effectively monetise the service** … [Singtel Singapore Consumer CEO Mr Yuen Kuan Moon] also said he was not overly concerned with who will win the 5G*

[6] Page 37, paragraph 114 of the Consultation Paper

[7] Article on "StarHub banks on digitalization trend to drive external sales, cut internal costs" published in The Edge Singapore, 27 August 2018:
https://www.theedgesingapore.com/starhub-banks-digitalisation-trend-drive-external-sales-cut-internal-costs

licences as the winners have to sell network services wholesale to mobile operators who are not issued with the airwaves.

"In fact, there could potentially be only one network operation with everyone sharing it. [Singtel will] be happy to roll out, deploy that network and wholesale to all the rest of the people," *he added. (Emphasis added)"* [8]

30. As discussed in the preceding paragraphs, an MNO that takes on the role of a wholesaler while at the same time competes with its wholesale customers at the retail level will severely limit competition and service innovation at the retail level. Under IMDA's proposed CFP approach, 5G players in the retail market have to rely on their competitor for wholesale inputs – which unfortunately will limit their ability to innovate and grow their business, and to compete effectively on a level-playing field with other retail players. The problem will be exacerbated if there is only one 5G network in Singapore under the control of an MNO.

31. Crucially, unlike IMDA's proposed CFP approach, NetLink Trust's proposed regulatory approach assures equal and non-discriminatory access to wholesale inputs on the SWN's network and will support the development of a vibrant and competitive retail market for 5G applications and services, where traditional retailers of mobile services (including existing MNOs) operate alongside providers of 'vertical' applications that target specific market segments (e.g. industrial applications for autonomous vehicles).

Question 6: IMDA would like to seek views, comments and suggestions on:

i) The proposed network rollout and performance obligations to be imposed on the spectrum right holders;

ii) The methodology and measurement criteria for the coverage obligation;

iii) The network design and resilience challenges of 5G (in particular, enabling technologies, such as SDN, NFV and Cloud Computing that may fundamentally change how the network would be designed and deployed) and possible measures to address them, and whether there are other aspects that should be considered to enable trusted and resilient 5G network; and

iv) The framework for the provision of 5G wholesale services.

32. NetLink Trust's comments in response to Question 5(i) also apply to Question 6(iv).

[8] Article on "Singtel says it has 'right ingredients' to win a 5G licence in Singapore" published in The Straits Times, 4 June 2019
https://www.straitstimes.com/tech/singtel-says-it-has-right-ingredients-to-win-a-5g-license-in-singapore

Question 8: IMDA would like to seek views and comments on the trade-offs (particularly on resilience, 5G capabilities) and technical feasibility of the various levels of infrastructure sharing.

33. In its Consultation Paper, IMDA indicated that while it would like to encourage infrastructure sharing amongst MNOs to overcome the spectrum constraints in the initial years, this would have to be weighed against the potential impact that infrastructure sharing might have on network resilience with reduced network diversity, service differentiation and technology innovation due to technical complexities, and more broadly on competitiveness of the telecommunication markets.

34. NetLink Trust notes IMDA's concern regarding the said limitation of its proposed CFP approach, and would invite IMDA to consider NetLink Trust's proposed regulatory approach – whereby an SWN for 5G would be established to operate as a neutral and independent wholesale-only network provider.

35. An SWN for 5G will operate exclusively at the wholesale level and will be subject to a regulatory requirement to offer equal and non-discriminatory access to wholesale inputs on its network to all qualified persons, including existing MNOs. Unlike infrastructure sharing, NetLink Trust's proposed regulatory approach is designed to facilitate the development of a vibrant and competitive retail market for 5G applications and services, and to continually promote and sustain competition at the retail level. Please also refer to NetLink Trust's comments in response to Question 5(i).

36. Where the SWN leverages on the existing NGNBN infrastructure, resiliency features can be incorporated into the design of the SWN through relying on the various redundancy options that are currently supported on NetLink Trust's nationwide fibre network i.e. wireline diversity, duct diversity and path diversity. For IMDA's information, NetLink Trust is in the midst of evaluating the feasibility of introducing additional enhanced service offerings to complement the existing suite of fibre connectivity and redundancy services. Details of these enhancements will be shared with IMDA in due course.

Question 10: IMDA would like to seek views and comments on the following:

i) The interest from industry players to leverage 5G spectrum or other mobile spectrum bands for fixed-wireless services that support mobile connectivity; and

ii) The policies (e.g., spectrum allocation, numbering) that should be considered to facilitate such use-cases.

37. IMDA noted in its Consultation Paper that *"… the availability of a nationwide fibre broadband network with residential wired broadband household penetration rate of more than 90%, capable of delivering 1 Gbps for as low as $34 per month, reduces the need*

for an alternative fixed-wireless last-mile access service in Singapore." [9] NetLink Trust agrees with IMDA's observation.

38. Fixed Wireless Access ("**FWA**") is commonly deployed in places with sparse or low population density, such as countryside (or other rural areas), where it is not commercially viable for operators to employ fixed-wireline solutions to provide broadband services to their customers due to the high cost associated with rolling out a wireline network to a remote location. FWA, which costs relatively lesser to roll out a broadband connection to an end-user, albeit wirelessly, is preferred under these circumstances where the business case for a fixed-wireline solution is challenging.

39. As a city state, Singapore is densely built-up with residential, commercial and industrial developments and buildings. There are no rural areas in Singapore. Importantly, NetLink Trust's fibre network coverage is pervasive and extends nationwide. NetLink Trust also operates subject to the Universal Service Obligation ("**USO**"), as imposed by IMDA, to provide fibre connectivity services to all existing and new physical addresses in Singapore. This universal fibre coverage for all residents and businesses, coupled with a highly developed and competitive retail fibre broadband market, eliminate any need for an alternative last-mile access in Singapore.

40. Allowing an alternative fixed-wireless last-mile access service will lead to a less efficient outcome for consumers and businesses, as 5G spectrum and other physical resources, such as rooftop space on public housing buildings and private developments, would have to be set aside to support the rollout of fixed-wireless services. Space on rooftops, within telecommunication risers and Main Distribution Frame ("**MDF**") rooms will have to be set aside and reserved for network equipment and associated telecommunication facilities for the deployment of fixed-wireless technology, putting an additional strain on public and private infrastructure and resources that are already limited in supply (especially with the impending rollout of 5G technology).

41. NetLink Trust therefore submits that IMDA should not allow the use of 5G spectrum, or other mobile spectrum bands, for fixed-wireless services. The successful rollout and implementation of the NGNBN, and the consequent development of a vibrant and competitive retail fibre broadband market, ensures that all end-users in Singapore can enjoy ultra-high-speed Internet access at fibre broadband prices that are highly competitive and affordable. Furthermore, through NetLink Trust's USO, end-users are assured that fibre network infrastructure will be rolled out to their premises in a timely manner and/or ahead of demand, thereby facilitating service take-up by them.

[9] Page 11, paragraph 25 of the Consultation Paper

SINGAPORE 5G POSITION PAPER

A report for NLT

April 2019

CONTENTS

EXECUTIVE SUMMARY

Context

Singapore consistently scores highly in indices of digital infrastructure and development, reflecting initiatives such as the Next Generation Nationwide Broadband Network (NGNBN), which has delivered world class fibre connectivity to residential customers, businesses, and public entities in Singapore.

Singapore performs well compared to many other countries in terms of the coverage and speeds of its 3G and 4G networks. Despite the strong performance to date, demand for mobile data has been moderate, likely reflecting in part, the strength of Singapore's fibre network. In order to maintain its competitiveness, Singapore also aims to be at the forefront of 5G developments, with the Smart Nation Strategy assuming roll out by 2020.[1]

The ITU has set out a series of objectives and use cases for 5G technologies. 5G is intended to offer higher speeds and extend the applications delivered by mobile networks. In particular, there is an increased emphasis on machine to machine communication (massive machine type communication (mMTC) and the Internet of Things) and applications that cannot be supported by existing networks (such as ultra-reliable low latency communications services (URLLC) for industrial uses). As such, 5G will require the use of higher frequency spectrum than previous technologies (such as millimetre wave spectrum) and will require a dense network of small cells to be deployed.

A number of necessary conditions for the launch of 5G services, including initial technology standards (set by the ITU) and the awarding of spectrum, are underway globally. Whilst IMDA has begun consulting on 5G in Singapore, it is currently unclear how 5G will be approached in Singapore.

NetLink Trust (NLT), the network operator responsible for providing the fibre infrastructure for NGNBN in Singapore, has asked Frontier to consider the factors which will be important in the delivery of a 5G network in Singapore, and to consider whether a Single Wholesale Network (SWN) model, akin to the NGNBN, could be an appropriate mechanism for delivering a high quality 5G network.

Assessment of the case for a 5G SWN

There is a great deal more uncertainty in relation to 5G than there was for the last upgrade, from 3G to 4G. Mobile network operators (MNOs) are likely to introduce some features of 5G technology to support existing business cases such as mobile broadband (and complement the existing 3G and 4G networks). However, delivery of the full capabilities of the technology could require a significant increase in investment, over and above the level that the MNOs currently incur, without clarity on the returns from this investment. Without intervention, a number of barriers exist

[1] Smart Nation 'Smart Nation: The Way Forward' https://www.smartnation.sg/docs/default-source/default-document-library/smart-nation-strategy_nov2018.pdf

which could prevent Singapore from becoming a leader in the delivery of high quality 5G networks.

In particular, the key barriers are that:

- There is uncertainty about demand for potential new use cases (e.g. mMTC and URLLC), and the extent to which MNOs will be in a position to benefit from new and expanding value chains in the provision of a wide range of services that may rely on 5G connectivity in the future;
- There is a shortage of contiguous spectrum in the 'extended C band' (a key spectrum band for delivering 5G) in Singapore, which could mean that MNOs lack the necessary spectrum to deliver 5G services fully and efficiently, or that not all MNOs will be able to acquire a licence for this spectrum; and
- There are practical barriers to the deployment of small cells. Sites may be a 'scarce resource' for both indoor and outdoor coverage and lampposts and street furniture may not be sufficiently robust to sustain equipment from multiple operators.

Due to these factors, absent government intervention, there may be significant delay in the roll out of 5G networks delivering the enhanced capabilities of the technology (rather than simply providing additional capacity for mobile broadband). In addition, the lack of sufficient spectrum for all operators to deliver the full capabilities of 5G and practical and financial barriers to the roll out of dense networks could lead to any 5G roll out being restricted to one or two of the existing MNOs, potentially leading to a reduction in competition compared to the current situation.

One potential solution we have been asked to consider is an SWN operator for 5G. The success of the NGNBN, which has delivered an extensive, high quality fibre network in Singapore, demonstrates the potential benefits of adopting an SWN model. Within a programme of government intervention, SWNs can potentially remedy issues which arise when applying the traditional model of network competition. The most important of these concerns is that competing operators may lack the incentives to invest to roll out quickly leading to the loss of some of the benefits related to a fast, full roll out of 5G technology. Government intervention, including an SWN could lead to improved outcomes whilst maintaining competition at the retail level:

- Under a 5G "NGNBN2", the Government could determine the optimal roll out of a 5G network to support the Smart Nation initiative;
- By removing some degree of duplication of network costs (the extent of which depends on the precise model used), an SWN could lead to significant cost savings which would in turn allow faster roll out and lower end user prices;
- If spectrum were allocated to an SWN then this could bring significant efficiency benefits, as capacity could be allocated between operators dynamically, according to their precise needs at any given point in time; and
- Limiting deployment to one operator can alleviate some of the practical barriers associated with the deployment of multiple networks (e.g. limited availability of suitable sites) and reduce disruption caused by network roll out. Co-ordinating with the existing NGNBN infrastructure could also reduce costs, and this would be beneficial for both fixed and mobile users.

At the same time, there is a risk that relying on a de facto monopoly such as an SWN network might result in worse outcomes than the current competitive mobile market due to a lack of competitive pressure. In light of this, a tender process to determine the SWN operator followed by regulation of network companies operating the SWN may be required. Further, the potential benefits of an SWN could be maximised by establishing an NGNBN2 with the following characteristics:

- Coverage and quality of service obligations to ensure ubiquitous roll out of a high quality network delivered in a timely way.
- Separation of the control of the shared network from the downstream retail market - in order to remove the incentive of the network operator to attempt to distort competition in downstream markets.
- Requiring non-discriminatory access and monitoring the market and the prices charged by the operator. A regulator can intervene on prices if and when it is clear that the SWN has significant market power and the ability to increase prices above a competitive level.

It is also important to note that there is already effective competition between mobile networks delivering 3G and 4G services in Singapore and that, for the foreseeable future 5G technology is likely to be a complement to 4G technology rather than a substitute. As such, an effective SWN model in Singapore is likely to complement the existing mobile networks rather than directly replace or compete with them. Areas where an SWN could differentiate itself from the existing MNOs could include:

- **Use cases,** focusing on 5G capabilities that are not well served by existing 4G networks, such as URLLC;
- **Spectrum**, e.g. it would use higher frequencies than those currently used by the MNOs;
- **Infrastructure**, e.g. it would use small cells at street level rather than macro-cells on rooftops and towers; and
- **Wholesale services**, it would focus on a range of wholesale customers, including 'vertical' users as well as traditional mobile retailers.

Such a wholesale 5G network could either offer passive infrastructure only (a passive SWN), or both passive and active infrastructure (an active SWN).

Potential passive SWN infrastructure models include:

- Offering sites and backhaul; or
- Offering sites, backhaul and shared antennae.

Potential active SWN models include:

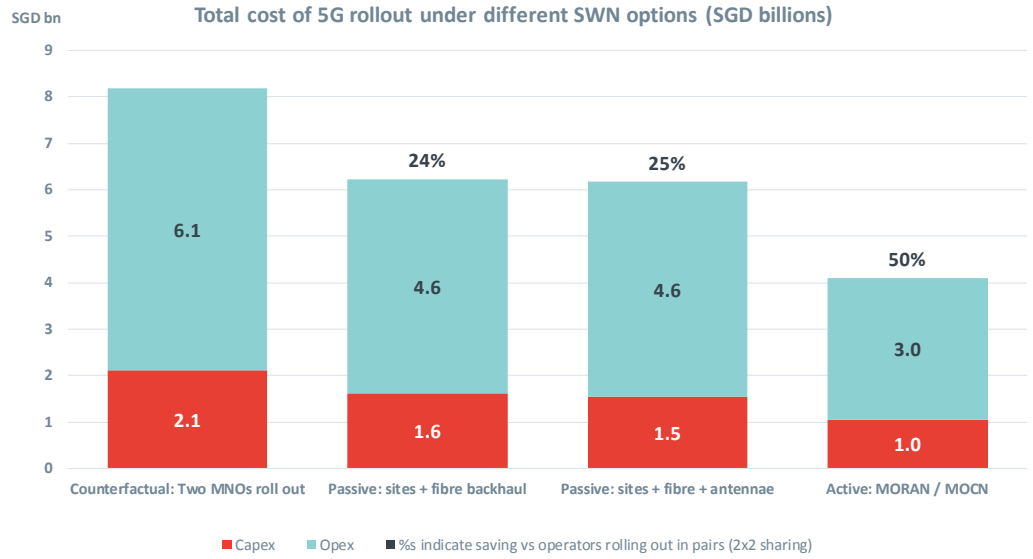
- Multi-operator radio access network (MORAN) where shared sites, backhaul antennae and other RAN equipment are provided but MNOs use their own licenced spectrum; or
- Multi-operator core network (MOCN) where in addition to the shared RAN equipment under the MORAN, the SWN is allocated spectrum.

There are advantages and disadvantages for each of the above models. The larger the proportion of the value chain that is shared, the greater are the cost savings. However, a greater degree of sharing limits the extent of differentiation possible

between downstream providers and removes some competitive pressure. This may, in turn, mean that more regulation would be required.

We have undertaken a high-level modelling exercise to assess the likely degree of total avoided cost under each of the model options presented above compared to a counterfactual where the existing MNOs rolled out a similar network. Compared to a counterfactual where the MNOs rolled out two 5G networks (e.g. where the 4 MNOs grouped into two network sharing joint ventures for the purpose of 5G roll out), the avoided costs are significant as shown in the figure below. Compared to an alternative counterfactual where MNOs rolled out independently, the avoided costs from an SWN would be even greater.

Figure 1 Relative avoided cost under different SWN models (undiscounted)



Source: Frontier based on 5G NORMA inputs

Conclusion

There is a clear policy goal to accelerate the roll out of 5G networks in Singapore to deliver the 'Smart Nation'. While initial 5G technologies are becoming available, there is still significant uncertainty over the business case for the investments required to deliver the advanced capabilities that 5G can offer. In the absence of government intervention there is a risk that deployment of 5G technology will be slow and piecemeal, meaning that the full benefits will not be delivered to potential customers. In addition, even if there were roll out of 5G, a combination of spectrum, operational and financial constraints could reduce the level of competition compared to that for 4G.

A neutral single wholesale network for 5G would reduce the costs of 5G deployment and potentially lower other barriers – in particular, access to spectrum and suitable locations for deployment of sites. As such, intervention to stimulate the creation of a 5G SWN could improve outcomes for 5G deployment in Singapore, both in terms of availability and cost. Whilst the lack of clarity about

demand and the business model for all potential use cases persists, allowing a neutral operator to deploy the network may mitigate some of the risks of investing in this new technology.

There are a range of models available which offer the potential for significantly reduced investment which could feed through into improved outcomes, in terms of roll out and efficiency, if effectively implemented. In turn, this would translate to greater uptake of 5G enabled applications and the consequent benefits to the wider Singapore society.

A 5G-specific SWN operating alongside the current vertically integrated MNOs could potentially enhance downstream competition by providing services to a range of wholesale customers - both retailers of traditional mobile services (including the existing MNOs) and also new customers offering vertical applications, for which 5G connectivity may be a small (but essential) part of their offers.

While there are a number of implementational challenges, it is worthwhile for these models to be investigated further and considered by the IMDA and other stakeholders.

1 INTRODUCTION

NetLink Trust (NLT), the network operator responsible for providing the fibre infrastructure for the Next Generation National Broadband Network (NGNBN) in Singapore, has asked Frontier Economics Ltd (Frontier) to consider the factors which will be important in the delivery of a 5G network in Singapore, and to consider whether an SWN model, akin to the NGNBN in the fixed broadband market, could be an appropriate mechanism for delivering a high quality 5G network.

In this report, we review:

- The current characteristics of the Singapore mobile market;
- The key characteristics of 5G technology, and potential challenges for deployment;
- The potential reasons for intervention for 5G deployment in Singapore; and
- The potential models of intervention.

Finally, we set out preliminary conclusions.

Below we set out the context for this analysis, in terms of IMDA's goals and the current performance of the mobile market in Singapore.

1.1 IMDA goals

Singapore consistently scores highly in indices of digital infrastructure and development, reflecting initiatives such as the NGNBN, which has delivered world class fibre connectivity to residential customers, businesses, and public entities in Singapore.

In order to maintain its competitiveness, Singapore also aims to be at the forefront of 5G developments.

In its consultation on 5G, IMDA has recognised the potential wide-reaching benefits that could arise from 5G:

"*The rapid growth in mobile data traffic and consumer demand for enhanced mobile broadband experience have led to an increasing emphasis on the upcoming fifth generation of mobile technology ("5G"). Seen as a comprehensive wireless-access solution with the capacity to address the demands and requirements of mobile communication beyond 2020, it is projected that this technology will operate in a highly heterogeneous environment and provide ubiquitous connectivity for a wide range of devices, new applications and use cases.*"[2]

Meeting the requirements of 5G, set out by the ITU (and described in more detail in the following sections), will involve making significant improvements across mobile networks, from air interfaces to the core network. One key differentiator will be the use of higher frequency spectrum to provide sufficient capacity, which will necessitate a greater number of cell sites in order to provide seamless coverage.

[2] https://www.imda.gov.sg/-/media/imda/files/inner/pcdg/consultations/consultation-paper/public-consultation-on-5g-mobile-services-and-networks/5g-public-consultation.pdf?la=en

Singapore may be ideally placed to be at the forefront of 5G deployments in the same way as it was at the forefront of full fibre fixed broadband networks with the NGNBN, as:

- The small size and very high population density of Singapore makes it less costly to roll out networks of small cells with high frequency spectrum to deliver seamless coverage across the country; and
- There is high demand for innovative technology in Singapore, with the Government also a potential purchaser of 5G delivered applications.

The dense fibre network (NGNBN) throughout Singapore could also play an important role in facilitating the roll out of 5G, as access to fibre backhaul will be an important component in the delivery of 5G.

1.2 Singapore's mobile market

1.2.1 Performance

Singapore has three established MNOs (Singtel, StarHub and M1), all with their own 3G and 4G networks, providing services to residential and business customers. A fourth entrant (TPG Telecom) was also licensed at the end of 2016.

Singapore performs well compared to many other countries in terms of the coverage and speeds of its 4G networks. Mobile broadband speeds in Singapore are also high, reflecting the high coverage and penetration of 4G, which means that most customers are using 4G, with only a small proportion using 3G (the decommissioning of 2G networks in 2017 means that all subscribers are relying on either 3G or 4G technology). Penetration is very high – significantly above 100% – as shown in the table below.

Figure 2 Singapore Mobile Subscriptions

Measure	Jan-19
Mobile Population Penetration Rate	149.6%
Proportion of subscriptions on 4G	79%
Proportion of subscriptions Post-paid	64%

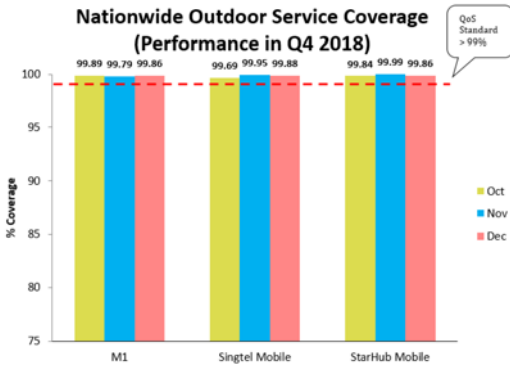
Source: *https://www.imda.gov.sg/industry-development/facts-and-figures/telecommunications/statistics-on-telecom-services/statistic-on-telecom-service-for-2019-jan*

Likely due to the IMDA's Quality of Service requirements, which set targets for nationwide mobile coverage including in-building coverage, both indoor and outdoor coverage in Singapore is strong. The IMDA has provided supporting regulation to enable the MNOs to meet these targets – the Code of Practice for Info-communication Facilities in Building (COPIF) ensures that developers and owners of buildings provide adequate space and facilities within buildings and on rooftops for MNOs to house equipment for the provision of indoor and outdoor coverage free of charge.[3]

[3] https://www.imda.gov.sg/regulations-licensing-and-consultations/frameworks-and-policies/interconnection-and-access/imdas-requirements-to-be-included-in-land-use-proposal-submissions-to-ura/code-of-practice-for-info-communication-facilities-in-buildings

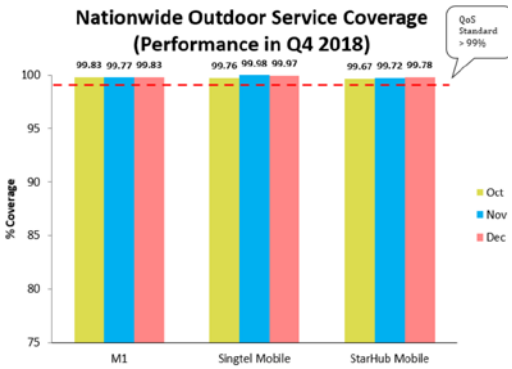
The three current MNOs are all performing above the targeted level of 99% outdoor coverage for both 3G and 4G as shown in the figures below.

Figure 3. 3G Outdoor coverage



Source: IMDA 3G Quality of Service Performance Results for Oct-Dec 2018

Figure 4. 4G Outdoor coverage



Source: IMDA 4G Quality of Service Performance Results for Oct-Dec 2018

In-building coverage is required to be above 85%. In the IMDA's most recent assessment (Q4 2018), two of the three current MNOs had above 85% coverage in all of the 60 buildings selected for performance testing, with one MNO (Starhub) having above 85% coverage in 58 of the 60 buildings tested. All MNOs also met the requirement to achieve minimum service coverage of 95% for existing and 99% for new road and MRT tunnels respectively.

The independent company OpenSignal found that:

- Singapore was ranked 1st out of 88 countries assessed for 4G speeds in February 2018 with an average download speed of 44.21Mbps.[4]
- Singapore was ranked 4th in terms of overall speeds (3G and 4G) in February 2017 with an average download speed of 30.05Mbps.[5]

In contrast to many other countries, Singapore performs well in terms of both mobile and fixed broadband speeds, with very high Wifi speeds compared to other countries due to the high quality of the fibre network (as shown in the figure below).

[4] https://opensignal.com/reports/2018/02/state-of-lte

[5] https://opensignal.com/reports/2017/02/global-state-of-the-mobile-network

Figure 5 Mobile and Wifi Speeds

Source: *https://opensignal.com/reports-data/global/data-2018-11/state_of_wifi_vs_mobile_OpenSignal_201811.pdf*

1.2.2 Demand side characteristics

Despite the strong performance of Singapore's mobile networks to date, demand for data has been moderate. Data usage has been growing – it grew nearly 23% from 2.2GB per subscriber per month in Q2 2018 to 2.7GB in Q3 2018.[6] However, compared to the OECD, average usage is relatively low – in Q4 2017 average data usage was 1.9GB per subscriber per month, 1GB lower than the OECD average of 2.94GB.[7]

Moderate demand may be in part due to the strong performance of the fixed network in Singapore. There is a high prevalence of free Wifi in Singapore (over 10,000 hotspots). Based on OpenSignal data, in February 2017, 50% of the time mobile devices in Singapore were connected to Wifi rather than cellular data networks (Singapore is a median country in this respect).[8]

1.2.3 Supply side characteristics

The three established MNOs – Singtel, StarHub and M1 – all have strong 3G and 4G mobile networks, with all three performing well in terms of speeds and coverage compared to other networks internationally.[9]

The fourth entrant, TPG Telecom, was awarded a spectrum licence in December 2016. Although it has not yet begun full commercial operations, it has embarked on a 'soft launch' of trial services in 2019.[10]

6 IMDA

7 December 2017, OECD, Broadband Portal, www.oecd.org/sti/broadband/oecdbroadbandportal.htm

8 https://opensignal.com/reports/2017/02/global-state-of-the-mobile-network

9 https://opensignal.com/reports/2018/05/singapore/state-of-the-mobile-network

10 https://www.straitstimes.com/singapore/tpg-telecom-to-offer-free-mobile-service-in-year-long-trial

To date, there has been limited network sharing between the MNOs, with MNOs only sharing antenna or fibre cables. However, discussions of more extensive sharing have taken place throughout 2018, with M1 and Starhub reportedly considering shared RAN and backhaul.[11]

[11] https://www.telegeography.com/products/commsupdate/articles/2018/10/16/starhub-considers-network-sharing-in-bid-to-cut-costs/

2 WHAT IS 5G?

The nature of mobile networks means that, for users to take full advantage of mobility, a common set of standards needs to be supported across a wide geographic scope, to allow usage of services over a wide area.

Technologies have been developed in 'generations' to ensure a common baseline for interoperability between network and device equipment. While both network equipment and terminals will evolve within generations to allow for increased functionality, all terminals and equipment within a generation should be interoperable (for example, current GSM networks will in theory support handsets from the 1990s). The use of multi-mode handsets since the introduction of 3G, with devices being able to fall back to previous generations, has meant that coverage in new generations can be built up slowly or be geographically limited. Whilst Singapore has performed well in terms of the provision of mobile services up to and including the fourth generation of mobile technology (4G), the next generation of technology, 5G, may present new challenges.

In this section we consider:

- The technology and different use cases for 5G;
- The spectrum required for 5G;
- The need for a dense layer of small cells;
- How 5G differs from 4G and the extent to which there may be overlap; and
- The challenges for 5G roll out globally.

2.1 The technology and different use cases

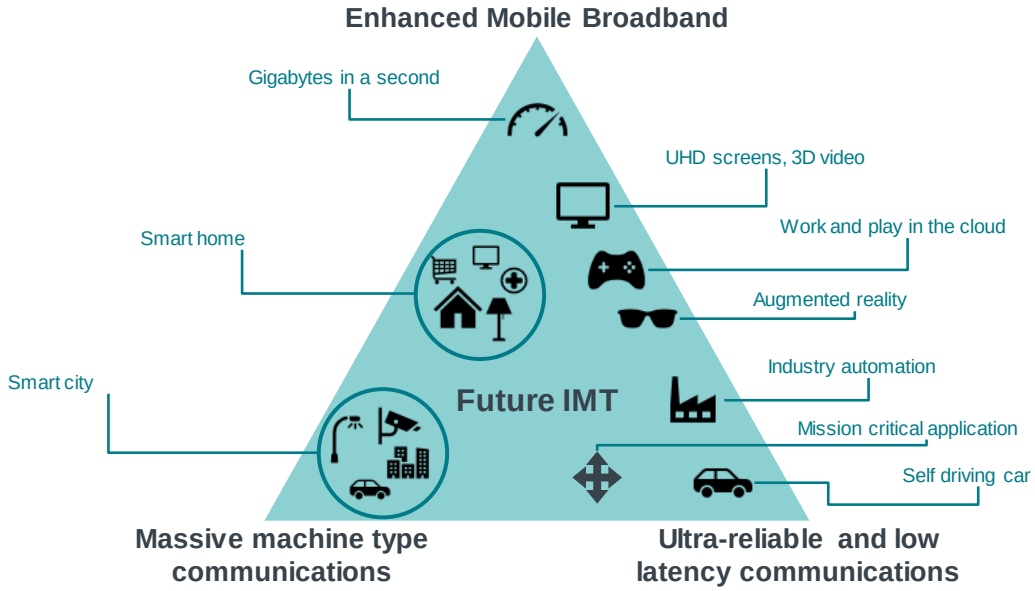
As described above, mobile network technologies are introduced in a series of generations at intervals of around a decade, with 4G technology being introduced around 2010. The ITU has set out a series of objectives and use cases for 5G technologies (IMT-2020).

The use cases are split into three main groups:

1. Enhanced mobile broadband (eMBB);
2. Massive machine type communications (mMTC) (Internet of Things, or IoT); and
3. Ultra-reliable low latency communications services (URLLC) for industrial uses and VR/AR.

The figure below illustrates some of the wide range of use cases that sit under these groups.

Figure 6 Proposed 5G use cases



Source: Frontier based on ITU

Increasing the use cases that can be supported by mobile networks should in theory bring economic and commercial benefits due to economies of scope (with a single network serving a number of uses) and scale (as moving to a single technology standard globally means an increased volume of equipment will be needed, reducing unit costs). As such the aim of 5G technology is not only to improve existing service offerings in terms of quality and cost, but also to allow additional use cases to be served using mobile networks.

A relevant parallel is the transition from 2G to 3G technology which allowed a mobile broadband (MBB) use case to be added to the mobile voice and messaging use cases supported by 2G networks.[12]

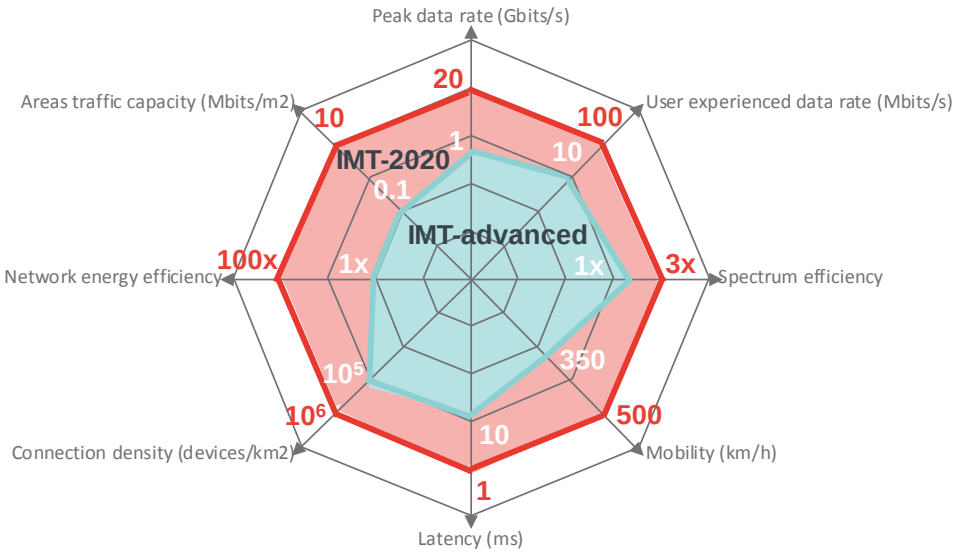
One significant difference compared to the transition from 2G to 3G is that while MBB has been largely sold to the same customers who purchase voice services (with voice and data services generally sold in a single bundle), some of the use cases supported by 5G services are likely to be purchased by different customer groups. For example mMTC may be largely purchased by industrial users rather than individuals and provided to end users either as part of a broader service (for example public transport) or embedded in devices (for example within cars for tracking purposes). While this provides potential opportunities, in that mobile services will not be subject to the budget constraints of households, it may require different business models as the mobile service component may be a small part of the overall good or service purchased by the end user.

In order to meet all of these use cases with a single technology, improvements are required in a number of dimensions of network performance. This is illustrated in

[12] Although in the same way that some of these 5G use cases can be partially supported by developments of 4G technology (such as IoT), MBB was also partially supported by 2.5G networks.

the figure below, which shows the manifold areas in which 5G (IMT-2020) should outperform 4G (IMT-advanced).

Figure 7 5G performance improvements compared to 4G



Source: Frontier based on ITU

5G standardisation and timing

Unlike previous generations where there were competing standards, for 5G there is a single candidate technology which 3GPP is developing. The resulting standards will cover both the air interface and core network developments, which will build on the networks developed for previous generations. Key elements of the 5G standards will be:

- **5G New Radio (NR)** for the air interface, which should provide benefits in terms of spectral efficiency, data rate and latency compared to 4G;
- **Network function virtualisation (NFV)**, which will allow network functionality to be delivered using commodity hardware rather than specialised equipment; and
- **Network slicing**, which will enable separate logical networks over a single physical network, allowing use cases with differing qualities of service to be deployed.

The key releases are:

- **Release 15**, which includes 5G phase 1, focused on the eMBB use case and was 'frozen' in June 2018[13] meaning that network and terminal equipment manufacturers can begin to produce products which are standards-compliant;
- **Release 16**, which will include 5G phase 2 aiming to meet all of the IMT-2020 requirements and which will be 'frozen' in 2020.

[13] http://www.3gpp.org/news-events/3gpp-news/1965-rel-15_news

In parallel with the development of 5G standards, 3GPP will also further develop 4G standards, which will overlap to a significant degree with the functionality provided by 5G. In particular, 4G developments share techniques such as massive MIMO or small cells which could increase spectral efficiency and hence capacity. Given these developments, the fact that existing 4G networks deliver a quality of service which is sufficient for many existing use cases, and the fact that there are considerable sunk costs both in 4G network equipment and 4G terminal equipment, mean it is likely that 4G networks and 5G networks will co-exist for a period of time.

The first partial standards, frozen in December 2017, defined the air interface (5G NR), but not the core network, and only allowed for the 5G air interface to be deployed alongside an existing 4G network ('non standalone' – NSA) to provide additional capacity. Release 15 includes the full specification for core network and allows for standalone 5G operation.

On a forward-looking basis, new equipment (antenna and RAN equipment) should allow both 5G and 4G technologies to be used simultaneously and in the same band. Once the specification is frozen, equipment manufacturers can start to develop and produce standards-compliant network equipment and terminal equipment. There will be a lead time (approximately 18 months) associated between the standard being frozen and network equipment (or software upgrades in some cases) being available on the market.

Mass market smartphone availability may lag behind network deployments due to the need to miniaturise components for a smartphone form factor and ensure power consumption is consistent with a reasonable battery life. Some analysts are forecasting that 4G phones will form the majority of handsets in use for at least the next 5 years.

2.2 The spectrum required

2.2.1 Global 5G Spectrum

The ITU is responsible for managing the globally harmonised radio-frequency spectrum and standards for 5G which will be a key enabler in the development and implementation of 5G.

For IMT-2020, the ITU is considering a range of high frequency bands (in the range of 24-86GHz) for determination as part of WRC-19 which takes place in October-November 2019.[14]

From a global perspective, there is a range of potential spectrum available for 5G use. Spectrum is required across different frequency bands for different purposes:

- **Basic coverage layer spectrum** - below 3GHz band: spectrum in the 700/800/900MHz band may be available through re-farming of old GSM frequencies;

[14] http://www.itu-apt.org/5g/docs/motorola.pdf

- **Capacity layer spectrum** - in the 1GHz – 6GHz band: the "C-Band" is the initial focus (3.5GHz, which has been identified as the pioneer band for 5G in Europe) but others may also be considered;
- **Hotspot/Capacity layer spectrum** - Above 6GHz**:** the millimetre wave band, in which there is some global fragmentation as 26GHz is more available in Europe and China, whilst in America, South Korea and Japan 28GHz is more available.

Large spectrum blocks will need to be allocated to each network in order to allow for the required data throughput needed for 5G. Millimetre wave (mmWave) spectrum is considered central to the future of 5G, due to the large bandwidth available, but poses challenges due to the propagation characteristics exhibited at high frequencies.

Globally, mobile operators are getting ready for 5G, despite the uncertainty about spectrum bands. For example, in Europe the main operators published a 5G manifesto in 2016 which announced the target of launching 5G in at least one city in each of the member states by 2020. In the US, operators have been testing mmWave technologies. In South Korea, Japan and the Middle East, specific operators have announced that they will launch commercial services in 2019/2020, whilst China Mobile plans to deploy 10,000 base stations by 2020.[15]

In many countries 5G spectrum auctions are planned (e.g. Romania, Germany, Belgium) or have taken place (UK, Italy, Finland, US).[16]

In the figure below we considered three case studies: Hong Kong, the UK and the US.

[15] https://www.itu.int/dms_pub/itu-r/oth/0a/0E/R0A0E0000D40001PDFE.pdf

[16] https://www.telecompaper.com/news/last-week-in-telecoms-feeling-the-impact-of-5g-auctions-and-new-entrants--1273506

Figure 8 Case studies on 5G progress

Country	Progress
	The HK Government announced plans to award spectrum for 5G services by 2020. This was criticised by HKT, which argued for earlier release as well as coordination of the release of spectrum in different frequency bands (in addition to other laws affecting network rollout and 5G planning). In July 2018, regulator OFCA began a consultation on the allocation of 4,100MHz of frequencies in the 26GHz and 28GHz bands. In July 2018 Hong Kong's communication authority proposed to allocate free spectrum to mobile operators depending on the level of interest expressed by industry players, based on a level of demand that was indicated by initial discussions. • Hutchison 3 is the only operator to have completed outdoor 5G trials. • Other operators have conducted some initial tests but have not announced firm plans for launches.
	Ofcom held its first 5G spectrum auction in April 2018, auctioning spectrum in the 2.3GHz and 3.4GHz bands, and plans to auction further spectrum in 2020. All operators obtained spectrum in the first auction. The UK Government announced a 5G strategy in 2017 and continues to assess progress against the plan, and also consider potential policy interventions to aid this. Ofcom published a 5G discussion document in 2018 outlining steps it will take to support 5G. • In November 2018, EE announced plans to switch on 5G sites in 16 cities in 2019. • In June 2018, Vodafone UK stated that 5G trials would be conducted in 7 of the largest cities, with those trials expected to begin in October and December of 2018. • Three UK and O2 UK have undertaken trials of 5G technology, but neither had outlined any firm launch plans as at November 2018.
	The FCC opened bidding for 28GHz band spectrum in November 2018. 24GHz band spectrum will be auctioned once the 28GHz auction has been completed, with spectrum in the 37GHz, 39GHz, and 47GHz bands expected to be auctioned in late 2019. The FCC also has a strategy called 'FAST' in place, which aims to support the US as a leader in 5G technology through spectrum policy, infrastructure policy, and modernisation of regulations. • AT&T has commercial plans for 5G to begin in late 2018 (initially in 6 cities). • Verizon plans to commercialise 5G mobile technology from 2019, but its residential FWA 5G service already launched (in limited areas) in October 2018. • T-Mobile is aiming for a 2019 launch in 30 cities, with expectations of nationwide coverage by 2020. • Sprint has announced launch plans for early 2019 in 6 US cities.

Source: *Telegeography;*
China Morning Post (https://www.scmp.com/news/hong-kong/hong-kong-economy/article/2157078/hong-kong-aims-cheaper-faster-5g-roll out-proposal);
US Federal Communications Commission (https://www.fcc.gov/5G)

2.2.2 Singapore 5G Spectrum

The IMDA is currently consulting on spectrum to be designated for 5G in Singapore but is behind many other countries in terms of plans for licensing of new bands:

- **Sub 1GHz:** 700Mhz and 900MHz spectrum was recently auctioned. Whilst there are no immediate plans to release any additional low frequency spectrum, it is possible that 800MHz may be made available for use for 5G in the future.
- **1Ghz- 6GHz:** IMDA is exploring the possibility of allocating two bands in the mid-range for 5G IMT services:

  - The 1427 – 1518 MHz band ("L-band"): this band has been made available for trial by IMDA.
  - The 3400 – 3600 MHz band ("Extended C-band"): although the extended C-band spectrum is generally under-utilised in Singapore, there is still a lack of contiguous spectrum to support the deployment of new services. Coexistence may not be possible given the geography of Singapore. Therefore in the event that IMDA makes available the extended C-band for IMT services, they will have to fully or partially migrate satellite users from the bands re-assigned for mobile use.
- **mmWave:** There are currently no incumbent users in any of the mmWave frequency bands that have been identified for 5G. Bands in the mmWave category have been made available for trial by IMDA.

To facilitate 5G technology and service trials by the industry in Singapore, IMDA has waived frequency fees for a range of spectrum bands for interested companies until 31 December 2019. Industry players have been conducting field trials (Huawei with M1, StarHub with Nokia, and Singtel with Ericsson) to validate the use of different mobile radio access technology.

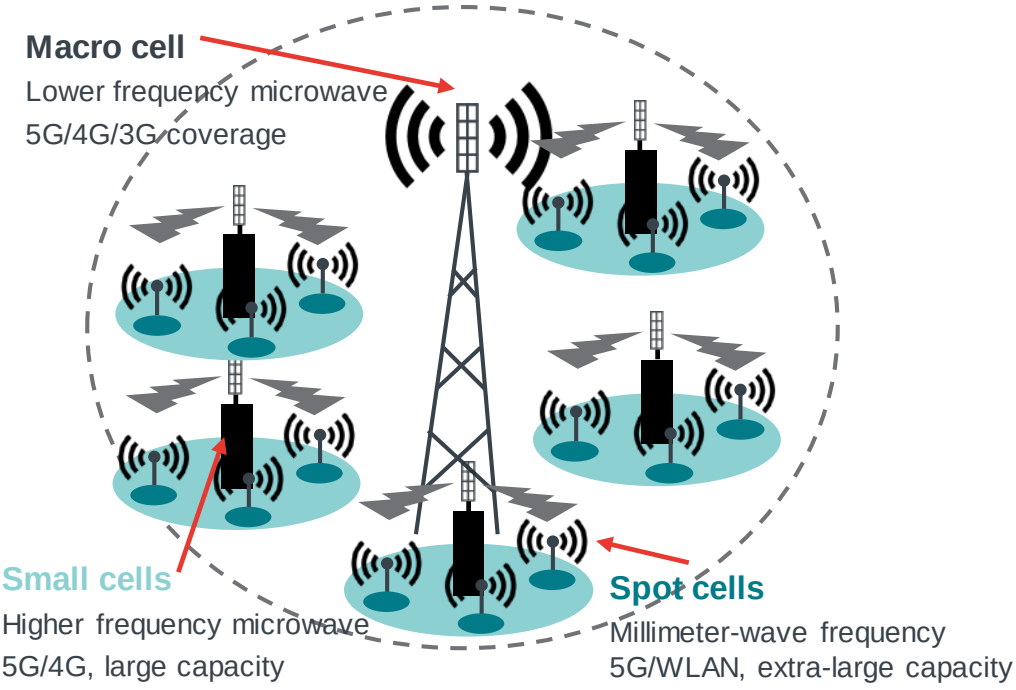
2.3 The need for a dense layer of small cells

Infrastructure for 5G

Given the wide range of spectrum that will be deployed, including much higher frequencies than those used in previous generations, 5G is likely to be delivered through a combination of different cells as shown in the figure below:

- Macro cells – which will deliver 5G coverage alongside previous technologies relying on low frequency spectrum (mainly sub-3GHz);
- Small cells – which will sit within the cell radii of Macro cells and provide additional capacity through higher frequency spectrum (3-6GHz spectrum); and
- Spot/Pico cells – which will provide extra large capacity in high traffic areas based on mmWave spectrum.

Figure 9 5G network cell types



Source: Frontier based on ITU

The smaller cells relying on higher frequency spectrum will have much lower cell coverage ranges due to the weaker propagation characteristics of these frequencies. Although small cells have been used to some degree with 4G, particularly for indoor coverage, they will be required on a much larger scale for 5G to deliver the full IMT-2020 capabilities such as very high bandwidths or low latency communication.

2.4 Is 5G a substitute or complement to 4G?

As noted above, internationally, 5G developments are rapidly progressing – many jurisdictions have issued licences for 5G 'pioneer' bands and the initial standards for the new air interface 5G NR have been finalised. However, most operators' current plans for 5G are to use it to complement existing 4G (and 3G) network equipment to serve existing MBB customers.

This focus reflects two issues:

- The uncertainty of demand from mMTC and URLLC use cases; and
- The high cost of rolling out dense networks of small cells.

As such, it may be some years before the full 5G requirements are met on a widespread basis in many countries.

Whilst 5G may deliver higher speeds and lower latency than 4G, for many use cases such as IoT, 4G will be sufficient. As such, we can expect that there will be significant overlap in what 4G and 5G can effectively deliver, at least in the short term. This means it is unlikely that 5G will be seen as a full replacement for 4G and

instead the technologies may be seen as complementary; this is reflected in MNOs' current plans for 5G.

Going forwards, new antennae and RAN equipment should allow both 4G and 5G to be delivered simultaneously. As such MNOs may not need to make a decision about whether to prioritise 5G roll out over 4G upgrades/replacement, as both can be achieved with the same equipment.

Similarly, smartphones developed to be compatible with 5G are expected to be multi-mode – capable of use with both 4G and 5G – therefore there is no strong push from the demand side to move away from 4G, until consideration of other use cases such as mMTC and URLLC comes into play.

2.5 The challenges for 5G roll out globally

Given the global trend of growing data usage over the past few years, and the forecasted continued growth, MNOs are likely to consider that 5G will be necessary to serve future eMBB demand.

Over time, traffic and what customers perceive as an acceptable level of user bandwidth will continue to increase. For example, the usage and quality of mobile video has increased continuously since it initially became available with 3G and following the launch of 4G. To some degree this continued growth in demand can be met through: the deployment of additional spectrum where not all spectrum is currently deployed; densification of the network; continued refarming of spectrum from 2G and 3G technologies to 4G and technology advances in 4G. However, in areas where 4G networks are currently heavily congested, these approaches are unlikely to provide sufficient capacity to fully remove congestion as demand grows.

MNOs may be able to deliver 5G to a certain standard by deploying new spectrum and equipment on existing cell sites. However in order to deliver 5G to its full potential, very large investments (considered in more detail in the following sections) would be required to:

- Enable the use of massive MIMO to increase the capacity (and coverage) associated with higher frequency spectrum; and
- Densify the network in high traffic areas by rolling out small cells.

Over and above the roll out to congested areas, an accelerated rate of 5G deployment will depend on demand for 5G-specific use cases:

- For evolutions of existing use cases, including eMBB, the extent of roll out will depend on whether there are expected to be sufficient benefits specific to 5G. The incremental benefits brought by 5G compared to 4G must be sufficient (or be perceived by customers to be sufficient) to justify roll out of 5G to complement or replace existing 4G investments in areas where congestion or coverage is not an issue; and
- Whether there is sufficient demand from new use cases such as IoT and URLLC which cannot be supported by existing networks to justify roll out of incremental 5G equipment.

eMBB

Currently MBB performance is more limited by congestion and capacity than any fundamental shortcoming of 4G technology, which can offer theoretical data rates far in excess of those generally used on smartphones. Later releases of 4G technology will increase the peak bandwidth available for 4G.

However, more ubiquitous 5G roll out may be necessary if there are use cases that require significantly higher user bandwidth or generate more traffic when users are outside of the home or office (where Wifi networks are likely to continue to provide most capacity). While developments such as ultra-high quality video (e.g. 4K video) could provide a requirement for greater bandwidth, the likely limited additional perceived utility of such services on a smartphone compared to HD video means this improvement may not drive incremental revenues and hence incentives for roll out.[17]

The existing MBB market in many countries is saturated, with high penetration. ARPUs have been flat in recent years, even as usage has increased dramatically, suggesting that consumer behaviour could be characterised more as consumers setting their budget for mobile (including the cost of a smartphone) and adjusting their consumption with the resulting data cap (using Wifi where available). Previous differences in performance, e.g. the early introduction of 4G or the introduction of carrier aggregation (which allows higher speeds for 4G services), do not appear to have allowed operators with an advantage to charge a significant premium or attract/retain a significantly greater proportion of customers. Unless there is a 'killer app' for eMBB it may be unlikely that operators will find it profitable to roll out a denser small cell network for 5G outside of congested areas, only to support eMBB with consistently much higher user bandwidths but without any significant growth in revenues.

However, while the business case for investing in an extensive small cell 5G network to support consumer eMBB services alone is currently unclear, such a network could offer the potential of new B2B applications which may deliver wider benefits.

Internet of Things

The Internet of Things (IoT) captures a wide range of use cases involving machine to machine connectivity, whereby devices communicate with each other. This includes many devices under the bracket of 'smart homes' – allowing efficient and remote control of household appliances, heating and electricity, and 'smart cities' with connected traffic signals and sensors.

While IoT can clearly lead to significant benefits for users in the long term, a degree of process re-engineering along with integration of connectivity into devices will be required to deliver these benefits.

[17] For example to be able to perceive any benefits from a move from HD to UHD, BT estimate that the viewer would need to view the screen from a distance less than 3 times the height of the screen (http://www.mediaandbroadcast.bt.com/wp-content/uploads/Research-paper-UHDTV-final-v1.01-.pdf) which for an iPhone X would require the viewer to be around 7 inches from the screen.

IoT use cases may require communication either within a defined area (e.g. smart home, smart cities) or near-ubiquitous access for fully mobile applications. The importance of good coverage, including indoor, for these types of applications means that IoT would benefit from the use of low frequency spectrum (e.g. sub-1GHz spectrum). The typically low bandwidth required means that absolute performance is less of an issue than it is for eMBB, meaning that IoT services can be delivered using low frequency bands and large cells.

There are a number of competing technologies for IoT wide area coverage, including Narrowband IoT (NB-IoT), which is based on 4G technology. 5G IoT services will not be standardised until 2020. This suggests NB-IoT will play a key role for a number of years.

The need to ensure low-cost device connectivity through economies of scale is likely to mean that mass adoption of 5G for IoT will be dependent on 5G being adopted as the global de facto standard in the same way that Wifi is currently the de facto standard for home automation (where neither range nor power consumption are significant constraints).

At this point it is unclear what incremental revenues will accrue to network operators providing wide-area connectivity for IoT services and to what degree operators will be able to use 5G technology to differentiate from other competing technologies.

Ultra-Reliable and Low Latency Communications

MBB services are delivered on a ‘best effort’ basis, with no guarantees of performance. URLLC services are those that require secure data communications with ultra-high reliability and very low latency requirements, such as those that require time-sensitive responses. Examples include industrial automation, unmanned and autonomous vehicles and remote control of sensitive equipment involving tactile feedback.

URLLC will also be standardised in 2020. URLLC will require a good level of underlying network coverage and performance which is likely to restrict its use initially to limited geographic areas where such a level of coverage can be guaranteed, for example industrial parks, campuses, etc. Again, the need to build an eco-system around these use cases may limit take-up initially.

If such localised use cases prove successful then this could be a signal for a wider roll out of the network infrastructure required to support these use cases.

3 THE REASONS FOR POTENTIAL INTERVENTION FOR 5G IN SINGAPORE

In its Smart Nation strategy, the Singapore Government has recognised the critical importance of digital technology in the next phase of the country's development. Digital technology could have a transformative impact on the way people live their lives as well as providing a boost to competitiveness and productivity. Delivering this vision will require, amongst other changes, improvements in digital infrastructure and service delivery, including telecommunications networks and services. The Smart Nation strategy identifies 5G roll out as a key element of these improvements.

Whilst Singapore has delivered high quality 3G and 4G mobile networks with competition from three network providers to date, 5G presents new challenges. There is a great deal more uncertainty in relation to 5G than the last upgrade from 3G to 4G on both the supply side and the demand side. In particular there is uncertainty about potential new use cases, and the extent to which MNOs will be in a position to benefit from new and expanding value chains in the provision of a wide range of services that may rely on 5G connectivity in the future. Without intervention a number of barriers exist which could prevent Singapore from becoming a leader in the delivery of high quality 5G networks, and Singapore could fall behind compared to other countries such as South Korea, Japan and the US, which are already pushing forward with plans for 5G.

Without intervention there is a risk of market failure, i.e. competition alone not leading to the optimal outcome for a number of reasons:

- The uncertainty over demand for advanced 5G services means that investors and hence operators may adopt a 'wait and see' approach to investments in the infrastructure and equipment required to deliver such capabilities (such as small cells);
- For many potential applications, 5G capabilities are only one element of the digital infrastructure required to deliver the full end to end service, creating a co-ordination problem across the value chain (a 'chicken and egg' problem); and
- Rapid development of 5G networks could provide wider benefits to Singapore, as part of the Smart Nation initiative, which would not be taken into account by operators when making investment decisions, i.e. there are significant positive 'externalities'.

Within the context of fixed networks, similar concerns relating to full fibre roll out were resolved with the creation of the NGNBN – which included an effective open access fibre network allowing access to downstream service providers to offer high speed broadband, for which NLT acts as the network company responsible for delivering the physical fibre optic platform. NLT has asked Frontier to consider whether a similar model (NGNBN2) could also deliver benefits in relation to roll out of 5G in the mobile market in Singapore.

There are some similarities between the situation in terms of fibre roll out and 5G, however there are also a number of key differences which influence how an SWN model for mobile, established as part of an NGNBN2, could work in Singapore.

In the cases of both fibre and 5G there was/is uncertainty about the level of demand and whether this would be sufficient to allow network operators to recover the high fixed costs of rolling out to all customers. Whilst there were some fixed costs for the delivery of other generations of mobile technology, the dense layer of small cells will present much higher costs than previous upgrades.

In the case of fibre technology, NGNBN was a substitute for the legacy DSL and cable networks, delivering superior broadband speeds over a new network – end customers had no need for a DSL or cable connection if the fibre connection was in place. In contrast, as we have described above, 5G, at least in the short to medium term, is not a pure substitute for previous generations of technology (3G, 4G) and many customers will use multiple generations concurrently. The different generations of mobile technology are expected to coexist, with hybrid configurations using many of the same components to deliver both 4G and 5G elements expected.

Whilst the creation of NGNBN involved writing off sunk costs in legacy copper networks, this does not apply for mobile, given the role that 4G will continue to play. As such, any proposed wholesale network would need to co-exist with 3G/4G networks allowing the market to continue to benefit from the current network competition.

Given the initial necessity for non-standalone 5G, creating technology exclusivity for a single wholesale 5G-only network would be difficult as neither the existing MNOs nor the SWN would be able to deliver 5G services. Where MNOs faced capacity constraints in the delivery of 4G, they would be limited in their ability to relieve this without using 5G. As such, a viable model would likely be one where the existing MNOs had the freedom to deploy 5G technology on their existing cell sites, typically using low frequency spectrum (re-farmed from previous generations or acquired through future auctions). Any wholesale access network would more naturally focus on the provision of a new small (and pico) cell network. This might provide only the passive network layer or both active and passive layers (with or without spectrum).

In this section we present the potential justifications for an SWN in Singapore, including the extent to which an SWN could deliver the full benefits of 5G to all customers. In particular, we consider:

- The potential barriers to achieving the full benefits of 5G quickly without intervention;
- The benefits of a single wholesale network operator in the provision of a 5G network;
- The benefits of a neutral, wholesale-only operator; and
- The benefits that can be achieved with intervention to ensure the ‘best’ model to deliver 5G.

3.1 Barriers to achieving full benefits quickly without intervention

In the previous section, we discussed some of the main barriers which are considered globally for the deployment of 5G. A key issue in many countries is the business case for the delivery of innovative use cases. In addition the dense urban environment in Singapore creates other challenges, particularly in relation to spectrum and the need to deliver a dense network of cells.

We discuss the key barriers to achieving the full benefits of 5G in Singapore without intervention in the remainder of this section.

3.1.1 Spectrum shortages

Whilst there is still some uncertainty about which spectrum bands will be identified by ITU for 5G, there is a good deal of consensus across the globe that a combination of spectrum across bands will be necessary and that both “mid band” and mmWave spectrum will be necessary. In Europe and many other places, the 3.5GHz spectrum band has been identified as the pioneer band for delivering 5G, as mmWave developments are likely to come later. In Singapore there are significant issues around interference to the incumbent satellite users in relation to 3.5GHz spectrum (the ‘extended C band’) which is likely to be a crucial component of spectrum allocations for the delivery of 5G mobile services.

As noted in the previous section, whilst the extended C-band spectrum is generally under-utilised, there is a lack of contiguous spectrum to support the deployment of new services. Since 5G requires minimum block sizes of approximately 50 to 100MHz per operator for mid-band spectrum, this could mean that MNOs lack the necessary spectrum to deliver 5G services fully and efficiently, or that fewer than four licences may be made available for spectrum in the 3.5GHz band, meaning some network operators run the risk of acquiring none of this spectrum.

Asymmetric allocations of 5G spectrum could lead to distorted outcomes in the delivery of 5G and in the wider market: if some operators have access to this spectrum whilst others do not, this may distort outcomes and may mean that some customers cannot benefit from 5G capabilities without switching operators. Alternatively if all operators have access to only a small share of this spectrum it may limit the capabilities of 5G networks in Singapore substantially. Whilst a limited number of licences for C-band spectrum is the most likely outcome, this could mean the level of competition in the market is reduced significantly when it comes to 5G. This reduction in competition could result in slower roll out and innovation across the market.

3.1.2 Uncertainty in relation to the business case for investments

As noted in the previous sections, given that mMTC and URLLC open up a new set of use cases that have not previously been possible given technology limitations, there is a great deal of uncertainty regarding demand.

For MNOs it may be unclear what role they will play in the delivery of new use cases beyond eMBB and, if they deploy networks for these use cases, how they can recover the associated investments effectively. Whilst MNOs currently have a relationship with mobile end users and have themselves been the vendors of handsets and other devices that require a dedicated mobile connection, their role and relationship with customers is less clear when considering other use cases, and therefore the future payoffs from investment into the network are highly uncertain. This may lead to reluctance to deliver full 5G networks until more is known about use cases.

In Singapore specifically, despite the strength of mobile network performance to date, mobile data usage has not grown as quickly as in many other countries. Indeed, the level of mobile penetration has been falling since its peak in 2014[18] and MNOs have been discussing cost cutting methodologies, suggesting concerns about profitability in the long run if savings are not made.[19] This may be due, in part, to the strength of fibre networks in Singapore, and the prevalence of Wifi hotspots, allowing users to "offload" traffic by using Wifi on mobile devices rather than using mobile data. With these current pressures in mind, MNOs in Singapore may be particularly cautious about investing heavily in 5G (beyond using it to supplement their existing 4G networks) before demand for other use cases, and the business case for greater investment, becomes more apparent.

The "wait and see" approach, however, could put Singapore behind and limit the speed at which innovative use cases are developed. Many potential use cases may only be developed – and can only be fully tested – when the network infrastructure is in place. As such there may be a virtuous cycle between investment into networks and investment into use cases, but uncertainty could act as a barrier for Singapore being at the forefront of 5G and benefitting fully from all its prospective uses.

Whilst Singapore is in many ways an ideal location for many IoT and URLLC use cases, such as many smart city functionalities, and there is demand for technological innovations in Singapore, uncertainty about the ability to capture this demand to recover network investment may lead to a slow and cautious approach to 5G in the absence of intervention.

3.1.3 Practical barriers

In addition to the fact that deploying a dense network of small cells requires significant investment, operators may also face a practical barrier in finding appropriate sites to deploy small cells. Tall buildings create a barrier for mobile signal, particularly for high frequency spectrum which may require line-of-sight or very close cells locations. Therefore street furniture that is close to street level is likely to be important for outdoor coverage in addition to the small cells required for indoor coverage.

However, given the limited outdoor public spaces in Singapore, finding suitable sites for all network operators to install their equipment may be a significant

[18] https://data.gov.sg/dataset/mobile-penetration-rate

[19] https://www.businesstimes.com.sg/companies-markets/starhub-ceo-seeks-to-share-network-to-cut-costs-further

challenge as in effect sites are a 'scarce resource' in the same way that spectrum is. Lampposts and street furniture may not be sufficiently robust to sustain equipment from multiple operators. Therefore even if multiple operators have the desire (and spectrum) to roll out dense networks, there may be significant limitations.

For in-building coverage, as noted previously, although the IMDA has regulations in place to allow MNOs access to a specific amount of space indoors for indoor mobile equipment, this will need to be upgraded for 5G and new equipment may need to be added which may create issues. Since MNOs are now expected to decide on the optimal location for Mobile Installation Space to be provided in-buildings, there is the potential for delays or drawn out negotiations if the different MNOs have opposing views regarding the appropriate arrangements for 5G.[20]

3.2 Benefits of single wholesale network operator in the provision of a 5G network

Through the NGNBN, wholesale network deployment has delivered an extensive, high quality fibre network, giving access to high speed fixed broadband across Singapore more quickly than if the Singapore Government had not intervened.

As we noted at the beginning of this section, one potential solution we have been asked to consider, in order to address some of these barriers to the timely and full roll out of a 5G network in Singapore, is a government intervention including an SWN operator for 5G, i.e. an NGNBN2. In a number of other jurisdictions the question of whether, as part of wider policy intervention, an SWN could be a viable option for increasing the rate at which 5G is deployed has been raised.[21]

Using an SWN to roll out the underlying network in an NGNBN2 could potentially remedy issues which arise when applying the existing model of network competition. The most important of these concerns is that competing operators may lack the incentives to maximise coverage quickly, resulting in inadequate, or slow deployment of certain capabilities of 5G networks due to the market failures set out above.

An expected advantage of SWNs is that they avoid the inefficient duplication of infrastructure, thereby reducing total costs, whilst allowing competition at the retail level of the market, with access available to any companies wishing to offer retail services.

At the same time, there is a risk that relying on a monopoly such as an SWN network could result in worse outcomes in terms of speed of roll out and innovation compared to competitive markets due to a lack of competitive pressure. In light of this, regulation of network companies operating SWNs is typically foreseen.

[20] https://www.imda.gov.sg/-/media/imda/files/regulation-licensing-and-consultations/consultations/completed-consultations/consultation-papers/12/copif-2018-industry-briefing-on-7dec2018-cleanpptx.pdf?la=en

[21] For example in the US: https://www.economist.com/leaders/2018/02/10/a-national-5g-wireless-network-is-not-such-a-stupid-idea and in the UK: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/732496/Future_Telecoms_Infrastructure_Review.pdf

As will be discussed in more detail in the next section, a viable model for a 5G SWN in Singapore is one that coexists with MNOs and 3G/4G networks but offers an open access network of small cells. Below we discuss some of the key potential benefits of an SWN of this type in removing some of the barriers to full and timely 5G deployment.

3.2.1 Cost reduction

Any government intervention to accelerate 5G roll out must demonstrate an ability to maximise end user benefits and minimise costs, which will feed through to more competitive prices for consumers and businesses. It should also achieve a faster roll out of networks and services with minimum disruptions to the public and road users.

In theory a single or shared network may alleviate issues relating to the high cost of 5G roll out in a number of ways. An SWN removes the additional costs of duplication of network infrastructure which occur when multiple operators roll out their own networks, leading to cost savings. This reduction in the level of costs, in particular upfront investment costs, could mean that investments in a higher level of coverage may be more profitable for an SWN than would be the case under network competition.

The precise level of avoided cost depends on the extent of the SWN. Factors to consider include:

- The number of operators rolling out in the counterfactual, if a single wholesale network is not implemented;
- The extent of the single wholesale network – i.e. whether it includes active as well as passive infrastructure;
- Whether the single wholesale network model allows preferential access to facilities (such as, key sites or access to the fibre backhaul network); and
- The degree to which the relevant network infrastructure is ‘greenfield’, i.e. new infrastructure rather than upgrades of existing infrastructure.

We have modelled the potential cost savings for roll out in Singapore under different SWN options (covered in detail later in the report) which vary in terms of the extent of sharing and assumptions relating to preferential access. We also compare to two different potential counterfactuals.

A single wholesale network only results in cost savings in terms of investment if it does not itself duplicate existing infrastructure. In the case of the existing 3G/4G networks in Singapore, it would be inefficient for a wholesale operator to replicate these networks, which would be necessary if the intervention limited the deployment of 5G technology to a single operator only. As we have discussed, this does not seem like a sensible approach for 5G, as the costs of removing existing competition and limiting the competitiveness of existing MNOs networks make this approach unattractive. However, there may be a degree of overlap between the capabilities of the existing networks and that of a potential SWN, for example if the SWN needed to provide complete geographic coverage throughout Singapore, which would require the deployment of some macro-cells, or the existing MNOs wished to deploy small cells to increase capacity in high traffic areas. However, to

a large degree this could be achieved efficiently through wholesale infrastructure access arrangements – for example the SWN buying access to existing macro-cells.

3.2.2 Spectral efficiency

As noted above, the extent of a single wholesale network will affect cost savings. If the single wholesale network operates the active equipment that broadcasts the spectrum, there are two options:

- The existing network operators have the spectrum rights and the single wholesale network broadcasts this spectrum on their behalf; or
- The single wholesale network itself controls the spectrum and offers the network operators capacity on this network.

Whilst under an active sharing model the decision regarding which parties hold spectrum may not have a significant impact on capex costs, it may have an impact on the ability to deliver high quality services to all customers.

Pooling of spectrum under the control of a single wholesale network may allow the full extent of spectrum available for 5G to be used more efficiently. For existing cellular networks, spectrum pooling has limited benefits because most MNOs experience similar levels of demand in similar locations and so all need access to a relatively static share of the overall spectrum. This may not be the case in 5G; for example, if one MNO is contracted to provide services to one commercial entity in a given location – such as on their campus – they may be the majority user of spectrum.

Another potential benefit from sharing 5G spectrum is that there may be some services that require large bandwidth, for example as high as 100MHz. As discussed earlier, there is insufficient spectrum for all MNOs to have dedicated allocations of this size. As an alternative, spectrum could be shared so that any MNO could momentarily gain access to large bandwidth as needed.

However, sharing is complicated by the likely deployment of 5G on existing cell sites and the need for 5G to work in tandem with 4G, at least in early years. It would also require an active SWN, a topic we discuss further below.

3.2.3 Removal of some practical barriers to deployment

As noted in the previous section, one barrier to the fast deployment of 5G networks may be limited availability of suitable locations in which to deploy small cells and 5G equipment for both outdoor and indoor coverage. Given the limited outdoor public spaces in Singapore, finding sufficient sites for all operators to install their equipment may be a significant challenge. Lampposts and street furniture may not be sufficiently robust to sustain equipment from multiple operators. Therefore a key benefit of a single wholesale network operator would be the reduction in amount of equipment to be deployed as shared antenna and equipment could be deployed for all small cells.

For in-building coverage, a single wholesale network operator could decide on the optimal network design to be provided in-buildings, based on the best location for

provision by all operators, and this would remove any potential for delays or drawn-out negotiations in the deployment of this equipment even under the terms of the COPIF.[22]

3.2.4 Less disruption

Given the need for a dense network and the necessity of line-of-sight connectivity for high traffic areas such as shopping centres and public spaces, the disruption caused by deploying this network equipment could be significant. In addition to the benefit of having to deploy less equipment, the disruption to the public in relation to the deployment of 5G small cells would be minimised if only one provider needs to deploy equipment.

3.2.5 Relationship with NGNBN

One necessary requirement for 5G networks delivering the full IMT-2020 feature set is fibre backhaul to provide the necessary capacity and meet the low latency requirements. With a dense network of small cells, this will require a similarly dense, high capacity network of fibres.

The current passive fibre network operated by NLT would provide an appropriate foundational platform for this backhaul network as it covers all urban areas of Singapore and has a high density of fibres, and is offered to all operators on an open access and non-discriminatory basis. Using this existing network would provide benefits for the NGNBN2, in allowing faster roll out of small cells. By increasing the demand on NLT's existing network it would also reduce the unit cost of provision, which should feed through to lower fixed broadband prices on the NGNBN as well as lower 5G prices.

3.3 The benefits of a neutral wholesale-only operator

A neutral wholesale-only operator can deliver greater benefits compared to a scenario where vertically integrated operators share their networks to some extent. Currently network sharing in Singapore is limited. Although some MNOs have reportedly been discussing the possibility of sharing, little progress appears to have been made on forming an agreement so far.

Network sharing can lead to cost savings compared to all MNOs independently rolling out their own equipment, and may remove some of the practical barriers if shared equipment is deployed on street furniture etc. However, the cost and space savings from bi-lateral network sharing will typically be significantly lower than the savings from having only one operator. Network sharing may also pose other issues, as discussed below.

Firstly, whilst sharing agreements may be established between two operators, they are not typically established between more than two MNOs. This is because establishing network sharing agreements generally requires a certain degree of

[22] https://www.imda.gov.sg/-/media/imda/files/regulation-licensing-and-consultations/consultations/completed-consultations/consultation-papers/12/copif-2018-industry-briefing-on-7dec2018-cleanpptx.pdf?la=en

symmetry between parties to reach a negotiated settlement. Where there are high levels of asymmetry between the parties, for example one operator has a competitive advantage, agreements may be difficult to conclude or be restricted, as this party may lose competitive advantage by entering into a comprehensive agreement. Thus, some potential fixed cost savings and network expansion may be foregone by network sharing parties as they seek to differentiate or, due to asymmetric information or uncertainty, cannot negotiate a mutually acceptable division of any benefits.

Under a network sharing agreement, the pace and scale of investment may be dictated by the party with the lowest incentive and/or ability to invest. Although this may still result in benefits compared to independent roll out, it will produce lower benefits than in the case where a single wholesale network operator has full control and is able to recover costs across the entire customer base.

Finally separating the control of the shared network from the downstream retail market removes the incentive of the network operator to attempt to distort competition in downstream markets, for example by discriminating between different wholesale customers.

3.4 Benefits that can be achieved with intervention to ensure the 'best' model to deliver maximum benefits

As in the case of the NGNBN, the IMDA is likely to impose regulations and requirements on a neutral wholesale-only network provider in order to maximise the benefits and ensure the risks of a monopoly network are mitigated.

In this section we consider some of the ways the IMDA could intervene.

3.4.1 Coverage targets

A government or regulator can impose quality and coverage targets/obligations on a wholesale network provider to ensure ubiquitous roll out is being delivered in a timely way. Without this there is a risk that the provider would first cover the most 'economic' areas – i.e. the most densely populated areas and the most commercially attractive applications such as mobile broadband – but would be slow to provide full coverage across Singapore or to provide network capabilities for which there is limited immediate demand.

Targets could be set as part of the tendering process of the NGNBN2. Such targets must be set at a feasible rate, with appropriate commitment mechanisms (either through penalties for failure to deliver or through incentives for meeting or exceeding targets) to ensure that coverage is achieved but not at the cost of quality.

If there were capabilities where the commercial case was not clear, targets could be supported through subsidy (either directly, or indirectly through lower spectrum

fees). A competitive tender process should allow the extent of any such subsidy to be minimised.

3.4.2 Separation of the wholesale provider

A single wholesale network is an attractive option for creating additional competition in downstream markets as the company can be required and incentivised to give access to all interested parties, which could open up the market to greater retail competition.

One notable feature of the NGNBN is the strict separation in control between the NetCo (now NetLink Trust) and downstream players. This neutrality leads to improved competition in downstream markets as there is no risk that the NetCo will seek to discriminate between customers in order to affect competition by favouring one player.

A wholesale network model could lead to greater competition at the retail level by making it easier for new entrants and smaller network players to deploy equipment, spectrum or rent capacity on a wholesale network (depending on the model of wholesale network chosen) to offer innovative retail services. A neutral host should have incentives to maximise the return on their assets by minimising costs and maximising the number of wholesale customers. As such, effective regulation on access arrangements and cost recovery should provide a good environment for new entrants. Unlike a vertically integrated operator, a wholesale-only operator has incentives to maximise its wholesale customer base (as it does not have its own retail arm which it would be incentivised to treat preferentially). This may be particularly important in the case of 5G given the wide scope of use cases – it is likely that parties beyond MNOs may have interests in network access.

In the case of NGNBN, a significant number of retail providers offer broadband services to residential, business and public customers and this retail competition creates competitive dynamics, leading to lower prices and improved retail offerings.

3.4.3 Impact on competition

The structure of the NGNBN was designed to allow competition in higher levels of the network and in the retail market, while benefiting from the faster roll out and lower costs that a single wholesale network can deliver.

Given the potential limitation on the number of network operators that could gain access to C-band spectrum, and the uncertainty about demand for innovative services, without a wholesale operator the level of retail competition for advanced 5G services could be lower than it is currently for 4G. On the other hand, the impact of any reduced competition at the network level that may result from the wholesale-only model is likely to be fairly low.

The coexistence of the 5G single wholesale network operator with existing MNOs, who will continue to offer 3G and 4G services, and could offer some 5G services deployed on their existing networks and spectrum, is also likely to act as a

safeguard for competition. In order to attract MNOs and other access seekers to use the 5G network, the wholesale operator will have to make 5G services sufficiently attractive and distinctive to encourage MNOs to purchase capacity on this network rather than building more infrastructure themselves. As such, this provides incentives for differentiation, cost minimisation, high quality and low prices at least in the short-to-medium term.

The wholesale 5G operator will wish to attract other parties to deliver new use cases through 5G such as IoT applications (so-called 'vertical' applications, such as those related to transportation). Since many of these could also be delivered through 4G (excluding those that strictly require the low-latency characteristics of 5G), the wholesale operator will also have to compete with MNOs to attract other parties to use the network.

3.4.4 The mechanism to deliver benefits to all customers

If deployed as part of an NGNBN2, a tender mechanism would allow the Singapore Government to determine the scope of the networks required to deliver maximum benefits to the wider Singapore nation in line with the Smart Nation initiative. Such a tender process can also specify the economic terms on which access is offered in the initial period. However, over the longer terms it will be impossible to determine how the market will develop and there may be a need for a clear regulatory framework to be implemented following this initial period.

A neutral, wholesale-only network operator should have incentives to offer access to all interested parties, to maximise the customer base from which to recover costs, with the ability to raise prices constrained by co-existence with the MNOs. In the future, however, the wholesale-only operator could develop a degree of market power. Without regulation an operator with market power has an incentive to maximise profits by setting an access price above the competitive level.

However, unlike the NGNBN, this is not necessarily the most likely outcome given the uncertainties surrounding demand for 5G services and co-existence with the MNOs.

As such the appropriate approach is likely to be for the IMDA to monitor the market and the prices charged by the operator and to intervene in the future only if and when it is clear that the wholesale-only operator has significant market power due to demand for 5G services having developed to the point where it is possible to increase prices above a competitive level, and that the MNOs do not constrain the pricing of the wholesale-only network.

If regulation is required on the level of prices that the wholesale-only operator can charge for access to its network, IMDA can regulate this entity in terms of the price it sets and/or the level of return it is allowed to make.

Various methods can be used to assess the appropriate level of prices, costs and/or pricing mechanism. It would also be necessary to set regulatory reporting requirements in order to ensure compliance and to inform the setting of future regulation.

With these regulations in place, the benefits in terms of cost savings from an efficient and unduplicated network can be passed onto downstream operators,

whilst competition at the retail level should ensure these benefits are then passed on to all end customers.

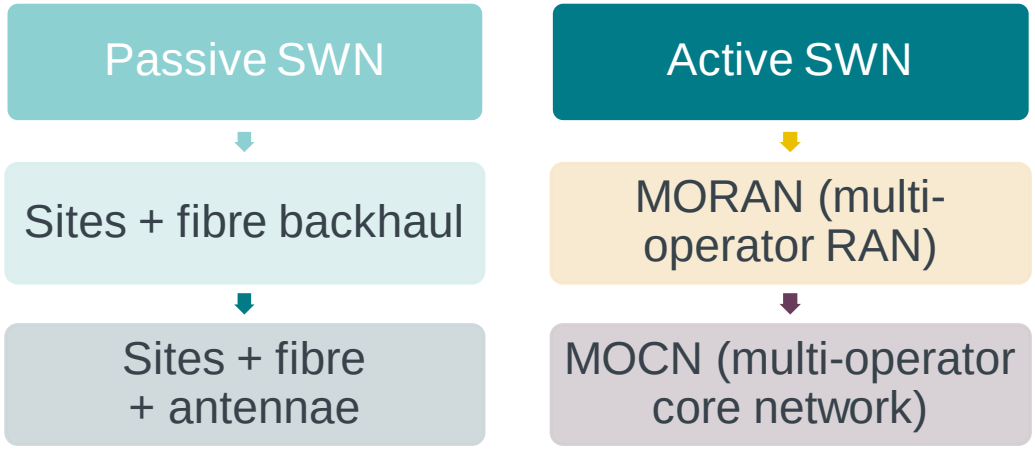
4 THE POTENTIAL MODELS FOR INTERVENTION

Within an NGNBN2, an SWN for 5G in Singapore could be delivered in a number of different ways. A key consideration is whether the network would provide just passive infrastructure (broadly the sites and connectivity needed for operators to deploy their equipment on) or would cover both passive and active infrastructure including the electronics needed for transmission. A secondary consideration is whether the network would obtain a licence for 5G spectrum to be deployed on these sites, or instead allow other operators to deploy using their own spectrum.

In the NGNBN, passive and active infrastructure is offered by structurally separate companies: the NetCo (NLT) and the OpCos (requesting licensees).

If only passive infrastructure is offered then there is a choice between offering only sites and backhaul, or of offering sites, backhaul and shared antennae. If active infrastructure is also included there is a choice between a multi-operator radio access network (MORAN) or a multi-operator core network (MOCN). MOCN would require the SWN to own or have access to spectrum. These potential models, shown in the figure below, are discussed in more detail in the remainder of this section. Based on a cost modelling exercise, we have considered the potential cost savings from these different levels of sharing.

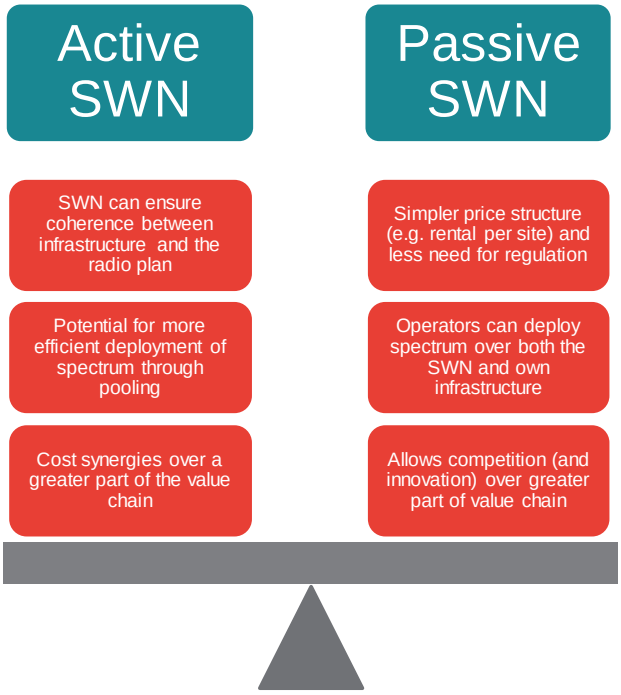
Figure 10 Potential models of network sharing or wholesale networks



Source: Frontier

Passive-only and active shared network models have different advantages. These are covered in the figure below and in more detail under each heading in the remainder of this section.

Figure 11 Advantages of active and passive sharing models



Source: Frontier

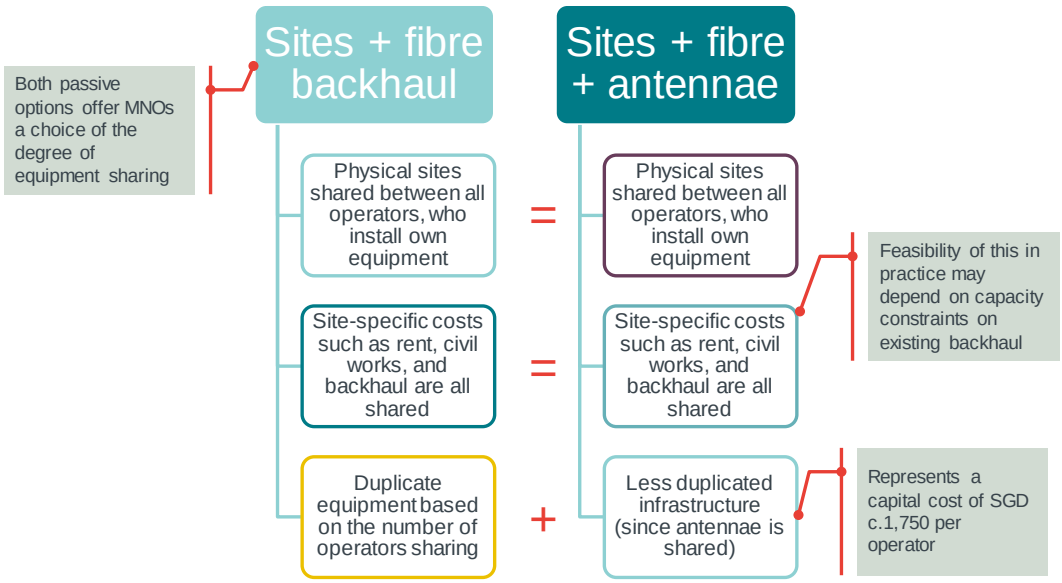
4.1 Passive SWN

The simplest model is a passive-only SWN. In its most limited form, this would mean that the SWN would provide the physical sites and give access to fibre backhaul to MNOs which could then deploy their own equipment onto these sites. If a greater degree of sharing was considered optimal then the SWN could also operate shared antennae on the sites.

This form of SWN would deliver cost savings whilst still allowing competition over a large proportion of the value chain. Coverage obligations could be applied to the SWN and the pricing structure could be a simple fee per site.

The key differences, benefits and limitations of both potential forms of passive SWN are summarised in the figure below and in more detail under the following headings.

Figure 12 Differences, benefits and limitations of Passive SWN models



Source: Frontier

4.1.1 Benefits

With a passive SWN the extent of the value chain that is delivered on a wholesale basis is minimised, and therefore this potentially gives MNOs more freedom to differentiate through innovation or cost minimisation. MNOs would have the ability to decide how they deploy equipment and spectrum over both their own sites and the SWN sites. To the extent that MNOs are able to differentiate, greater competition could lead to benefits for end users in terms of innovation, quality and price.

By managing the acquisition and construction of sites, disruption to the public is minimised and negotiations/communications with landlords etc. is limited to one party – the SWN.

If shared antennae were used then this would prevent street furniture or other sites with limited space from becoming overcrowded.

A passive SWN would have a simple price structure. The network company could charge a rental price per site based on the capital costs it has to recover across all access seekers in terms of:

- Site acquisition and civils;
- Feeder, install and test and commission;
- Backhaul; and
- Antennae (if included).

A rental charge would also have to recover ongoing opex that is incurred by the network company in operating the sites, such as site rental (unlikely to be significant in Singapore due to COPIF[23]) and backhaul rental.

[23] For this reason we have assumed site rental to be equal to zero in our modelling.

4.1.2 Limitations

One of the key limitations of such a model within an NGNBN2 is that the Government could not specify requirements for 5G services in a tender from the SWN but only the infrastructure that would be provided. The Government could leave it to competition between the MNOs to deliver a full range of innovative services over this passive network. Alternatively the Government could designate a separate OpCo to provide active services over this infrastructure, in the same way that Nucleus Connect was the designated provider of active services with the NGNBN.

However, in mobile networks there needs to be close co-ordination between the passive infrastructure and active equipment due to the need to site antennae according to a radio plan (compared to the NGNBN where the providers of active equipment are essentially indifferent to the routing of fibres between OLTs and ONTs). A passive-only SWN will need to ensure that the design and placement of sites is closely co-ordinated with operators of active networks. This may increase the complexity when setting up the SWN or may lead to inefficiencies in roll out due to lack of co-ordination. This is in addition to the inefficiencies due to the likely duplication of active equipment, as MNOs need to deploy their equipment on all small cell sites.

Under a passive SWN model it would be unlikely that there would be other access seekers, beyond MNOs using the SWN, as the access seekers would need their own networks and spectrum in addition to gaining access to small cell sites from the SWN in order to provide retail services.

If all MNOs wished to use the sites with their own antennae, there might be physical limitations on how many antennae can be used on some small cell sites such as street furniture. Therefore it would have to be established whether in these cases there was a ‘first come first served’ approach or a different approach. This might affect the coverage of different networks which could lead to some MNOs gaining a competitive advantage, and may mean that the full benefits of 5G cannot be experienced by all customers.

4.2 Active SWN

The alternative model of SWN is one that covers active as well as passive equipment.

Compared to a counterfactual where MNOs roll out separate networks, an active SWN would deliver greater cost savings than a passive SWN by further reducing duplication. However, this would reduce the share of the value chain over which MNOs could differentiate themselves and compete. As with a passive SWN, coverage obligations could be applied as part of the tendering process along with other technical requirements. The pricing structure would need to be more complex to potentially reflect not only the fixed and ongoing costs of the site and equipment but also any costs related to traffic.

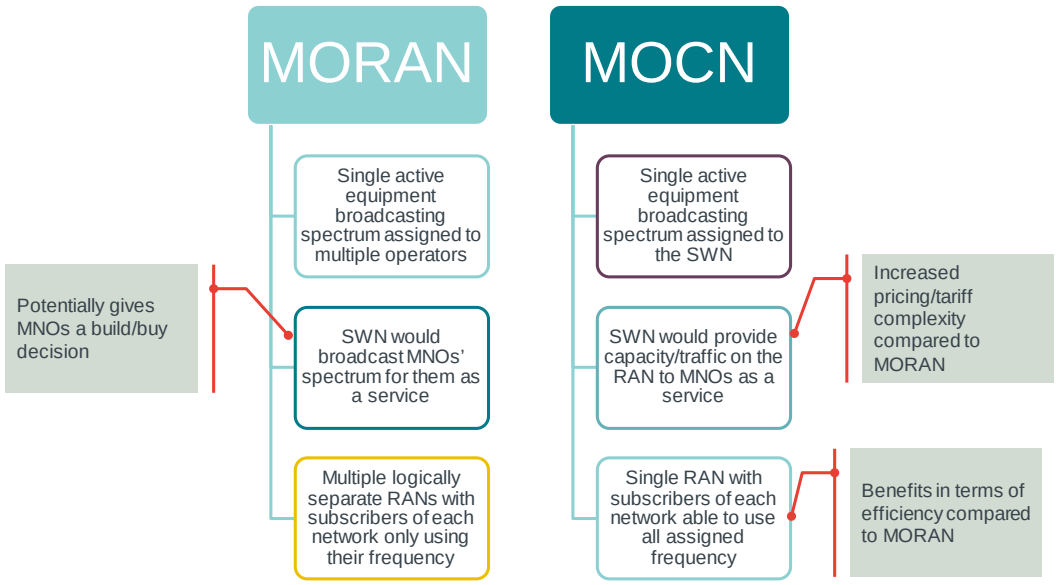
We consider two possible technical models of active sharing that could be adopted for 5G in Singapore:

- Multi-operator radio access network (MORAN); and
- Multi-operator core network (MOCN).

Both of these models allow similar sharing of active equipment. The key difference is that MOCN would require the SWN to have control of spectrum whilst access seekers would rent capacity rather than deploying their own spectrum onto the equipment, while under MORAN the SWN would broadcast spectrum controlled by the MNOs.

The key differences, benefits and limitations of both potential forms of active SWN are summarised in the figure below and in more detail under the following headings.

Figure 13 Differences, benefits and limitations of Active SWN models



Source: Frontier

4.2.1 Benefits

Deploying such an SWN as part of the NGNBN2 would allow the Government to specify in more detail the service capabilities that they require from the 5G network rather than solely the physical characteristics of the underlying infrastructure. By allowing a single entity to co-ordinate both the passive and active elements of the network, the desired level of service could be delivered more efficiently.

With an active SWN the extent of the value chain that is shared is greater, and therefore the cost savings from a shared model are more substantial. This could result in a number of benefits:

- Greater and more rapid roll out of new 5G capabilities;
- Reduced need for any subsidies under an NGNBN2 tender; and
- Lower costs to end users in the long run.

As with a passive-only SWN, by managing the acquisition and construction of sites, disruption to the public is minimised and negotiations/communications with landlords etc. is limited to one party – the SWN.

The use of shared antennae and equipment would mean the most efficient use of space on sites and remove the risk of street furniture etc. becoming overcrowded. This means all access seekers could use all sites without concerns about space held by others. In addition, with both passive and active equipment being operated by a single operator, this number of required sites can be fully optimised.

An active SWN would potentially require a more complex pricing structure compared to an SWN that covers only passive elements. This may involve a two-part tariff structure. The network company could charge a rental price per site based on the capital costs it has to recover across all access seekers in terms of:

- Site acquisition and civils;
- Feeder, install and test and commission;
- Backhaul;
- Antennae; and
- Active equipment.

A rental charge would also have to recover ongoing opex incurred by the network company in operating the sites such as site rental, backhaul rental, utilities etc.

The network company would also have to charge a traffic-based tariff if operators also rent capacity from the SWN under a MOCN model.

4.2.2 Limitations

With a greater degree of sharing, potential competition is removed across a larger proportion of the value chain with a single active network. Therefore MNOs may have less ability to differentiate through innovation or cost minimisation in the longer term potentially reducing innovation in networks. However, the MNOs would still have the ability to enter this space in the long term, when the business case for 5G is more developed, which may limit this risk.

4.2.3 MORAN vs. MOCN

Under MORAN, shared active equipment is used to broadcast spectrum assigned to the different operators using the SWN (presumably the MNOs). The MNO faces a “build or buy” decision when considering using the SWN and they could potentially have the ability to acquire their own sites and deploy spectrum and equipment on these, leading to competitive pressure on the SWN which could support cost minimisation incentives. The MNO’s decision to build rather than buy will depend on the size of the cost savings from sharing and the extent to which they can differentiate from other MNOs by deploying their own small cells. If the SWN is widely available it is unlikely that there would be a strong incentive for an MNO to deploy its own small cells rather than using the SWN.

Since spectrum must be allocated to MNOs under the MORAN approach, then due to limitations of spectrum availability discussed earlier, there is a risk that not all

MNOs would have spectrum, or that the spectrum allocations would not support the different operators' levels of traffic.

Under a MOCN solution, the SWN would use all available spectrum. Access seekers, including the MNOs, would buy the capacity they needed from the SWN, which could be allocated on a dynamic basis. Therefore all wholesale users would be able to potentially use all of the spectrum available to the SWN (subject to overall demand at the time). This dynamic allocation means spectrum is used more efficiently under a MOCN scenario. In addition, a range of different wholesale customers could access the SWN on an equal access basis, including the existing MNOs but also providers of vertical applications and/or the public sector. This could enhance competition compared to an outcome where a small number of MNOs control access to the network.

While a MOCN solution could remove some level of differentiation between MNOs which may reduce competition in the RAN part of the value chain, opening up the market to a wider range of access seekers could increase innovation in downstream markets, which may be critical in delivering 5G use cases.

As noted above, MOCN would require the network operator to charge based on traffic. Charges would need to recover any spectrum licence fees as well as the fixed and ongoing costs of the network.

4.3 Avoided cost under different models

We have undertaken a high-level modelling exercise to assess the likely degree of total avoided cost under each of the model options presented above. Given the high degree of uncertainty on 5G business plans, including both the costs of equipment and the required network dimension the outputs of this modelling exercise are intended to be illustrative, rather than accurate forecasts of the expected costs of rolling out 5G networks.[24]

In order to estimate the level of avoided cost each model delivers, we compare the costs under each SWN model to a "counterfactual" without an SWN, based on the same level of network coverage to ensure a like for like comparison.[25]

Our modelling relies on 5G network cost information informed by the 5G NORMA study commissioned by the EC. We make some modifications and assumptions in order to make this exercise Singapore-specific:

- We assume the topology of Singapore corresponds to the "Dense Urban" geotype from this model, so we apply only these network dimensioning assumptions (e.g. ignoring the rural geotypes); and
- Mandatory rent-free building access for operators implies no site rental costs.

We consider the costs that would be duplicated by the operators under each sharing option in order to estimate capital and operating costs over a 10-year

[24] In particular we have made some simplifying assumptions: we have not modelled the roll out of the network over a period of time but have used an 'instantaneous build' assumption and; the network dimension and hence cost is assumed to be solely a function of coverage and hence independent of the level of traffic.

[25] As one of the key objectives of an SWN would be to deliver a greater and more comprehensive roll out of 5G, the counterfactual is not a forecast of the expected incurred cost if an SWN did not occur, as we would expect the roll out to be less comprehensive.

period. We then calculate this cost as a net present value (NPV) based on a real discount rate of 5.7%.[26]

Our central counterfactual is a situation in which two of the existing MNOs roll out networks and provide access to the remaining MNOs through network sharing or national roaming agreements. This seems like the most likely counterfactual given that the limited availability of 3.5GHz spectrum may mean only two licences are made available. We also compare the costs with an alternative counterfactual in which all four MNOs roll out independently.

We assume that the 5G network is overlaid onto existing networks, based on the premise that MNOs continue to operate 3G/4G networks and the 5G network is dimensioned to cover the whole area of Singapore with a network of small cells only.

For simplicity, we assume that the network is rolled out instantaneously (i.e. we are comparing the models in a "steady state"), which reflects the expectation that if an NGNBN2 were to be set up, roll out would occur rapidly. Also, given the current uncertainty related to the practicalities of large-scale 5G network roll out, this approach avoids making speculative assumptions about any differences in the rate of roll out between options.

The costs under MORAN and MOCN are assumed to be the same as the equipment would be shared and the key difference between these models relates to how the spectrum is allocated. Although spectrum costs would have to be paid, we have assumed that this does not affect the total costs as spectrum costs are either paid directly (through licensing fees to MNOs) or indirectly (through the traffic component of an SWN two-part tariff under MOCN).

4.3.1 Central case

In the table below we present the costing and network dimensioning assumptions for the counterfactual and each SWN sharing option, where the counterfactual is assumed to be a scenario where two of the existing MNOs roll out networks and provide access to the remaining MNOs through network sharing or joint venture agreements (2 x 2-operator JVs).

[26] Based on NLT's regulated nominal pre-tax WACC of 7% and a forecast inflation rate of c. 1.3% (Sources: IMDA; Statista): http://www.netlinktrust.com/medias/investor-media/media/press-releases/163-netlink-trust-accepts-price-revisions-follwoing-imda-s-review.html and https://www.statista.com/statistics/379423/inflation-rate-in-singapore/

Figure 14 Cost assumptions under the central counterfactual

	Costs in SGD	Counter-factual: Two MNOs roll out	Passive sharing: sites + fibre backhaul	Passive sharing: sites + fibre + antennae	Active sharing: MORAN / MOCN
[A]	Total number of sites	74,869	37,434	37,434	37,434
[B]	Capex, per site	28,040	42,915	41,165	28,040
	(of which backhaul)	3,540	3,540	3,540	3,540
	Opex (p.a.), per site	8,129	12,355	12,355	8,129
[C]	Opex (10yr NPV), per site	64,145	97,496	97,496	64,145
[D] = [B] + [C]	Total cost (10yr NPV), per site	92,186	140,412	138,662	92,186
= [A] x [D]	Total cost (10yr NPV)	6,902 million	5,256 million	5,191 million	3,451 million
	% cost reduction vs independent roll out		24%	25%	50%

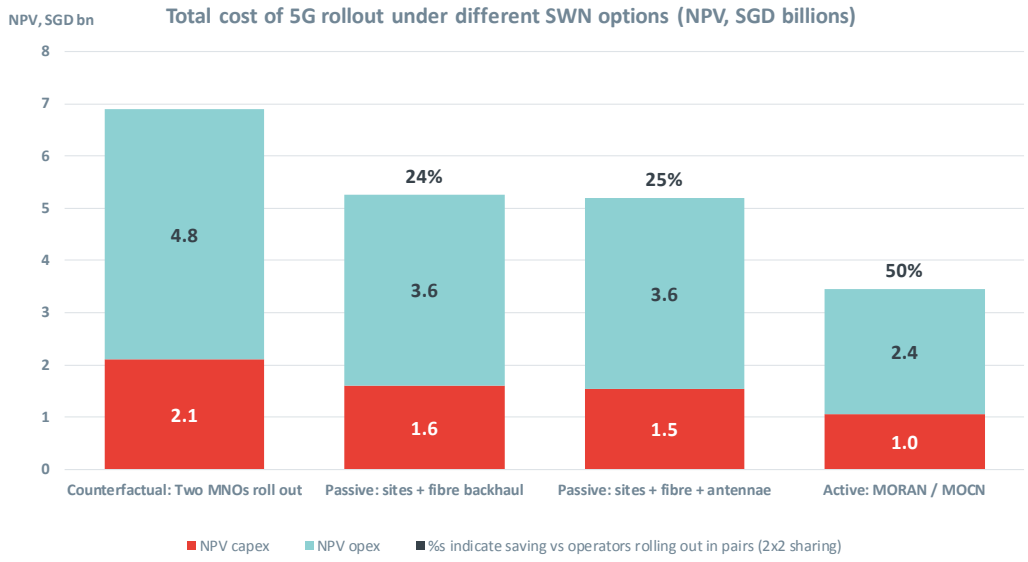
Source: Based on 5G NORMA and Frontier assumptions

The relative costs shown in the figures below demonstrate that significant costs that can be avoided under both passive and active SWN models. Under passive options, the reduction in the number of sites reduces the cost, although the cost per site increases due to two sets of active equipment being placed on each site. The antennae costs make little impact on aggregate to the costs of the two passive options. The cost savings from active SWN models are significantly higher than from the passive SWN models as the need to have duplicate active equipment at each site is removed.

We have assumed that mobile operators or the operator of the SWN, will have to lease backhaul from NLT or build their own backhaul. If NLT were to operate the SWN, then it would not have to lease this backhaul as it could use its own network. In terms of cost incurred, there should not be a significant difference between NLT deploying the fibre for a separate SWN or if it operated the SWN. However, if NLT were operating the SWN the costs to end users may be lower as there may not be 'double marginalisation'[27] on the backhaul costs.

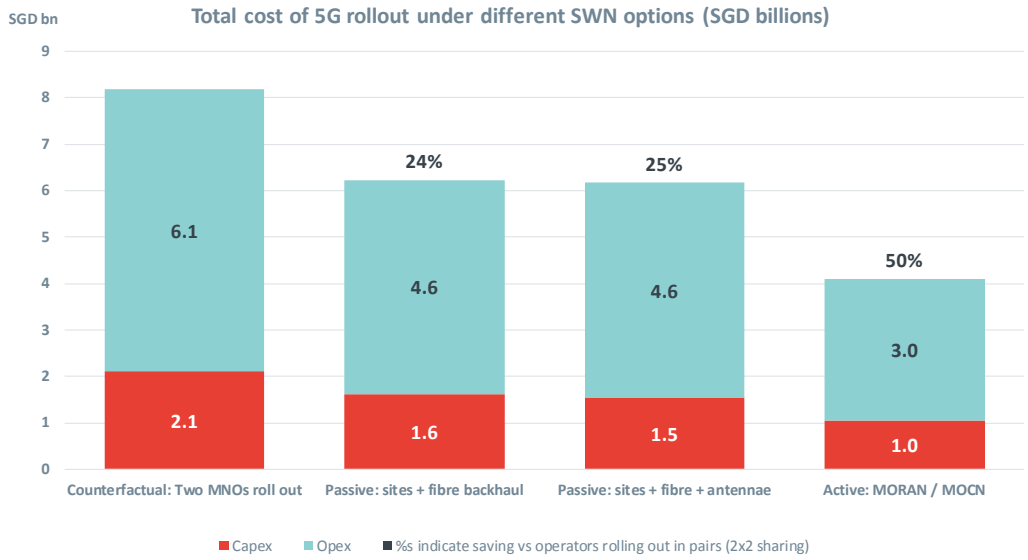
[27] Double marginalisation occurs when mark-ups are applied by firms at two levels of the supply chain (i.e. in this case, NLT and the SWN and/or mobile operators). In this case double marginalisation may occur as NLT's fibre rental prices will include recovery of a proportion of fixed cost, therefore a non-NLT SWN would incur the backhaul charges including this margin and then charge a price to MNOs that included their own margin. NLT as the SWN provider would face only the incremental costs of the fibre backhaul and therefore could apply a lower margin allowing prices for 5G services to be set at a lower level to stimulate demand.

Figure 15 Relative avoided cost under different SWN models (discounted)



Source: Frontier based on 5G NORMA inputs

Figure 16 Relative avoided cost under different SWN models (undiscounted)



Source: Frontier based on 5G NORMA inputs

4.3.2 Alternative case

In the table below we present the costing and network dimensioning assumptions for the alternative counterfactual, where the counterfactual is assumed to be a scenario where all four MNOs roll out their own 5G networks independently.

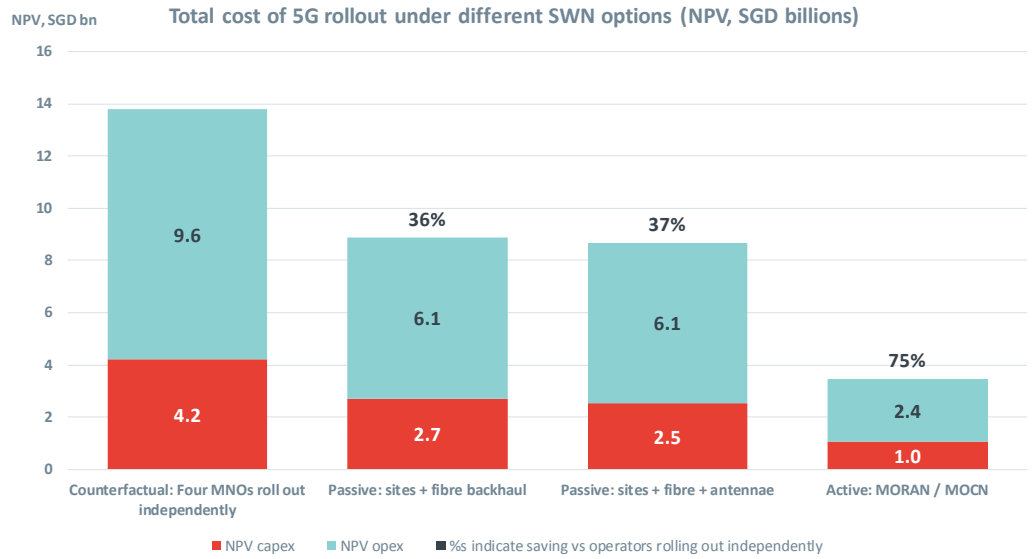
Figure 17 Cost assumptions under the alternative counterfactual

	Costs in SGD	Counter-factual: 4 MNOs rolling out independently	Passive sharing: sites + fibre backhaul	Passive sharing: sites + fibre + antennae	Active sharing: MORAN / MOCN
[A]	Total number of sites	149,737	37,434	37,434	37,434
[B]	Capex, per site	28,040	72,665	67,415	28,040
	(of which backhaul)	3,540	3,540	3,540	3,540
	Opex (p.a.), per site	8,129	20,807	20,807	8,129
[C]	Opex (10yr NPV), per site	64,145	164,198	164,198	64,145
[D] = [B] + [C]	Total cost (10yr NPV), per site	92,186	236,864	231,614	92,186
= [A] x [D]	Total cost (10yr NPV)	13,804 million	8,867 million	8,670 million	3,451 million
	% cost reduction vs independent roll out		36%	37%	75%

Source: Based on 5G NORMA and Frontier assumptions

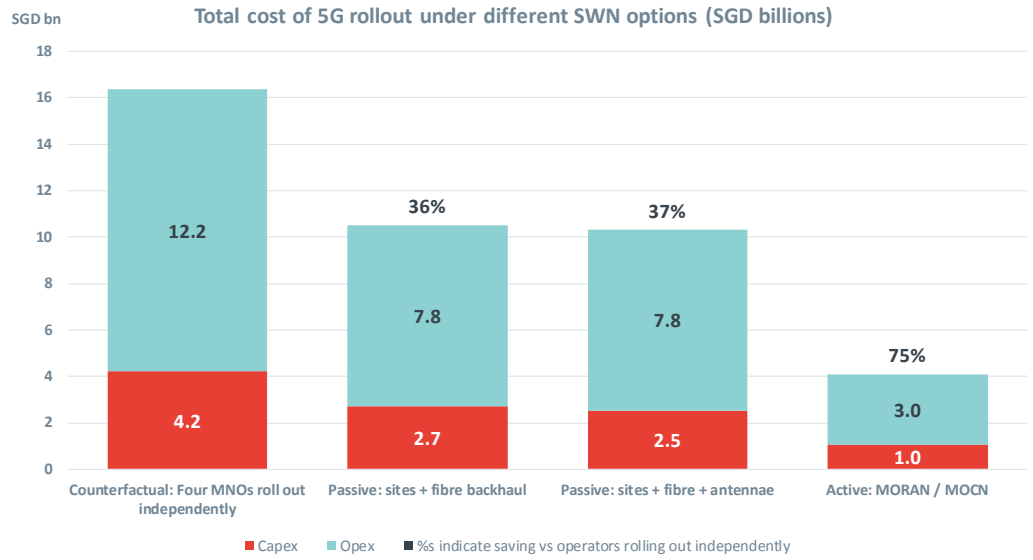
As we would expect, compared to this alternative counterfactual the cost savings in percentage terms are even higher. Under this counterfactual twice the number of sites are rolled out compared to the central counterfactual, increasing costs significantly. The reduction in the number of sites under the SWN is consequently greater, although costs per site are higher in the passive options as we assume each MNO will deploy their own equipment at each site. The consolidation of this into a single set of active equipment at each site under the active scenario means the implied percentage avoided cost increases (this is shown in the figures below).

Figure 18 Relative avoided cost under different SWN models (discounted)



Source: Frontier based on 5G NORMA inputs

Figure 19 Relative avoided cost under different SWN models (undiscounted)



Source: Frontier based on 5G NORMA inputs

The alternative counterfactual demonstrates the high costs MNOs face if they choose to roll out independently. We consider it unlikely that there would be 4 separate small cell roll outs in the absence of intervention, given the spectrum restrictions in addition to the high costs. In practice this may mean that without some form of network sharing the extensive roll out modelled in the exercise would not take place, and hence some of the benefits of 5G would potentially not materialise.

5 CONCLUSION

Delivering the full capabilities of 5G poses a new challenge in all countries, due to the complexities presented by using high frequency and mmWave spectrum: the need for significant investment into a dense layer of small cells, and the high costs associated with this. In addition there is significant demand uncertainty: it is clear that there is significant potential for a wide range of use cases; however, it remains unclear what the demand and willingness to pay will be for these use cases, and when demand will materialise. Making a business plan for investment in advanced 5G capabilities is further complicated because it is not clear that the profits that may arise from 5G networks (in particular the 'vertical' use cases that arise in the categories of mMTC and URLLC) will flow to MNOs – the parties that would incur the costs of rolling out these networks.

The Singapore Government has identified 5G as an essential building block for the Smart Nation initiative. Singapore has advantages over other countries due to its geography – meaning there are no large and costly rural areas to cover; and because its high quality fibre network – NGNBN – is already in place to provide backhaul to a future 5G network. Further there is an appetite for innovative technology in Singapore which may encourage investment at an early stage.

However, there is still a significant risk of market failure and it is likely that absent intervention, the roll out of the advanced capabilities of 5G may be slow or only partial. Given the fundamental uncertainties on the business case, MNOs may operate a "wait and see" approach which would put Singapore behind in terms of 5G development and could reduce the overall benefits (and spill-overs) that could occur if Singapore became a leader in 5G network deployment.

In addition there are some barriers to a full featured 5G roll out:

- The costs of roll out are high, even in Singapore;
- There are spectrum shortages in the 3.5GHz band, likely to be crucial for 5G, which could limit the viability of competitive network roll out using this band; and
- There are practical barriers to deployment given a lack of public areas and limited space available for new small cells.

This means that it would be difficult for all 4 mobile operators to roll out full featured 5G networks, which could result in a reduction in competition compared to that for 4G.

A programme similar to the existing NGNBN, i.e. a 5G NGNBN2, could prevent a market failure. A single neutral wholesale network for 5G would reduce the costs of 5G deployment and mitigate other barriers in relation to the lack of spectrum and practical barriers to deployment of sites. As such, an NGNBN2 which includes the creation of a 5G SWN could improve outcomes in terms of 5G deployment in Singapore by increasing the rate and level of deployment. Whilst the lack of clarity about demand and the business model for all potential use cases persists, allowing a neutral operator to deploy the network may mitigate some of the risks of investing in this new technology.

In this paper we have considered a number of single wholesale network models that could be potential options for a 5G network in Singapore, with the single wholesale network either providing passive assets only (as was the case with the NGNBN) or also providing active equipment. It is clear that the models offer the potential for significant cost savings and therefore a model that leads to some removal of duplication could deliver improved outcomes in terms of roll out speed and cost efficiency if effectively implemented.

IMDA is familiar with the requirements and regulations for the implementation of a wholesale network from its process to establish the NGNBN. The issues for a 5G SWN differ to some extent: the fact that such a network would likely co-exist with the established network operators potentially reduce the need for detailed regulation initially, but potentially increases demand uncertainty. However, the broad framework provides a useful template for such a process.

Importantly, absent government intervention, there may be significant delay in the roll out of 5G networks delivering the enhanced capabilities of the technology. The lack of sufficient spectrum for all operators to deliver the full capabilities of 5G, and practical and financial barriers to the roll out of dense networks, could lead to any 5G roll out being restricted to one or two of the existing MNOs, potentially leading to a reduction in competition. Government intervention in the form of mandating a 5G SWN would lead to significant cost savings which would in turn allow faster roll out and lower end user prices. This would also enable the Government to determine the optimal roll out of a 5G network to support its Smart Nation initiative.

Given the potential benefits of a 5G SWN in terms of faster roll out and cost savings, it is worthwhile for the various single wholesale network models, as presented in this paper, to be investigated further and considered by the IMDA and stakeholders.

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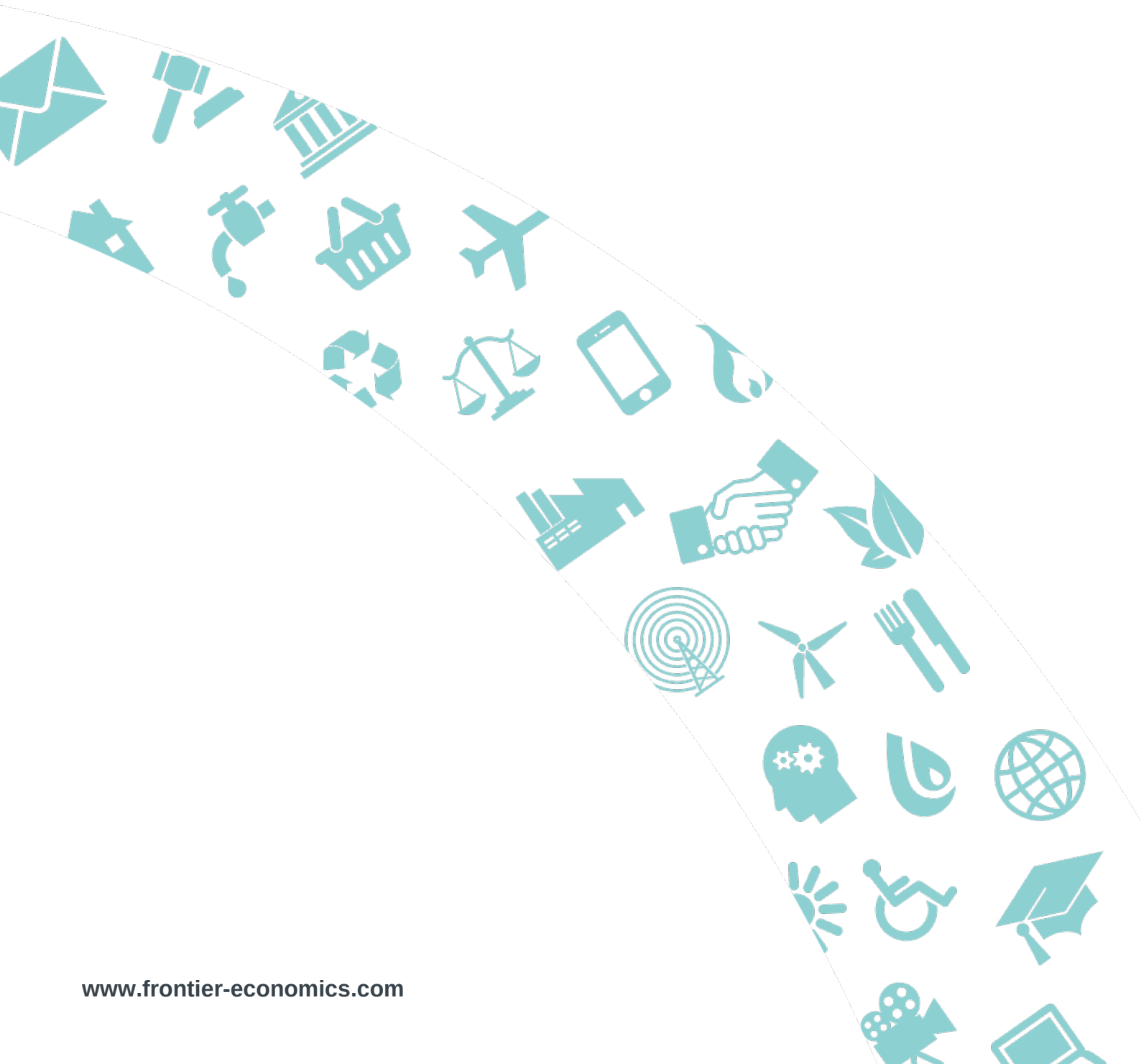

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